A DEVELOPMENT OF YARN FROM THAI SILK WASTE TO CREATE KNITTED FABRIC

By
MRS. Peeraya SRAMALA

A Thesis Submitted in Partial Fulfillment of the Requirements
for Doctor of Philosophy DESIGN ARTS (INTERNATIONAL PROGRAM)
Graduate School, Silpakorn University
Academic Year 2017

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Title	A Development of Yarn from Thai Silk Waste to Create Knitted Fabric
By	Peeraya SRAMALA
Field of Study	DESIGN ARTS (INTERNATIONAL PROGRAM)
Advisor	Namfon Laistrooglai

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PEERAYA SRAMALA: A DEVELOPMENT OF YARN FROM THAI SILK WASTE TO CREATE KNITTED FABRIC. THESIS ADVISORS: ASST. PROF. NAMFON LAISTROOGLAI, Ph.D., AND ASSOC PROF.PAIROJ JAMUNI, Ed.D. 189 pp.

This research aimed to develop yarn from Thai silk waste to create knitted fabric. The methodology of this research was related to “practice to design.” It consisted of two parts; the first part involved the collecting of information related to Thai silk waste and its benefits. The second part involved experimenting to determine a suitable method and related equipment for the production of yarn and knitted fabric through a craft and industrial process. The process required fiber preparation, spinning, dying, knitting, fabric property testing and creating a new yarn and knitted fabric .

The results of the study show that the solid waste produced from Thai silk can be classified into three types: Incomplete cocoons, broken silk yarn, and silk fabric waste. Generally, this waste has been re-used in manufacturing for items such as fashion accessories and decorative products. Regarding the experiment, the results suggest fiber preparation through the craft process was superior to the industrial process. Yarn spinning was carried out by using a traditional Thai hand spinner to be single yarn, ply yarn, core yarn. This process was able to create unlimited forms, textures, and colors. Moreover, dyeing different types of silk waste, silk hankies, roving and yarn produced a variety of colors. Besides, shade and value were done by mordant. The knitting process was accomplished through hand knitting and a domestic knitting machine. The process produced basic and applied fabric structures and was able to create texture and form with thick, thin, three-dimensional, complex and continual structures. The character of fabric was shown to be shiny, sticky, lightweight and flexible. The results obtained from this research can be beneficial and used as a guideline for create knitted fabric. In addition, the information gained from the craft process can be utilized by villagers for small-scale production and also by the Thai silk industry. The results from this study can be aid the recognition of the value of waste products from their business and thus assist in the reduction of environmental damage.

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I would like to acknowledge my indebtedness and render my warmest thanks to my advisor, Assistant Professor Namfon Laistrooglai, Who made this work possible. Her friendly guidance and expert advice have been invaluable throughout all stages of the work.

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for the support materials, tools and facilities for dyeing, spinning experiments and design production.

Spacial thanks must go to Rajamangala University of Technology Krungthep for the financial support

Last but not least, I would like to express my deepest gratitude to my family and friends. This thesis would not have been possible without their warm love, continued patience, and endless support.

Peeraya SRAMALA

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Introduction

Statement of the problem

Recently, the concept of environmental protection become to be the part of design. That is a result of designer awareness about the impact of global warming and realise the responsibility to reduce this effect. The beginning of product design for environment protection had found among academic designer agreement of the optimal effective to reducing the environmental impact should start from product design process. Thus, it was found the concept of environment-friendly design call "Eco-Design" and also known as "Economic & Ecological Design" (A Driving Force for National Science and Technology Capability, 2014). A definition of EcoDesign is Environment-friendly design and Sustainable Design is the harmony of technology, procedure and aesthetics. (Kannika Yimnak and others, 2013). The principle of EcoDesign are Reduce, Reuse, Recycle and Repair, it's applied on all stages of production (Santana Amornchai, 2009: 31)

In the case of textile and clothing industries, there is a lot of action for social responsibility such as the regulations of environment action programme VI, Eco-Design and Ecolabel. Even each county has specific rules, but the concept still the aim at environment protection. (UNEP, 2012). This can be shown by the last few years have seen dramatic advances in material and textile technology, but designers at the greener end of spectrum appear to be ignoring these in favour of simple, low-tech solutions and rediscoveries of past technic. Many are making materials themselves, harnessing natural processes, or using recycled substances in what amount to a return to a craft-based cottage-industry approach to design rather than industrial approach (Cara Brower, 2005: 48). In the other hand, in the year 2014, VTT Technical Research Centre of Finland is collaborating with Helsinki's School of Arts, Design and Architecture (Aalto) to develop a revolutionary method for producing high-quality textiles from worn out and heavily soiled fabrics that have reached the end of their life cycle. The resulting in a finished product that is as good as, or possibly even better, than the original material (Textile world, 2014).

In Thailand, Thailand Textile Institute presented a report of "Creative Economy Roadmap for Thai Textile & Clothing Industry 2013 – 2017". The vision of report is "To be the highly efficient and diverse trading and design centre for ASEAN textile and clothing with focusing on sustainability". The strategic framework emphasis on environment protection is focused on green business as a social responsibility and environment in conjunction with the development of standards to be accepted internationally (Thailand Textile Institute,2011: 35). In the term of "sustainable textile" there are many definitions such as "Sustainable textiles is Textile product that has been environmentally friendly, support communal harmony, as well as capable of support fashion needs (Charu Jain,2007). and "Sustainability has always targeted the idea of dematerialisation, converting the linear part of materials to a circular material flow that reuses materials as much as possible, much like the cycling and reuse of waste in natural" (Reena Aggarwal, 2010).

The Thai silk is a part of Thailand regional cultural heritage. The unique characteristics are gummy, sticky substance and shiny. Thai silk industry produces a

large amount of solid waste which can be classified into three types: incomplete cocoons, broken silk yarn, and silk fabric waste. The detail among the three types are as follows:

1. Incomplete cocoons: the imperfect cocoons which cannot be reeled commercially. Examples are double cocoons, feeble cocoons, pierced cocoons, piques, and rates.

2. Broken silk yarn: the waste product from reeling, winding, throwing, and weaving.

3. Silk fabric waste: the waste produced in apparel industries, and decorative product industries

However, the full amount of this waste cannot be accurately estimated because the factories are under different management. (Thai Textile Institute, n.d.: 52, 63) Generally, these waste products are reused by businesses for items such as fashion accessories and decorative products. A fabric from spun silk has been a frequent choice for home textiles such as upholstery and pillowcase. Spun silk fancy yarn also use in fashion fields such as a hat, scarf and bag. In addition, silk fibre use to made a thread and bio-composite in the medical field. (Thai Textile Institute, n.d.: 60-61)

In the academic field, Thai researchers have conducted studies of waste in several areas in order to achieve high benefit. For example, *Kachamas Tumrongsak* (1994: จ; 5th Thai alphabet) studied how to produce non-woven fabric from silk waste. Furthermore, *Kittisak Ariyakuare* (2010: 369), produced a new mixed fiber from waste cocoon and other plant fibres, and *Siriluk Wongkasema and Puripong Aksornpim* (2015: 801-806) developed a Carding Machine and a Twisting Silk Machine for Eri Silk. *Pisut Chankum* (2011: ง; 4th Thai alphabet) also experimented spinning yarn from silk waste in weaving process.

In regards to the production of knitted fabric, it is formed by intermeshing loops of a single yarn or set of yarns together. There are three types of knitting tools: hand knitting tools, domestic machine and automatic machine. knitted fabric has high flexibility and thus produces comfortable clothing for everyday wear. Whether thick and thin, the fabric produced is soft and is resistant to wrinkles and can easily recover its form and shape. Knitted fabric can be produced by body sizing and it is suitable and convenient for fitted wear (Pornchai Tulpijit, 2009: 2-5). In recent years, knitting has seen a resurgence in popularity. There are various different approaches that have emerged from creative international fashions and from the application of knitting for household interiors in the form of light shades, cushions, floor coverings, chairs, and blinds. These products are all based on the versatility of the stitch structure. Furthermore, conceptual artists who have exploited the traditional craft of knitting can create installations of all dimensions, from large-scale public sculptures to miniatures and wearable art. All of these challenges the publics' preconceptions of knitting. (Carol Brown, 2013: 6)

In the case of environment protection, knitted fabric designers remind the environmental impact and have interweave sustainable and Ecodesign to be a guideline of Eco knitted fabric design as follows:

1. Knitted fabric design process should be reduced material, energy and wastage.

2. Knitted fabric should be design into multi-functional.

3. Knitted fabric should be design under re-usability or recycle, recycle and

up-cycle concept.

4. Knitted fabric production should be environmental impact reduction.

(Uraiwan Paradee (Pitimaneeyakul), 2012: 133-145).

As previously mentioned, show that people are aware of the environment and work together to find a solution to solve a problem. In Product design area, there was found a principle of environment-friendly design that uses 4R; Reduce, Reuse, Recycle and Repair as a guideline. Also, textile and clothing designer express the participation by applied 4R concept into their works.

The Thai silk industry produces a large amount of solid waste which can be classified into three types: incomplete cocoons, broken silk yarn, and silk fabric waste. These silk waste can be utilized to achieve various objectives. Therefore, the field should be studied and developed in order to obtain more advantages from Thai silk waste. Furthermore, to add value to the waste, the concepts of recycling and the knit fabric properties should be studied. This can inspire practitioners to produce more flexible, flat, seamless and three-dimensional products to truly present the aesthetics of Thai silk waste through the knit fabric.

Objectives of the research

The purposes of this research are:

1. To study the categories of a Thai silk waste.
2. To conduct an experiment of yarn spinning from Thai silk waste fibre.
3. To create a method to produce knitted fabric from the yarn of Thai silk waste.
4. To present the aesthetic values of new knitted fabric made from Thai silk waste through textures, colours, structure and pattern.

Scope of the study

This research focuses on added value to Thai silk waste that inspires by the environment-friendly design concept. Therefore, to achieve this objective, the scope of work is as follows:

1. Raw material study especially Thai silk waste, which is produced in Thai silk industrial in Thailand.
    1.1 Incomplete cocoons, specified Thai species
    1.2 Broken silk yarn
    1.3 Silk fabric waste
2. Study silk waste utilisation in Thailand and abroad, then adapt to experiment in Thailand academic laboratory. The laboratory location is:
    2.1 Rajamangala University of Technology Krungthep, Faculty of Textile Industry.
    2.2 Rajamangala University of Technology Phra Nakhon, Faculty of Industrial Textile and Fashion Design.
3. Spinning and knitting experiments are focus on hand method and machine method.
4. The experiment focused on the process that relates to the environment-friendly design concept.
5. The research will be present properties and aesthetic as a workpiece of yarn

and knitted fabric.

Research Methodology

This research focus on “practice based research and pure practice”. The methodology consisted of two part. The first part relates to the collection of information regarding Thai silk waste and its benefits. The second part concerns the experiment in order to determine a method and list of equipment for the production of knitted fabric through a craft and industrial process. The steps of the process relate to fibre preparation, spinning, dyeing, knitting, fabric testing and created a new yarn and knitted fabric.

1. Practice based is research in material, art and design.
    1.1 Identify properties and benefits of Thai silk waste.
    1.2 develop yarn and knitted fabric.
2. Pure Practice is synthesis and experiment in fabric development.

To experiment with knitted fabric from Thai silk waste and colouring by alternative technics and tools.

2.1 Material development
    2.1.1 Silk waste: Incomplete cocoons, broken silk yarn and silk fabric waste
    2.1.2 Dyestuff: Natural Dye
    2.1.3 Testing: Tensile strength bursting and Elasticity
    2.1.4 Standard: ASTM (American Society for Testing and Materials)
2.2 Knitted fabric development
    2.2.1 Equipment: Hand knitting, Domestic machine and Automatic machine
    2.2.2 Testing: bursting and elasticity
    2.2.3 Standard: BS (British Standards Institute)
2.3 Create a new yarn and knitted fabric.

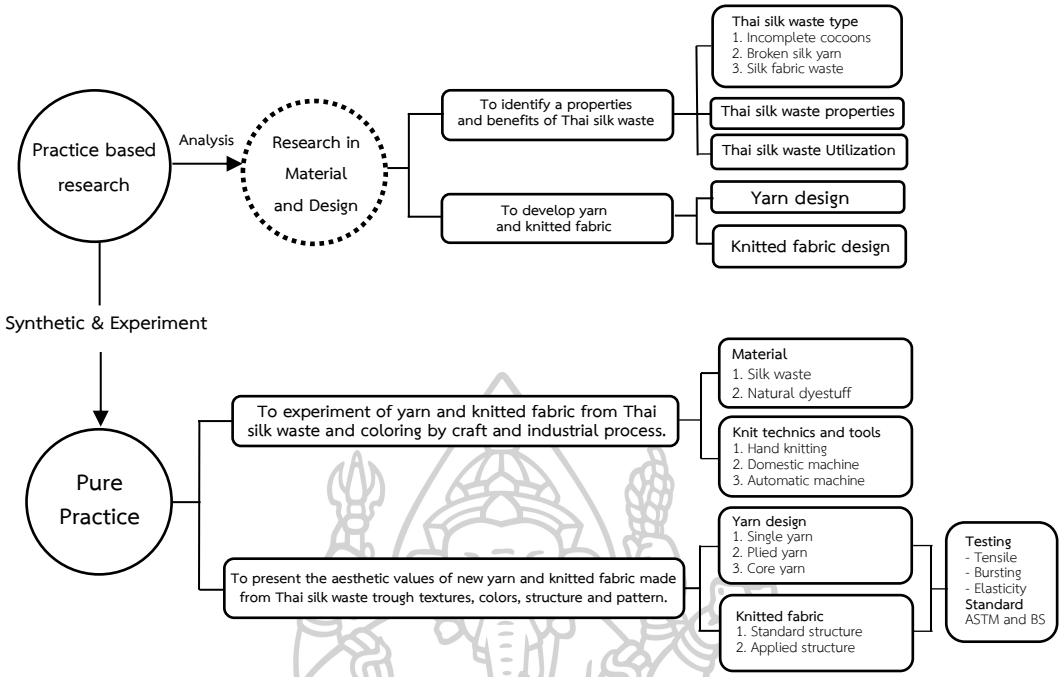


Diagram 1 Research methodology

Research outcome

1. The research can be shown that the waste from Thai silk industries can add value by produce into yarn and knitted fabric. That remains the unique characteristic: gummy, sticky substance and shiny.

2. The yarn and knitted fabric can be used in daily-life products and can be developed to advance purpose forward.

3. The expected result of the experiment was the suitable process and equipment that relate to environment-friendly design concepts, such as using natural materials, reducing production steps and energy.

4. The results from this study used as the information to villagers for small-scale production and also by the Thai silk industry. Moreover, it can be aid the recognition of the value of waste products from their business and thus assist in the reduction of environmental damage.

Dissertation Structure

Introduction of the research topic presenting, the research will present next to chapter 2: Literature review

Chapter 3 Research Methodology

Chapter 4 Design process

Chapter 5 Conclusions and Recommendation

Chapter 2
Literature review

Review of relate literature are consist of

Silk and silk waste

- Introduction of Silk
- A Definition and classification of silk waste
- The silk waste utilization
- Spun silk: machine spinning method
- Spun silk: hand spinning method
- Yarn type and yarn design by hand spinning method
- Silk dyeing: natural dye stuff

Thai silk and Thai silk waste

- Introduction of Thai silk
- Thai silk waste
- Thai Silk waste utilization
- Spinning Thai silk waste
- Natural dyes silk in Thailand

The knitted fabric

- Introduction of knitted fabric
- Knitted fabric types
- Knitting tools
- Knitted fabric structure and pattern
- Knitting and lifestyle product
- The sample of knitting lifestyle products
- sustainable knitted fabric
- Knitted fabric testing

Research relation

Summerry

Silk and silk waste

Introduction to silk

Silk is a natural fibre and was amongst the earliest fibres discovered by man with others being wool, hemp, linen and cotton. Silk is a fibroin made of proteins secreted in the fluid state as single filament by a caterpillar, popularly known as 'silkworm'. These silkworms feed on selected food plants and spin cocoons as a 'protective shell' to perpetuate their life. A silkworm has four stages in its life cycle viz., egg, silkworm, pupa and moth. Man interferes this life cycle at the cocoon stage to obtain the silk, a continuous filament of commercial importance, used in the weaving of the dream fabric. (International Sericulture Commission, 2017)

J. Wilson (2011, 6) classified silk into three types, they are;

1. Tussah silk, it is a cultivated from ‘wild’ silkworms.
2. Cultivated silk, it is a farmed silkworm (sericulture).
3. Organic silk, it is farmed from silkworms which are allowed to emerge from the cocoon before processing

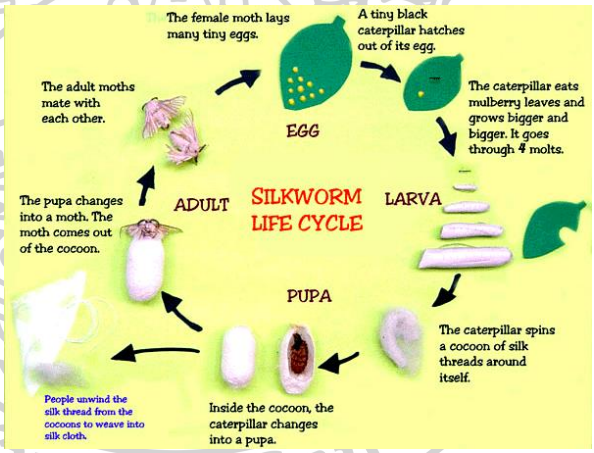


Figure 1 A silkworm life cycle. (Sangita Srivastava, 2012: 69)

Figure 2 The silkworms (left) and cocoons (right).
(Clive Hallett and Amanda Johnston, 2014: 116)

Silk has several natural properties that make it distinct from all other fibres both natural and man made (International Sericulture Commission, 2017). It is composed of two protein groups, forming respectively the fibroin and the sericin. In the fibroin, alanine and glycine together account for 70 % of the total composition, whereas in the sericin they make up about 15 %. The chief component of sericin is another amino acid, serine (30 % of the total). (Robert R Franck, 2001: 10-11)

– Silk is the only natural fibre which exists as a continuous filament. Each Bombyx mori cocoon can yield up to 1600 metres of filament. These can be easily joined together using the adhesive qualities of sericin to form a theoretically endless filament.

– The silk fibre's triangular cross-section gives it excellent light reflection capability.

– The silk fibre is smooth, unlike those of wool, cotton and others. This is one of the reasons why silk fabrics are so lustrous and soft.

– Silk can absorb up to 30 % of its weight in moisture without creating a damp feeling. When moisture is absorbed it generates 'wetting-heat' which helps to explain why silk is comfortable to wear next to the skin.

– Silk has a tenacity of approximately 4.8 grammes per denier, slightly less than that of nylon.

– Silk has poor resistance to ultraviolet light and for this reason is only recommended for those curtains that are lined or not exposed to direct sunlight.

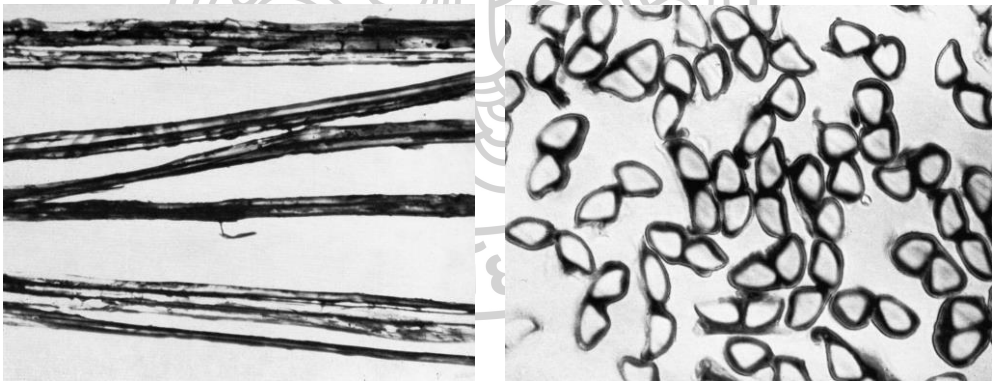


Figure 3 The silk fibre coated with the gum sericin.(left) and Silk fibre cross section.(right) (J. McLoughLin and S. hayes, 2013: 8)

Silk has been considered one of the most elegant and luxurious of fibres. It is still recognised as such all over the world. It is called "the queen of all textile fibres" (Sangita Srivastava, 2012: 63). Over the centuries, silk has been regarded as a highly valued textile fibre. Its qualities of strength, elasticity, softness, absorbency, affinity for dyes and adaptability to various forms of twisting continue to meet various applications (K. Murugesh Babu, 2013: 1-2). Silk is very fine fibre with translucent filaments and encased by a protein called sericin which enables the fibre to withstand

prolonged exposure to weather, making the fibre very weather resistant due to this coating of sericin. (J.McLoughLin and S. hayeS, 2013: 7). It has a natural sheen, and inherent affinity to rich colours, high absorbance, light weight yet stronger than a comparable filament of steel, poor heat conduction that makes it warm in the winter and cool in summer, low static current generation, resilience and an excellent drape (International Sericulture Commission, 2017: n.p).

Silk fabrics have been the fashion designer's frequent choice, but silk has remained the designer's dream because it possesses a magnificent, shimmering richness that can express a lush, sumptuous personality when woven into precious satins, jacquards, and brocades. It is also capable of a sensuous, supple, liquid drape that will be forever associated with the ultimate in luxurious lingerie and glamorous evening wear. The lush optical qualities of silk moiré are showcased in this late-nineteenth-century corseted evening dress by Mae Primrose, from the Victoria and Albert Museum collection. The distinctive "watermark" effect that characterizes this fabric is achieved by pressing the ribbed construction of the silk weave with heated rollers. The bow on the bustle of the gown highlights the exceptionally crisp and sculptural quality of the fabric, and a peacock blue and emerald green duchesse silk satin ensemble by Haider Ackermann conveys the incomparable luster and structural properties of couture-quality silk. That presented in figure 5. (Clive Hallett and Amanda Johnston, 2014: 105 and 123)

Figure 4 The natural silk yarn-dyed (researcher's photo: 2 April, 2017)

Figure 5 The late-nineteenth-century corseted evening dress by Mae Primrose (left) A peacock blue and emerald green duchesse silk satin ensemble by Haider Ackermann conveys.(right) (Clive Hallett and Amanda Johnston, 2014: 123)

A Definition and classification of silk waste

Hollins Rayner (1903, 36-41) mention the term “silk waste” as it covers all classes of the raw silk which are unwindable and altogether unsuited for the throwing process. Here are some of the most common methods of waste production.

1. The silkworm commences to spin its cocoon by first fastening itself to the twig of a tree or between two leaves. Where the worm is reared by the peasants in their cottages, the peasants use straws, to which the worms attach themselves. All this silk is unwindable, coarse, and uneven, and consequently of no use to the throwster. Naturally this first waste is very much mixed with straw and leaves, and is of a dull, lustreless nature.

2. The cocoons are made up of layers of silk, and the outside ones, or the first spun by the worm, are too coarse and uneven for reeling, so the outer coating is stripped off and cast aside as waste.

3. As the silkworm nears the completion of its cocoon, the thread becomes finer and finer, insomuch that several of the last layers are made up of silk too fine to be strong enough to unwind, so that after the better or middle layers are reeled from the cocoon, the remaining part is discarded as useless for further reeling

4. Among the cocoons there are some which are altogether un- suitable for reeling, included among which are the pierced cocoons. Although of no use for reeling, they are very acceptable to the silk waste spinner.

5. During the process of reeling from the cocoon into hanks or skeins, the silk sometimes breaks, and in consequence there is waste made by the attendant in finding the true and sound thread.

6. Waste is produced in reeling tsatlees into re-reels.

7. All the wastes produced in the throwster's mill, are described fully under the heading “Throwing."

F. R. McGowan, Charles W. Schoffstall, and A. A. Mercier (1924, 582-583) define silk waste as all waste from the operations in preparing the true silk fibre that results in some waste. It is described and classed as follows:

1. Fibres which can not be used in the reeling process:

1.1 Blaze. The first fibre produced by the silkworm when the cocoon is being made is known as blaze. They are fine in texture, weak, and wrapped loosely around the cocoon.

1.2 Imperfect cocoons which can not be reeled commercially

1.2.1 Double cocoons: Cocoons which have not been properly constructed.

1.2.2 Feeble cocoons: Cocoons which have not been developed properly on account of sickness of the worm.

1.2.3 Pierced cocoons: Cocoons from which the chrysalis has emerged, causing a small hole. These usually result from breeding when the worm is permitted to emerge for reproduction purposes.

1.2.4 Piques and rates: Cocoons which have a hole eaten by moths or rats.

2. By-products of reeling process of cocoons:

2.1 Frisons or knubs: the fibres which are brushed from the cocoons until the thread which unwinds properly is found.

2.2 Bassinets and pelettes are partly reeled cocoons which, because the filament on the inner layers of the cocoon is fine and weak, break during the reeling process and drop to the bottom of the basin. Bassinets contain 20 to 45 percent and pelettes contain 12 to 20 percent of the original weight of silk on the cocoon.

2.3 Frisonettes or crapauds.—Small silk mills frequently combine frisons, bassinets, and pelettes under the name of frisonettes. The value of the lot depends on the proportion of each of these kinds present.

3. Wastes produced in reeling, winding, throwing, and weaving of raw silk are called, variously, bourres, bourettes, gum waste, and winders' and throwsters' waste.

K. Murugesh Babu (2013: 48). describes waste cocoons as consisting of

1. Waste from cocoons: floss, spelaia (Italian), discarded cocoons, pierced cocoons, double, stained cocoons, etc.;

2. Reeling waste: cooker's waste, reelers' waste, basin re-use or boiling off waste

3. Thread waste: re-reeling, winding or throwers' waste, weaving waste (hard waste).

Sangita Srivastava (2012, 71-72) said that during the process of reeling large quantities of silk waste are obtained. This is composed of inner and outer layers of cocoon which are removed during reeling. In local hybrids 20 to 30% silk comes as waste. The silk waste is divided into three parts:

1. Blaze and unreelable cocoons.
2. Reelable waste.
3. Throwesters waste.

Before spinning a cocoon, the larva builds a hammock an anchorage to hold its cocoon. These are the first threads secreted by the silkworm, when it mounts a cocoonage to form its cocoon. The quality is poor and the quantity is small, but it can be used for noil spinning. Some wastage occurs while finding the end of cocoon filament before reeling. This is known as Knubbs or Kibizzo, although the term basically refers to reeling waste in respect of univoltine quality.

Figure 6-7 show various types of silk waste, diagram 1 show the silk waste statement in silk industry.

Figure 6 The cocoon blaze. (left) (The National Institute of Sericulture Queen Sirikit, 2008: 66), A sample of unreelable cocoons.(center) (Naoko INOUE, 2014:5) And The Silk niol (right)(researcher's photo: 24 Mar, 2015)

Figure 7 The Knubbs or Kibizzo. (left) (Green Glossary : 19 Jan, 2018), The throwesters waste.(center), and The silk thread waste. (right) (researcher's photo: 24 Mar, 2015)

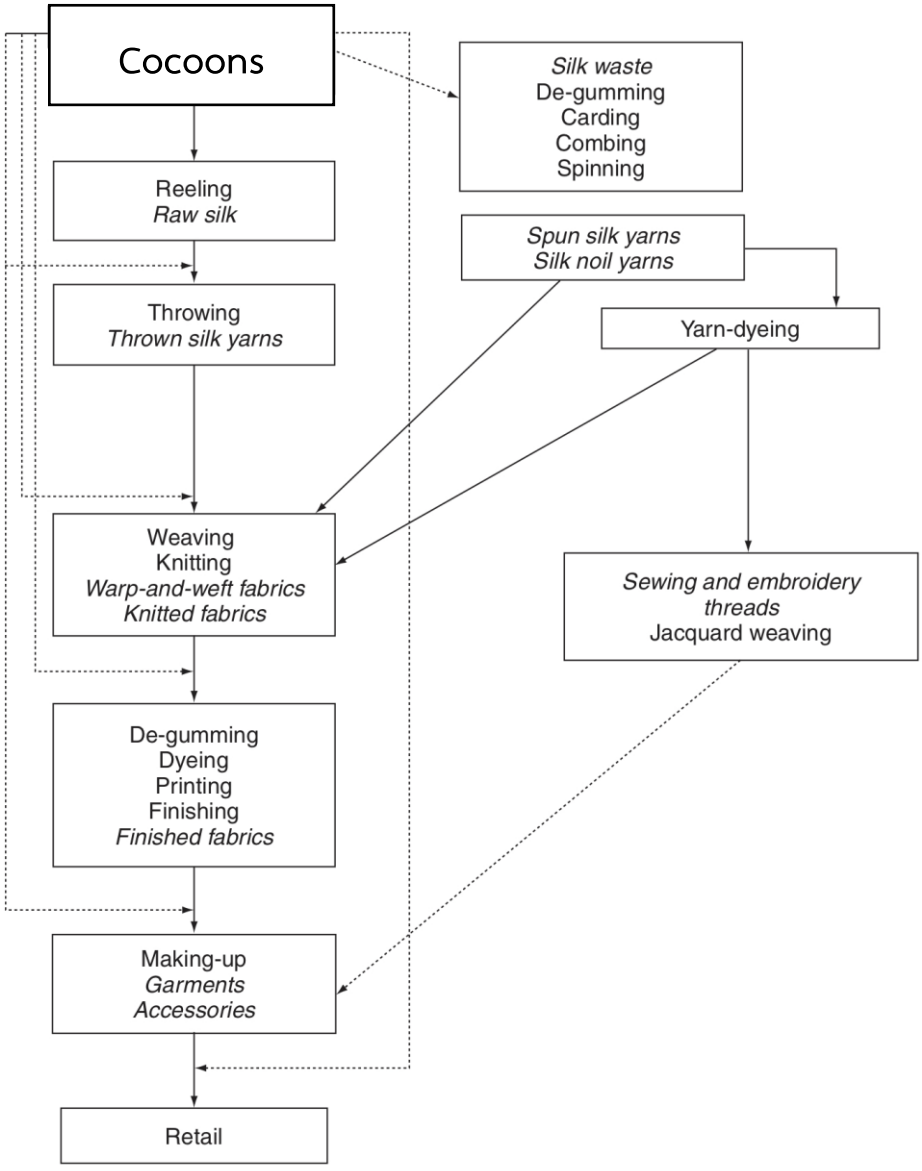


Diagram 2 the silk waste statement in silk industry. (Robert R Franck, 2001: 12)

The silk waste utilization

As mentioned before the waste from the silk industry can be classified in to three types. There are waste from cocoons, reeling waste and thread waste. J. Gordon Cook (2006: 156) mentions that waste silk is much too valuable to throw away. It can be used for making the yarn we know as ‘spun silk’.

Spun silk is a yarn consisting of fibers from partly degummed silk waste, usually bound together by twist. These yarns are used for making scarves, ties, velvets and pile fabrics, woven dress materials, knitted goods, lace, shirts and a variety of union fabrics.

Figure 8 Knitted and weave fabric from spun silk waste. (left) (Sara Lamb, 2014: 129) and A various product from spun silk waste. (right) (spunsilkworld, 2018)

K. Murugesh Babu (2013:52) describes silk waste or floss that is used in making spun-silk yarns for the manufacture of lining silk, knit goods, hosiery, mufflers, cheap silk neckties, coarser qualities of sewing thread, pile fabrics, elastic webbing and certain kinds of dress goods, and are mixed with wool for particular effects. Spun silk is also used in the manufacture of lace and embroidery but is less fine and stronger than reeled silk. The best grades of spun silk yarn are used as filling or weft in several varieties of silk fabrics, both plain and twill, and in pile goods such as velvets. High-grade spun-silk yarn is also used as warp in goods that have a cotton or wool filling. A considerable amount is also used in the production of embroidery and knitting silks. Lower grades of spun-silk yarn are used in making ribbons and silk cords, while the cheapest grades are used to make knitted goods and coarser silk or silk-mixed fabrics. The poorest grades of spun silk, which are carded rather than combed, are used as filling in cheaper grades of silk dress goods, silk upholstery fabrics, polishing cloths and coarse grades of knitted goods.

Spun silk can be done by both machine and the hand spinning method. The fibre preparation is very important for spinning. It can be done by following these steps.

1. Degumming, it is the removal of the serecin from cocoons. The process consists of placing a broken silk cocoons and waste fibers in through a series of degumming baths consisting of very hot water, detergent or cleaning agent, and an alkaline substance that helps soften and dissolve the serecin.

Moreover, J. Gordon Cook (2006: 156) refers to the English process of degumming where the gum is removed by boiling the silk in soapy water. This

dissolves the sericin and leaves a clean, smooth filament. The Continental process uses a fermentation technique, and about 20 percent of the gum remains on the silk.

Figure 9 Degumming cocoons (left) and the result (right) (researcher's photo: 28 May, 2016)

2. Cocoons are mechanically torn apart and aligned on a large drum cylinder fitted with sharp teeth; similar to carder cloth, until a sufficient quantity is wound onto the cylinder. This preparation, called a lap, is then removed and sent to a machine that further draws out the fibers and cuts them into uniform lengths for further preparation. Filament waste fibers do not need to go through this process.

3. The aligned fibers are put through a combing process that chops the fibers at random, then sorts and straightens them and removes any remaining bits and pieces of cocoon and other foreign matter. The first pass through the equipment produces Grade A-1 fiber. Many passes through the process may be required before a batch of fiber is completely cleaned and aligned. Each subsequent pass produces sheets of fiber with a shorter and shorter length. The sixth or seventh sheet contains only very short fibers that are considered of lesser grade.

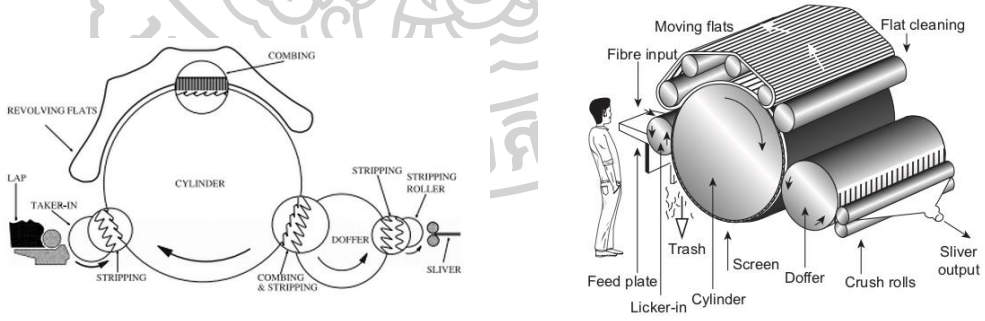


Figure 10 Setting of Carding Machine. (left) (TextileLearner, 2017) and Carding Machine. (right) (I.A. Elhawary, 2017: 195)

4. The combed sheets of silk are passed through a series of belts and toothed cloth that attenuate them in to a thin film. The film is then wrapped around a metal core that's pulled through another machine in which the fiber is drawn into top, or sliver, which is the most common preparation available to spinners. (Sara Lamb, 2014: 37)

Figure 11 Silk fiber is available in many forms, including top (left), folded into a brick (center), or in laps (right).(Sara Lamb, 2014: 38)

Spun silk : machine spinning method

After fibre preparing, the silk waste fibre in various forms such as top, sliver and lap are subjected to processes similar to those used for wool, cotton and other short-staple fibres. Generally, the spinning method that are available in making yarn include ring-spun, rotor-spun, twistless, wrap-spun and core-spun yarn (R. Alagirusamy, A. Das, 2015: 161). However, K. Murugesh Babu (2013, 51) suggests to ring spinning process to spin the silk waste fibre . R. Alagirusamy and A. Das (2015: 176) describe the conventional steps for processing staple fibre into spun yarn consists of opening, carding, drawing, combing, roving and spinning. The details are as follows:

1. Opening: This is the basic operation in the spinning of yarn from raw fibres. Opening is the process of reducing compressed cotton fibres from a bale into smaller-fibre tufts. It removes the particles of dirt, dust and other impurities by using spiked rollers. After this process the fibre will be transferred to another process.

2. Carding: After blending and opening, loose fibres are transferred to a carding machine. Carding is performed by opposing sets of teeth or small wire hooks known as card clothing, which cover the machine parts and include a licker-in, a cylinder, revolving flats and a doffer. The cylinder and the flats may rotate in the same or opposing directions but at different speeds to tease the fibre tufts into a thin, filmy web, which is then collected into a loose rope-like structure called a sliver, which is often coiled, and deposited in cans. Carding further opens the fibre tufts and extracts any fine particles, neps and short fibres enclosed by the fibre aggregates. The drawing frame uses a series of rollers arranged in pairs and rotating at different speeds. Slivers are passed between the rollers and combined. The fibres will be well parallelised and mixed after going through this process.

3. Combing: Combing is the process used to remove short fibres and neps from sheets of silk waste fibres (lap). A roller with fine-toothed elements fixed on a half-lap is used. The amount and length of the short fibres extracted will depend on the combing parameters selected. The fibres will be straightened and paralleled during this process.

4. Roving: In this process, slivers are reduced to around one-eighth of their original diameter by three pairs of rollers, rotating at different speeds. The required

level of twist is also imparted to keep the rovings stable under the stretching caused by winding and unwinding.

5. Ring spinning: The conversion of roving into yarn is called the spinning process. This is usually done in a roller drafting system that will have some means of fibre control, such as a double apron. Twist is imparted to the fibre strands to prevent slippage through the ring and traveller. The yarn is then wound onto suitable bobbins known as ring cops for further processing.

6. Finishing is the process to produce a yarn that is suitable for final use in a product.

There are a number of processes involved in finishing, including:

6.1 Doubling: Two or more threads are combined to make weaving or sewing threads respectively. After doubling, a second twist is imparted by the throwing machine, the number of turns varying with the properties required of the thread.

6.2 Gassing: The twisted yarn is then moved to the cleaning and gassing frame where it passes through a gas flame under friction obtained by winding the yarn round a number of runners. It is passed repeatedly through the flame at a speed of 500–600 mpm. The friction imparted by the runners helps to eliminate neps, other impurities and weak areas in the thread, while the flame burns away protruding fibres and imparts a gloss to the silk. Any adhering burnt particles are removed from the thread by passing it between rotating steel rollers in a process termed as cleaning. These gassing and cleaning operations are performed by a single machine.

6.3 Reeling: The gassed yarn is then reeled onto frames (straight or cross reel) to form a hank. The hanks are dressed and folded in bundles which are press packed into bales ready for the market. The usual counts (metric) of yarn spun in Indian silk mills are 60, 140 and 210 s (two-fold).

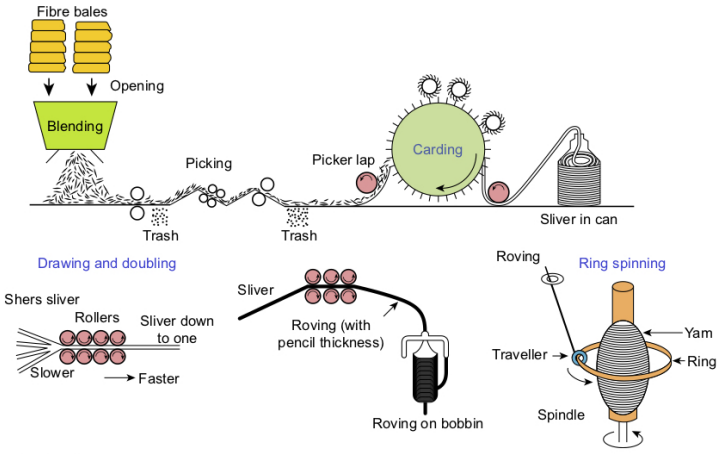


Figure 12 The ring spinning process (R. Alagirusamy and A. Das, 2015: 177)

Figure 13 Ring spinning machine (left) (Roxanna Cody, 2012: 10) and a sample of yarn from machine spinning. (Mathias Camenzind and others, ed., 2014: 13)

Spun silk : hand spinning method

1. The hand spinning equipment

1.1 Spindles

Spindles are an excellent portable choice for spinning silk. In its most basic form, a spindle is easily to add twist a fibre into spun yarn, call singles. As the yarn is spun, it is wrapped around the spindle for temporary storage. The yarn wrapped around a spindle is called a “cop”. It can knit with individual cops of singles, or spin two or more cops together to make plied yarn. As far as classifying spindles into types, there are two major families: drop spindles and supported spindles, and within each family there are several different types. (Shannon Okey, 1975: 21)

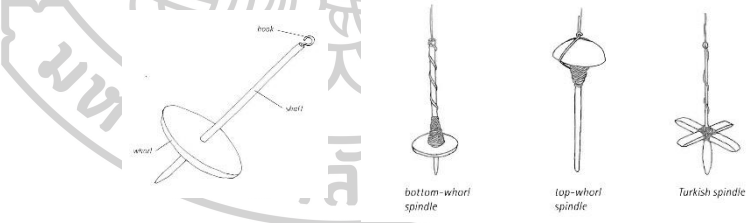


Figure 14 The basic part of a spindle (left), drop spindle family (right) (Shannon Okey, 1975: 21)

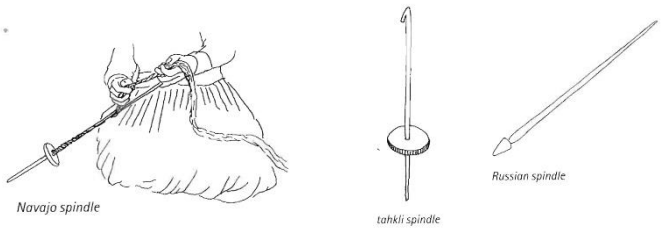


Figure 15 The supported spindles family (Shannon Okey, 1975: 22)

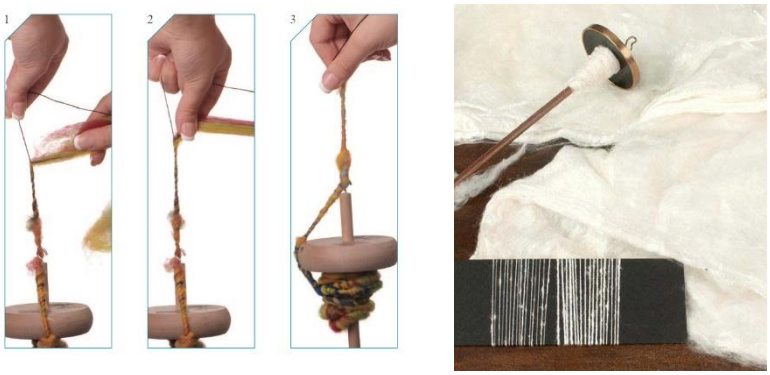


Figure 16 A sample of spindle spinning method. (left) (Ashley Martineau, 2014: 92) and A sample of spun-yarn from spindle. (right) (Sara Lamb, 2014: 72)

1.2 Spinning wheel

There are many types of spinning wheel. This research defines them into two types by different processes. There are Double-drive Wheels and Single-drive Wheels

1.2.1 Double-drive Wheels

Double-drive wheels use a single long drive band that turns both the bobbin and the flyer. In order for the yarn to be pulled onto the bobbin, there must be a difference in diameter between the groove on the bobbin and the groove of the whorl. The tension is adjusted by moving the entire mother-of-all, tightening or loosening the drive band. Many double-drive wheels can be converted to single-drive. Double-drive wheels are great for spinning very fine yarns, although they are capable of producing a wide range of yarns. (Amy King,1973: 39)

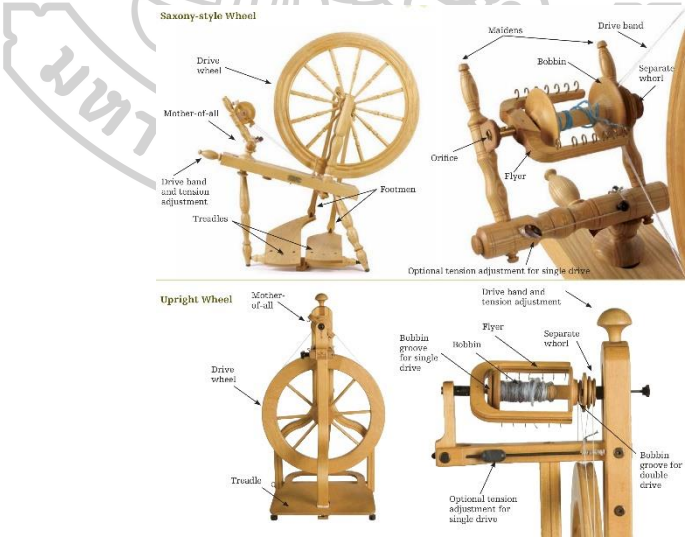


Figure 17 The structure and composition of Double-drive wheels: Saxony style wheel (top) and upright wheel (below). (Amy King,1973: 41)

1.2.2 Single-drive Wheels

On single-drive wheels, there is one drive band and one brake band. On Irish-tension (bobbin-lead) wheels, the drive band turns the bobbin and the brake band slows the flyer. Bobbin-lead wheels are excellent for spinning bulky yarns, though they can also create fine and medium yarns. On scotch-tension (flyer-lead) wheels, the drive band turns the flyer and the brake band slows the bobbin. Flyer-lead wheels are wonderful for spinning a wide variety of yarns. (Amy King,1973: 39)

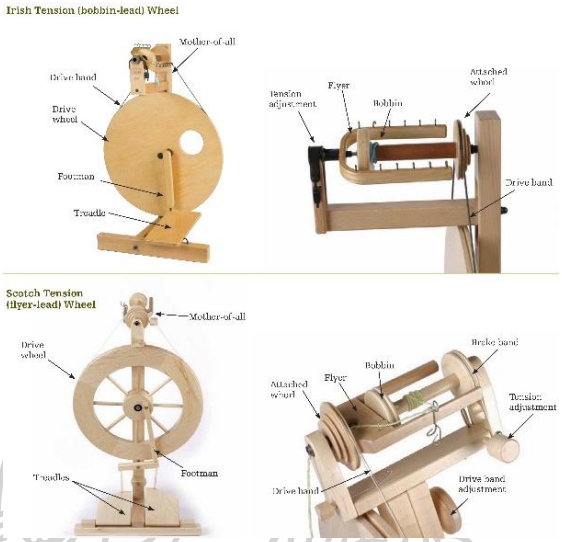


Figure 18 The structure and composition of single-drive wheels: Irish tension wheel (top) and Scotch tension wheel (below). (Amy King,1973: 42)

1.3 Yarn winder

After spinning, yarn winder is necessary for managing a yarn before knitting. A skein of yarn is placed on a collapsible swift, then the swift rotates as the ball winder is used to wind the yarn into a tidy center-pull ball. The parallel yarn is a result of flow feeding yarn into the knitting machine, making it easy to knit and give a neat fabric look.

Figure 19A swift rotate (left) and ball winder (right) (Shannon Okey, 1975: 7)

2 The fibre form classified

Both hand and machine fibre preparing could be used to create spin by hand. Fibre format is important to end use yarn and each form is different in its spinning method.

2.1 The class of fibre form to hand spinning

Sue Hiley Harris (Autumn 2009: 26-27) divides silk waste fibre into three categories and therefore three different approaches to spinning, the detail as follows:

2.1.1 The short and long fibre

1) The shortest fibres, there are silk noils and some form re-processed waste that are as short as one centimetre. Fibres of this length and up to approx 6 cm can be spun by the long-draw woollen spinning method.

2) The Long fibres are classed as being from seven to eighteen centimetres. There are combed silk top, such as roving and sliver. It can be spun by the worsted spinning method.

2.1.2 Silk throwsters. Silk batts and lap can be cut to appropriate lengths for woollen or for worsted spinning depending on the required character of the yarn and the end use.

2.1.3 Silk mawata, caps or squares. It is very long, virtually continuous fibres, that require specific preparation and spinning method.

2.2 Worsted yarn and wooden yarn

2.2.1 Worsted yarns is the traditionally spin from combed top. These are best for hard-wearing garments like socks and mittens. They tend to pill less, are less fuzzy, and last longer than woolen yarns.

2.2.2 Woolen yarns are made from airy carded preparations. These trap a lot of air between the fibers making them great insulators. Woolen yarns make warm hats and sweaters. They tend to pill more and wear out faster, so they’re best used for garments that won’t get hard wear. To spin a woolen yarn, choose carded fibers, which include rolags, batts, and roving. (Amy King,1973: 22-23)

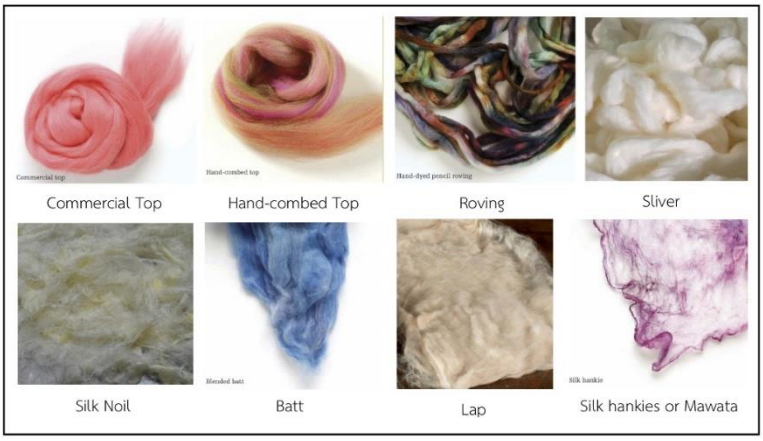


Figure 20 The sample of fibre forms for hand spinning.

3. Spinning silk noils

Silk noils is the short fibres that are combed out of waste silk during the production of combed tops, are predominantly the fine broken fibres from the centre of the cocoon. Silk noils require carding into rolags before spinning. Sue Hiley Harris suggest to use curve-backed leather carder ones with flexible teeth. Then transfer into rolag by rods or knitting needles.

The instructions for carding silk noils into roll form are present as pictures below:

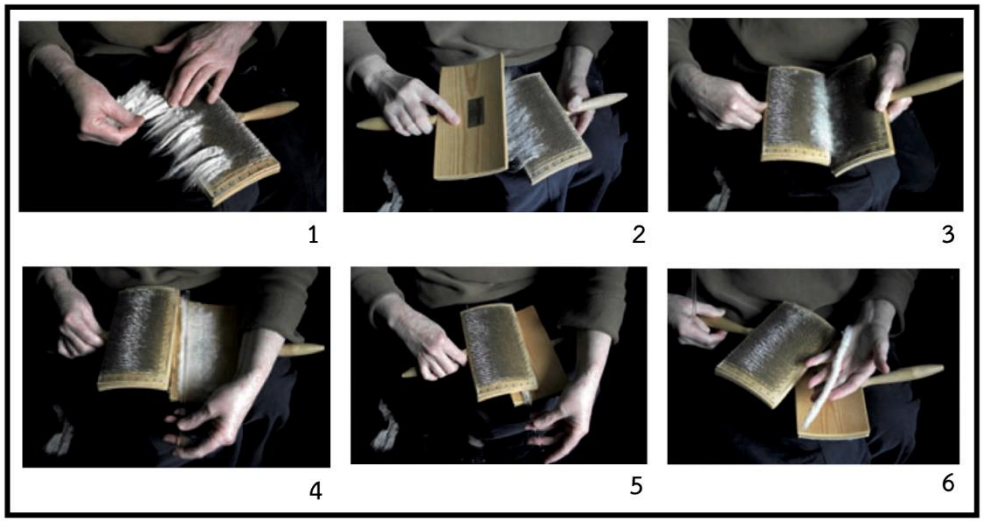


Figure 21 The silk noil carding process (Sue Hiley Harris, 2009: 27).

1. Place the noils in a row on the teeth along the edge of left carder furthest away from the handle.
2. Card with the right carder using only the teeth holding fibre.
3. Transfer the silk from the right to the left carder so that the two layers of noils are one on top of the other
4. Using a dowel rod or knitting needle roll the fibres into a rolag.
5. Smooth the surface of the roll rolling it between the two carders.
6. The resulting roles should be well formed and firm but not too dense.

The method of spinning rolag can be done by pulling each end of a rolag and then feeding it into the spinning machine the same as spinning top and lab that will be shown in the following paragraph:

4 Spinning top

Top is the most refined of the silk preparations to spin, whether it's cultivated or wild silk in origin. It's the final form before machine spinning, and it has a smooth, uniform appearance. Even top can contain chaff, threads, strings, and bits not removed during fibre processing, so some hand picking might be necessary as you spin. During mechanical spinning, top is wound through a series of rollers that move at different speeds to attenuate it further. This process allows the machinery to spin a smooth uniform yarn from the end of the top. Although this method works well for mechanical spinning, the spinning procedure is as follows:

4.1 The first step is to break a small amount of top or brick from the continuous preparation and open it gently by pulling on both ends with your hands. Gently pull the fiber bundle until the fibers begin to slip and loosen the compacted fibers for drafting.

4.2 Fold the fiber bundle over the index finger of your fiber hand.

4.3 Insert twist as you draft back, keeping an eye on the drafting zone to ensure a uniform amount of fiber is drawn into the yarn.

4.4 Hold the folded bundle in your hand instead of over the tip of the finger.

4.5 Attenuate lumps by retarding the twist while drafting back.

4.6 Allow the twist to enter the attenuated fibers.

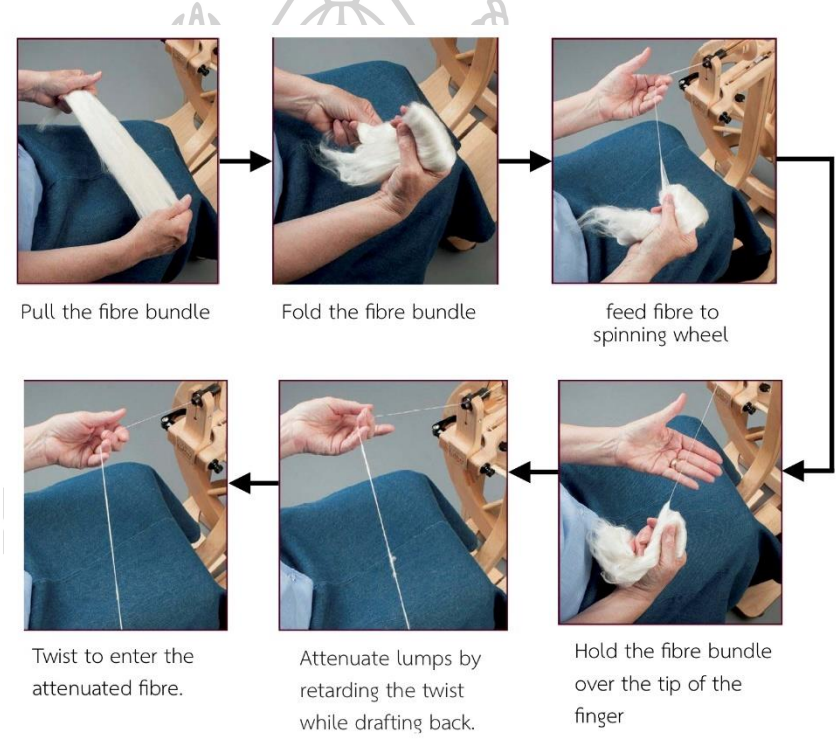


Figure 22 Spinning silk top process. (Sara Lamb, 2014: 66-69)

5. Spinning lap

Laps are loosely carded or combed fibers in batt form. Laps include the fibres that remain on the mechanical carders after the first tearing apart and opening of the waste cocoon. These preparations contain semiparallel fibres and often include a lot of small foreign bodies and other inclusions bits of cocoon and vegetable matter, stiff and soft threads, and clumps of short fibers, nepps, or noils. Laps are typically further processed into bricks or top. The spinning detail are as follows:

5.1 Pull a small amount from the lap.

5.2 Hold the fibres loosely as the twist pulls them into the forming yarn.

5.3 Retard the twist with your forward hand.

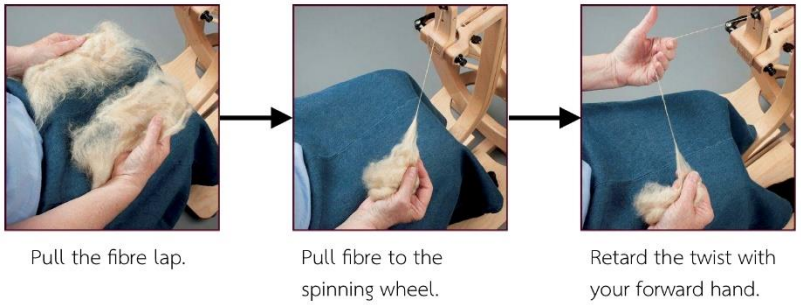


Figure 23 Spinning silk lap process. (Sara Lamb, 2014: 66-69)

6 Spinning silk mawata

Mawata was first found in Japan. Dorothy Miller (1986, 132) explains that before World War II Japanese women spun, or rather twisted through their finger. The silk fibres are drawn out from mawata. It is the outer fibres of the cocoon which are broken and the threads cannot be reeled. The fibres are pulled out into the shape of a handkerchief and spread between pegs on the top of a holder, a disk of wood into which pegs or nails are pounded. After that, women pull out the long fibres and wets her hands. Then she puts a twist in, inch by inch, to make a continuous thread.

In addition, Chasing Rainbows Dyeworks (2017) mention, the Japanese name mawata, pronounced just like it looks. It means expanded cocoon. According to oral or literature tradition, in the era of Emperor Sujin, the process of expanding boiled cocoon by hand was called “Mawata-kake”. This was the first step in the procedure of making the silk fabric called Yuki Tsumugi. Yuki Tsumugi was inscribed on the Representative list of the Intangible Cultural Heritage of Humanity UNESCO for its artisan work traditions which have been passed down from generation to generation. Yuki Tsumugi is still hand-made through these delicate artisan works in the middle of Kanto Plains, situated at the border between Ibaraki and Tochigi prefectures. (The Journey of Authentic Japanese Silk, 2016).

The mawata production and spinning are as follows:

6.1 Material and equipment consists of baking soda 12 grams (4 grams / 1 liter of hot water) , Water 3 liter (3 times the amount of cocoon), pot or kettle, electric or gas cooker, inside lid / weight, cloth bag (thick gauze), ginkgo, chopsticks and lining frame (crate)

6.2 The process to make the cocoon into mawata involves degumming, expanding into hankies, then hanging out to dry. The detail of process is as follows:

Figure 24 The mawata production. (Japan Floss Silk Association, 2016)

1. Soak cocoons in water about one hour.
2. Place a weight to floating protection.
3. Place the baking soda in boiling water.
4. Put the bag go cocoons in the pot.
5. Boil about one hour, reverse the cocoon bag from top to bottom.
6. Rinse baking soda and wastewater util clear water.
7. A boiled cocoon (degummed).
8. Remove pupa out of cocoon.
9. Immerse the cocoon in water and extend it with left and right hands.
10. Hang cocoon on the wooden frame.
11. Place cocoon util four layer.
12. Remove cocoon Hanky out of the frame.
13. Fold and squeeze to clear water off.
14. Hang to dry in shade and airy.
15. The finished mawata. Medium size 38.5 × 38.5 cm, about five grams.

6.3 The Japan traditional method to spin Mawata

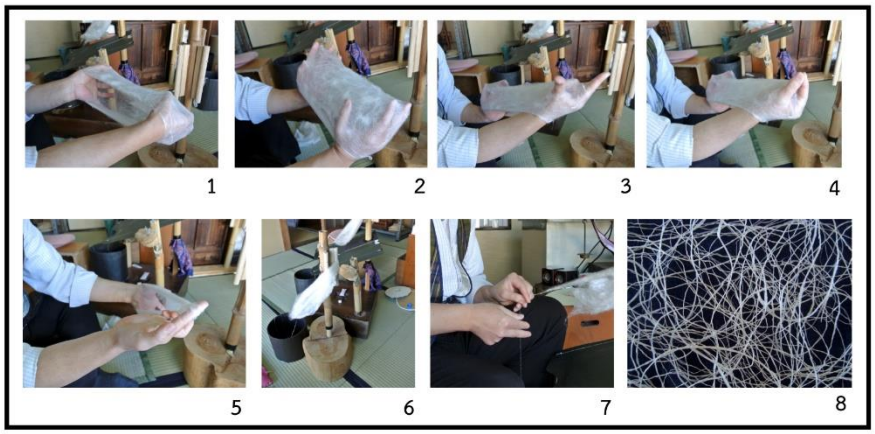


Figure 25 A presentation of mawata spinning at Yuki City, Ibaraki Prefecture; Oyama City, Tochigi Prefecture, Japan. (Researcher's photo, 2016)

1. Explaned a stack of mawata into cap shape. 2. expands a cap
3. Use forefinger and thumb make a hole 4. close finger together
5. tern the hand away from cap, pick-up a hole mawata by forefinger. Then,hook the hole to spinning tool. 6. reel mawata into spinning tool
7. Pull and twist, inch by inch, to make continuous thread. 8. A yarn from mawata.

6.4 The hand spinning wheel method

Figure 26 Spinning silk Mawata process (Amy King, 1973: 35).

1. Peel a single layer of silk from the stack. 2. Make a hole in the center and stretch it wide.
3. Draft the fiber to the desired thickness. 4. Wind the fiber into a nest and spin.

Figure 27 A sample of yarn from hand spinning: The noil top (left), the small neps or noils show up in the yarn as bumps of texture (center and right). (Sara Lamb, 2014: 80)

Yarn type and yarn design by hand spinning method

1. The yarn types

A spun yarns consist of staple fibres combined by spinning into a long, continuous strand of yarn. The key elements of a staple yarn are content, fineness and length, yarn ply and twist. There are many ways of creating a staple yarn from groups of fibres. Typical yarn formations include:

1.1 Single yarn, it is fibres combined into a single yarn.

1.2 Ply/ plied yarn, it is two or more yarns twisted together.

1.3 Cabled / corded, it is several plied yarns twisted together.

1.4 Blended / compound, it is different fibre types combined in a yarn.

1.5 Core spun, it is a yarn with one type of fibre, usually a lament, in the centre (core) of the yarn, which is usually covered (wrapped) by staple fibres.

1.6 Fancy or effect yarns, these are yarns with special effects or deliberate irregularities, such as slubs (thicker portions) or loops occurring regularly or randomly along the length of the yarn) (R. Sinclair, 2015: 8)

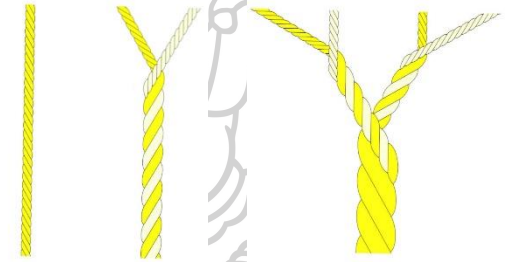


Figure 28 Single yarn (left), ply yarn (centre) and corded yarn (right) (Rob Thompson and Martin Thompson, 2014: 61).

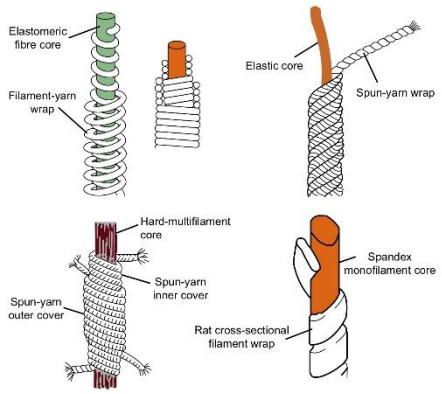


Figure 29 A different types of covered yarns (R. Alagirusamy and A. Das, 2015:175).

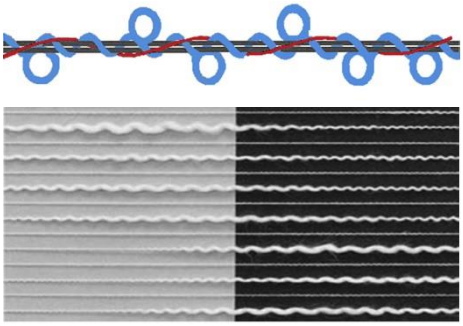


Figure 30 A structure of loop yarn (top) and slub yarns (bellow) (R. Alagirusamy and A. Das, 2015:175).

2. The direction of yarn twist.

The direction in which the yarn is spun is called twist. Yarns are characterized as S-twist or Z-twist according to the direction of spinning. Tightness of twist is measured in TPI (twists per inch or turns per inch). Two or more spun yarns may be twisted together or plied to form a thicker yarn. Generally, handspun single plies are spun with a Z-twist, and plying is done with an S- twist. (Roxanna Cody, 2012: 68)

Figure 31 The S and Z yarn twist direction. (Roxanna Cody, 2012: 67).

Yarn twist as it relates to yarn measurement is called yarn count. The count number of a yarn indicates the length of yarn in relation to the weight. The linear density is measured rather than the width of a yarn to take into account irregular yarns.

Spun silk yarn are defined by counts in the same way as cotton yarn. The count is the number of hanks, each 840 yards (756m) long, that will weigh 1 lb (454g). (J. Gordon Cook ,2006: 156)

$$\text{Cotton count } (Ne_C) \text{ or (Hank) or } (^{S}) = \frac{\text{(7,000 grain) or (1 pound) x Length (yard)}}{\text{weight (grain or pound) x 840 yard}}$$

Example

Length of the sample = 150 yard

Unit of weight (1 kilogram) or 1,000 grams = 2.2 pound

Unit of weight of the sample 50 grams = (50x2.2) / 1,000 = 0.11 pound

Cotton count (Ne_C) or (Hank) or (^{S}) = $\frac{\text{1 pound x 150 yard}}{\text{0.11 pound x 840 yard}}$

Cotton count (Ne_C) or (Hank) or (^{S}) = 1.6 or 1.6^S

A yarn direction has an effect on the fabric characteristics, as the sample fabric spinning singles Z, or left, and it will lean to the right when knitted (as in the green sample). And when it has an S spin, or right spin, it will lean to the left (as in the peach sample). Thus, to counteract the biasing, knit through the back loops (even in ribbing) or work in garter stitch, knitting with two opposite- twist singles held together, the fabric will lie straight.

Figure 32 A sample of the knit fabric from Z yarn twist direction (left), S yarn twist direction (centre) and a fabric knitting through the back loops (even in ribbing) or work in garter stitch (right)(Amy King, 1973: 69).

3. Yarn design

3.1 Single yarn

Single yarn is a fibre combined into a single yarn. Spinning single yarn by hand can produce a variety of sizes, textures and forms by the following methods:

3.1.1 Energized singles

Energized singles can be spun in any weight and direction: wooden and worsted, that relate to end-use product. To make energized singles, set a wheel for a moderate amount of twist: a ratio between 12:1 for a thicker yarn and 22:1 for a finer yarn.

3.1.2 Low-twist singles

Low-twist singles need less than one twist per inch for thicker results. For all low-twist singles, adjust your wheel for a faster uptake and lower twist ratio than you would use to make energized singles or yarns for plying. Do not hold onto the yarn for so long that a lot of twist builds up; let it feed onto the wheel fairly quickly. The suitable material is airy fibres that easy draft whether to draft thin or thick. Strip down the fibre and feed it onto the wheel without drafting, it can make a heavy, dense yarn.

3.1.3 Thin low-twist singles

With thin low-twist singles aim for about two to three twists per inch. This yarn is excellent for lace. It's difficult to find from commercial sources, so you have the opportunity to make something unique. The basic process to make it is the same as for other low-twist yarns—use strong draw-in to add less twist. It is especially important to use airy, easily drafted fibres.

Figure 33 A sample of thin low-twist single yarn (left) and knitted fabric from low-twist single yarn (right) (Amy King, 1973: 71).

3.1.4 Marled singles

This yarn is a two-ply made with two different-coloured singles. Both sources should be the same kind of fibre prepared in the same way. Thus, do not choose one fibre from top and one from a batt; they will be hard to draft together evenly. Your goal is to draft them at the same rate, keeping the fibres side by side without having sections that are all one colour.

3.1.5 Thick-and-thin singles

This highly textured yarns could easily fit in the novelty category, but they are basic singles. Thick-and-thin singles can even be made with more than one kind of fibre and are very freeing to make. Spin without any predrafting, use a fibre that is a bit grabby and resists drafting out smoothly. Then, feed the fibre into the orifice fairly fast and keep the twists per inch low so this can create thinner and thicker spots.

To make this yarn is spinning with draft, pull the fibre forward unevenly to create clumps, sometimes drawing in front of the drafting triangle, sometimes from behind it. The twist will run toward the thin spots and leave the thicker areas with less twist.

Figure 34A sample of Marled single yarn (left) and Thick-and-thin single yarn (right)(Amy King, 1973: 73-74).

3.2 Plied yarn

Plied yarn is a product of single yarn twist together. The basic plied yarn is two-ply, it tends to be flat instead of round. The most common commercial two-ply is lace yarn. The flatness and little nubs along the edges help grab the stitches and hold the lace together. Moreover, three or more-ply yarn is not more different in principle from making two-ply yarn. These produce a unique yarn to make various fantastic end-use products. Plied yarn can be made into several form as follows:

3.2.1 Lace two-ply

The worsted spinning style makes the thin yarn more durable and gives the best stitch definition. While woolen spinning style makes lace yarn for airy garment with lots of halo.

3.2.2 Brushed two-ply

This yarn is similar to some commercial yarns that are marketed as mohair lace yarn. It produce by brushing yarn before plying, the sample of yarn as below

Figure 35 A sample of lace two-ply yarn (left) and A sample of Brushed two-ply yarn (right) (Amy King, 1973: 78 and 80).

3.2.3 Self-striping two-ply

This yarn is made from a handpainted top or roving. First, recognize the pattern in your fibre. Most handpainted fibre is dyed with a regular pattern or repeat. Break the fibre into pieces that have the same pattern and lay them out, split handpainted fiber lengthwise, keeping the two halves as even as possible. The samples have four roughly equal pieces; for a two-ply yarn, that gives two sections per bobbin. Spin the bobbins as evenly as possible, matching the diameter of the singles on each bobbin and keeping track of the order of the colour sequence.

Figure 36 The divided of top to same color pattern. (left) and a sample of Self-striping two-ply with gradual transitions (Amy King, 1973: 83).

3.2.4 Silky tweed

Tweed is all about the fiber, and the yarn can be spun in many ways. The fiber is usually a solid or semisolid color with bits of fiber in other colours in it. Fiber for tweeds is mostly available as roving and batts. The kind of tweedy look want will determine how to choose a fiber for a particular project. The combing process is meant to take out the little bits and neps that give tweeds their texture and look. Some tweed blends will have tiny neps all the way up to large blob-like neps. The sample, created by carding purple corriedale with tussah silk and silk noil-added. Then, spin the purple yarn from rolag-style chunks into a true woolen yarn.

Figure 37 The sample of silky tweed yarn and knitted fabric (Amy King, 1973: 85).

3.2.5 Multiple plied

Three-ply and four-ply yarns are rounder, which is fantastic for stitch definition. They look incredible knitted in cable patterns; cables “pop” when knitted in multi-ply yarns. For the same reason, multi-ply yarns are also great for colour work. Multi-ply yarns are perfect for spinners who like to make incredibly thin singles. It’s a great way to make strong and professional-looking yarn while making it thicker and stronger. The more plies, the more regular the yarn becomes. The technically speaking, to ply three singles that are each 12 twists per inch, a balanced plied yarn should have 4 twists per inch. For a four-ply with the same singles, we’d aim for 3 twists per inch.

Woolen Three-ply: Woolen yarns tend to be warm and lofty. They make fantastic outerwear, although they don’t hold up as well as worsteds, so it’s best to consider wear and tear and need of warmth more than the strength. The sample is made from blended wool and ocal fleece pool with a bit of sparkle.

Worsted Four-ply: More plies make a stronger yarn— both in tensile strength and abrasion The sample is especially true for worsted yarns. For the four-ply yarn that made singles in each of four different colors of top. This worsted yarn is smooth, crisp, and strong, with each of the colours well defined.

Figure 38 The sample of Woolen Three-ply yarn and knitted fabric and Four-ply yarn and knitted fabric (Amy King, 1973: 91)

3.2.6 Chain plying

This method is commonly called Navajo plying. These are essentially making a crochet chain from one bobbin of singles while adding ply twist. The advantages of this yarn is it requires only one bobbin of singles and is worked until that bobbin is empty. The disadvantage, the yarn is weaker than a true three-ply yarn. The little joins where a new loop of the chain begins are the weakest points. Additionally, it's structurally only one piece of yarn, so if one strand breaks, the whole yarn can ravel. If one ply breaks on a true three- ply, there are still two strands there, and it's much easier to fix.

To begin chain plying, tie a large knotted loop and hold it open. After that, reach through the loop, pick up the singles, and draw it through, forming another loop. Next step is to turn the wheel in the plying direction and allow the twist to enter all three strands. Then, repeat steps 2–3 until all the yarn is plied.

Figure 39 The process of chain plying (Amy King, 1973: 92-93).

1. To begin chain plying, tie a large knotted loop and hold it open.
2. Reach through the loop, pick up the singles, and draw it through, forming another loop. (The knot is visible at the front of the loop.)
3. Turn the wheel in the plying direction and allow the twist to enter all three strands.

3.2.7 Cables

Cables are made by plying two or more singles together, then plying two or more of those together in the opposite direction to make one yarn. The most basic of these is a four-stranded cable made from two two-plies. Note that when cable ply, do not add twist again in the plying direction; each time combine yarns, add twist in the opposite direction. In other words, if you originally spun the yarn clockwise (Z) and plied it counterclockwise (S), you would cable clockwise (Z).

.

Figure 40 The sample of Four-strand cable and components
(Amy King, 1973: 92-94).

3.3 Core spinning yarn

Core spinning produces a wide range of yarns with two common elements: a strong core and an outer layer of unspun fiber. The spinning techniques are exclusive to this, great things mix in other elements , such as unspun fibres and plies held under different tension. There are infinite variations and choices of materials for making a core spun yarn as follows:

3.3.1 Basic core spun yarn

The example made from a pink crochet cotton core and a merino top for the outer layer. Because the top was a little condensed, this split it in half lengthwise and swung it in the air to fluff it up and make it easy to draft. Then spun the two together in the same direction that the crochet cotton was last twisted.

3.3.2 Core- spun locks

Core spinning can also be used to produce a novelty lock yarn. Holding a bunch of locks in a lap or in a basket within easy reach, begin twisting the core and add the locks as the outer layer. It can pinch and pull the ends of the locks away from the core to keep them from lying flat. This yarn is soft and fluffy, but the core makes it a tough and usable yarn. To make this fabulous yarn even funkier, ply two bobbins of it together in the direction opposite the core spinning. Plying will help lock in any flyaway fibres and make the yarn resistant to shedding.

Figure 41 The sample of Basic core spun yarn (left) and core- spun locks yarn (Amy King, 1973: 92-99).

3.3.3 Elastic-core spinning

This yarn uses an elastic as core. The process begins with attaching the elastic to the leader and hold it taut. After that, hold the fibre against the elastic and allow it to be trapped. When the yarn is relaxed, it is appealingly springy. The process and the result are presented below:

Figure 42 The elastic-core spinning yarn processing (left) and a sample of knitted fabric (right) (Amy King, 1973: 101).

1. Attach the elastic to the leader and hold it taut.
2. Hold the fiber against the elastic and allow it to be trapped.
3. When the yarn is relaxed, it is appealingly springy.

3.3.4 Core plying: Coils and bobbles

Core plying involves using essentially the same techniques as core spinning. The one difference is that the yarn instead of fibre wraps around the core. Spin one bobbin of singles as enough for a two-ply yarn. The coiled yarn can be delicate or chunky, depending on the diameter of the singles. Adjust the wheel for moderate draw-in and low twist. As for regular plying, add twist in the opposite direction that spun the singles in. Hold the singles at a 60° to 90° angle to the core. Hold the singles fairly loosely and allow it to loop around the core. Do not let it create loose loops; the coiling yarn should be fairly snug on the core. If necessary, push the coils up to wrap them closer together.

For a coiled yarn (Figure 56), spin a bobbin of singles with the same amount of twist as enough for plying. For the coils to be even, the singles should be even.

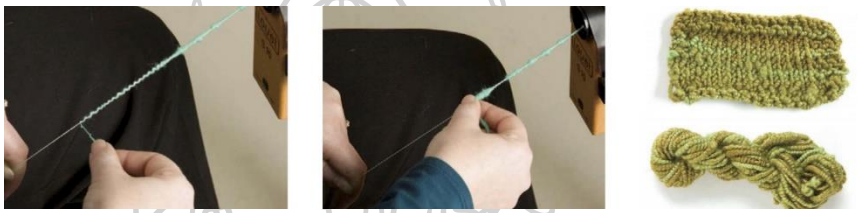


Figure 43 The coiled yarn processing (left) and a sample of knitted fabric (right) (Amy King, 1973: 103).

For a bobble yarn, spin thick-and-thin singles for the wrapping yarn and push the thick sections so they snug together on the core. Hold the core fairly taut.

Figure 44 The bobble yarn processing (left) and a sample of knitted fabric (right) (Amy King, 1973: 103).

3.3.5 Bouclé

Bouclé consists of three elements: the core, the loopy layer, and the top binder. These can be put together in a variety of combinations, though the loopy layer is best in a fiber such as mohair or a longwool such as Wensleydale or Lincoln. These glossy long-staple fibers make crisp, shiny loops.

To start, spin three sets of singles, one spun S with low twist, one spun S with high twist, and one spun Z (clockwise) with high twist.

First step to spin is attach two yarns to the leader, the low-twist S-spun singles and the Z-spun singles, and begin spinning counterclockwise (S). Hold the low-twist yarn taut and the Z-twist yarn at a 60° to 90° angle, allowing the Z-twist yarn to wrap loosely around the core. Unlike coil yarn, where the loops were pushed

snug against each other and the core, the wraps for bouclé should be loose and messy. This state can be push the loops forward on the core to add more loops, although they should not completely cover the core; the more loops added now, the curlier and funkier the final yarn.

Next, set up this messy-looking yarn to ply with the remaining high-twist S singles, which is the binder. Start the wheel spinning Z (clockwise) and hold both the curl-covered yarn and the binder singles under equal tension. The binder is added as a "normal" ply, without one yarn held out at an angle. Although the tension is even, this may need to use one hand to arrange the loops in a pleasing manner. This can be tricky; you hold both yarns in one hand and use the other hand to rearrange the loops and keep it all even. The loops can be moved around easily before plying with the binder, but once the binder yarn is added, the loops are securely in place.

It can be interesting to make a yarn that is a partial bouclé, alternating loopy and non loopy areas. You play with colours and textures and make samples. Bouclés offer a lot of opportunities to experiment. They are time-consuming, especially if they get caught in the spinning wheel frequently, but they're also rewarding. Small amounts of bouclé can be used as accents to dress up an otherwise plain piece.

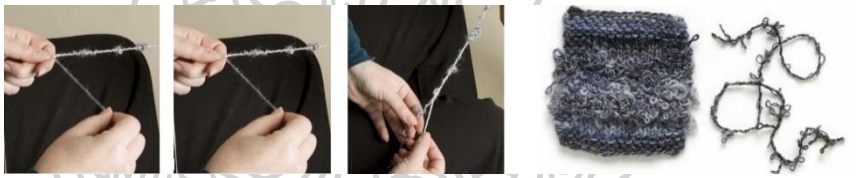


Figure 45 The Bouclé yarn processing (left) and a sample of knitted fabric (right) (Amy King, 1973: 104-105).

1. With the wheel turning counterclockwise (S), hold the low-twist yarn taut, with the Z- spun singles held loosely to the side at a 60° to 90° angle.
2. If desired, push the loops forward on the core so that you can add more loops.
3. Twist the looped yarn with the remaining singles clockwise (Z)

3.4 Novelty yarn

A fibre content resulting from changing the spinning techniques to produce a novelty yarn. Plying very different kinds of singles or singles with another element can create different and surprisingly effective results.

3.4.1 Plying effects: ewelash

To spinning ewelash, Start by spinning two bobbins of singles in the Z direction, one with a typical twist amount (as for plying) and the other overtwisted and with about one-third more yardage than the other. Attach both singles to the leader and start to ply in the S direction. Hold one singles in each hand, keeping the two under equal tension. After a few inches (or the desired length), relax the tension on the overtwisted singles so you can see it twist up on itself and then resume even tension and "capture" the tail by plying normally. Continue to alternate the tension in the overtwisted singles at even or irregular intervals.

Figure 46 The ewelash yarn processing (left) and a sample of knitted fabric (right) (Amy King, 1973: 108).

Figure 47 The playing with tread or yarn processing (left) and a sample of yarn (right) (Amy King, 1973: 109).

3.4.2 Plying effects: playing with tread or yarn

The thread is super thin and slippery, while the wool is puffy and thick. The process to make playing with thread or yarn, attach your singles and the thread to the bobbin and turn the wheel in the plying direction. Hold the commercial thread and the fluffy singles under even tension while plying. The examples are as follows:

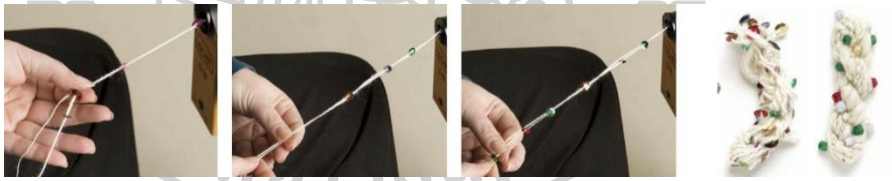


Figure 48 The Add-ins processing (left) and the sample of beads and pom-poms add-ins (right)

1. String beads or sequins onto one or both of the singles and attach them to the bobbin.
2. Ply the singles, using your left hand to keep the beads or sequins back.
3. Push the beads or sequins forward one by one at regular intervals.

3.4.3 Add-ins

There are many things that can string on a bobbin of handspun singles or a commercial thread and it can become part of yarn. For example, beads and sequins, felted beads, flowers, and pom-poms. Moreover the loose spin technique can be used to add-in and make a beautiful yarn as presented in the figure below.

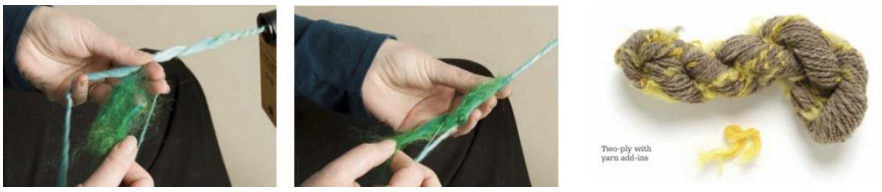


Figure 49 The loose Add-ins processing and the sample yarn (Amy King, 1973: 114).

1. Hold the yarns apart while placing the add-in between the strands.
2. Allow the twist to run through the singles and add-in, locking it in place.

3.4.4 Feathers

A process to make a feather yarn is to begin by attaching the singles and binder to the leader as for a regular two-ply and ply for about a foot. Holding the singles taut, lay a feather flat against the yarn with the quill. Hold the binder loosely and let it wrap the yarn and feather together as if core plying. To hold the feather in place, start to wrap in front of the quill, catching some of the downy parts of the feathers. Resume plying normally until you need to add another feather.

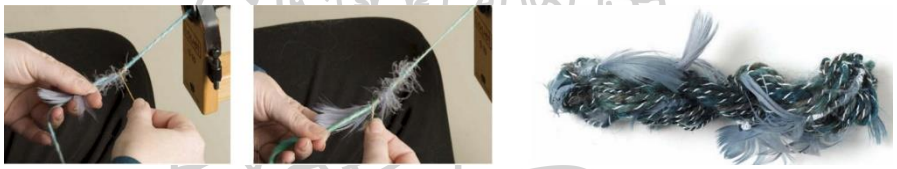


Figure 50 The feathers processing and the sample yarn (Amy King, 1973: 115).

1. With a feather laid against the handspun singles, allow the binder to wrap around the quill.
2. Wrap some of the down of the feather to catch it securely.

Silk dyeing: natural dye stuff

Dyeing is the process of transferring colorant to fibers, yarns, fabrics, or ready-made garments. Colorants take the form of dyes, which are in liquid form, or pigments, which are in fine powder form. (Clive Hallett and Amanda Johnston, 2014: 31).

Silk is dyed very usually in the form of hanks or woven pieces. There is an immense range of dyestuffs available for use with silk; almost every class of dyestuff used for cotton or wool can be used for dyeing silk. In general, the dyestuffs are applied by techniques similar to those used for wool or cotton. (J. Gordon Cook ,2006: 157). Silk and wool are animal fibres that are easy to dye using a method called acid dyeing. The “acid” refers to the pH of the water—acidic water causes the dye to adhere permanently to the fibre. Water can be turned acidic by the addition of vinegar, citric acid, or even lemon juice. Cotton is plant fibre and is dyed using a method called fibre-reactive dyeing. Fibre-reactive dyes are also known as cold-water dyes because they do not require heat to make them permanent (Ashley Martineau, 2014: 64-65). Acid dyestuff, direct dyes produce better fast shades on silk than acid dyes; some direct dyed shades even possess excellent brightness without requiring subsequent after-treatment.

Natural dyes produce moderately bright colours on mulberry silk, but deep shades can only be produced on tussar, spun and textured varieties. These dyes often

require a mordant to make the colour permanent. A few dyes have good light and wash fastness, although some of the mordants are harmful to silk. Colouring matter is extracted by a complex series of processes from the roots, stems, leaves and flowers of various plants, as well as from certain insects and shell-fish. Bright shades are produced with turmeric, berberis, dolu (yellow), annato (orange) and henna (brown). The substantivity of these dyes could be partly due to the presence of tannins which act as a natural mordant. Substances which assist in the dyeing process include acetic acid to neutralize calcareous water, cream of tar- tar which brightens colours when used in conjunction with mordants, and Na2SO4 to control even dyeing. The use of boiled-off liquor causes colouring matter to be attracted more slowly and evenly by the silk, thus helping to preserve lustre (K. Murugesh Babu, 2013: 138).

1. natural dyes method

1.1 Natural dye type

1.1.1 Roots such as madder, alkanes, turmeric and rhubarb.

1.1.2 Wood and bark such as Brazilwood, logwood, cutch, buckthorn, sanderswood, osage orange and quebrao.

1.1.3 Flower and leaf such as gorse, goldenrod, French marigold, henna, weld, tea, stinging nettle and tansy.

1.1.4 Fruits and vegetables such as anent, elderberry, walnut, blackberry, red cabbage, onion, avocado and ivy.

1.1.5 Special colours such as indigo, cochineal and lac.

1.2 Equipment

1.2.1 Large pan or pot

1.2.2 Steel rod or knitting needle

1.2.3 Tong

1.2.4 Rubber groves

1.2.5 Dust mask

1.2.6 Waterproof apron

1.2.7 Thermometer

1.2.8 Sieve

1.2.9 Jelly bags, muslin or coffee filters

1.2.10 Scale

1.2.11 Plastic sheeting

1.2.12 Heat source

1.2.13 Large bowl

1.2.14 Glass jar

Figure 51 Equipment for dyeing (Jackie Crook, 2007: 9).

1.3 Mordants

Mordant are minerals that are added to the material before dyeing. They react chemically with the dye and enable the prepared material to absorb the dye and also improve the lightfastness and washfast properties of colour. Different mordants can produce various colours and shades.

The mordants most commonly used are alum, chrome, copper, iron and tin. For some fibres an assistant is added to improve the absorption of mordant into the material. These include cream of tartar, clear vinegar, tannic acid and washing soda. The amount of mordant required is measured as a percentage of the dry weight of the material. For example, 100 gram (3 1/2 oZ) material processed with 10 per cent mordant is 10 gram (1/3 oZ)

Diagram 3 Mordant quantities for silk (J. Gordon Cook, 2007: 15).

Modant	**Quantity (percentage)**	**Assistants**
Alum (potassium aluminium sulphate)	10	7 per cent cream of tartar
Chrome (potassiun dichromate)	4	None
Copper (coper sulphate)	5	30 ml (1 fl 0z) clear vinegar
Iron (ferrous sulphate)	3	None
Tin (stannous chloride)	1	2 per cent cream of tartar

2. Dyeing process

The preparation of dyestuff is the same for both hot water and cool water. After simmering, leave the liquid dye to stand to develop its full strength. Straining the liquid beefier by adding it to the dye bath ensures that no pieces of plant material or undissolved powder can affect the evenness of the dye when the material is processed in it. The details for the dyestuff and dyeing preparation are as follows:

2.1 Hot water dyeing

The process of hot water dyeing are as follows:

2.1.1 Break or cut up the plant material into small pieces and place in a

dry pan. Pour in water to cover the dry material. If using powdered concentrated extract, mix it into a paste with warm water and add this to water in the pan.

2.1.2 Simmer for about one hour, top up with more boiling water if necessary.

2.1.3 Remove the dye pan from the heat and leave to steep for one hour, strain the liquid into a bowl.

2.1.4 Turn the liquid dry to the pan and add the mordant. Put the material into the pan: material should be wet and wring out any excess liquid. Add enough warm water so the material a fully immersed and to allow for free movement of the natural. Stir two or three times.

2.1.5 Bring the water to simmering point and simmer for 1 hour. Remove the dye pan from the heat. Leave to cool or until you obtain the depth of colour required.

2.1.6 Remove the material and rinse in water until water is clear. Squeeze dry, then hang out the material to dry.

2.2 Cool water dyeing

2.2.1 Break or cut the plant material into small pieces and place the natural dye in the dry pan.

2.2.2 Pour water to cover the dry enough to reach boiling point. If using powdered concentrated extract, mix it to paste with warm water and add this to water in the pan.

2.2.3 Remove the dry pan from the heat and leave to steep for one hour. Filter the liquid into a larger bowl.

2.2.4 Return the liquid dry to the pan and add the mordant material. If the material is not still wet from mordant it will need to be wet first. Add warm water so the material is fully immersed and allow for free movement of the material. Stir two or three times. Heat the water to just below simmering point, then remove the dye pan from the heat and allow the liquid to cool, or until the depth of colour required is obtained.

2.2.5 Remove the material from the pan, rinse in water of similar temperature to the cooled liquid. Continue until the water is clear. Squeeze dry, then hang material to air dry. (Jackie Crook, 2007: 9-28).

Figure 52 Natural dyed process (Jackie Crook, 2007: 22-25).

3. Dyeing technique

Silk waste fibre in form of silk noils, silk top, roving, sliver, batts, lap, mawata and silk from waste yarn, also cocoon can be dyed by various techniques as follows:

3.1 Immersion dyeing

Immersion dyeing is the process of creating a dye bath in large pot, adding fibre or materials, and heating over a period of time. The bath contains water and dyestuff. Heating the dye bath triggers the dyestuff bond between fibre and dye. Because large pots are used, this process is sometimes called kettle-dyeing. Immersion dyeing is traditionally used to dye solid colors. This method can also be used for semisolid and rainbow dyeing yarn, roving, wool lock and fabric. (Barbara Parry, 2009: 68). The example of immersion dyeing and its result are as follows:

Figure 53 Immersion dyeing the skeins (left) and the result (right) Barbara Parry, 2009: 74-77).

Figure 54 Immersion dyeing the roving (left) and the result (centre and right) (Barbara Parry, 2009: 78-82).

Figure 55 Immersion dyeing the fabric (left and centre) and the result (right) (Barbara Parry, 2009: 89).

3.2 Hand-paint dyeing

Hand-paint is the process of applying dye directly to the material and then steaming to set the dye. The term hand-painting encompasses a range of techniques that create a variety of results. Painting the dye onto yarn or roving using a brush, painting with squeeze bottles or depth fibres directly into containers of dry.

Hand-paint can have variegated design with a distinct repeating colour pattern, looser fashion, allowing adjacent colors to merge. There are many ways to experiment with colours and pattern, like the example below:

Figure 56 Hand-paint dyeing by brush (left), and spray (centre) and the result (right) (Barbara Parry, 2009: 97-98)

Figure 57 Hand-paint dyeing by squeeze bottle and the result (right) (Barbara Parry, 2009: 116-119)

Figure 58 A sample of roving hand-paint and result (Barbara Parry, 2009: 102)

3.3 Freestyles dyeing

This technique is used for playful colour experimentation, applied freestyle, that yield random results. The method deviates from traditional modes of dyeing. In some cases, recipes and formulas do not apply. Many of the methods presented are great ways to use leftover dyes from other projects. Freestyles dyeing sample are as follows:

Figure 59 A sample of Kool-aid slow cooker dyeing and result (Barbara Parry, 2009: 136-137)

Figure 60 A sample of microwave casserole dyeing and result
(Barbara Parry, 2009: 146-148)

Figure 61 A sample of sun-soaked skeins dyeing and result
(Barbara Parry, 2009: 150-153)

Thai silk and Thai silk waste

Introduction of Thai silk

Thai silk is a part of the national cultural heritage of Thailand. Thai sericulture began centuries ago. Sericulture is the art of rearing silkworm for the production of cocoons as the raw material for silk production. Records shows that in 1903 AD. (2446 BE.) His Majesty King Chulalongkorn founded the "Silk Artisan Department" in Bangkok to promote Thai sericulture. Thenceforward, a development of Thai Sericulture has steadily grown. Her Majesty Queen Sirikit established the "Foundation for the Promotion of Supplementary Occupations and Related Techniques of Her Majesty Queen Sirikit" to further promote and sustain this industry. The Queen has said "Silk sericulture is a part of increasing farmer income. In addition, it is a cultural heritage and aesthetic of Thailand that has transferred from generation to generation for a long time. Therefore, if the Thai economy is changing, Thai silk sericulture should continue to develop with it." The Queen Sirikit Department of Sericulture has acted on the Queen's speech by collecting local Thai silkworm breeds for research and breeding in order to get strong silkworm varieties

and to increase yields. At the present time, 24 breeds of pure Thai silkworm and crossbreeds are in the collection. (The National Institute of Sericulture Queen Sirikit, 2008, pp. 45-53)

The silkworm rearing process consists of two steps: rearing the newly born silkworm and waiting until the worm develops into a cocoon. Thai cocoons have special properties, they are small and slim in shape, but durable in many environments as well. The filament silk yarn is very fine and has special physical characteristics never seen in another silk, it's cross-section is triangular shaped making beautiful light refractions. Thai silk yarn is hand reeled and when dropped in a wicker basket it becomes a fine silk yarn. In this process the spinster has found that the yarn is more soft to the touch, more flexible and shinier than when processed through the machine reeling method. Moreover, when Thai silk clothed is worn and moved, it produces a special noise called silk sound. The strongest Thai silk ever found is the yellow silk type which consists of 18 kinds of amino acid. The percentage of the amino acid is over 34.5% higher than those of other countries. (The National Institute of Sericulture Queen Sirikit, 2008, pp. 34-39). All of this is a result of the unique characteristics of Thai silk, it is quite a gummy, sticky substance and very shiny. Nowadays, Thai silk producers remain both in households and in industrial factories , most of which are in the northeast area of Thailand.

Figure 62 Local Thai cocoon (The Queen Sirikit Despartment of Sericulture: 2014, 66).

Figure 63 Local Thai silk reeling (left) and Thai silk yarn (right) (The Queen Sirikit Despartment of Sericulture. (2012: 48,52).


Figure 64 Thai silk reeling (left) and Thai silk yarn (right)
(The Queen Sirikit Despartment of Sericulture. (2012: 32,45).

Thai silk waste

The Thai silk industry is a large scale industry consisting of three subdivisions; upstream, middle stream and downstream.

Firstly, upstream industry begin from sericulture and is the cultivation of silkworm to produce silk yarn. This production mostly uses Thai cocoons and is done by hand. This produces the most wastage in the industry. The waste comes from incomplete cocoons and knubs. During the reeling process, blaze and cocoons after reeling are about 0.5 and 0.5 percentage of fresh cocoon respectively. The 0.5 percent of fresh cocoon is 18 percent of yarn from cocoon, that means that one cocoon loses 36% to waste. It is estimated the waste from the upstream silk industry is at least more than 4,600 tons per year.

Secondly, the middle stream industry is the weaving process. A report in 2011 found that there were 1,270 silk factory in Thailand. Each weaving process produces waste from warp and weft yarn measuring about 1.4 metres. Estimates vary as to the quantity of waste because of different production management.

The last is downstream industry, the silk product production industry such as scarves, neckties and other clothes. This industry makes waste from sewing. Similarly to the middle stream industry, there are not a lot of accurate reports as to the level of this waste volume.

The consideration of the Thai silk supply chain can be classified into its waste production in four section as follows:

1. Farmers, who produce silk by craft process.
2. Silk reeling factory, produce by machine. This provides silk throwster.
3. Silk weaving factory and handicraft process. This provide silk thread waste.
4. Silk product factory, provide silk fabric waste.

(Thai Textile Institute n.d., 62-64)

Agricultural Research Development Agency (Public Organize) (2018), classified Thai silk waste into three types as below:

1. Waste from incomplete cocoons.
2. Waste from reeling, spinning and weaving process.
3. Waste from pulling or garneting warp and weft yarn by machine.

As mentioned previously, most silk waste comes from the cocoon. There are various breeds of Thai cocoons, therefore all cocoons that are factory received from

farmers should be inspected for quality control with the aim to separate complete and incomplete cocoons. The complete cocoons will be sent to the reeling process, the incomplete cocoons will be categorised for suitable future production. Incomplete cocoons are double cocoons, pierced cocoons, inside and outside stained cocoons, thin shell and lose shell cocoons, malformed cocoons, coarse cocoons, crushed cocoons and mildwed cocoons (Acharaporn Sailasoot and Shikeru Watanabe, 1977: 31-32). The Queen Sirikit Department of Sericulture (2012, 34-36) explain the detail of incomplete cocoons as below:

1. Double cocoon, it is a cocoon with more than one silkworm nest together. This cocoon fibre can tangle easily. It is a result of broken yarn during reeling.

2. Pierced cocoon or perforated cocoon. When maggots grow up inside a cocoon and then break out, making the fibre break out and unsuitable for reeling.

3. Innerside stained cocoon, it is a cocoon where the pupae died inside the silkworm. That is the result of dirty cocoons, produce black coloured silk yarn of low quality.

Figure 65 Double cocoons (left), Pierced cocoons (centre) and innerside stained cocoon (right) (The Queen Sirikit Department of Sericulture. (2012: 32,45).

4. Outside stained cocoon or soiled cocoon. There are two factor of this cocoon type. The first is pupae present in nesting cocoons and the second is maggots breaking into and cracking the cocoon. That result is dirty cocoons and cocoons made difficult for reeling.

Figure 66 Outside stained cocoon (left) thin shell cocoon (centre) and fluffy cocoon (right) (The Queen Sirikit Department of Sericulture. (2012: 32,45).

5. Thin shell cocoons are where the pupae gets a disease and dies during nesting as a result of a thin panel.

6. Fluffy cocoon, loose shell cocoons or double-layered cocoons. This is caused by irregular temperature as a result of uneven layering during nesting.

7. Thin end cocoon, there are various results of this type. The first is a result of the silkworm species chosen, the second is caused by high temperatures during the incubation stage and the third is caused by the low temperature during cocoon nesting.

8. Malformed cocoons are cocoons that result from insanitary cultivate or weak pupae.

9. Coarse cocoons. These are the cocoons that have nesting fibre near the basket panel which results in an unusual and thick layer.

Figure 67 Thin end cocoon (left), malformation cocoon (centre) and coarse cocoon (right) (The Queen Sirikit Department of Sericulture. (2012: 32,45).

10. Crushed cocoons are caused by careless transportation.

11. Mildwed or musty cocoons are incomplete caused by mistakes made during the drying process and/or uncontrolled humidity while in storage.

Figure 68 Crushed cocoon (left) and mildwed cocoon (right) (The Queen Sirikit Department of Sericulture. (2012: 32,45).

Thai Silk waste utilization

Silk is known as a luxurious fabric, especially silk fabric from craft production. However, spun silk in Thailand is mostly done by industrial processes. The result of spun silk is that the shine can be reduced but it remains soft to the touch. It is easily made into many different products from here. A fabric made from spun silk can be used for home textiles such as upholstery and pillow cases. High quality spun silk yarn is also used in the field of fashion making products such as hats, scarves and bags. The cocoons are usually used to create decoration on products such as lamp shades and artificial flowers. In addition, silk fibres are used to make threads and bio-composite in the field of medicine field. (Thai Textile Institute, n.d.: 60-61)

Angus Hutcheson, Chief designer of Ango British is a designer based in Thailand for the last ten years dedicated to working with light. Forging new forms, using materials that were to hand, many of them natural, the Ango collection was gradually built up, and gained recognition in Thailand and internationally, with a string of awards and special pieces being shown at the Museum of Arts and Design in New York, the Hara Museum in Tokyo, and V.I.A in Paris. Angus describes it: “each material has its own character so I concentrate on creating the diffuser that is unique in how it refracts and reflects light”. Forging new forms, often using materials that were to hand, many of them natural, the whole low impact / low energy intensive process of how Ango designs are realised also represents a view of how enlightened, environmentally responsible 21st century design and production can be. A sample of Angus's design by unprocessed cocoons in natural colour is in figure 69

Figure 69 Mains voltage celling light made from unprocessed silk cocoons (Ango, 2017: 45)

Spun Silk World, a Thai limited company, make use of the outer cocoon shells, the completely reeled cocoons, and the unreelable breeder cocoons collected after moths emerge naturally. This company produces products through sustainable and eco-friendly raw material acquisition. The production process is waste-free as all by-products and waste-water are fully recycled. To comply with the extreme user-concern policy, they carefully extract the silk fibre and fabricate them to form smooth, lightweight but durable, and lustrous textures that surpasses any other spun silk. (Spun Silk World, 2017) The products are shown in figure 83

Figure 70 natural coloured spun silk yarn (Spun Silk World, 2018)

Chul Thai Silk company limited and Arisara Dangprapai have created products using mawata while preserving all its outstanding properties under ‘The Cooperation 3 Project' of Thailand's Creative and Design Centre. Arisara develops the mawata silk pair together for this project and uses the material to create new products the shows the potential of mawata. The mawata developed by the pair was durable enough to hold its form and could also be dry-cleaned. For early stages of the experiment, Arisara decided to design decorative items. Nature is the inspiration of

the collection and therefore the shape, colour and texture of the pieces are echoes of our natural surroundings. The final products were ‘Mushroom’ lamp collection and ‘Ground’ throw blanket.

The ‘Mushroom’ lamp collection is a series of decorative lamps created by sewing mawata together to strengthen the material. The freeform pleated texture and the gradient colouring, a representation of a beautiful sunset, were strategically designed to catch the light from the lamp.

‘Ground’ throw blanket was inspired by the earth. The material was folded to create layers and a wrinkled pattern that resembled the texture of the ground. Gradient colouring and folding techniques helped create depth and texture for the blanket.

Figure 71 ‘Mushroom’ lamp collection (left) and ‘Ground’ thrown blanket (right)
(Thailand creative and design centre, 2018)

Spinning Thai silk waste

The process of spinning Thai silk waste can be done by both hand spinning and machines that depend on raw material: incomplete cocoons and silk yarn waste and silk fabric waste.

1. Spinning incomplete cocoons

The incomplete cocoons almost always made by handicraft processes. It begins from degumming cocoons , hand carding and spinning by a local spinning tool. A yarn from hand spinning is soft and shiny but weaker than filament silk.

2. Spinning silk yarn waste and silk fabric waste

In the case of silk fabric waste warp and weft yarn should be separated before carding. Both silk yarn waste and silk fabric waste could be opened and carded by machine. Then it is taken to be spun by hand and machine.
(Thai Textile Institute, n.d.: 57, 59).

Figure 72 Tradition Thai spinning tool.

Tradition Thai spinning tool properties (Department of Sericulture, 2018)

1. The tool using for twisting and plying silk yarn.

2. The structure is made from hardwood with polish finishing and has a wheel and spindle.

3. The wheel is made from vine or bamboo and 45 centimetres in diameter, 2 wheels are set parallel and connected by bamboo rod about 8 centimetres in length.

4. The length from spindle to steel shaft is 90 centimetres.

Natural dyes silk in Thailand

Silkworm Mulberry Research and Development of The Queen Sirikit Department of Sericulture (2018) describe dyeing with natural colors using available Thai materials as a local wisdom inherited from generations up to the present day. Natural dyed silk fabrics make delicate fabrics. Some dyes are herbs which benefit human health. However, some natural dyes easily fade or easily have their colour changed due to washing. Some dyeing processes requires a large amount of dye materials.

1. Natural colour extraction

Various plant parts can be extracted as dye substances for silk dyeing. There is bark, fruit, fresh leaves and flowers, the process to extract colour from them are as followings:

1.1 Colour extraction from bark: chop the tree bark into small pieces and soak in water overnight, then simmer for one to two hours until the solids are filtrated. Ratio of fresh bark per silk is 6:1, in the case of dried bark it is 2:1

1.2 Colour extraction from fruit (pods): crush the driver pods and extract the dry with the same method as tree bark extraction. For fresh fruits, crush or pound until softened then simmer for one to two hours depending on the kinds of plant.

1.3 Colour extraction from fresh leaves and flowers, Steam the leaves or petals for five to ten minutes then soak in cool water immediately. Boil over a mind flame for one hour and filter out the solids. The ratio of leaves or petals per silk is 8-10:1

2. Dyeing method

There are two main methods for dyeing silk yarn

2.1 Cold dyeing, soaking and gently squeezing in extracted solution at room temperature until reaching a desired colour.

2.2 Hot dyeing, boiling in solution at 80-85 degrees celsius for an hour. During the dyeing process, silk skeins are regularly turned over for an even color.

Usually “cold dyeing” runs first, which is then followed by “hot dyeing” for sixty minutes or until you reach the desired colour. The silk skeins must be washed in warm water 1-2 times and once in colourless and odourless liquid cleanser, respectively. Bubbles and excess water are firmly squeezed out. Afterwards straighten the silk skein and dry in the shade.

Normally “cold dyeing” for one kilogram of silk yarn requires 20 - 25 litres of extracted solution whereas “hot dyeing” requires 30 litres.

Soaking the silk yarn in mordant solution, for example alum solution, leaves extracted solution such as eucalyptus or memecylon scutelatum naudin leaves can increase the quality in colour fastness to light and washing.

The National Institute of Sericulture Queen Sirikit. (2008: 246-247) has summarized and compiled colours and dyestuff as the detail in the table below shows:

Diagram 4 Thai Natural dye method, mordant and outcome

Color	Dye method	Mordant	Sample
Apple green	Pheka: bark	Rice straw lye	
Grass-green	Cassod tree, Thai copper pod tree	Rice straw lye	
Greenish-Brown	Mango tree: leaves, bark	Ebony fruit, mud	
Yellowish-green	Indian almond : leaves	Alum	
Red	Lac	Alum	
Red	Lac and Anatto tree seed	Alum	
Red	Lac	tamarind leave	
Black	Ebony fruit and myrobalan tree bark	Alum or mud or limewater	
Black	Ebony fruit	Mud	
Blue	Indigo	tamarind juice	
Light brown	Yo pa	limewater	
Brown	Gloden shower pod	Alum	

Color	Dye method	Mordant	Sample
Brown	Narva bark	-	
Pinkish brown	Teak leaves	-	
Black-brown	Narva bark	Ferric oxide	
Violet	Lac	Mud	
Yellow	core of jackfruit tree	Salt	
Lemon Yelloe	Eucalyptus	Alum	
Yellow	Turmeric	-	
Orange	Anatto tree seed	Alum	
Bright- orange	Safelywer	Salt	

note:

The plant name is from natural dyestuff data base, Silkworm Mulberry Research and Development of The Queen Sirikit Department of Sericulture website.(2018)

The yarn-dyed sample is from natural dyeing folk wisdom, The Queen Sirikit Department of Sericulture website. (2018)

The knitted fabric

Introduction of knitted fabric

Knitted fabric is formed by intermeshing loops of a single yarn or set of yarns together. There are two main types of knitted structure:

1. Weft knitting is a method of making a fabric where the yarn is fed more or less at right angles to the direction in which the fabric is produced.

2. Warp knitting is fabric composed of knitted loops in which the yarn forming the loops travels in a warp-faced direction down the length of fabric generally parallel to the selvedge. (J. Mcloughlin and S. Hayes, 2013: 24)

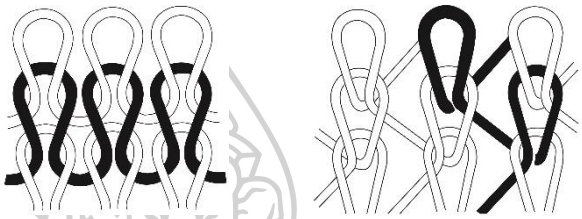


Figure 73 Weft knit structure (left) and warp knit structure (right)
(Jacquie Wilson, 2001: 93- 94)

Characteristics of weft-knitted fabrics are unique in that they possess a high order of elasticity and recovery. Unlike woven fabric, which possesses a low degree of elongation, knitted fabric can be stretched to a considerable length and yet, when it is released, it will gradually return to its original shape and configuration. It is this feature of the fabric, plus the air permeability arising from its looped structure, that imparts to it the following properties: a high degree of wrinkle resistance; good drape; a high degree of comfort; a porous nature allowing the skin to breathe freely; and elasticity allowing freedom of movement. (Jacquie Wilson, 2001: 99)

Knitted fabric types

Jacquie Wilson (2001, 94-99) and J. Mcloughlin and S. Hayes (2013, 24-26) explain, the common knit fabric type are plain fabrics, ribbed fabrics, purl fabrics and interlock fabrics.

1. Plain fabric

The simple fabric is made on one set of needles with all the loops intermeshed in the same direction. The face of the fabric is smooth and shows the side limbs of the loops as a series of interlocking ‘v’s. The reverse is rough and looks like columns of interlacing semicircles. Plain fabric can be unroved (unravelled) from either end. It has a tendency to curl towards the back at the sides and towards the front at the top and bottom. (Jacquie Wilson, 2001: 96)

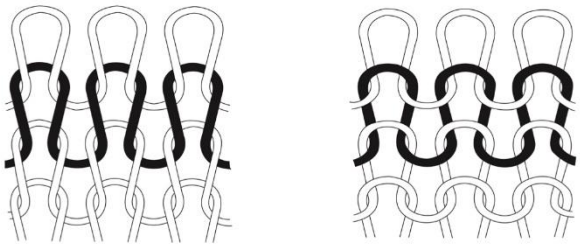


Figure 74 Loop diagram showing face of plain weft-knit fabric (left)
and loop diagram showing reverse of plain weft-knit fabric (right)

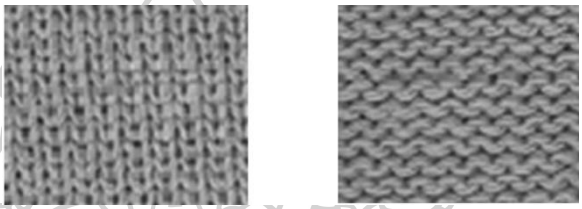


Figure 75 Characteristics of plain weft-knit fabric: face (left) and reverse (right)

2. Ribbed fabric

Ribbed fabrics are made as fabrics in which both the back and face loops occur along the course but in which all the loops contained within any single wale are of the same type. This means back or face loops.

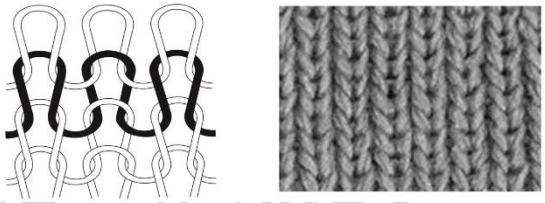


Figure 76 Loop diagram 1x1 rib (left) and Characteristics of knit rib fabric (right)

3. Purl fabrics

Purl fabrics are described as a fabric in which both back and face loops occur in some or all of the wales. The structure may be identified by the particular knitting sequence used.

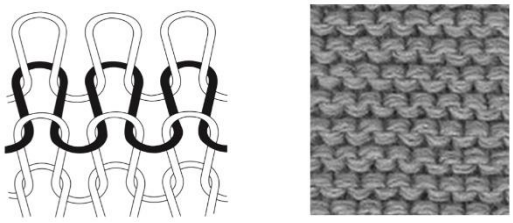


Figure 77 Loop diagram 1x1 purl (left) and Characteristics of purl knit fabric(right)

4. Interlock fabrics Interlock machines are weft-knitting machines that have two sets of needles on a back and front bed (or dial and cylinder). Unlike rib machines however the needles in one bed are directly opposite those on the other bed. The fabrics are constructed so that opposite needles are not lifted at the same time. The fabrics produced are double-knit structures; essentially two fabrics interlocked together.

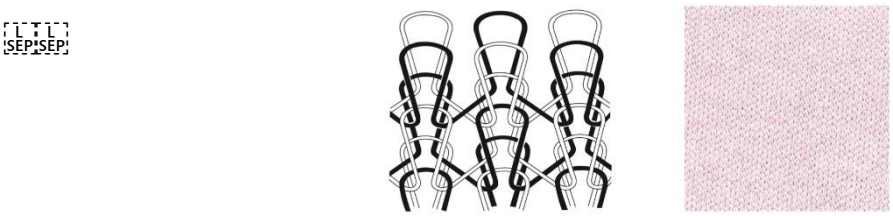


Figure 78 Loop diagram 1x1 interlock (left) and Characteristics of interlock knit fabric(right)

Knitting tools

There are two main tools to produce knitted fabric. The first is a hand tool and the second is a machine tool, the details are as below:

1. Hand tool

Since the inception of knitting, hand knitting technology has been in existence. Hand knitting is the basis for all modern forms of knitting. Basically two pins (needles) are used for making loops as well as inter-looping. As shown in Fig. 88(a), the pin 'P1' gripped by left hand of the knitter is retaining the previously formed loop and the pin 'P2' gripped by the right hand of the knitter is about to form the next loop. Figure 79 (b) shows that the newly formed loop (NL) has been drawn through previously formed loop (OL). The resultant fabric, a matrix of rows and columns of loops, is formed by creating a single element in each knitting cycle. Hence, if a fabric needs to have 100 loops in each row, then 100 cycles of knitting operation would be needed to produce one course. All these 100 loops are to be held by one pin/needle as shown in Fig. 79(c) and subsequently the loops are to be transferred to the other pin/needle for making the next row. (Sadhan Chandra Ray, 2012:3-4)

Figure 79 Hand needle (left) and Principle of hand knitting using pin (Sadhan Chandra Ray, 2012:3-4)

2. Machine tool

There are many types of knitting machine, from the simple domestic knitting to a wide range of industrial machines. Each machine has its own specialist

capabilities.

2.1.1 Domestic knitting machines are the most popular machines for home knitters and small design studios. They are easy to operate and are available in fine, standard gauge, and chunky gauge. The machine knitting gauge refers to the distance between the needles on the machine bed and also defines the thickness of yarns the machine can handle. A fine-gauge machine knits lightweight fabrics and a standard-gauge machine knits good sportswear fabrics, while the chunky gauge is better suited to light, bulky yarns, hand-knit type yarns, and more textured novelty yarns. Machines usually have an integrated punch- card mechanism or pattern stitch mechanism for programming pattern stitch repeats, such as Fair Isle, tuck, and lace patterning.

Domestic knitting machines have various attachments and additional carriages that are usually sold separately, including lace and intarsia carriages and yarn changer and ribber attachments. Domestic machines have a single bed of needles. If a ribber is added it forms two flat beds, which then creates a double-bed machine—the ribber can be used to knit the ribbing of a garment and then lowered to allow the main body of the garment to be knitted on a single bed, if required. A full garment can be produced on a single-bed machine; however, a double bed gives greater versatility, producing both plain and purl fabrics. The single bed produces knit stitches and the ribber knits the purl. A double bed allows for the production of an almost unlimited range of fabrics, including double-bed jacquard, circular tube fabrics, and ribbed structures. (Carol Brown, 2013: 21)

Figure 80 Domestic knitting machine (Juliana Sissons 2010:30)

2.1.2 Electronic machines

Electric machines have a built-in programming capacity. Some machines use Mylar sheets to create the patterns, which can be repeated, reversed, knitted upside down, mirror imaged or doubled in length and width. (Juliana Sissons 2010:30)

Figure 81 Electric knitting machine (Juliana Sissons 2010:30)

2.1.3 Hand-operated industrial machines

Hand-operated industrial machines are incredibly versatile, these machines have two fixed beds and are known as V-beds. The beds are equally positioned in angle, which allows the knit to be equally weighted. They also have a greater range of gauges, offering the opportunity to experiment with very fine knit on gauges of 10 and 12. Tension can be altered for different parts of a garment, such as a rib border, full cardigan stitch knit and jersey stitch knit. (Juliana Sissons 2010:31)

Figure 82 Double hand operated industrial machine (Juliana Sissons 2010:31)

2.1.4 Circular knitting machines

Circular knitting machines are available in a wide range, from those that are powered mechanically or electronically to those that are controlled by computer. All produce lengths of seamless tubular fabric in various gauges, including single to double jerseys, jacquards, ribbed fabrics, fleece, mesh, and double-faced fabrics for specific purposes, including hosiery, sports outerwear, and household and medical textiles. (Carol Brown, 2013: 22)

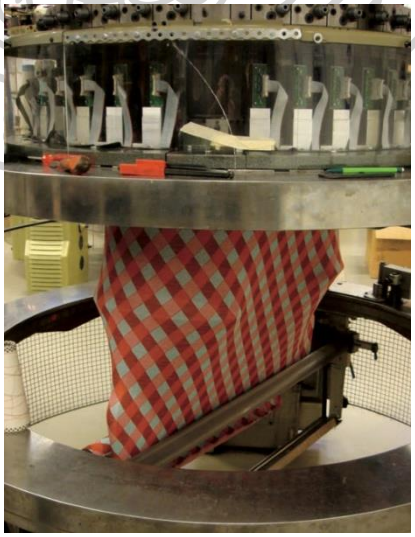


Figure 83 Circular knitting machines (Carol Brown, 2013: 24)

2.1.5 Electronic industrial machines

Today's automatic, electronically programmed machines are highly sophisticated. Some have four needle beds, allowing greater possibilities with shape. They can be used to knit different weights of yarn with having to change needle sizes. The latest machines produce complete garments with seams and with only one thread to sew in at the end. eliminating hand-finishings costs. The body and sleeves can be knitted at the same time, via a tubular knitting technique. Ribs, cuffs and hems can be knitted at the start, neckline at the end. The complete garment machines and programme systems are extremely expensive, having taken years of research and development to perfect; highly skilled sample technicians are required to operate them. The two main models offering the complete garment system are Shima Seiki of Japan and Stoll of Germany. (Juliana Sissons 2010:31)

Figure 84 Stoll electronic industrial machine (Carol Brown, 2013: 24)

Knitted fabric structure and pattern

All knitted stitches produce a textured surface, but the results depend on the type of yarn knitted, the tension, the stitch combination, and the performance of the yarn. Textures in knitting can be created using any of the following:

1. Particular yarns: bouclés, slubs, crêpes, chenilles, smooth silks, ribbons, tapes, faux fur, marled yarn, mercerized and speciality yarns.

2. Stitch formation: lace, laddle, tuck, weave, slip stitch, or a combination of techniques worked together.

3. Three-dimensional knitting: incorporating ridges, bobbles, knitted flaps, and cables

1. Knit fabric texture from particular yarns

The structure and raw material of a yarn is crucial to the form and rhythm it will create when knitted. That will be present in fabric surface, such as texture and touch; thick, thin, soft, rough and also dimensional.

The example of knitted fabric textures by Carol Brown, 2012 is shown in Figure 85 (left) show a close-up of garment detailing, exploring weights of yarn, the right figure present detail of textured knit fabric, comprising black and gray softly brushed mohair, ribbon yarns, silver Lurex, and cotton and linen twist strands latched into the main base knitted fabric. (Carol Brown, 2013: 98)

Figure 85 The detail of textured knit fabric knitting by particular yarn.

2. patterned knitting

2.1 Stripes of colour

One of the easiest methods of introducing more than one color into a design is the use of stripes in varying widths of color. Stripes can be created using a very subtle blend of colors, hardly distinguishable from one stripe to the next, or for impact they can be completely the opposite in contrasting bright colors that clash with one another. (Carol Brown, 2013: 86)

Figure 86 The detail of stripes colour knitted fabric.

2.2 Fair isle and Jacquard

Fair Isle and jacquard are methods of knitting using two or more colors in one row of knitting to produce allover repeats in a garment design. The traditional hand-knitted Fair Isle technique originated on Fair Isle, one of the Shetland Islands. This term is used very loosely, however, and is often referred to in both hand and single-bed knitting. Hand-knitted Fair Isle designs can be knitted in the round using a circular needle or alternatively using two or more needles, knitting the stitches and carrying each color knitted along the row to form a repeat pattern, which can be relatively time consuming. Machine-knitted Fair Isle is quicker to produce, as the pattern is preselected using a punch card or by programming the design into the machine.

Jacquard knitting is produced on a double-bed knitting machine, which gives a similar effect in appearance to Fair Isle knitting. (Carol Brown, 2013: 89)

Figure 87 Fair Isle design by Alexander McQueen, forming part of his A/W05 collection, entire 'The Man Who Knew Too Much'
(Juliana Sissons 2010:92)

2.3 Punch cards

Punch cards provide a fast method of selecting needles, but patterns with repeats need to be worked out on paper before knitting. This is done by sketching out a rough drawing first, and then putting a stitch plan on squared paper. Decide on the stitch repeat size for design; this is limited by the size of the punch card. A width of 24 needles is usual for a standard gauge machine and 30 needles for fine gauge machine. If using a chunky gauge machine, a width of 12 needle is usual. For a square of knitting there are always more rows than stitches, which can make the pattern on the card seem elongated. There is special graph paper available for knitters, which consists of shorter squares to enable you to see what the finished design will look like. (Juliana Sissons 2010:94-95)

Figure 88 Patterned knit design by Cathrin Evans. The punch card clearly illustrated the pattern of knit.

2.4 Intarsia

Intarsia is a technique used for colour patterning in which there are no floats, as each colour is separately knitted in to its own shape. Many colours can be knitted into one row and because there are no floats. Large, bold pattern shapes can be made. Special intarsia carriages are available for the more sophisticated machines. Always start with needles at intarsia position: latches open and needles forward about 1 centimetre. This is usually achieved by a pass of empty intarsia carriage.

Figure 89 Intarsia design by Hannah Taylor.(Juliana Sissons 2010:94-98-99)

3. Stitch formation

3.1 Lace

Lace knits are made using the basic transfer stitch technique, which involves transferring stitches from one set of needles to another, with the use of multi-point transfer tools. it is possible to transfer many stitches in one move. Stitches may either be transferred to other needles on the bed or allowed to drop and ladder the full length of the fabric. Automatic lace carriages are available for some single bed domestic machines. Selected stitches are transferred automatically to adjacent needles. Several stitches can be transferred to a single needle, either to reposition stitches for patterning or to alter the shape of a ladder. A variety of eyelets designs and small buttonholes are based on the transfer stitch technique. The eyelet hole loop diagram, chart lace and knitwear design by Mark Fast S/S 10 present in figures 90 (Juliana Sissons 2010:76-77)

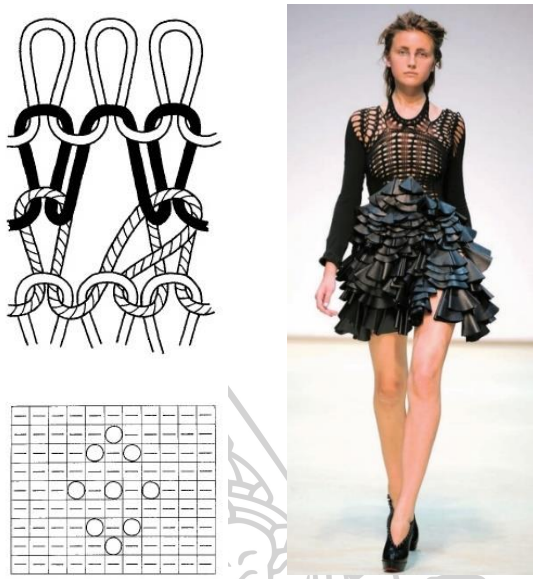


Figure 90 The eyelet hole loop diagram, chart lace (left) and knitwear design by Mark Fast S/S 10 (right)

3.2. Ladders

Ladders create a lacy effect, made by an exaggerated version of the transfer stitch technique. Ladders can be made into shapes or they can built up horizontally by transferring a stitch on one side of the ladder and putting an empty needle back into it. The action is repeated after every row or every second row of knit. The ladder knit, with eyelet hole chart and knitwear design by Rodarte A/W08 present in figures 91 (Juliana Sissons 2010:79-79)

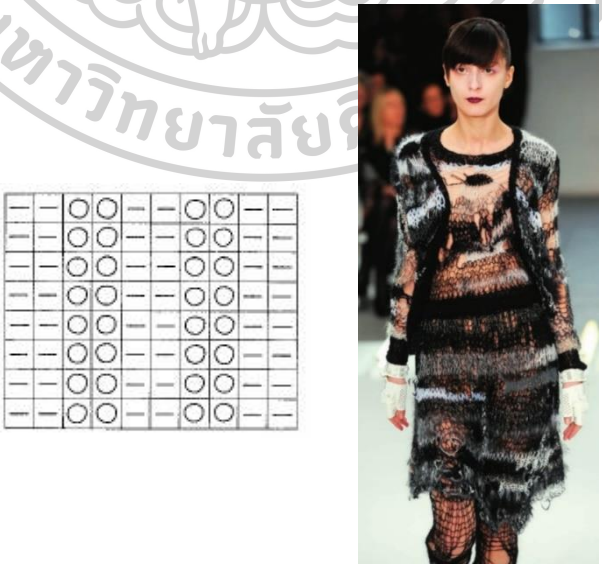


Figure 91 The ladder knit, with eyelet hole chart (left) and knitwear design by Rodarte A/W08 (right)

3.3. Tuck

Tuck stitch can produce a textured pattern on both sides of the fabric; however, the purl side is most common. A small-scale pattern will produce a honeycomb effect and a larger-scale pattern will produce wider, raised pattern areas. The stitch is held in the hook of the needle until it is knitted in. The tuck loops distort the knit by pushing the stitches out of line, creating interesting patterned textures. A bumpy texture can be made by collecting loops in the needle head through tucking several rows at a time, on the same needles, before knitting in. Bear in mind that there is a limit to the number of rows that can be held on any one stitch. This depends on the tension and the type of yarns that are used.

Select needles manually to override the carriage and the information on the punch card or Mylar sheet, allowing you to experiment with more patterns. Tucks can also be created manually without the use of punch cards and Mylar sheets, by taking the selected needles out of action, and setting the holding cam levers in action on the carriage. After several rows of tucking, the holding cam levers are then taken out of action and a row of plain knit is knitted. This can vary the amount of rows in hold or knit position.(Juliana Sissons 2010:82). Figures 99 present a tuck loop diagram and a sample of tuck knit fabric designed by Hannah Risen. The centre is four-colour "circular" textured tuck pattern. The right is two-colour "honeycomb" tuck stitch produced by holding selected stitches while continuing to knit the remaining stitch as normal, creating a three-dimensional tuck, distorting the fabric. (Carol Brown, 2013: 101)

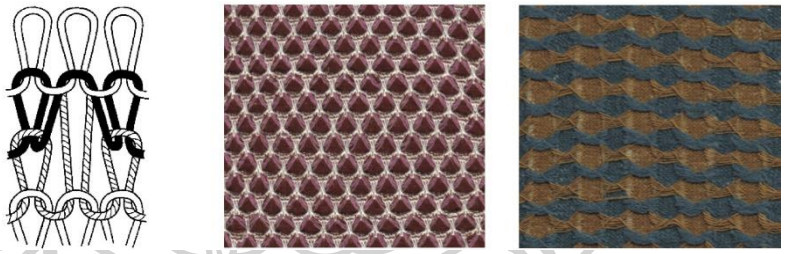


Figure 92 The tuck loop diagram (left), (left) and sample of tuck knit fabric (centre and right)

3.4 Weave

Weave is known as inlay. These knits have similar characteristics to woven textiles and have little stretch. Knitting is carried out in the normal way but at the point when the additional yarn is woven in, the yarn is taken across the needle bed first, passing under and over alternate needles. It is then knitted in to the fabric, catching under alternate stitches. Yarn can be wrapped around the needles and stitches; it can be woven through the knit; it can make overall patterning and stripes and it can be used to create pile loops and fringing.

A basic punch card method can be used for yarns such as fine boucle and mohair. The punch card is set and the weaving brushes lowered. The secondary yarn is placed in the weaving yarn guides and the carriage is moved across the machine. if the yarn is very thick or knobbly, a manual weaving method can be used. (Juliana Sissons 2010:86)

Figure 93 shows a knit weave sample, the left picture is a laying in the yarns, using a range of soft, muted colors in a range of textured yarns, including mohair, silk slub, chenille, bouclé, and ribbon yarns. The right picture is a felted sample of knit weave with cut floats using pure wool, mohair, and fine wool blend, producing a soft, distressed finish due to the milling process. (Carol Brown, 2013: 120)

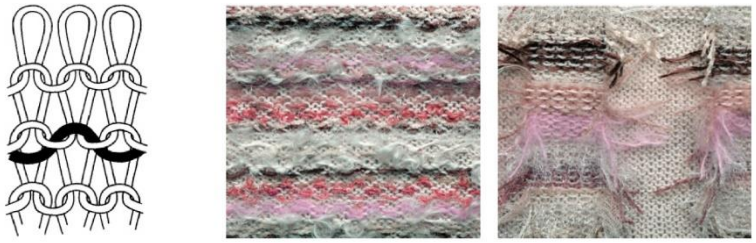


Figure 93 The weave loop diagram (left) and Knit weave sample (centre and right)

3.5 Slip stitch

Slip stitch misses the non-selected needles, allowing the yarn to lie in front of them and from 'floats'. The purl side of the work shows the texture of the pattern, with all the floats. The strands of yarns ring over the knit tend to be quite compressed, narrowing the width of the fabric and allowing very little stretch. On punch card machines, the punched holes knit and the blank spaces slip. On electronic machines, it can mark the slip stitches on the Mylar sheet and the result will be reversed, if you select the negative option button.

Slip stitch is also the basis of a two-colour or Fair isle patterning. The pattern can be knotted in two rows of each colour. If using slip stitch in conjunction with striping. It can be achieve intricate, mosaic-like pattern on the technical parts of the fabric. (Juliana Sissons 2010:84-85)

Figure 94 The slip stitch loop diagram (left, centre) and slip stitch knit fabric sample (right)

4. Three-dimensional knitting

4.1 Incorporating ridges

Pin tucks can be used to add texture in a series of small ridges. They look particularly effective when worked in contrasting colors and textures, adding weights to the fabric, and also providing a guideline for picking up. Rows of pin tucks, when pinched together and darned into position with contrasting yarn,

create a smocked ridge effect.

It can be achieve sculptural effects by producing wide stripes of knitting in alternate colors on a loose tension, as shown in the piece on the opposite page center right. After pressing, manually ruche up the knitted fabric using French knots, working the embroidery in a contrasting colour to create a simple yet effective design.

Figure 95 presents a textured knit of ridges and bobbles by Jade Drew, inspired by rock formations, earth layers, and Aboriginal art, using a variety of yarns for textural contrast. and stunning, sculptural three-dimensional fabric by Jade Drew, inspired by natural structures of pinecones and seed pods. (Carol Brown, 2013: 103)

Figure 95 Texture knit of ridges and bobble (left) and stunning, sculptural three-dimensional fabric.(right)

4.2 lifting stitches

Stitches can be lifted from previously knitted rows and hung again on the needles; then when the carriage is taken across the bed, the lifted stitches will be knitted into the fabric, resulting in a gathered effect. This technique can be used to lift single or multiple stitches as well as floats and ladders. Figure 96 present a bag design by Justin Smith, a lifting stitch technique has been used to create different textural effects. (Juliana Sissons 2010:88-89)

Figure 96 A bags design, sample of different lifting stitch technique.

4.3 Partial knitting or short-row knitting

This technique involves knitting selected needles and knitting only part of a row. It is worked either by selecting needles manually and putting them into nonworking position or alternatively by using the cam controls and punchcard, which then preselects the needles to be knitted. It is an effective technique for molding and sculpting a fabric and can be used to add fullness to the middle of a row of knitting, to

lengthen one side of the fabric, to form a dart, to miter a corner, or to create curves or vertical gathers, ruffles, and decorative trims.

This fabrics can be created by putting needles on hold, knitting a row, and binding off those needles on hold, and then casting on and continuing knitting. In hand knitting, the same effects can be produced by knitting selected stitches, then turning the work and working backward and forward across selected stitches, giving greater fullness and shaping the knitting in a particular area of the garment, for example at the heel of a sock, across the chest, or to create an interesting sleeve design. The sample is in figure 97, it is short pin tucks and whole-row pin tucks positioned at regular and irregular intervals, produced on a domestic knitting machine, combine to create this heavily textured fabric by Carol Brown. (Carol Brown, 2013: 105) and Holding technique created by Natalie Osborne (Juliana Sissons 2010:102)

Figure 97 A sample of short-row knitting created by Carol Brown (left) and holding technique created by Natalie Osborne (right)

4.4 Flared shapes

The fullness in shaped garments, such as those with frills or flare, is often achieved by inserting a triangular goddess. These goddesses can be knitted horizontally at any length or width required. Tiny ruffles can be achieved just as easily as a full-length flare. These can be knitted in continuously with the use of the partial knitting technique. The sample is in figure 98 (Juliana Sissons 2010:106-107)

Figure 98 A sample of Flared shapes

4.5 Cables

Cables are created by crossing two groups of stitches between knitting rows. Two transfers tools are used to remove the two groups of stitches from their needles; the stitches are crossed as they are returned and then knitted as normal. A sample of cables, large-scale cable with foil print embellishment by Pamela Leung and ‘Emotional Sculpture’ collection by Johan Ku, made in raw wool using fingers and giant needles. (Juliana Sissons 2010:90-91)

Figure 99 Large-scale cable with foil print embellishment by Pamela Leung (left) and ‘Emotional Sculpture’ collection by Johan Ku (right)

5. Comparison of weaving and knitting

The comparison of future of the techniques, machines and products of weaving and knitting (Sadhan Chandra Ray, 2012: 12)

Diagram 5 Comparison of weaving and knitting

	Weaving	Knitting
1	Fabric is made by interlacement of threads	Fabric is made by inter-looping of threads
2	Two sets of threads: warp and weft are used in making the fabrics	One or one set of thread(s) either warp or weft is use d in making the fabric
3	Weaving requires more number of preparatory processes	Knitting requires less number of preparatory processes
4	Machines are mostly flat	Machines are flat as well as circular
5	Fabric is comparatively more rigid	Fabric is comparatively less rigid
6	Fabric is less stretchable	Fabric is more stretchable
7	Fabric dose not bend easily and results less comfort and form fitting property	Fabric bends easily and results good comfort and form fitting property
8	It is easy to tear the fabric	It is difficult to tear the fabric
9	For same GSM the fabric is less thicker	For same GSM the fabric is more thicker
10	Fabric has low wrinkle (crease) resistance	Fabric has high wrinkle (crease) resistance
11	Fabric is stiffer and has harsh feel	Fabric is less stiffer and has soft feel
12	Fabric is less porous and our permeable	Fabric is more porous and air permeable
13	Fabric is strong and durable	Fabric is comparatively weaker and less durable
14	Lesser inherent tensions cause minimum shrinkage and loss of size	During conversion of yarn into loop tension development is high which results higher shrinkage
15	Moisture absorption power is less due to compact structure	Moisture absorption is more because of comparatively loose and voluminous construction
16	Fabrics are more dimensional stable due to tighter construction and intersecting of warp and in right angle	Because of loop structure and inability of yarn to return to original position, the dimensional stability is poor

knitting and Lifestyle product

1. Lifestyle product

There is not a definitive meaning for “lifestyle product”. However, it can be inferred from the definition of these two words bellow:

1.1 Lifestyle

Someone’s way of living; the thing that the person or particular group of people usually do things. (Cambridge Dictionary,2018)

The typical way of life of an individual, group, or culture (Merriam Webster, 2018).

The way in which a person lives English (Oxford Living Dictionaries, 2018).

The habits, attitudes, tastes, moral standards, economic level, etc., that together constitute the mode of living of an individual or group (Dictionary.com, 2018).

A set of attitudes, habits, or possessions associated with a particular person or group (Farlex, 2018).

In conclusion, the typical way of life of an individual, group, or culture that relate to habits, attitudes, tastes, moral standards, economic level, family and environment.

1.2 Product

Something that is made to be sold, usually something that is produced by an industrial process or, less commonly, something that is grown or obtained through farming (Cambridge Dictionary,2018)

The totality of goods or services that a company makes available; output (Dictionary.com, 2018).

An article or substance that is manufactured or refined for sale (Oxford Living Dictionaries, 2018).

Something produced by human or mechanical effort or by a natural process (Farlex, 2018).

A good, idea, method, information, object or service created as a result of a process and serves a need or satisfies a want (Businessdictionary, 2018).

In conclusion, a product is an object or service produced by humans or mechanically as a result of a process and serves a need or satisfies a want.

As per these conclusions, it can be said that the meaning of a lifestyle product is an object or service produced by humans or mechanically as a result of typical way of life of an individual, group or culture that relate to habits, attitudes, tastes, moral standards, economic level, family and environment.

In Thailand, Thai Lifestyle Products Federation (TLPF) was established with an aim to expand the lifestyle product sector in Thailand, including following 6 alliance associations:

1. Thai Gifts Premiums & Decorative Association
2. Thai Toy Industry Association
3. Thai Housewares Trade Association

4. Northern Handicrafts Manufacturers and Exporters Association (NOHMEX)

5. Thai Stationeries and Office Supplies Association

6. Home Decorative Design Association

Thai Lifestyle Products Federation (TLPF) has been authorized by the Department of Export Promotion, Ministry of Commerce to become a "Bangkok International Gift Fair and Bangkok International Houseware Fair (BIG + BIH)'s official supporter". The fairs have been held twice a year in April and October to bolster the Thai lifestyle products industry. With more than 600 exhibitors in 1,600 booths, inspired and qualitative goods including home decorative, gifts, houseware, Northern handicrafts, toys and games, stationery, and designed items are chosen to be exhibited in this fair. Presently, these multinational exhibitors attract over 90,000 visitors to every event.

Thailand is well-known for its skills in handmade and creative produce. BIG+BIH is the International Trade Show which presents the group of Gift, Premium and Decorative items to the market. Artificial flowers products, ceramic pottery, candle products, decorative products, leather products, metal product, premium products, and more are widely distributed to the global market. Our Thai exotic products are very valuable for clients. Thai products are not only handmade but made with the brain and the heart. (The Associations of Thai Lifestyle Products Federation, 2018)

2. Knitting and lifestyle relation

In relation to knitting, it can be suggest that knitting is a part of the textiles is a lifestyle product sector as can seen by all of the many products around us all the time in everyday life. And sometime it is necessary to sustain our life. As Jacquie Wilson (2001:8) describes that textiles are found in a hugely diverse range of products. Clothing us from birth until death, textiles protect us and make us feel good. Our homes are made more comfortable by textiles that keep in heat and by textiles that shield us from the sun. Keeping us warm at night, textiles also dry us when we are wet and can support injured limbs. Textiles allow us to make tea directly in a cup. More recently specialized textiles have been developed for medical use as artificial replacement ligaments and arteries, and geotextiles are used in the construction of dams and motorways and even bunkers on golf courses.

Jacquie Wilson (2001:8) describes the end-use textile products as follows:

1. Apparel textiles

The clothing or apparel market includes most garments that are worn. A huge consumer of fabric, clothing manufacture can be split by market, e.g. men's, women's and children's clothing, sportswear, casual wear or formal wear. However, not all fabrics for garments are considered part of the apparel market. Fabrics such as the specialized protective clothing for fire-fighters, pilots and those in similar hazardous occupations are considered part of the industrial textiles market, and specialist clothing for leisure and ski wear, etc. are considered as being consumer textiles.

2. Furnishing fabrics or interior textiles

The furnishing market is another huge consumer of textiles, for curtains, upholstery fabrics, carpets and wall coverings, either domestic or contract. Domestic furnishings are those found in the home, while contract furnishings are those used in offices and public buildings such as schools, hotels and hospitals.

3. Household textiles

This category includes all textile products used within the home except furnishings, including sheets, pillowcases, towels, blankets, tablecloths, etc. When these products are used in the contract market they may be referred to as 'institutional fabrics'.

4. Industrial textiles

Car tyres, medical textiles and geotextiles are all examples of industrial textiles. Industrial textiles also covers such textile products as filters, conveyor belts, car safety belts and parachute cords. Performance is of prime importance in this category.

5. Consumer textiles

This category could be described as including any textiles not falling into the previous categories. Recreational items such as tents and back packs may be referred to as consumer textiles, as well as awnings and umbrellas and luggage. Although in this category performance can be very important, aesthetics can be equally so.

Thomas Gries, Dieter Veit and Burkhard Wulfhorsr (2015, 18) explain that the textile products that are depending on their field of application, textile products have to fulfill the following specific requirements.

1. Aesthetic Properties: handle, optical appearance and look, cooler and luster, and susceptibility to dirt.

2. Physiological properties for wear: skin-friendly wear properties, air permeability, water resistance and moisture take-up.

3. Physical properties: strength, elongation, wrinkle resistance and abrasion resistance.

4. Chemical and biological properties: resistance to chemical cleaning agents, resistance to microorganisms and pests, fastness against light, sweat, and friction and water-fastness.

J. Wilson has given us reminds us that knitted products are a part of everyday life as well as lifestyle .He describes knitting as one of the textile products that produces fabrics like no other. These fabrics have many functions:

1. The clothing or apparel market includes most garments that are warn. These can be classified by the wearer or by the type of apparel.

1.1 By wearer : menswear, womenswear and childrenswear.

1.2 By type: sportswear, casual wear and formalwear.

2. Specialised fabrics that go into protective clothing for fire-fighters, pilots are usually considered part of the industrial and consumer textiles market.

3. Furnishing market or interior textiles, such as curtains, upholstery, carpets and wall coverings.

4. Household textiles are those used in the home except furnishings and include: sheets, pillowcases, towels, blankets and table cloths.

5. Industrial textiles: car tyre components, medical textiles, geo textiles, filters, conveyor belts, safety belts and parachute cords.

6. Consumer textiles that could be described as textiles not falling into the other categories and including tents and back packs.
(J. Wilson, 2011: 3-4)

The sample of knitting lifestyle product

The sample of knitting lifestyle products aims to present what is happening globally within knitting by exploring the multiple outcomes being produced by knitwear designers and product designers, including their design philosophy, their creative process, aesthetics, materials technologies, environmental influences, and stitch and yarn choices

1. Knitwear

Knitwear can be found at all levels of the fashion market, from the industrial mass production of hosiery, underwear and sportswear to the use of its sculptural qualities in high fashion and accessories, such as bags, shoes and jewellery. (Juliana Sissons, 2010: 7)

1.1 Alice Lee

Alice Smith and Lee, husband and wife worked together on projects for several global design companies before forming their own knitwear label, Alice Lee. Respected for their attention to detail, they create beautifully made pieces on a domestic knitting machine, often pushing the technique of partial knitting. Alice Lee were recipients of the British Fashion Council's Newgen scheme for three consecutive seasons in 2001–2, and were one of Vauxhall Fashion Scout's Ones to Watch in 2012. The label was also included by Selfridges in their 2012 Bright Young Things line-up, which resulted in a window display at the famous London store. The duo describe themselves as having a 'couture aesthetic with a modern edge'.

The direction of the knit has been cleverly considered by the designers for their Stephanie Dress. It has been adjusted so that it gently hugs the body, with added fullness in the skirt. (Figure 109) and Leather lacework adds shape to and enhances the silhouette of this broken-check dress, made from embroidered knit. (Figure 110). The stand-out dress embraces a multitude of holding techniques possible with the domestic knitting machine. It showcases not only the versatility of the machine, but also the expertise of the designer and the skills of the makers. (Figure 100) (Samantha Elliott, 2015: 10-15)

Figure 100 Stephanie Dress. (left), Leather lacework (centre), and The multitude of holding techniques. (right)

1.2 Mark Fast

The Canadian Mark Fast graduated from London's Central Saint Martins in 2008. Mark's unmistakable womenswear pieces, which are created on a domestic knitting machine, have challenged perceptions of knitted garments. Mark is famous for devising his own innovative stitches, and embracing stretch yarns to create contemporary sculptured garments. The designer pieces have a unique design signature and a large following. A champion for women: having famously sent a plus-size model down a London catwalk in 2010 to prove that his knitwear could look good on any woman, Mark takes pleasure in the joy he creates with his garments. (Samantha Elliott, 2015: 26-32)

Figure 101 Autumn/winter showcasing a range of techniques. (left) and spring/summer black and grey dress with fringes. (right)

1.3 Brooke Roberts

Brooke Roberts, London-based knitwear designer studied fashion design at the London College of Fashion, and then studied innovative pattern making at London's Central Saint Martins. In 2009 she established Brooke Roberts Ltd., a new and visionary knitwear label that explores and challenges the knit process, crossing the boundaries between science, art, and knitting. She works as the creative director of the company, and as a design and technical consultant to other luxury brands. Brooke's work is recognized for its intelligent approach to design, and its strong, technical understanding of knitted structures. Her designs are heavily influenced by human anatomy, medical X-rays, and computed tomography scans, creating three-dimension cross-sectional images. Many of Brooke designs have a 1950s retro feel combined with cutting-edge technology. Owing to the high-level patternmaking skills she applies to her work, many of her silhouettes are strongly tailored, with interesting style lines and stunning detailing.

The "Calibration" collection, Fall/Winter 11/12, by Brooke Roberts, who is inspired by "an investigation of X-ray calibration films," and programmes her knits from X-rays and CT scans to produce graphic jacquard patterns. (Figure 102: left left) and jacquard patterning, combining a range of luxury yarns including cashmere, wool, cotton, extra-fine wool bouclé, silk, techno- plastic, metallic, and retro-reflective yarns. (Figure 102: right) (Carol Brown, 2013: 92-93)

Figure 102 The "Calibration" collection, Fall/Winter 11/12, by Brooke Roberts.

1.4 Alice Palmer

Alice Palmer graduating from London's Royal College of Art with a master's degree, Alice has held fashion shows in London, Tokyo, and New York. In September 2008, while showing her Spring/Summer 2009 collection in New York with NY Profile, she was presented with the Best Womenswear Designer award by sponsors, ASOS. Alice is especially interested in pattern, form, and shape, creating garments mainly inspired by art and architecture. Unconventional knitting techniques are combined with traditional methods to form garments with a bold and modern look. Her label has a strong, unique aesthetic, coupled with sustainable production methods, which result in no fabric waste.

The design's Spring/Summer 2012 "Interstellar" collection drew inspiration from David Bowie and glam rock, as well as polyhedra, topology, and Op Art. This luxurious collection was created in fine knitted silk and bamboo yarns, resulting in light, delicate textures, and the silhouettes featured manipulated tailored forms with

softly structured jackets and draped dresses that combined distorted stripes with laddering. (Figure 103) (Carol Brown, 2013: 116-117)

Figure 103 The “Interstellar” collection, Spring/Summer 2012, by Alice Palmer.

1.5 Shima Seiki

Shima Seiki Shima Seiki was established as a business by Masahiro Shima in 1962. During the half-century that it has been trading, the company has become a world leader in the manufacture, development, sales and marketing of computerized knitting machines and software systems. Shima Seiki introduced whole-garment knitting technology to the industry, enabling designers to realize knitted garments without seams, a development that continues to revolutionize knitwear. The company now has a global sales network spanning more than 80 countries, including all major knit-manufacturing markets around the world.

A Shima Seiki design on the catwalk during the 3rd Knitwear Designers Contest at the A/W13 Hong Kong Fashion Week. (Figure 104: left) The Contrast is a key feature of this design, accentuated by the use of different yarns. (Figure 104: centre) and shown partial/hold knitting -a machine-knitting technique in which only part of a row is knitted – for a striking textural effect. (Figure 104: right)
(Samantha Elliott, 2015:74-77)

Figure 104 The Shima Seiki knitwear design

1.6 Missoni

The Italian knitwear label Missoni is renowned for producing stunning knitwear featuring their signature stripes and intricate geometric patterning. Designs by Missoni illustrate the creativity that can be achieved by playing with color. Designer Sonia Rykiel, known as the "Queen of Knitwear" is also legendary for her exciting knits in kaleidoscopic colors and playful striped patterning. (Carol Brown, 2013: 86)

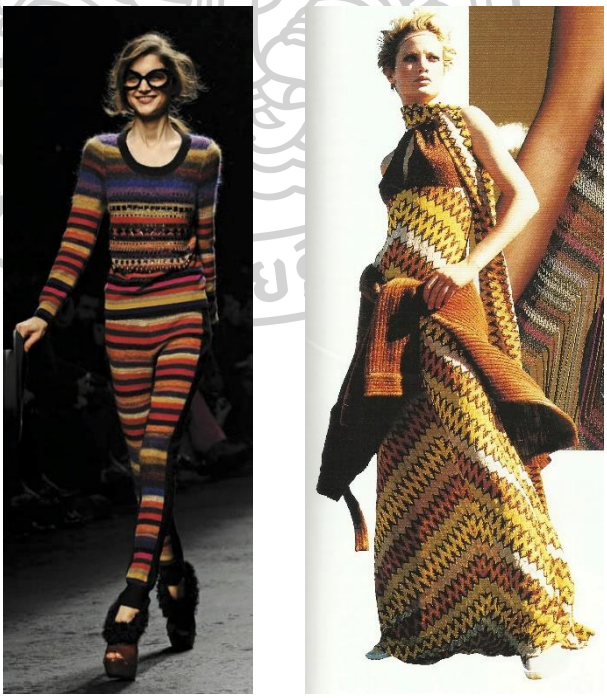


Figure 105 The multicolored knitwear in a profusion of bright colors,Fall/Winter 10/11 (left) and A classic Missoni look from 1970s, 'Zigzag' fabric knitted, Autumn/Winter 1996/97 (Sandy Black, 2002: 31)

1.7 Simone Memel

Simone Memel, ‘Hard Rope’, 1994/95. Memel branched out from designer’s fine arts and three-dimensional studies into the craft of shoemaking in order to express dichotomies and perceptions associated with male and female role. Simone first shoe project was a sock boot, combining sock and shoe, and she has since created many versions of one-off shoes using a range of knitted and other materials. The hand-knitted string is used to simulate the toughness of rope in a classic wearable style outlined by the knit and purl stitches and the plaited edging. (Sandy Black, 2002: 58)

1.8 Ann-Louise Roswald

Ann-Louise Roswald, capitalising on her father’s traditional clog-making business, Roswald was inspired to create matching clogs for her stylized floral printed knitter. These were quickly taken up by Italian house Marni for their winter 1999 collection, patterned to look like cows, and are now manufactured on a large scale in Sweden. (Sandy Black, 2002: 58)

1.9 Vivienne Westwood

Vivienne Westwood, ‘On Liberty’ collection. autumn/winter 1994/95. Hand-Knitted wool stockings with intricate lace and embossed leaf design and appliquéd flowers, finished with knitted tassels, were made to accessorise elaborate corseted and bustled hand-knitted outfits based on historical costume. Note how the knitted decoration extends to the shoes. Bags and jewellery were also created to accessorize. (Sandy Black, 2002: 59)

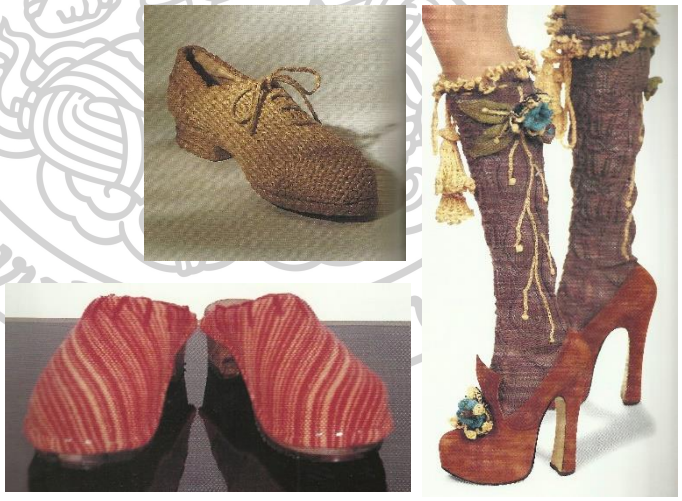


Figure 106 The ‘Hard Rope’shoe design by Simone Memel (left: top), Ann-Louise Roswald clog shoe (left: below), and Vivienne Westwood, ‘On Liberty’ collection. autumn/winter 1884/95.(right)

2. Product design

2.1 Claire-Anne O’Brien

Claire-Anne O’Brien is from County Cork in Ireland, she graduated with a degree in textiles from London’s Central Saint Martins in 2006, then completed a master’s degree in textiles at the Royal College of Art in 2010. In 2011 she set up her East London studio, specializing in constructed textiles.

Claire-Anne has exhibited at the London Design Festival, Milan Furniture Fair, Wool Modern and Spin expo, and she received a Future Makers Award in 2011 from the Crafts Council of Ireland. Her studio works on private and commercial commissions, and is committed to working with natural materials and local artisans, including a team of loyal hand-knitters. (Samantha Elliott, 2015: 206-213)

The ‘Olann’ collection is a series of simple furniture pieces, inspired by the Irish traditions of fishing and knitting, and featuring patterns based on Aran sweaters, fishing knots and willow baskets; Olann means ‘wool’ in Irish. Each item is made entirely by hand using Laxtons Mill wool, with natural materials such as coconut fibres and duck feathers replacing the usual synthetic upholstery materials. (Figure 107: left) The Casta chair, knitted tubes are twisted together and coiled around the seat and back of a wooden frame to create an organic shape. (Figure 107: right)

Figure 107 The ‘Olann’ collection. (left) and the Casta chair. (right)

2.2 Ariel Zuckerman

Ariel Zuckerman, Graduated with a Bachelor's degree in Industrial Design from Shenkar College of engineering and design,Israel. As the industrial designer Ariel combines digital and traditional manufacturing process to bring a sharp clarity to form, structure and texture of his work. Alongside his commercial product designs, his individual creations have appeared in museums and galleries worldwide.

The Knitted collection of lame, created in collaboration with Oded Sapir, contrasts the sleek silhouette of a translucent sphere with the warm texture of a knitted skin. The pattern for this acrylic knitted skin was designed digitally, together with textile designer Adva Bruner, to incorporate a delicate three-dimensional structure of peaks and openings, ensuring a robust surface with large light penetration. The feathered lattice design is produced as a seamless of the pattern knitting machine, resulting in an immaculate execution of the pattern. Each tube is finished by a dressmaker with wire and a contrasting woollen crochet stitch, and stretched over an acrylic sphere, made from a translucent material using conventional rotational moulding. (Lucy Johnston, 2015:276)

Figure 108 The Knitted collection, 2013, created in collaboration with Oded Sapir.

2.3 The Coopa-Roca

The Coopa-Roca: Rocinha Seamstress and Craftwork Co-operative Ltd, brand presented its first collection, a small range of fashion items, accessories and light shades, at the Salon Internazionale del Mobile in 2011, heralding a new phase in the collective's development. The initiative had originated in the early 1980s to help the women of the Rio de Janeiro's Rocinha favela, possibly the largest in South America, to earn an income and hence contribute to their family budget whilst working from home. It was founded by Maria Teresa Leal, a sociologist and arts educator who turned her attention to the children of Rio's urban slums, setting up free Saturday craft classes. It was not long before she recognised the skill of the mothers who attended the sessions and worked alongside their offspring, encouraging them by demonstrating traditional Brazilian handwork technique such as patchwork, crochet and fuxico: a form of embroidery that uses scrap fabric gathered at the centre to form flower. A cooperative was formed to organise the women and train them to improve and standardize their work, which at first they sold in local markets. Today the group numbers over one hundred artisans, and over the years has established links and collaborated with international fashion houses, retailers, designers and installation artists, including Cacharel, Paul Smith, Agent Provocateur, Lacoste, C&A, Ford Boontje and Ernesto Neto. (2013: 269)

Figure 109 The Coopa-Roca lampshade project.

2.4 llot llov

llot llov was founded in 2006 by Ania Bauer, Jacob Brinck, Lena Hirche und Ramon Toshiro Merker. Since 2014 Ania Bauer and Jacob Brinck have been Head of Design. Their office is located at Kottbusser Damm in Berlin. llot llov's design is both functional and emotional. Often playful, always visionary, they work conceptually to aesthetically improve our day-to-day world. The guiding principles are: content, efficiency, clarity and sustainability. Usefulness is a priority without foregoing complexity. llot llov acts on many levels. Their projects include building and furnishing shops, design and production of serial products, individual pieces and conceptual events bordering on art and culture.

The knitted light object Matt promises its user a high level of entertainment. It is made for being moved and played with. Through the use of an environmentally friendly energy saving bulb, there is no heat emission and Matt can be your friend all the way through long, platonic reading nights. Shown as figure 110 (left)

The 'Ray' lamp, which has the capability to follow its owner on heel. The cable of a hanging lamp is prolonged by 12 metres, thus enabling Ray to become a lying, hanging, or atmospheric lamp. The possibilities for using the device are unlimited, adapting to any method of playful arrangement. (Figure110: right)
(llot llov, 2017)

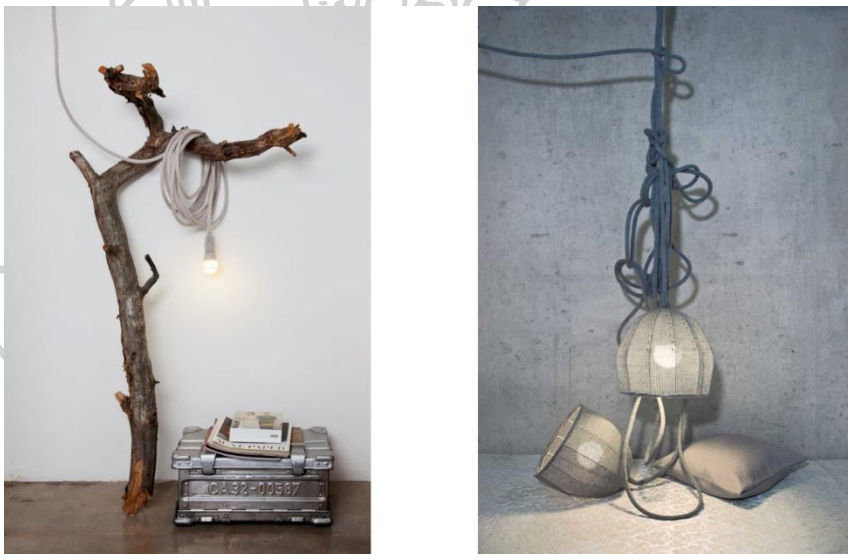


Figure 110 The 'Matt' knitted light (left) and the 'Ray' knitted light

2.5 Catherine Tough

Catherine Tough graduated from the Royal College of Art, London, in 1999. She is known for her knitted products, showcasing pattern and colour. A trailblazer for the knitted gift market, Catherine's products and accessories are sold in boutiques and department stores around the world. Catherine is also a respected author and a teacher. (Samantha Elliott, 2015: 214)

Catherine's passion for textiles began when she was still at school, inspired by her mum's knitting skills. Catherine and her dedicated team handcraft beautiful quality products from the finest natural materials. By fusing traditional craft practices

with contemporary, elegant design. Manufacturing in the UK where possible has always been at the heart of the business; mini factory at the studio in Hackney and a selection of highly skilled and knowledgeable manufacturers and suppliers now work together to produce the designer's entire range.

Catherine produces a wide range of fun characters. Filled with lavender, and gently felted, the knitted toys can also be used as doorstops, the knitted hearts are filled with lavender for encouraging sleep or for imparting a subtle scent to linens and lingerie. Catherine was one of the first designers to turn a knitted hot water bottle cover into a desirable trend item. All products are shown in figure 111

Figure 111 The knitted toys (left), the knitted hearts are filled with lavender (centre) and a hot water bottle cover (right)

2.6 Toshiko Horiuchi MacAdam

Toshiko Horiuchi MacAdam trained at the Tama Fine Art University in Tokyo, and then attended Cranbrook Academy of Art in Michigan. After graduating she worked as a textile designer in New York. Toshiko has taught at numerous colleges and universities, and is the author of the two-volume book From a Line, which references textile structure work. A highly regarded textile artist in Japan in the 1970s, Toshiko aims to make works designed for children's play rather than for exhibition in galleries and museums. Toshiko first high-profile playspace was created in 1979 and housed at Okinawa Memorial National Park, followed by Knitted Wonder Space at the Hakone Open-Air Museum. Toshiko is currently working on pieces to be installed in the USA and Canada, where she is now based.

The Harmonic Motion, a work by Toshiko Horiuchi MacAdam and Charles MacAdam with Interplay Design & Manufacturing, Inc., with structural design by Norihide Imagawa with T.I.S. & Partners, Co. Ltd.; 2013 Edition of Enel Contemporanea at MACRO Museo d'Arte Contemporanea Roma, December 2013–January 2015, present in figure 112 (Samantha Elliott, 2015: 198-201)

Figure 112 The Harmonic Motion at MACRO Museo d'Arte Contemporanea Roma, December 2013–January 2015

sustainable knitted fabric

In recent years, there has been greater awareness of social and environmental issues and the interest in ethical fashion has grown as a result. This is partly due to increased media exposure and also to changes in attitudes to consumerism, with an increased awareness among the public, who are able to make informed decisions. With celebrity endorsements and support from models such as Laura Bailey, designers Stella McCartney and Wayne Hemingway, and broadcaster and naturalist David Attenborough, together with the birth of ethical fashion labels such as North Circular (an ethical fashion label established by British model Lily Cole) acting as key driving forces, sustainability in fashion is creeping up the agenda.

The knitwear industry has been forced to react, and designers are now working in collaboration with scientists and various professional associations to review and improve the recycling agenda. New developments have included the use of eco-friendly and biodegradable yarns, improved methods of dyeing and finishing, and greater improvements in machinery and manufacturing processes, and construction techniques, all of which are designed to work toward reducing the impact of the industry on the environment as a whole. (Carol Brown, 2013: 162)

Figure 113 "Eco" collection comprising layered knits in a range of fabric weights, by American designer Lauren Siegel, who was awarded the Rising Star Award at Vancouver Fashion Week 2010.

According to N. Francis and B. Sparkest (2011, 83) the environmental disadvantages associated with the fashion and textiles industry have led to the emergence of designers who responsibly address ethical issues surrounding 'fast fashion'. In 1997 Orsola de Castro developed a capsule collection where she customised second hand knitwear and has since created a label that 'consistently addresses the issue of waste within the Fashion Industry'. De Castro's garments utilise discarded and unwanted pre consumer waste produced by the industry. She is a co-founder of 'ESTETHICA' the sustainable fashion section that was introduced to London Fashion Week in September 2006.

N. Francis and B. Sparkest present two examples of companies who design sustainable knitwear: Keep and Share and Makepiece.

1. Under the Keep and Share label, which is based in Hereford, Amy Twigger Holroyd produces luxury handmade knitwear pieces that 'transcend short lived trends and age gracefully' (www.keepandshare.com). Her company donates 1% of profit to an African charity which is dedicated to reducing poverty through developing small enterprises and self-sufficiency.

2. Makepiece, based in Todmorden was founded in 2004 by Nicola Sherlock and Beate Kubitz. The company designs and produces knitted garments that are manufactured locally, using sustainable yarns made from natural fibres through environmentally friendly processes. This is a small but vertical company that organically rears their own mixed flock of sheep to produce various woollen fibres for their unique design range. The company sets out to create knitwear that respects and works with the local community producing clothes with longevity that 'when they've

finally been worn to shreds, they can be composted' (www.makepiece.com).

3. Another example of a textile designer who focuses her work around ethics and sustainability is Annie Sherburne who 'has been incorporating environmentally friendly materials into her design work for ten years'. Sherburne specialises in felted textiles and has contributed to the collections of Hussein Chalayan and Jean Muir. Sherburne's work is exhibited in galleries such as the Victoria and Albert Museum, London and the Musée Des Modes in the Louvre, Paris.

Kate Fletcher (2014, 117-118) suggests some textile waste management strategies. They consist of three types, those organized in a hierarchy based on the relative amounts of energy and materials that are needed to carry them through. From most to least resource efficient, the strategies are:

1 Reuse of products, normally for the same purpose, sometimes with redistribution and resale. Strategies that promote the reuse of goods require fewest resources to enact, generally only involving collection and resale.

2 Repairing and reconditioning of either whole products or parts of products to keep them useful as long as possible. Repair and reconditioning strategies require more resources and can involve a manufacturing infrastructure to provide parts and labour for maintenance work.

3 Recycling of raw materials to provide inputs to the manufacture of other goods. Recycling strategies, where the products go back to fibre, or even polymer, require more resources still and are the least efficient of the strategies from a materials perspective, although in most cases they are still less resource intensive than the production of virgin materials.

In addition, A. Sherburne. (2009, 29) suggest other alternatives waste management strategies, the details are as follows:

1. Reuse and recycling: this is the key to all fully functioning cradle- to-cradle systems of production; this is where the loop closes. Working hard at this point will reap rewards, because it is a major source of raw materials. Reuse is where a product is used again as is, or slightly changed and adapted. Recycling is where the materials transform into a new form either by composting and feeding the next renewable cycle of a natural fibre, or, in the case of non-renewables such as polyester, by being returned to feedstock for repolymerisation.

2. Local sourcing: maintains and honours natural geographic and cultural diversity, enables specialism and is low on carbon emissions. An ideal is local self sufficiency where possible and appropriate on a global scale. It does not exclude the possibility of global, specialist, individual trade if shop windows on the internet can use carbon neutral or more energy efficient transport systems.

3. Slow design: an antidote to fast fashion, this is less stressful, and allows us to value materials and processes for their own sake. There are fewer 'deadlines' and more life. There is enough time for solutions and designs to evolve, for skills to develop and mature.

4. Tribal, ethnographic, regional, traditional design: the industrial revolution sped up and relentlessly reproduced original technologies that had evolved slowly from generation to generation to meet needs and desires. The making of Harris Tweed, or tartan involved problem-solving skills in harmony with the use of local

resources, efficiency, aesthetic expression and sophistication. These are the very images and allusions that fashion often emulates, but that market forces make uneconomic in their original form, while the workforce becomes redundant and the expertise is lost. But the originals are cultural treasures, whose creation gave dignity, identity and livelihoods. Not everyone wants to stack shelves or tweak computers. Can a new ecological economy revive and define traditional, tribal, regional and ethnic in a contemporary context

5. Vintage, collecting, heirlooms: husbanding resources, recognising and preserving value, enjoyment and entertainment. Economic vitality is enabled by passing things around, without expenditure of resources, allowing the culture to be reflected upon, maintained and vitalised. This is a way of sharing while maintaining economic movement.

Uraiwan Paradee (Pitimaneeyakul) (2012, 133-145) said knitted fabric designers can remind us of the environmental impact caused by knitted fabric design innovation.

Uraiwan presents us with guidelines of sustainable and eco knitted fabric design as follows

1. Knitted fabric design processes should reduce material, energy and wastage.
2. Knitted fabric should be designed to be multi-functional.
3. Knitted fabric should be designed to be reusable or recyclable; the recycle and upcycle concept.
4. Knitted fabric production should reduce its environmental impact.

The other example of knitted fabric design from waste is Muji's reused yarn T-shirts which maintain quality by avoiding mechanically pulling the fabric apart. Here, cotton yarn left over on roll ends of fabric is first unravelled and then knotted into a continuous lament ready for re-knitting. Recycled yarns and fabrics made with mechanical recycling methods remain a niche market and it is worth noting that until recycled materials are regularly specified in mainstream products, they will continue to be difficult to source, for without demand, supply is restricted. It is not enough to specify materials that can be recycled, for without a market for the recyclate, a high-value second life is unlikely. Kate Fletcher (2014, 122-123)

Figure 114 Muji's reused yarn T-shirts

Knitted fabric testing

The purpose of knitted fabric testing is done for evaluating the quality aspects of fabrics made in knitting. It helps to assess the quality of the end product, the performance of the fabric during the end use and the properties like comfort, feel and handle of the garment. The tests are mainly done keeping in view the following:

1. To evaluate the quality aspects of the fabrics made in knitting
2. To assess whether the quality of the fabric made is equivalent to the expected/predicted quality
3. To assess whether the quality of the knitted fabric matches the required quality of the end product
4. To assess the performance of the fabric during the end use
5. To evaluate the comfort properties, feel and handle of the fabric/ garment.

Traditionally the following tests are carried out for knitted fabrics are: fabric appearance, thickness, fabric pilling, fabric extension, air permeability, abrasion resistance and bursting strength.

In addition, some other tests as mentioned in the undergoing may be carried out for speciality fabrics according to their end applications.

- Thermal insulation value (TIV)
- Compressibility (compression behaviour)
- Tensile, tearing and impact strength
- Water permeability
- Water repellence/proof
- Fire resistance

These tests are carried out as per ASTM/BIS and as detailed in the standard text books on testing of textile materials.
(Sadhan Chandra Ray, 2012: 316-321)

Research relation

Autcha Hattayananont, Bussara Soiraya and Praparnporn Theeramongkol (2013, ค-ง) *Development of textile in SLUB Yarn fabric from textile material waste.* The research aimed to Developed of textile in SLUB Yarn fabric from textile material waste. The purpose was to developed Fancy yarn (SLUB Yarn) from textile material waste. To develop woven with Fancy yarn (SLUB Yarn) textile material waste. To study Fancy yarn (SLUB Yarn) properties and woven with Fancy yarn (SLUB Yarn) from textile material waste. The First step is sorting and scouring textile material waste from silk yarn and to spin 2 types of Fancy yarn SLUB Yarn as 50 percent silk fiber blended with 50 percent Cotton and other type as 100 percent Silk. The Second steps is to testing of physical properties in the textile testing laboratory. The testing results are Silk, Fancy yarn (SLUB Yarn) from textile material waste, have twisted more than Silk blended with Cotton. It make textile material waste from Silk yarn smaller and stronger than Silk blended with Cotton and also more tenacity meanwhile it has highest tensile, strength and elongation than Silk blended with Cotton. The Third steps to produce woven fabrics with plain weave structure. The weaving results have 2 fabrics, the first types from Fancy yarn (SLUB Yarn) weaved by 50 percent Silk fiber blended with 50 percent Cotton in Industrial woven system and the second types from Fancy yarn (SLUB Yarn) weaved by 100 percent silk in hand woven

system or with traditional weaving loom. The Last steps are to test the 8 topics physical properties of 2 woven in the textile testing laboratory.

First, Colorfastness to washing testing was found that Silk fabrics of Fancy yarn (SLUB Yarn) from textile material waste is durable to washing than 4.58 percent.

Second, Water absorbency Testing was found that both of two fabric types are equal to 60 (seconds).

Third, Moistures Management testing was found that the moisture absorption and wet textile as follows at 6 parts : the duration of the wet cloth was found that Silk fabrics of Fancy yarn (SLUB Yarn) from textile material waste is more absorbed than Silk fiber blended with Cotton and the duration of adsorption rate was found that Silk fiber blended with Cotton fabrics of Fancy yarn (SLUB Yarn) from textile material waste is better than Silk fabrics. The radial distribution of moisture on the both side of fabric surface was found that Silk fiber blended with Cotton fabrics of Fancy yarn (SLUB Yarn) from textile material waste is better and more effective and also there are the distribution and direction of motion better than Silk fabrics of Fancy yarn (SLUB Yarn) from textile material waste. Moreover,It was humidity control overall properties.

Forth, Pilling Resistance Testing was found that both of 2 fabrics are Pilling Resistance, fur and beads up on the surface, slightly.

Fifth, Fabrics Thickness testing was found that Silk fabrics of Fancy yarn (SLUB Yarn) from textile material waste more over was 0.10 mm.

Sixth, Dimensional stability to washing after 5 times Testing (changes size after washing) was found that Silk fiber blended with Cotton fabrics of Fancy yarn (SLUB Yarn) from textile material waste was shrinkage after washing in the warp yarn more than -7.6 and shrinkage after washing in the weft yarn more than -7.0.

Seventh, pH-Acid Value Testing was found that Silk fiber blended with Cotton fabrics of Fancy yarn (SLUB Yarn) from textile material waste has pH-Acid less than 0.07.

Eighth, Heavy Metal Testing was found that Silk fiber blended with Cotton fabrics of Fancy yarn (SLUB Yarn) from textile material waste has 3 Heavy Metals such as chromium, lead and copper while Silk fabrics of Fancy yarn (SLUB Yarn) from textile material waste has 2 Heavy Metals such as copper and lead.

Kachamas Tumrongsak (1994,astract) *Nonwoven Fabric Production Using Waste Silk.* This thesis was aim to studied the possibility in producing nonwoven fabric from waste silk by conventional carding followed by thermal bonding process. It also covers the study of physical and mechanical properties of the products to verify whether they are acceptable for textile applications. Waste silk from the mesh around the cocoons, so called Keba, was blended with bicomponent binder fibers, i.e., polyolefin and polyester which compositions were varied in contents between 20-35% by weight. The roller carding machine was used for forming the blended webs. The webs, then, were passed through the belt-thermal bonding machine for heat compression. Some basic properties, such as tensile and tear strengths, were evaluated. The results show that the nonwoven fabrics with areal density 60 g/m('2) can be effectively produced from the proposed process. The products are yellowish white, lustrous and soft. The uniformity of the web falls in an acceptable range with

coefficients of variation 8-10%. Their moisture regains were about 2.0-3.6%, and they show good air permeability. Generally, increasing binder fiber contents provide in stronger nonwoven fabrics. On the other hand, higher amounts of waste silk result in less stiffness and soft hand. Nonwoven fabrics blended with25-30% of polyester fibers have acceptable strength and softness.

Kittisak Ariyakuare (2010, 369-375) *The Development of New Mixed Fiber from Waste Cocoon and Other Plant Fibers.* The purpose of this research was to develop new mixed fiber from waste cocoon and other plant fibers. It was found that waste cocoon has qualitative properties to produce new mixed fiber when mixed with five kinds of plant fibers, namely cotton yarn, linen yarn, pineapple yarn, ramie yarn and hemp yarn. The processes included boiling waste cocoon in wetting agent water and Sodium Carbonate for 30 minutes at 90 C, and dehydrating it. After that, short cocoon yarn was obtained. Then mix it with the five kinds of plant fibers with the ratio of 50:50 in carding at silk card, and undergo mixing and spinning process. Qualitative test result of new mixed fiber from waste cocoon used as weft yarn, and five kinds of plant fibers used as warp yarn in industrial weaving showed that fiber from waste cocoon mixed with hemp yarn has the best breaking strength of 194 CN/tex, followed by waste cocoon mixed with ramie yarn of 149 CN/tex, waste cocoon mixed with linen yarn of 146 CN/tex, waste cocoon mixed with pineapple yarn of 145 CN/tex, and waste cocoon mixed with cotton yarn of 143 CN/tex. Meanwhile, fiber from waste cocoon mixed with heft yarn has the best mean elongation of 2.30 cm, followed by waste cocoon mixed with cotton yarn of 2.32 cm, waste cocoon mixed with ramie yarn of 2.77 cm, waste cocoon mixed with linen yarn of 3.42 cm., and waste cocoon mixed with pineapple yarn of 3.43 cm. Thus, the research results indicated that fiber from waste cocoon mixed with hemp yarn is good for producing home textile as it has the highest breaking strength while fiber from waste cocoon mixed with pineapple yarn is good for producing clothes.

Metta Suwanasorn, Pisanu Supanimit, and Sutha Leenawat. (2016, 1829-1846). *Thread of Love from Mother*. The objective of creation, Metta create the mixing new style between soft sculpture and installation art with crochet that inspired by her autism son. Metta chose crochet knitting technique because it is such a good therapy art. She would like to show the power of love that researcher feel to her son. Matta would like to make people realize how beautiful mother is. Metta present the inspiration of shapes and drawings from her autism son’s artwork.

The creation of ' Thread of love from mother' is such a great powerful of love from me to her son by crochet knitting to be strong and graceful soft sculpture. It is a unique and different from other art works because Matta have tried to knitted million times to do my work. It is more than take a pencil and paint color but she keep her heart to move her work on to show how much she love her son. A thread could be compared to my million love-her billion soul that she neatly did it. It is inspired by imagination- therapy of my autism son, who is special one and super creative in my life, he is so wonderful to me. In researcher’s opinion therapy art is excellent because it can makes people to relax. 'Love' and 'Relationship' are very important because they are like roots of family foundation to make people strong and graceful. Metta knitted her art like she knitted her son with two hands to let him perfection from

imperfection. Now Metta's son is perfect one.

The thread of love from mother one set show to public for motion of modern art circle. The objective is making powerful of mother who had autism child. He or she is not strange but your child is unique and has very special gift from heaven. Parents will know and understand something in autism mind by art therapy. If autism child always practice and intend art therapy, he will be dare to show his feeling and when he grow up he will be strong when he learn for social skill. Art is the symbolic national language since ancient era of the world, it is amazing. When we know and understand what autism think and feel, we can estimate about his skills that he is ready for his everyday life or not. Include with relationship while you pay time with your autism child, it is love and beautiful.

Pisut Chankum (2011, ง) *Yarn Spinning from Silk Wastes in Weaving Process.* The research aimed to recycle silk wastes from weaving process by transforming into spun yarns using ring spinning system. In this study silk wastes from both handloom and rapier loom were used and cut at length of 38 mm. suitable for cotton spinning process. Then fibers were fed into opener, carding machine, draw frame, roving machine and ring spinning machines. Physical properties were then used characterize the properties of resulted yarns. The yarns were knitted to make gloves, socks and knit fabrics. It was established that silk wastes from both handloom and rapier loom were able to make yarns. The yarn count of the recycled yarn from waste of handloom was 18.37 Ne with the average twist of 17.22 turns per inch. The tenacity of yarn from waste of handloom was 14.40 cN/tex. The yarn count of the recycled yarn using waste from the rapier loom was 16.51 Ne with the average twist of 16.53 turns per inch. The tenacity of yarn from waste of rapier loom was 20.27 cN/tex. The recycled yarns could be knitted into end-use product such as gloves, socks and knit fabrics.

Rungsima Chollakup, Suchada Ujjin and Kanittha Wattcharaporn (2008, 294-302) *A study on spinning waste yellow silk/brown cotton blends on open-end spinning system.* Blending of brown cotton and yellow silk fibers from silk waste for blended yarn was conducted in this study. The yellow silk fibers from silk waste were degummed in an optimum condition that provided less residual sericin in fibers enough for fiber extraction using a cocoon opener. Also yellow color still remained in silk fiber. It is found that degumming method using boiling water at 105oC for 60 min, the silk fibers were still light yellow color and had residual sericin less than 15%. Thus, the brown cotton and yellow silk fiber were blended at ratio of 50/50 with yarn count of 30 tex in a cotton spinning industry. Their physical properties were evaluated and then compared with the white cotton and yellow silk spun yarn. The blended yarn had lowest in the tenacity, similar elongation and %CV values compared to the white cotton spun yarn, and had highest imperfections of neps. According to fine fiber of the brown cotton, it induced to decrease the hairiness of the blended yarn. Moreover, color values of the blended yarn were followed the mixing law of pure fiber color which resulted in more yellowish brown color and more bright luster.

Saowanee Areechongcharoen and others. (2013). *Development of Textile Products from Lemongrass Fiber*. A study on developing textile products from fiber lemongrass has been carried out aimed at processing yarn from lemongrass fiber, developing textile fabrics, such as clothing, hats, and shoes, and teaching product

design and technology to a community. Lemongrass leaves were processed with chemicals to produce a fiber lemongrass then spun to 100% lemongrass yarn with large unsmooth surfaces then used to produce handbag, hats and shoes. However, for garment fabrics, the researchers developed the lemongrass yarn for weaving by mixing cotton in a 60:40 ratio to produce hand-woven cloth. Using hand-woven folk wisdom, the Takfa community in Nakhon Sawan, produced natural dyes from Bengal Almond leaves, a performed surface finishing for a smoother touch. After weaving, lemongrass fiber cloth gives off a lemongrass odor, but this fades gradually. The physical properties of lemongrass fiber cloth are then tested for strength, resistance, and abrasion.

Processing lemongrass cloth fiber to textile products enables us to produce various products such as clothes, bags, and hats. In passing technology to the community, the residents recognized the advantages and benefits of using the fabric. Further research should investigate mixing lemongrass fibers with other natural fibers improved fiber durability, luster of the fiber to increase fiber value, or using lemongrass fiber for household products.

Siriluk Wongkasema and Puripong Aksornpim (2015, 801-806) The Development of a Carding *Machine and a Twisting Silk Machine for Eri Silk.*
The purpose of this research was to develop a carding machine and twisting machine for produce eri fiber and yarn. A carding machine decomposes degumming cocoons and forms it into cohesiveness silk filament. Silk filament was then spun and twisted in twisting machine. Factors to test machine functionality were teeth of carding head which were aligned in straight and zigzag pattern. Speeds of fiber feeding were 0.24, 0.32, and 0.4 meter per minute. From the experiments of carding machine, it can be found that almost cocoons were decomposed when using zigzag pattern. Speed of cocoon feeder was about 0.24 meter per minute. From twisting machine testing, results pointed out different speed of fiber feeding provided different size of yarn. The properties of eri silk obtained from machine were similar with eri silk produced from traditional method. Therefore, carding machine and twisting machine developed in this research can help farmers to increase production and support the eri silk industry development.

Chollakup, Sinoimeri, A., Osselin, J-F., Frydrych, R. and Drean, J-Y.(2005, 57-69) *Silk Waste/Cotton Blended Yarns in Cotton Microspinning: Physical Properties and Fibre Arrangement of Blended Yarn.* The microspinning technology has generally been used for cotton in the case of small scale spinning test methods (50 gram fibres). One type of silk fibre waste -pierced cocoon- prepared previously as short silk fibre with cut length of 35 mm is blended with cotton fibre to obtain further data concerning two blending techniques in this microspinning, and to compare pure and blended yarns. The intimate (before carding and drawframe blending as well as the roll settings in the drawing system are being examined. The silk content was changed at 0/100, 25/75 and 50/50 ratio for a yarn count of 30 tex. The physical properties, the irregularity and the fibre arrangement as terms of the Index of Blending Irregularity and the Migration Indices of the blended yarns have been studied. In addition, the effects of the blending techniques as well as those of the silk content have been brought to the fore.

In year 2014, VTT Technical Research Centre of Finland is collaborating with Helsinki's School of Arts, Design and Architecture (Aalto) to develop a revolutionary method for producing high quality textiles from worn out and heavily soiled fabrics that have reached the end of their life cycle. The process involves many steps, the first being cleaning and bleaching the fabrics to prepare them for cellulose extraction. Decoloring the fabrics, which can be anything from a large piece to loose bits and scraps, makes the cellulose in the fabric far more soluble and extractable. Separation of the cellulose molecules is carried out with non-toxic, environmentally friendly substances, such as ionized solvents being tested by researchers at Aalto University. This technology is only applicable for cellulose-based fibers like cotton, linen and viscose, but any other fibrous material blended with the cellulose like polyester or acrylic can be melted down and recycled into composites and plastics. Once extracted, the cellulose molecules are spun into fiber and yarn, resulting in a finished product that is as good as, or possibly even better, than the original material. (Textile world, 2014).

Summary

Silk and silk waste

1.Introduction of silk

Silk is a natural fibre made of the silkworm. It is the only natural fibre which exists as a continuous filament. Silk has been regarded as a highly valued textile fibre. Its qualities of strength, elasticity, softness, absorbency, affinity for dyes and adaptability to various forms of twisting continue to meet various applications.

2. A definition and classification of silk waste

Silk waste is covered all classes of the raw silk which are unwindable and altogether unsuited for the throwing process. The silk waste is divided into three parts: blaze and unreelable cocoons, reelable waste and throwesters waste.

3. The silk waste utilization

Silk waste used for making the yarn we know as spun silk. The best grades of spun silk yarn are used as filling or weft in several varieties of silk fabrics, both plain and twill, and in pile goods such as velvets. A considerable amount is also used in the production of embroidery and knitting silks. Lower grades of spun-silk yarn are used in making ribbons and silk cords, while the cheapest grades are used to make knitted goods and coarser silk or silk-mixed fabrics.

4. Spun silk: machine spinning method

The process was similar to those used for wool, cotton and other short-staple fibre. There are consists of opening, carding, drawing, combing, roving and spinning.

5. Spun silk: hand spinning method

The main equipments are spindles and spinning wheel. The fibre form to spinning is upon end use such as worsted yarn and woollen yarn. A method of spinning is upon fibre form such as role, top, lap and mawata (silk hankies).

6. Yarn type and yarn design by hand spinning method

There are many ways of creating a spun silk staple yarn. The typical yarn formations include single yarn, ply or plied yarn, cabled or corded yarn, blended or compound yarn, core spun yarn and fancy or effect yarn.

7. Silk dyeing: natural dye stuff

Natural dyes produce moderately bright colours on mulberry silk, but deep shades can only be produced on tussar, spun and textured varieties. Natural dye stuff is available from root, wood, flower and leaf, fruits and vegetables, a special color such as indigo and lac. Dyeing process can be done by both hot water dyeing and cool water. Silk waste in form of silk noils, silk top, roving, sliver, batts, lap, mawata and yarn can be dye by a various technique such as immersion dyeing, hand-paint dyeing and freestyles dyeing.

Thai silk and Thai silk waste

1. Introduction of Thai silk

Thai silk is a part of the national cultural heritage. Thai cocoon species has a special property, it is a small and slim shape, but it's durable in the environment as well. Filament silk yarn is very fine and has special physical characteristics never seen in another silk, it's cross-section is triangular shape making beautiful light refraction. The most strength of Thai silk never found in the yellow silk type which consisted of 18 kinds of amino acid. The percentage of the amino acid is over 34.5 that higher than those of other counties. All of this is a result of the unique characteristics of Thai silk, it is quite a gummy, sticky substance and shine.

2. Thai silk waste

Thai silk industry is large scale, there are consist of three subdivision: upstream, middle stream and downstream. All state produce a lot of silk waste that can be classified into three types: waste from incomplete cocoons, waste from reeling, spinning and weaving process, waste from pulling or garneting warp and weft yarn by machine. The most waste of all industry is cocoons. There are consist of double cocoon, pierced cocoon, innerside stained cocoon, outside stained cocoon, thin shell cocoon, fluffy cocoon, thin end cocoon, malformation cocoon, coarse cocoon, crushed cocoon and mildwed cocoon.

3. Thai Silk waste utilization

Thai silk waste products are reused by businesses for items such as fashion accessories and decorative products. For example, the cocoons usually use to create a decorative product such as lamp shade, artificial flowers. A fabric from spun silk has been a frequent choice for home textiles such as upholstery and pillowcase. Spun silk fancy yarn also use in fashion fields such as a hat, scarf and bag. In addition, silk fibre use to made a thread and bio-composite in the medical field. (Thai Textile Institute, n.d.: 60-61)

4. Spinning Thai silk waste

The process to spinning Thai silk waste can be done by both hand spinning and machine that depend on raw material: incomplete cocoons and silk yarn waste and silk fabric waste.

5. Thai silk dyeing: natural dye stuff

Thai natural dye material are available from various plant parts, that can be extracted the dyes substances for silk dyeing such as bark, fruit, fresh leaves and flower. Dyeing method are Cold dyeing and Hot dyeing. Moreover, value and shade can be adding by mordant, such as rice straw lye, mud, alum and tamarind juice.

The knitted fabric

1. Introduction of knitted fabric

Knit fabric is formed by intermeshing loops of a single yarn or set of yarns together. There are two main types of knitted structure: Weft knitting and Warp knitting. The unique character of knitted fabric is high elasticity and recovery, wrinkle resistance and comfort.

2. Knitted fabric types

There are four common knit fabric. First is plain fabric: the simple fabric is made on one set of needles with all the loops intermeshed in the same direction. Second is Ribbed: fabrics in which both the back and face loops occur along the course but in which all the loops contained within any single wale are of the same type. Third is Purl : fabric in which both back and face loops occur in some or all of the wales, the structure may be identified by the particular knitting sequence used. Four is Interlock: Interlock machines are weft-knitting machines that have two sets of needles on a back and front bed, the fabrics produced are double-knit structures; essentially two fabrics interlocked together.

3. Knitting tools

There are two main tool to produce knitted fabric. First is hand tool, second is machine. The machine tool can be divide into five type: domestic machine, electronic machines, hand-operated industrial machines, circular knitting machines and electronic industrial machines.

4. Knitted fabric structure and pattern

There are Three type knitted fabric structure and pattern

4.1 Particular yarns: bouclés, slubs, crêpes, chenilles, smooth silks, ribbons, tapes, faux fur, marled yarn, mercerized and speciality yarns.

4.2 Stitch formation: lace, laddle, tuck, weave, slip stitch, or a combination of techniques worked together.

4.3 Three-dimensional knitting: incorporating ridges, bobbles, knitted flaps, and cables

5. Knitting and lifestyle product

In relation to Knitting, It can be suggest that knitting; a part of Textiles is a lifestyle product by a result of its products is around us all time, all day and sometime is necessary to sustain our life. The knitted lifestyle product are

5.1 The clothing or apparel market includes most garments that are warn. These can be classified by the we are or by the type of apparel. By wearer : menswear, womenswear and childrenswear. By type: sportswear, casual wear and formalwear.

5.2 Specialised fabrics that go into protective clothing for fire-fighters, pilots are usually considered part of the industrial and consumer textiles market.

5.3 Furnishing market or interior textiles, such as curtains, upholstery, carpets and wall coverings.

5.4 Household textiles are those used in the home except furnishings and include: sheets, pillowcases, towels, blankets and table cloths.

5.5 Industrial textiles: car tyre components, medical textiles, geo textiles, filters, conveyor belts, safety belts and parachute cords.

5.6 Consumer textiles that could be described as textiles not falling into the other categories and including tents and back packs.

6. The sample of knitting lifestyle products

The sample of knitting lifestyle products are knitwear and product, that show in page 72-82

7. sustainable knitted fabric

A guidelines of sustainable and Eco knitted fabric design are

7.1 Knitted fabric design process should be reduce material, energy and wastage.

7.2 Knitted fabric should be design into multi-functional.

7.3 Knitted fabric should be design under re-usability or recycle, recycle and up-cycle concept.

7.4 Knitted fabric production should be environment impact reduction.

7. Knitted fabric testing

The purpose of knitted fabric testing are done for evaluating the quality aspects of fabrics made in knitting. Traditionally the following tests are carried out for knitted fabrics are given Fabric appearance, thickness, fabric pilling, fabric extension, air permeability, abrasion resistance and bursting strength.

Research relation

Autcha Hattayananont and others. (2013) had studied to development of textile in SLUB Yarn fabric from textile material waste. The purpose is to develop Fancy yarn (SLUB Yarn), woven with Fancy yarn and study Fancy yarn (SLUB Yarn) properties and woven with Fancy yarn (SLUB Yarn) from textile material waste. The results are Silk, Fancy yarn (SLUB Yarn) from textile material waste, have twisted more than Silk blended with Cotton. It makes textile material waste from Silk yarn smaller and stronger than Silk blended with Cotton and also more tenacity meanwhile it has highest tensile, strength and elongation than Silk blended with Cotton.

Kachamas Tumrongsak (1994) had developed Nonwoven Fabric Production Using Waste Silk. The aim of research was to studied the possibility in producinga nonwoven fabric from waste silk by conventional cardingfollowed by thermalbonding process. he results show that the nonwoven fabrics with arealdensity 60 g/m('2) can be effectively produced from the proposedprocess. The products are yellowish white, lustrous and soft. Theuniformity of the web falls in an acceptable range withcoefficients of variation 8-10%. Their moisture regains wereabout 2.0-3.6%, and they show good air permeability. Generally,increasing binder fiber contents provide in stronger nonwovenfabrics. On the other hand, higher amounts of waste silk resultin less stiffness and soft hand. Nonwoven fabrics blended with25-30% of polyester fibers have acceptable strength and softness.

Kittisak Ariyakuare (2010) had development of new mixed fiber from waste cocoon and other plant fibers. It was found that waste cocoon has qualitative properties to produce new mixed fiber when mixed with five kinds of plant fibers, namely cotton yarn, linen yarn, pineapple yarn, ramie yarn and hemp yarn. The research results indicated that fiber from waste cocoon mixed with hemp yarn is good for producing home textile as it has the highest breaking strength while fiber from waste cocoon mixed with pineapple yarn is good for producing clothes.

Metta Suwanasorn and others. (2016). create the mixing new style between soft sculpture and installation art with crochet that inspired by her autism son. Metta

chose crochet knitting technique because it is such a good therapy art. She would like to show the power of love that researcher feel to her son. Matta would like to make people realize how beautiful mother is. Metta present the inspiration of shapes and drawings from her autism son's artwork. Metta suggests that the art is the symbolic national language since ancient era of the world, it is amazing. When we know and understand what autism think and feel, we can estimate about his skills that he is ready for his everyday life or not. Include with relationship while you pay time with your autism child, it is love and beautiful. Pisut Chankum (2011) had developed yarn spinning from silk wastes in weaving process. The research aimed to recycle silk wastes from weaving process by transforming into spun yarns using ring spinning system. The result show, a yarn count of the recycled yarn from waste of handloom was 18.37 Ne with the average twist of 17.22 turns per inch. The tenacity of yarn from waste of handloom was 14.40 cN/tex. The yarn count of the recycled yarn using waste from the rapier loom was 16.51 Ne with the average twist of 16.53 turns per inch. The tenacity of yarn from waste of rapier loom was 20.27 cN/tex. The recycled yarns could be knitted into end-use product such as gloves, socks and knit fabrics.

Rungsima Chollakup and others. (2008) had studied on spinning waste yellow silk/brown cotton blends on open-end spinning system. It is found that degumming method using boiling water at 105oC for 60 min, the silk fibers were still light yellow color and had residual sericin less than 15%. Thus, the brown cotton and yellow silk fiber were blended at ratio of 50/50 with yarn count of 30 tex in a cotton spinning industry. The blended yarn had lowest in the tenacity, similar elongation and %CV values compared to the white cotton spun yarn, and had highest imperfections of neps. According to fine fiber of the brown cotton, it induced to decrease the hairiness of the blended yarn.

Saowanee Areechongcharoen and others. (2013) had development of textile products from lemongrass fiber. The researchers developed the lemongrass yarn for weaving by mixing cotton in a 60:40 ratio to produce hand-woven cloth, natural dyes from Bengal Almond leaves, a performed surface finishing for a smoother touch. After weaving, lemongrass fiber cloth gives off a lemongrass odor, but this fades gradually. The physical properties of lemongrass fiber cloth are then tested for strength, resistance, and abrasion. Processing lemongrass cloth fiber to textile products enables us to produce various products such as clothes, bags, and hats. In passing technology to the community, the residents recognized the advantages and benefits of using the fabric.

Siriluk Wongkasema and Puripong Aksornpim (2015) had development of a carding machine and a twisting silk machine for eri silk. A carding machine decomposes degumming cocoons and forms it into cohesiveness silk filament. Silk filament was then spun and twisted in twisting machine. The research shows that the twisting machine testing, results pointed out different speed of fiber feeding provided different size of yarn. The properties of eri silk obtained from machine were similar with eri silk produced from traditional method.

Chollakup, Sinoimeri and others.(2005) had developed a silk waste/cotton blended yarns in cotton microspinning: physical properties and fibre arrangement of blended yarn. The process was begin from cut waste -pierced cocoon into length of 35 mm., then blended with cotton fibre to obtain further data concerning two blending techniques in this microspinning. The intimate before carding and drawframe

blending as well as the roll settings in the drawing system are being examined. The silk content was changed at 0/100, 25/75 and 50/50 ratio for a yarn count of 30 tex.

VTT Technical Research Centre of Finland and Helsinki's School of Arts, Design and Architecture (Aalto) (2014). had developed a revolutionary method for producing high quality textiles from worn out and heavily soiled fabrics that have reached the end of their life cycle. The process begin from cleaning and bleaching, decoloring the fabrics, which can be anything from a large piece to loose bits and scraps, makes the cellulose in the fabric far more soluble and extractable. Separation of the cellulose molecules is carried out with non-toxic, environmentally friendly substances, such as ionized solvents being tested by researchers at Aalto University. Once extracted, the cellulose molecules are spun into fiber and yarn, resulting in a finished product that is as good as, or possibly even better, than the original material.

Chapter 3
Research Methodology

The methodology of this research was related to “practice to design”. It consists of two parts, the first part involved the collecting of information related to Thai silk waste and its benefits. The second part involved experimenting to determine a suitable method and related equipment for the production of knitted fabric through a craft and industrial process as seen in the following steps.

1. Practice based is research on material, art and design
    1.1 Identify the properties and benefits of Thai silk waste.
    1.2 A development of yarn from Thai silk waste to create knitted fabric.
2. Pure Practice is synthesis and experiment in fabric development.
    2.1 Experiment of yarn and knitted fabric from Thai silk waste and colouring by craft and industrial process.
        2.1.1 Material development
            2.1.1.1 Silk waste: Incomplete cocoons, broken silk yarn and silk fabric waste
            2.1.1.2 Dyestuff: Natural dye
            2.1.1.3 Testing: Tensile strength bursting and elasticity
            2.1.1.4 Standard: ASTM (American Society for Testing and Materials)
        2.1.2 Yarn spinning and knitted fabric development
            2.1.2.1 Spinning equipment: Hand spinning and machine spinning
            2.1.2.1 Knitting equipment: Hand knitting, Domestic machine and Automatic machine
            2.1.2.2 Testing: bursting and elasticity
            2.1.2.3 Standard: BS (British Standards Institute)

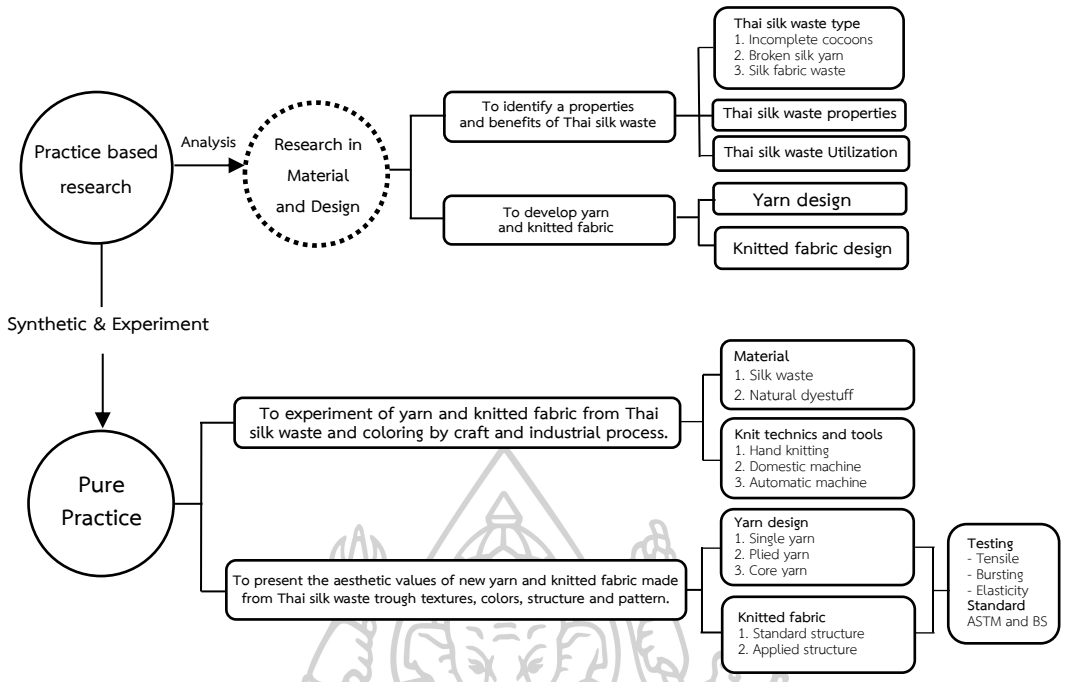


Diagram 6 Research methodology

Practice based: research in material and design

Identify a properties and benefits of Thai silk waste.

1. Thai silk waste classified

Thai silk is a part of the national cultural heritage. The unique characteristics is quite a gummy, sticky substance and shine. Thai silk industry like the other industries, it produces a lot of waste. A solid waste from Thai silk can be classified into three types as bellow:

1.1 Waste from reeling, spinning and weaving process

1.2 Waste from pulling or garneting warp and weft yarn by machine.

1.3 Waste from incomplete cocoons.

Among the three types, the most waste is cocoons. That can divide into eleven category: double cocoon, pierced cocoon or perforated cocoon, innerside stained cocoon, outside stained cocoon or soiled cocoon, thin shell cocoon, fluffy cocoon, thin end cocoon, malformation cocoon, coarse cocoon, crushed cocoon and mildwed cocoon

2. Thai Silk waste utilization

Generally, Thai silk waste use for reuse in the business roles such as fashion accessories and decorative product. For example, artificial flowers, hat, scarf and bag, cocoons lamp shade, pillow case. In addition, silk waste was recycle into spun yarn, which use to weave and knitted a fabric and transfer into various product. Moreover, the colouring by natural dyestuff and mordant for more shade and value can be done by Thai materials and method. The detail are as follows:

2.1 Spun silk process

2.1.1 spinning incomplete cocoons

The incomplete cocoons almost done by handicraft process, is begin from degumming cocoons , hand carding and spinning by local spinning tool. A yarn from hand spinning is softly and shiny, but weakness than filament silk.

2.1.2 spinning silk yarn waste and silk fabric waste

In the case of silk fabric waste, it should be separate warp and weft yarn before carding. Both silk yarn waste and silk fabric waste could be opening and carding by machine. Then take to spinning by hand and machine.

2.2 Natural dyes silk in Thailand

There are Various plant parts can be extracted the dyes substances for silk dyeing, such as bark, fruit, fresh leaves and flower. The main method to dyed silk waste are consist fo cold dyeing and hot dyeing. There can be add value and shade by mordant such as rice straw lye, mud, alum and tamarind juice.

knitted fabric and lifestyle products

Knit fabric is formed by intermeshing loops of a single yarn or set of yarns together. There are two main types of knitted structure: Weft knitting and Warp knitting. The common knit fabric type are plain fabrics, ribbed fabrics, purl fabrics and interlock fabrics. A method to produce knitted fabric is hand needle tool and machine, which divide into four types: domestic knitting machines, electronic machines, hand-operated industrial machines, circular knitting machines and electronic industrial machines. These methods used to make various structure and pattern, produce a unique property of the knitted fabric.

knitted fabric has high flexibility and thus produces comfortable clothing for every day wear. Whether thick and thin, the fabric produced is soft and is resistant to wrinkles and can easily recover its form and shape. Knitted fabric can be produced by body sizing and it is suitable and convenient for fitted wear. That is the result of the knitted fabric use for various lifestyle product such as clothing, Furnishing, Household textiles and Consumer textile.

In the case of sustainable knitted fabric, knitted fabric designers remind the environment impact especially knitted fabric design innovation. The designer suggest a guidelines of sustainable and Eco knitted fabric design as follows

1.Knitted fabric design process should be reduce material, energy and wastage.

2. Knitted fabric should be design into multi-functional.

3. Knitted fabric should be design under re-usability or recycle, recycle and up-cycle concept.

4. Knitted fabric production should be environment impact reduction.

The previously information used to be the guideline to Experiment framework as below:

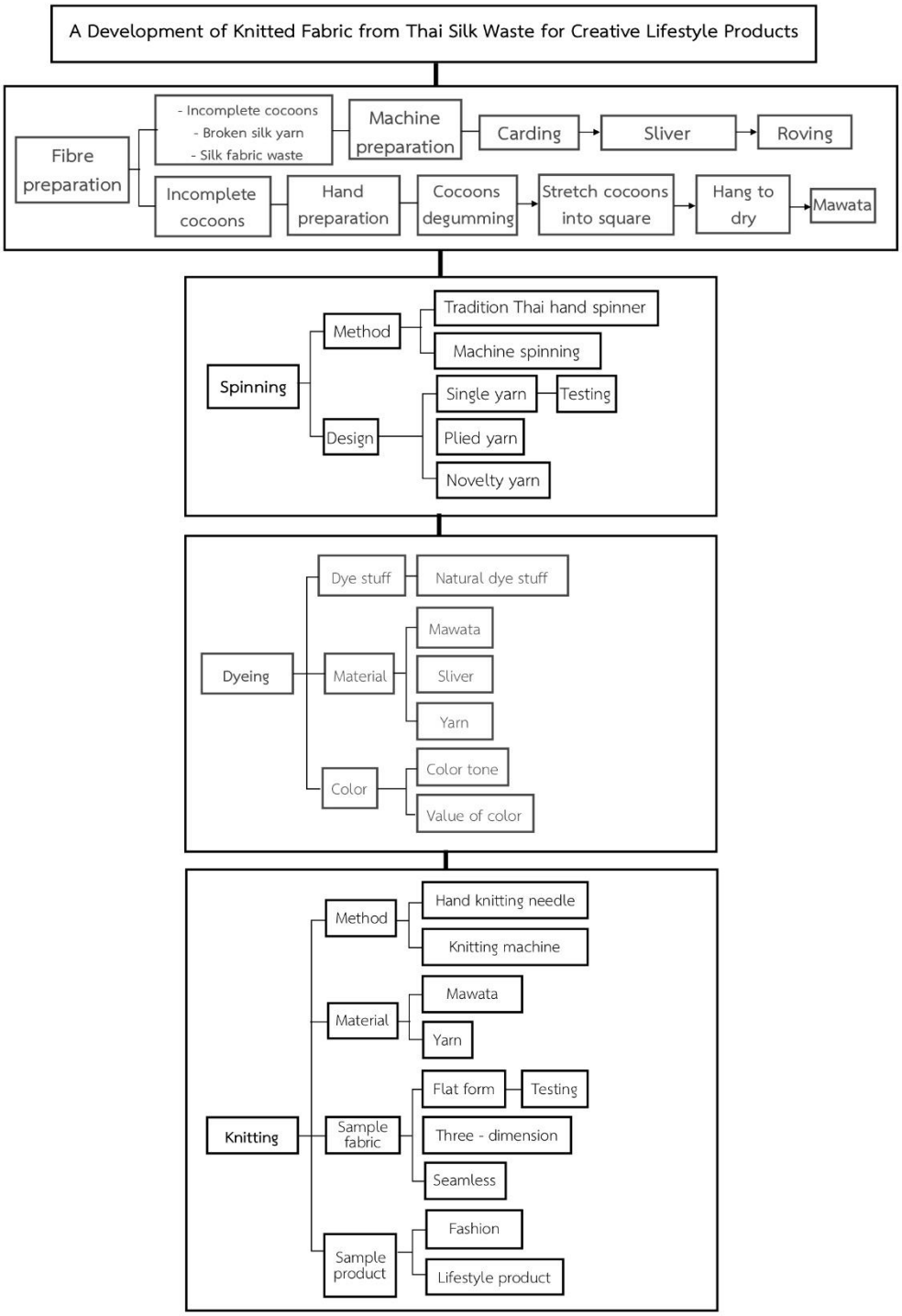


Diagram 7 The experiment framework

Pure Practice is synthesis and experiment in fabric development.

Experiment one

The first experiment consists of fibre preparation, spinning, dyeing and knitting.

1. Fibre preparation: the two methods were hand process and machine process. Hand preparation is a process using domestic equipment and a machine preparation process was done in a university laboratory.

2. Spinning process: the two methods are hand process and machine process. The hand spinning uses a traditional Thai spinning tool. The machine spinning uses ring spinning and open-end spinning.

3. Knitting: there are three method used. Hand knitting needle, domestic machine and automatic knitting machine.

4. Dyeing: this research used a natural dye stuff and was done by a university laboratory.

Fibre preparation

There were two methods to prepare the fibre. The first was hand preparation and the second was machine preparation. The three types of Thai silk waste have a different preparation procedure. Cocoons need degumming and cut into 3-5 millimetre pieces before carding. Broken silk yarn should be cut into 3-5 centimetre pieces. Silk fabric waste has to be separate weft yarn from warp yarn and cut into 3-5 centimetre pieces.

Cocoon degumming process. Its purpose is to remove of the serecin from the cocoons. The process is as follows:

Material

Cocoons	1 lb or 16 oz
Soap	4 oz
Sodium Carbonate	4 oz
White vinegar	85 ml
Water	2 litres

Process

1) Add the soap and soda to the pot, add a small amount of hot water to the pot, about a couple of inches.

2) Then turn the burner onto a medium heat and stir with a spoon to dissolve the soap and soda.

3) After the soap and soda have dissolved, add some tepid water to the pot, to about half-way. Add the cocoons, then add water.

4) Simmer the silk on a low heat for about 1 hour, after 1 hour, using a pair of old tongs or something similar, take out a small amount of silk and rinse it to see if it looks and feels softer.

5) Rinse the silk while it's still hot to remove the sericin.

6) When all the sericin, soap and soda is rinsed out, run some warm water into the sink or a bowl and add a third of a cup, about 85ml, of white vinegar. Soak the silk for around 10 minutes. This neutralises the effect of the soap.

7) Rinse the cocoons in clean, warm water, then remove and squeeze

the water out.

8) Separate the fibres, spread the cocoons out and leave to dry.

1. Hand preparation

The incomplete cocoons in the first experiment is separated into four groups. There are cocoons, floss and inner layer and mawata (silk hankies). The process of mawata or silk hankies is a different process. It is done by stretching the degummed cocoon into a frame and hung to dry.

Figure 115 A cocoons degumming into fibre procedure

Figure 116 A silk floss degumming into fibre procedure

Figure 117 A inner layer into fibre procedure

Figure 118 A mawata (silk hankies) into fibre procedure

2. Machine preparation

Broken silk yarn and silk fabric waste is hard to prepare into fibre by hand, because of its physical character. The method was conducted through a machine preparation process using the MESDAN LAB laboratory carding machine serial number 137 and the MESDAN LAB laboratory drawing machine serial number 21. This process was done by the academy lab at Rajamangala University of Technology Pranakorn

Figure 119 The MESDAN LAB laboratory carding machine serial number 137 (right) and the MESDAN LAB laboratory drawing machine serial number 21 (centre).

2.1 Broken silk yarn fibre preparation

The first step of broken silk yarn preparation is to make a parallel yarn by using a hand comb. After that cut it into 3 centimeter pieces. Next, weigh at 15 grams and fed into the carding machine three times. In this step, the fibre was separated and straightened, resulting in fibre lap. Then, after carding had drawn a fibre, the fibre lap was fed into the drawing machine. The result was a long bundle of fibre called sliver and roving as presented in figure 141.

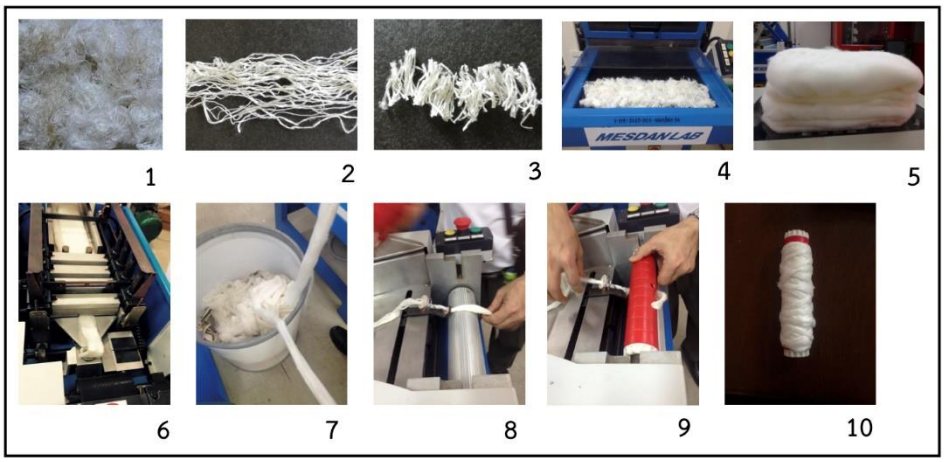


Figure 120 A process of preparing fibre from broken silk yarn.

1. Broken silk yarn. 2. Comb by hand.
3. Cutting into 3-5 centimetre. 4. Feed into carding machine for 3 times.
5. A result of 3 time carding is fibre lap. 6. Feed into drawing machine for 3 times.
7. A result of 3 time drawing is sliver. .8. Feeding sliver to roving section
9. feed roving to cone. 10. The cone of roving

2.2 Silk fabric waste fibre preparation

The process of preparing fibre from silk fabric waste is the same as broken silk yarn fibre preparation. The result is present in figure 7. In addition, cut cocoons was experimented on by this process, the result is present in figure 121

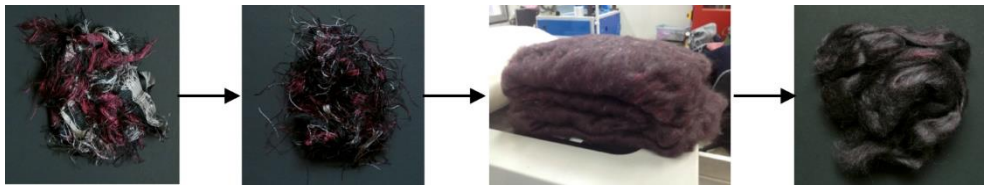


Figure 121 A part of silk fabric waste fibre preparation.

3. The result of fibre preparation

The result of this preparation is that all of the fibres are similarly soft in touch. The fibre from the hand preparation process was uneven and have more neb than the fibre from machine preparation.

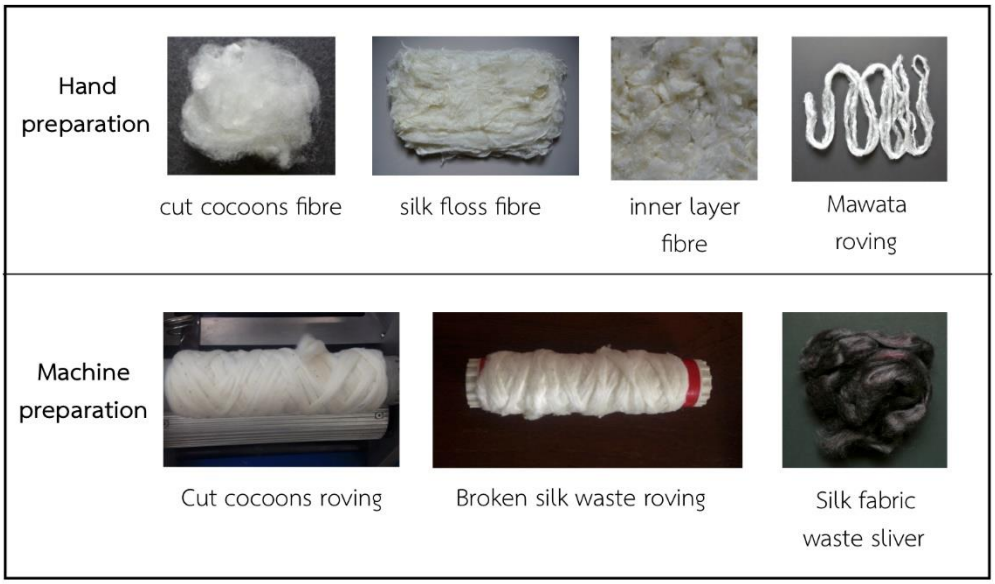


Figure 122 The result of fibre preparation by hand (top) and machine (bellow)

Spinning process

The objective was to group the fibres and twist them together to form a continuous strand by two methods as outlined below:

1. Tradition Thai spinning tool

A traditional Thai hand spinner was used to produce a single yarn. Direct spinning led to the production of both sliver and mawata (silk hankies). This process was done by a local spinner in the Bann Nong Bau Dang, Chaiyapum Province, Thailand.

Figure 123 Local spinner in Chaiyapum Province, Thailand and spinning tool.

Figure 124 A yarn from tradition Thai spinning tool produce by local Thai spinner.

The result of yarn produced from the Thai spinning tool that was spun by local spinner. A yarn number can not specified, it was controlled by depending on the raw material, spinning tool and spinner. All of the yarn was uneven. The yarn from mawata, inner layer, cocoon floss, cut cocoons, broken silk yarn and silk fabric waste were all respectively sticky. The yarn from silk fabric waste, broken silk yarn, cocoon floss, inner layer, cut cocoon and mawata were each soft to the touch respectively.

2. Machine spinning

A ring spinning and open-ended spinning machine was used in the experiment. This process was done by the academy lab at Rajamangala University of Technology Krungthep.

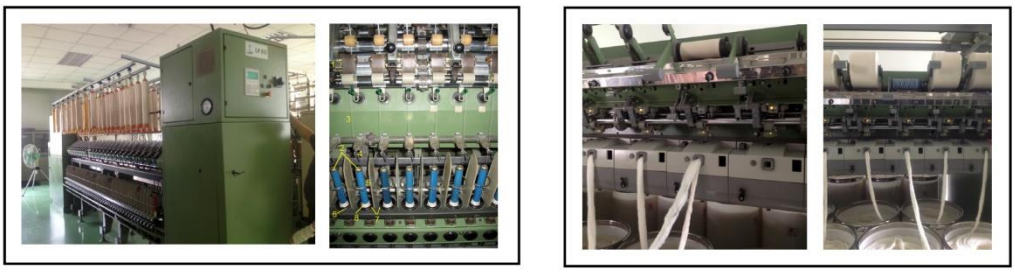


Figure 125 Ring spinning machine. (left) and open-end spinning machine. (right)

A cut cocoon sliver and silk fabric waste sliver was used to spin by the machine. Yarn from both materials were difficult to create by the machine because it broke during the spinning phase even though a low spinning cycle was used. A few yarn samples are present in figure 126. To solve this problem cotton with a 50:50 percentage blend was used and it could be completed by the open-end machine. The ring spinning machine could not be used.

Figure 126 Ring spinning machine: Yarn from cut cocoons sliver (left), open-end spinning machine: Yarn from cut cocoons sliver (centre) , and open-end spinning machine: yarn from silk fabric waste (purple) (right)

Figure 127 Open-end spinning machine, Yarn from cut cocoons sliver: cotton sliver was 50:50 (left) and open-end spinning machine, yarn from silk fabric waste sliver: cotton sliver was 50:50 (right)

3. Conclusion of yarn spinning process.

3.1 Hand spinning process

All of the fibre can be spun by the traditional Thai spinning tool, and it was easy to feed the spinning tool. A yarn was completed and that was similarly soft in touch and uneven. In the case of sticky and soft in touch properties, a yarn from mawata, inner layer, cocoon floss, cut cocoons, broken silk yarn and silk fabric waste were also each sticky respectively. The yarn from silk fabric waste, broken silk yarn, cocoon floss, inner layer, cut cocoon and mawata were softly touch respectively.

3.2 Machine spinning process

The 100 percentage waste fibre was difficult to use with the machine spinning because it broke during the spinning phase. This problem could be solved by using cotton fibre blend, with a 50:50 ratio. The yarn was even, but not soft in touch.

Knitting process

All of the yarn from the spinning process used to knit was done by three pieces of equipment. There was hand knitting needle No. 12, domestic machine (single bed and V-bed) and automatic knitting machine (Shima seike SES.122 / multi gauge).

Figure 128 Hand knitting needle (left), automatic knitting machine (center), domestic knitting machine (right top) and V-bed knitting machine (right bellow)

1. Hand knitting process

This process used the hand needle No.12 to knit 10x10 centimetre square. The result of this process was that the fabric had an uneven surface, medium flexibility and was soft to touch. The fabric from the inner layer was most softly in touch. Next in line was fabric from cocoon floss, silk fabric waste, broken silk yarn, cut cocoon and mawata respectively. (figure 129)

Figure 129 A fabric produce by hand knitting needle No.12

2. Domestic knitting machine process

2.1 Single bed knitting machine

This process using domestic knitting machine: brother HK-386, gauge 5 to produce a 10x10 centimetre square. The fabric resulting from the knitting machine had an uneven surface but was smoother than the hand knitted fabric. The fabric was less flexible than the knitted by hand type fabric. It was soft in touch the as same as the fabric knitted by hand. The most soft is the fabric from broken silk yarn. Next is the fabric from silk fabric waste, inner layer, cut cocoon, cocoon floss, and mawata respectively. (figure 130)

Figure 130 A fabric produce by domestic knitting machine: brother HK-386

2.2 V- bed spinning process

A yarn from cut cocoons sliver, open-end spinning was used to experiment by V-bed knitting machine, gauge 7. It could not be completed, the yarn was broken in the process. The results are shown in figure 131.

Figure 131 A fabric produce by V-bed knitting machine
material : Yarn from cut cocoons sliver, open-end spinning.

3. Automatic knitting machine

In the case of automatic knitting machine :Shima seike SES.122 / multi, gauge 12. It could be used only with yarn made from 50:50 percentage cut cocoons sliver and cotton. The other yarn had more neb that made it difficult to feed to the machine. The experiment result wa that the fabric had a smooth surface, medium soft in touch and flexible.

Figure 132 A fabric produce by automatic knitting machine :Shima seike SES.122 multi gauge
material : Yarn from 50:50 percentage cut cocoons sliver : cotton sliver.

4. Conclusion of knitting process

4.1 Hand knitting

All of the yarn could be knitted by the hand needle tool. The results is that the fabric has a similar uneven surface, is medium flexible and soft to touch. A fabric from the inner layer is the most soft in touch. The next in line is fabric from cocoon floss, silk fabric waste, broken silk yarn, cut cocoon and mawata respectively.

4.2 Machine knitting

All of the yarn could be completed by using a single bed knitting machine. The fabric resulted from this process. All of the fabric's surface was similarly uneven but soft in touch. The most soft is the fabric from broken silk yarn, next is fabric from silk fabric waste, inner layer, cut cocoon, cocoon floss, and mawata respectively.

Compare with knitted fabric from hand knitting:

4.2.1 Its touch was soft the same as fabric knitted by hand.

4.2.2 Its surface was smoother than hand knitted fabric.

4.2.3 Its less flexible than hand knitted fabric.

In the case of V-bed machine, used to knit a yarn from cut cocoons. It could not complete the work, the yarn was broken in the process.

4.3 Automatic knitting machine

The automatic knitting machine :Shima seike SES.122 / multi, gauge 12. It could be used only with yarn with 50:50 cut cocoons sliver and cotton. The experiment result was that the fabric had a smooth surface, was medium soft in touch and flexible.

Dyeing process

Dyeing method of first experiment is applied to yarn dyed and piece dyed by a natural base colour. There was mulberry, coffee grounds, red cabbage, and turmeric. The material for the dye was yarn and fabric from incomplete cocoons by the process shown below

1. Mulberry and coffee ground

The process of mulberry and coffee ground dyeing is similar.

1.1 First step is to mix one cup of mulberry, one teaspoon of salt or one cup of coffee grounds in four cups of water.

1.2 After that bring to boil, turn off the stove and leave to cool, strain and transfer only liquid to the pot.

1.3 Add damp yarn and a piece of knit fabric and simmer for about an hour, stir every fifty minutes to make sure the that fabric is picking up the dye evenly.

1.4 Finally, rinse with water until a clear solution is obtained and hung to dry with air drying.

Figure 133 Mulberry (left top), coffee ground (left below), A piece of fabric and yarn (right top), a glass of mulberry and coffee ground dyeing. (right bellow)

2. Red cabbage and turmeric

Red cabbage and turmeric dyeing has the same procedure.

2.1 To begin with put one cup of chopped cabbage or one cup of chopped fresh turmeric in four cups of water and bring to boil for about thirty minutes.

2.2 The next step is to strain and transfer only the liquid to the pot and continue to boil on medium heat.

2.3 Add damp yarn and a piece of knit fabric and simmer for about an hour, stir every fifty minutes to make sure that the fabric is picking up the dye evenly.

2.4 The last step is to rinse with water until a clear solution is obtained and hang to dry with air drying. The outcome is as presented in figure 158 and 159.

Figure 134 Red cabbage (left top), turmeric (left below), A piece of fabric and yarn (right top), a pot of Red cabbage dyeing. (right bellow)

3. The result of natural dyed process

The result of the natural colour dyed experime: the mulberry is pink, the coffee ground is light brown, the red cabbage is purple and the turmeric is reddish yellow. In the case of colour absorption, the yarn dyed absorbed better than the piece dye. The outcome is as presented in figure 135

Figure 135 The out come of natural dyed process: first experiment

Conclusion of experiment one

1. Fiber preparation

There were two methods to prepare the fibre: hand preparation and machine preparation.

1.1 Incomplete cocoons can prepare fibre by both hand and machine.

1.2 Broken silk yarn and fabric silk waste can be prepared fibre by machine only.

2. Yarn spinning process

There were two methods to spinning: hand spinning and machine spinning

2.1 Fibre from incomplete cocoons, broken silk yarn and fabric silk waste can be spun by hand.

2.2 The 100 percentage fibre could not completed by machine spinning, it worked with a blend of cotton 50:50 before you feed the fibre to spin.

2.3 The yarn produced by the machine was smooth in visuals, but not soft to touch.

2.4 The yarn produced by the traditional Thai spinning tool was uneven, but soft in touch.

3. Knitting process

There were three pieces of equipments used to produce knitted fabric: hand needle knitting, domestic machine and automatic knitting machine.

3.1 The knitted fabric by hand knitting needle No. 12 gave an uneven surface, soft in touch and medium flexibility.

3.2 The domestic machine: single bed gauge 5 produced a smooth surface, medium flexibility and was soft in touch. In the case of V-bed gauge 7 it could not complete to knit the fabric, the yarn was broken during the knitting process.

3.3 The automatic knitting machine: Shima seike SES.122 / multi gauge could knit only blend yarn (cocoon fibre: cotton/ 50:50). The fabric result was a smooth visual surface, but not soft in touch and less flexible.

4. Dyeing process

4.1 Natural dye stuff was used to colour the yarn and the piece of fabric made from the incomplete cocoon. The dyestuff was mulberry, coffee grounds, red cabbage, and turmeric.

4.2 The result of the colouring process: the mulberry was pink, the coffee ground was light brown, the red cabbage was purple and the turmeric was reddish yellow.

4.3 In the case of colour absorption, the yarn dye absorbed better than piece dye.

Figure 136 shows the conclusion of the procedure and the time to produce yarn from silk waste, each waste sample is 15 grams. The experiment was done in a university laboratory.

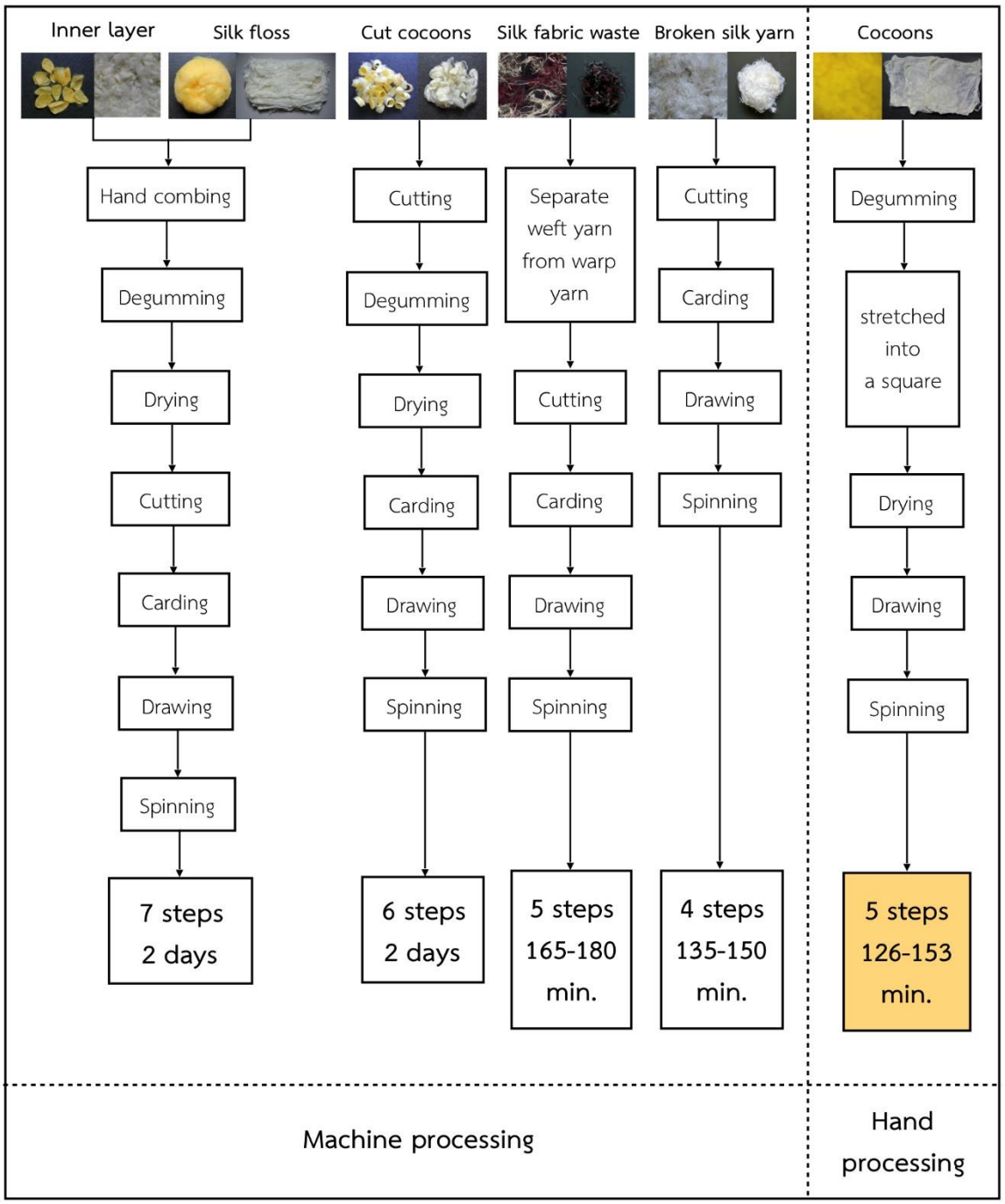


Figure 136 Yarn production : step and time analysis : raw material 15 grams.

Experiment one analysis

1. Fibre preparing process

The yarn production for raw material of 15 grams and the experiment was done in a university lab had a different result as followings:

Machine process : silk broken yarn take less steps and time, it was 4 steps and 135- 150 minutes. The inner layer and the silk floss took the most steps and time: 7 days and 2 days respectively.

Hand process: only incomplete cocoons can be done by this process. It was 5 steps and 126-153 minutes, with similar silk fabric waste and broken silk yarn to the machine process.

2. Spinning process

All the raw material that was prepared by machine and hand can be spun by traditional Thai hand spinning. The resulting yarn was uneven, but soft in touch. While the machine spinning should use cotton fibre blend to silk waste fibre 50:50 percentage The yarn result was smooth visually, but not soft to touch.

3. Knitting process

Knitted fabric from a hand needle and a domestic machine were similarly soft to touch and of medium flexibility. While the knitted fabric from blend yarn (cocoon fibre: cotton/ 50:50) and knitted by automatic knitting machine was smooth visually on the surface, but not soft in touch and less flexible.

4. Dyeing process

A sample natural dyestuff in a good condition was use to dye. In the case of colour absorption, the yarn dye absorbed better than piece dye.

The analysis was a guideline for next the development, which followed an environmentally friendly design concept. The analysis summary support developing fibre and yarn from incomplete cocoons using mawata process by using the following method.

1. A non-manufacturing process and low energy to reduce environmental pollution.

2. The equipment is locally sourced and easy to prepare. Therefore, it can be done by a family or village group industry.

3. The process is not to cut a cocoon, that will result in fibre longer than any another process. The long fibre produce a lustre yarn and keeps more of the filament silk character.

4. It is easy to spin, by its size spec and design. Easy to create yarn prototype and knitted fabric for lifestyle products as well.

As mentioned previously this leads to the framework of experiment two as shown in diagram 8

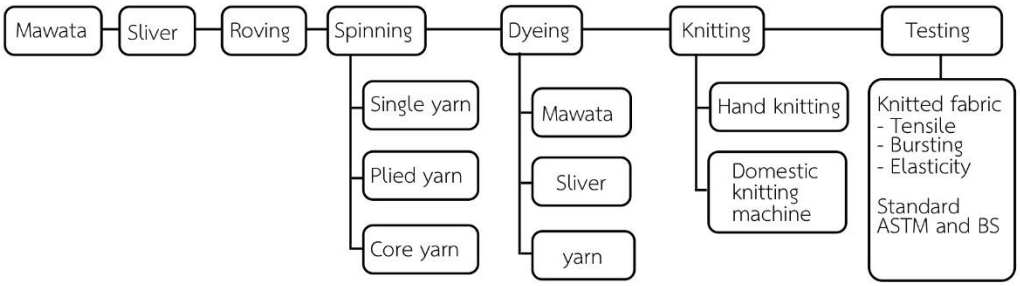


Diagram 8 The second experiment framework

Experiment 2

The second experiment consists of fibre preparation, spinning, dyeing, knitting and testing. The steps are as follows:

1. Fibre preparation: Mawata (silk hankies)
2. Spinning process: Hand spinning using traditional Thai spinning tool.
3. Dyeing: this research uses a natural dyestuff and is done by an academic laboratory.
4. Knitting: there are two method used, hand knitting needle and domestic machine.

Fibre preparation

1. Equipment

In the first experiment, the mawata processing it found that a perfect mawata size made from Thai cocoon was ten centimetres square. Therefore a frame should be designed and created that is suitable to produce mawata. The result of completed and best quality mawata sheets are good parallel fibres that are easy to expand for spinning.

The new frame design followed the Japanese mawata frame as a guideline. The main material is hardwood and a plastic basin. That is to avoid a rusting, because water was used in process. Moreover, the the knockdown concept was use to create a new frame. The aim is that the frame can be adjusted to the required size to make it easy to store and carry.

Figure 137 The Japan mawata's making frame.

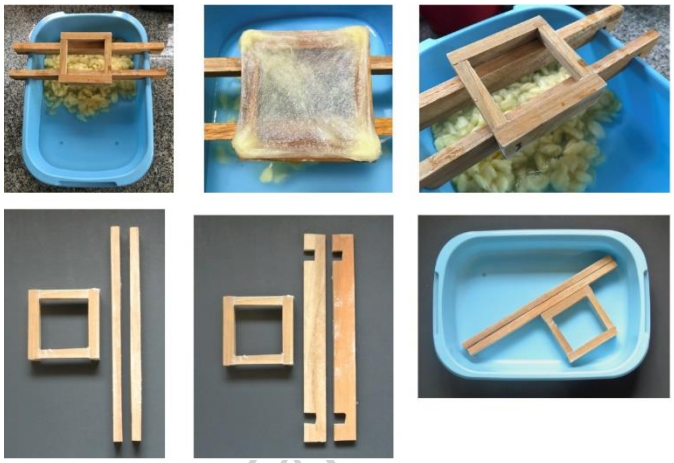


Figure 138 A new design frame for Thai cocoon

2. Fibre preparing

This method was applied to the Thai cocoons. The process began by degumming the cocoons and then gently stretched into a gossamer film on a square frame by hand. Approximately, ten sheets were overlaid. Next, the silk hanky was removed from a square frame and hung to dry. The dried silk square sheet is known as mawata or silk hankies. The last step, a hole was poked in the center of the silk hankies and the fiber stretched into a large band by hand. The circle was carefully extended and pulled thinner until the size reduced the fiber to the diameter of approximately one centimetre. The outcome was a long band fiber referred to as a roving as presented in figure 139

Figure 139 The process of turning cocoons into mawata or silk hankies and roving.

Spinning process

1. spinning

The spinning process using the traction Thai spinning tool to produce single yarn (figure 140). Moreover, raw material could create ply yarn and core yarn. The result showed that Thai silk mawata was easy to spin from all types of yarn. (figure 141)

Figure 140 A traditional Thai hand spinner.

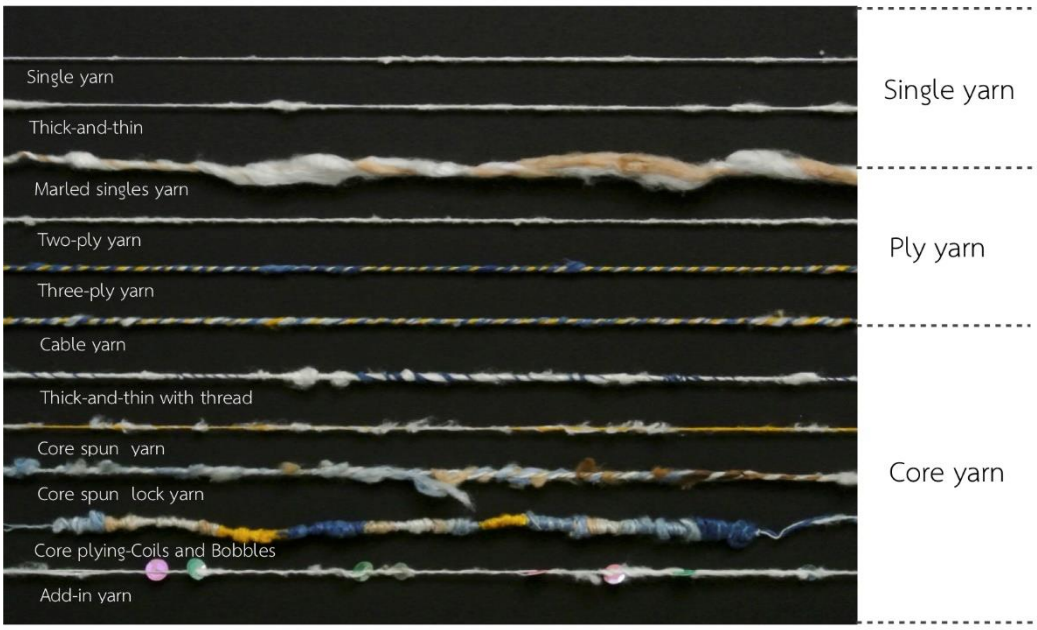


Figure 141 The sample of Single yarn, Ply yarn and Core yarn.

2. Yarn count

In this process, the single yarn was counted by an indirect system and yarn properties testing. This step was done by the academic lab at Rajamangala University of Technology Krungthep.

There were three samples to yarn count, each sample was 100 centimetres length. Total length of sample was 300 centimetres. The next step was weighing each sample, there was 0.093, 0.045 and 0.079 grams respectively. The total 3 sample weight was 0.217 ≈ 0.22 This number was used to be a divisor. The result is 8, that means the yarn count is 8. The calculated example is below:

$$\text{Cotton count } (Ne_C) = \frac{\text{(1 pound) x Length (yard)}}{\text{weight (pound) x 840 yard}}$$

$$\text{Cotton count } (Ne_C) = \frac{300 \times 0.0059}{0.22} = 8.04 \approx 8$$

3. Yarn testing

This testing purpose to tensile Strength Testing by Standard : ASTM D5035 Standard Test Method of Breaking Strength and Elongation of Textile. Testing machine was Uster 5 tester : Tensile Strength. The result was show in Table 4

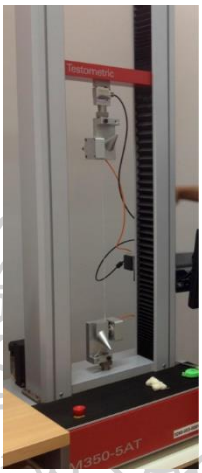


Figure 142 Testing machine was Uster 5 tester : Tensile Strength

Diagram 9 Yarn tensile strength testing

Yarn	Single yarn / No.8 Nec.
Test speed	200 millimetre per minute
Sample Length	500 millimetre
Result (Mean)	Force Peak (N) 7.333
	Elongation Peak (mm.) 28.090
	Tenacity (cN/Tex) 8.693

The result describes that at the point of tensile strength at 7.3 Newton at a speed of 200 mm per minute the yarn tears apart. Elongation peak was at 28.090 millimetres and equal to 5.269 percent. Yarn tenacity was found to be 8.7 centi-newton per yarn count. The results of the testing indicates the yarn has fastness and is highly flexible and therefore suitable for products that require high flexibility.

Dyeing process

This research concept was devised whereby natural coloured dyestuff was used in the experiment process. The natural dyestuff used in this study was found in Thailand. The dyeing method was applied to mawata in the form of a mawata sheet, sliver and yarn. In addition, the shade and value was done by mordant. The process used is as follows:

1) Natural dyestuff was boiled in water about for approximately 1 hour.

2) The liquid was strained and transferred. Dam yarn, silk hankies or sliver was added and simmered for about an hour. It was stirred every fifty minutes to ensure that the object evenly picked up the dye. This step of the process by boiling or not is dependent on raw material of dyestuff.

3) The material was rinsed with water until a clear solution was obtained and it was then hung to air dry.

4) In addition, it was found that mordant by alum, ferric oxide, tamarind gave a deeper shade and value of color.

1. Dyestuff and mordant

The light and dark shade was selected to experiment with. The natural dyestuff used in this study is base on local Thai raw materials, which is the following:

1.1 Dyestuff

1.1.1 Lac
1.1.2 Gardenia dulcet bark
1.1.3 Mangosteen leaf
1.1.4 Golden shower pod
1.1.5 Indigo
1.1.6 Turmeric
1.1.7 Coffe ground

1.2 mordant

1.2.1 Feric oxide
1.2.2 Alum
1.2.3 Tamarind juice

2. Dyestuff and mordant preparation

2.1 Dyestuff preparation

As mentioned before, natural dyestuff could be prepared by boiling materials in water for about 1 hour. Then filter only the water to use for dyeing.

2.2 mordant preparation

Mordant could be use before, during dyeing and after dyeing. The purpose was to colour fasten. This research use it after dyeing. The mordant could be prepared as follows:

2.2.1 Ferric oxide: Soak nails or scrap iron in water about 3-4 days, a rust will appear on the water surface. Leave it to be precipitate, pour only water to use (The National Institute of Sericulture Queen Sirikit, 2008: 115)

2.2.2 Alum: Add alum 5 grams in water of 1 litre, leave it to dissolve.

2.2.3 Tamarind: Put ripe tamarind, 1 kilogram, in water 1 litre, squeeze tamarind, then stir for blending. Leave it to precipitate, pour only water to use (The National Institute of Sericulture Queen Sirikit, 2008: 109)

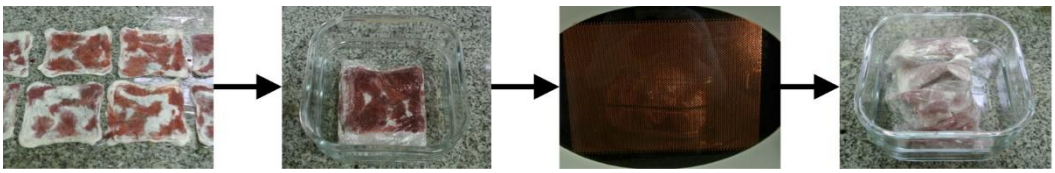
3. Mawata- dyed

The mawata-dyed process are as follows:

3.1 Drop colour dyed to a mawata sheet.

3.2 Wrap by plastic and place it in the microwave for 2 minutes, two times.

3.3 Take plastic off, drop mordant to mawata sheet, then leave to dry.



Drop colour to mawata | Wrap by plastic | place in microwave | The result

Figure 143 Mawata-dyed process

Each mordant produces a different colour. Figure 144 show a colour dyed by Lac (left). Then, mordant Feric oxide (centre) and Alum (right). Figure 145 presents a mawata-dyed in different dyestuff, and shows that it could be dyed only one colour and multi colour in sheet.

Figure 144 The result of Lac dyestuff and mordant on mawata

Coffee ground | Garcinia dulcis bark | Indigo | mangosteen leaf | golden shower pod.

Figure 145 A sample of mawata-dyed by natureal dyestuff

Figure 146 A sample of mawata-yed by four colours: Lac, golden shower pod, mangoteen leaf, garcinia dulcis bark. Mordant : Alum

4. Sliver-dyed

Sliver-dyed could be done by soaking it in dyeing colour, that was soaked all or some part as shown, for about 1 hour. After that, move to mordant pot for 10 minutes, then rinse with water and leave to dry. The sample shown as in figure 147

Figure 147 A sample of mawata-dyed

5. Yarn-dyed

Yarn-dyed could be done the same as sliver. Dam all of the skein or some part and simmer for about an hour. It was stirred every fifty minutes to ensure that the object evenly picked up the dye. After that, it was moved to the mordant pot for about 10 minutes. The last step was that the yarn-dye was rinsed with water until a clear solution was obtained and it was then hung to air dry.

Figure 148 A sample of yarn dyeing method

Figure 149 A sample of yarn-dyed : Turmeric, Coffee ground and Indigo

This research experimented to dyeing with different shade and value of colour. Especially deeper and bright colour, that depended on raw material and mordant as present in figure 150 and 151

Figure 150 A sample of yarn-dyed: deeper shade and bright colour

Figure 151 The sample of yarn-dyed and mordant.

Knitting process

The knitting equipment in second experiment were hand needle tool and domestic knitting machine. The mawata in the form of roving and single yarn were use to knitted.

1. Knit a mawata roving

The roving used to knit by needle No. 8, roving were produced by hand from mawata sheet, mawata-dyed one and multi colour, mawata-dyed and mordant. The result show different beautiful colour effects. The fabric was thick, lightweight and soft to touch, as shown in figure 152

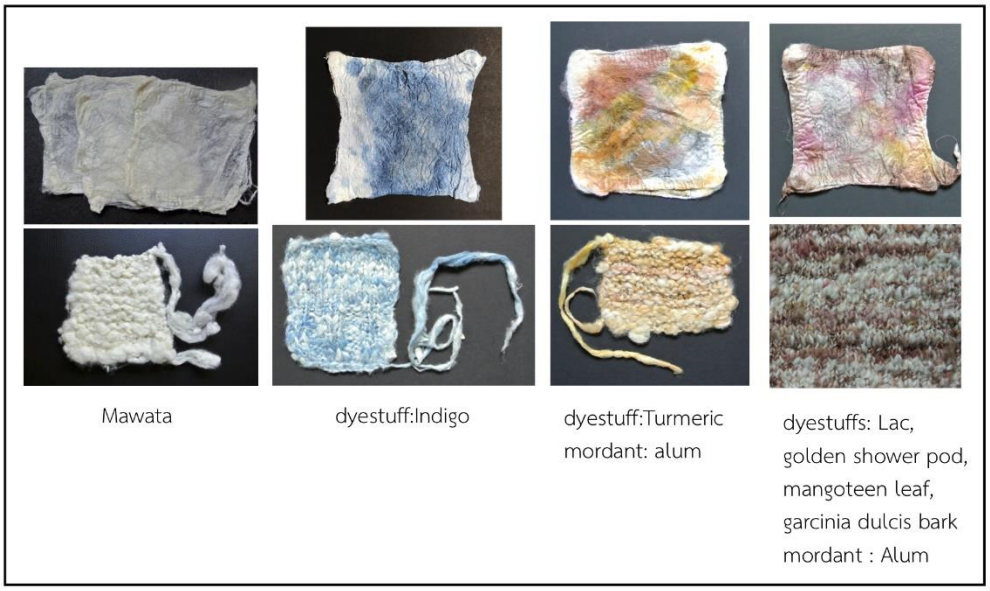


Figure 152The sample of knitted fabric from mawata roving.

2. Knit a Yarn

This experiment part used domestic knitting machines to produce fabric. A single yarn was spun from mawata, mawata-dyed and yarn-dyed.

2.1 Knit a single yarn from mawata-dyed

A knitted fabric of single yarn from mawata-dyed gave a new pattern and a beautiful colour, thin and lightweight. as presented in figure 153

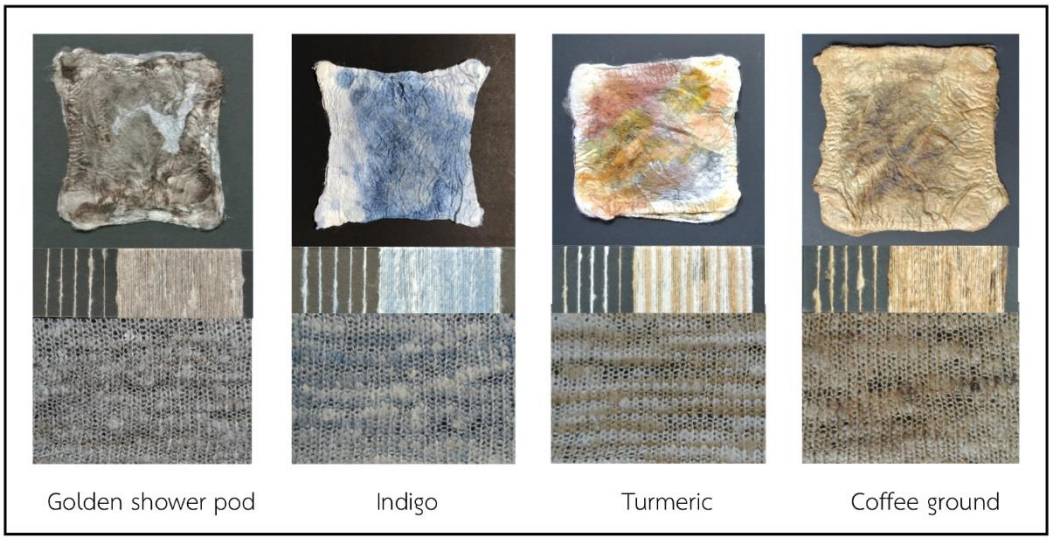


Figure 153 The sample of knitted fabric from mawata-dyed: single yarn.

2.2 Knit a single yarn from yarn-dyed

The yarn use to knit was yarn-dyed. The result surface was uneven, thin and medium soft in touch.

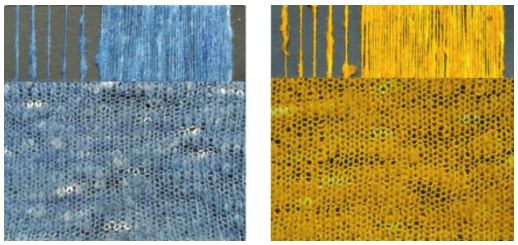


Figure 154 The sample of knitted fabric from yarn-dyed: single yarn, indigo (left) and turmeric (right)

2.3 Knit a fabric

This part was to experiment on knitting fabric from mawata spun yarn by various techniques to produce fabric in flat, three dimensions and to create a new pattern.

The hand spun yarn from mawata can be knitted flat form fabric in various patterns such as single jersey, pointelle, laddle, cable and pile loop. In the case of dimension form by lifting, increase-decrease technique and jaquaed was easy to knit. Although the surface was uneven, the fabric was soft in touch, thin and lightweight. The results are present in figure 155 to 156

Figure 155 A knitted fabric : sigle jersey tension 0-10

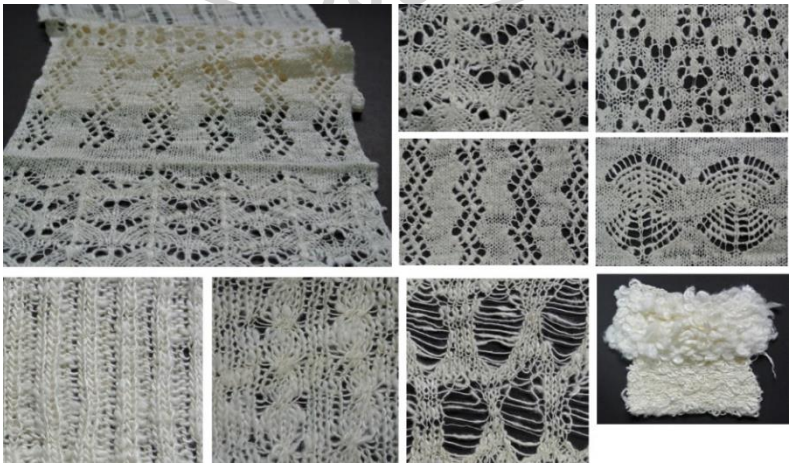


Figure 156 A knitted fabric : jersey, pointelle, laddle, cable and pile loop

Figure 157 A knitted fabric : lifting, increase and decrease technique

Figure 158 A knitted fabric : increase-decrease, jacquard technique

3. Knitted fabric testing

This research used yarn and knitted fabrics from mawata, produced by a traditional Thai spinner as a case study. The process was done in a university testing laboratory. The test was carried out to test the durability and flexibility of knitted fabric.

3.1 Bursting fabric testing.

Figure 159 Pneumatic: Auto Mode (left) and fabric test sampling (right)

Diagram 10 Bursting fabric testing.

Knitted fabric sample	domestic machine gauge 5.5/ tension 3 /Single yarn no.8		
Temperature	25 deg.C		
Rel Humidity	65%		
Specimen	3 knitted fabric		
Test Area (Dia)	10 sq.cm.(35.7 mm.)		
Diaphram Pressure	10 sq.cm.(35.7 mm.)		
Result (Mean)	Times (sec) 20.0	Distention (mm.) 16.7	Pressure (psi) 13.9

Diagram 10 shows that at the point of 13.9 pound of pressure per square inch per 20 seconds, the fabric stretched to 16.7 millimeters, the knitted fabric sample of the diameter of 35.7 millimetre then burst. The results of the testing indicate that the fabric is highly flexible and strong and suitable for producing products that require high flexibility and strength

3.2 Elasticity testing

This testing purpose to test elasticity by Standard: BS 4294:1968 Methods of test for the stretch and recovery properties of fabrics

Figure 160 Elasticity testing tool: Fryma Fabric Extensometer

Diagram 11 Elasticity testing

Knitted fabric sample	domestic machine gauge 5.5/ tension 3 /Single yarn no.8
Loading weigh	3 kg.
Specimens	2 / 3 testing/ time 10 sec.
Test Area	M1(couse) 110x100 mm. / M2 (wale) 100x100 mm.
Result (Mean)	M1: Elongation 102.8% Elasticity 94.41%
	M2: Elongation 64.33% Elasticity 80.9%

Diagram 11 explains that within 10 seconds, the course stitch fabric expanded to 102 percent and reverted to its original condition at 94.41 percent. The wale stitch fabric expanded to 64.33 percent and reverted to its original condition at 80.9 percent. The results show that the fabric elasticity is related to the knitted fabric properties, the sample had high elasticity and good restorative ability. This indicates that it is suitable for products that require high flexibility.

Conclusion of experiment two

The second experiment was to develop knitted fabric from incomplete cocoons by craft process. The production consisted of fibre preparation, spinning, knitting and dyeing.

1. Fibre preparation

1.1 Equipment

A suitable frame for thr Thai cocoon was 10 centimetres squared and made from hard wood. A plastic tray was used to avoid rusting because water was used in the process. A frame design was made that allowed for adjusting size and that was easy to store and carry.

1.2 Fibre preparation

Thai degumming cocoon stretched into gossamer film on a frame about ten sheets overlaid was perfect to be a mawata, a raw material to make roving for spinning.

2. Spinning process

2.1 Traditional Thai spinning can spin various types of yarn, there were single yarn, ply yarn and core yarn.

2.2 Yarn count from single yarn was number 8 of indirect system.

2.3 Yarn testing by Standard : ASTM D5035 Standard Test Method of Breaking Strength and Elongation of Textile. The results of the testing indicate the yarn has fastness and is highly flexible and therefore suitable for products that require high flexibility.

3. Dyeing process

3.1 Natural dyestuff were lac, lac, gardenia dulcet bark, mangosteen leaf, golden shower pod, indigo, turmeric and coffee ground. These produced light and dark colors.

3.2 Mordants were ferric oxide, alum and tamarind. These can add more shade and value.

3.3 Material forms to dye were mawata, roving and yarn . Dye methods were drop, dip, immersion and free stye dyeing. The colour can be dyed by one and more colour on one piece which is better for unlimited and extraordinary colour creation.

4. Knitting process

4.1 There are two methods used, hand knitting needle and domestic machine.

4.2 The raw material “mawata” can be use to knit in various from. Firstly was roving, it produces thick, lightweight and soft touch fabric. Secondly was yarn, it produces thin and lightweight fabric.

4.3 The hand spun yarn can be knitted flat form in various patterns such as single jersey, pointelle, laddle, cable and pile loop. In the case of dimension

form by lifting, increase-decrease technique and jaquaed it was easy to knit. Although the surface was uneven, the fabric was soft in touch, thin and lightweight.

5. Knitted fabric testing

A sample knitted fabric to test was produced by domestic gauge 5.5, tension 3, single yarn number 8 and knitted into 10 square centimetres. Each testing used 3 pieces of sample.

5.1 Busting fabric testing, the results of the testing indicate that the fabric is highly flexible and strong and suitable for producing products that require high flexibility and strength.

5.2 Elasticity testing, the results shown fabric elasticity is related to the knitted fabric properties, the sample had high elasticity and good restorative ability. This indicates that it is suitable for products that require high flexibility

Chapter 4
Design process

The aim of the design is to present a utility and artistic value of the yarn from Thai silk waste, the various yarns design will be transformed into the knitted fabric. The process is as follows:

1. Research analysis
2. Design development

Research analysis

A study has led to the practice-based research and pure practice as a guideline to developed method for produce knitted fabric from Thai silk waste yarn. The research begins with collecting information related to Thai silk waste and its benefits. The information was conduct to an experiment of yarn spinning and produce knitted fabric from Thai silk waste. The result of an experiment will be transformed into knitted fabric to present the artistic value of the waste through textures, colors, structure and pattern.

The experiment was two-part, that operation in both academic laboratory and the filed. The first experiment was tried out to prepare fibre, spun, dyed and a knitted fabric from three types of Thai silk waste: cocoons, broken silk yarn and waste from silk fabric. The result of the first experiment was the guideline to next step, to development the advantage material and method.

The incomplete cocoons were selected to the second experiment with the result of the environment-friendly procedure. The crafting process began from prepare fibre by mawata process: expand degumming cocoon on the wood frame and hang to dried, hand spun by traditional Thai spinning tool, natural-dyed and knitted fabric by hand and domestic, the result present:

1. Yarn

Tradition Thai spinning produces various types of yarn, there was single yarn, ply yarn and core yarn. Yarn count from single yarn was number 8 of the indirect system. Yarn testing by Standard: ASTM D5035 Standard Test Method of Breaking Strength and Elongation of Textile. The results of the testing indicate the yarn has fastness and is highly flexible and therefore suitable for products that require high flexibility.

2. Dyed

The natural dyestuff in Thailand can be applied to mawata sheet, roving and yarn. Dye method were drop, dip, immersion and free stye dyeing. The colour can be dyed by one and more colour on one piece, that better for unlimited and extraordinary colour creation. Moreover, it can be adding more shade and value by
mordant: ferric oxide, alum and tamarind juice.

3. Knitted fabric

3.1 Mawata sheet can be knit by hand knitting, it produces the light weight and soft touch fabric.

3.2 The hand spun yarn can be knitted flat form in various patterns

such as single jersey, pointelle, ladder, cable and pile loop. In the case of dimension form by lifting, increase-decrease technique and Jacquard were easy to knit. Although surface was uneven, the fabric soft in touch, thin and lightweight.

3.3 The result of busting fabric testing indicates that the fabric is highly flexible and strong and suitable for producing products that require high flexibility and strength.

3.4 The result of elasticity testing has shown fabric elasticity is related to the knitted fabric properties, the sample had high elasticity and good restorative ability. This indicates that it is suitable for products that require high flexibility.

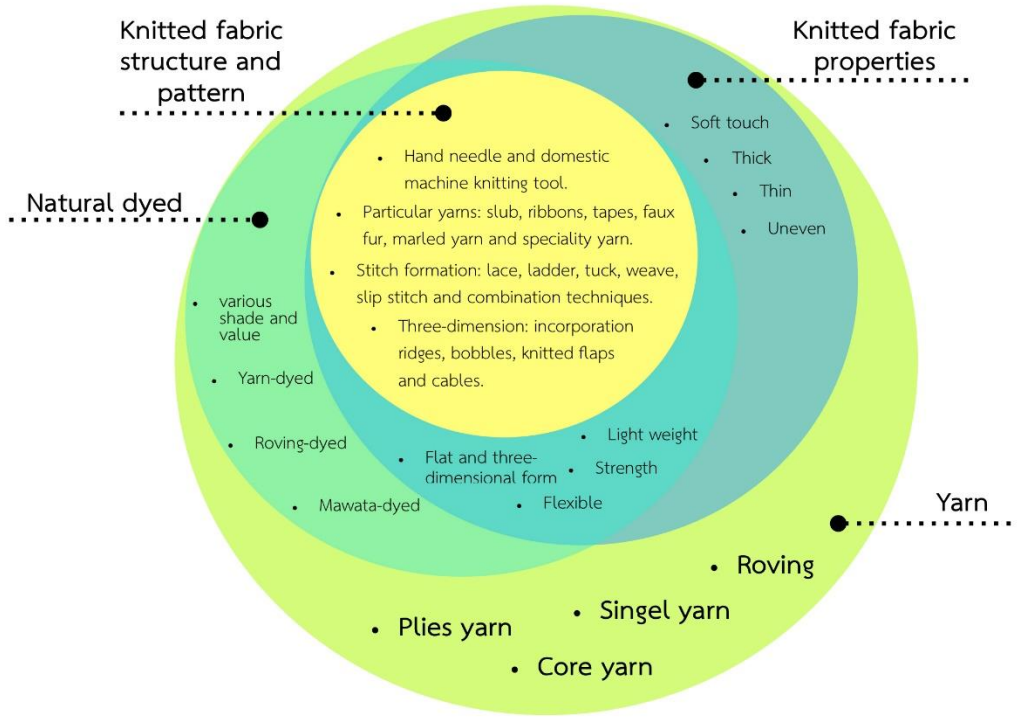


Diagram 12 Research analysis conclusion

Design development

The design development was a process to present yarn from Thai silk waste properties and transfer into knitted fabric. The procedure were consist of design concept specification, inspiration finding, expand over all idea on mood board, select material, knitted structure and tool. Finally, knitted a workpiece.

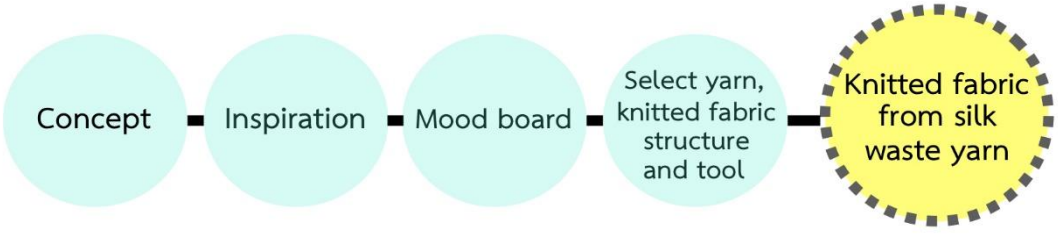


Diagram 13 Design development process

Concept design

The design concept was based on the research analysis, the details as below:

1. The knitted combining properties and artistic of yarn as following:

1.1 physical properties

1.1.1 Flexible

1.1.2 Strength

1.1.3 Lights weight

1.1.4 Thick

1.1.5 Thin

1.1.6 Soft in touch

1.1.7 Uneven texture

1.2 Artistic properties

Raw material was a yarn from Thai cocoon waste that transform into roving, single yarn, plied yarn and core yarn by craft process: mawata (silk hankies), natural dyed and traditional Thai spinning tool, the detail as bellows:

1.2.1 soft touch, uneven looks, flat knitted fabric and three-dimensional form.

1.2.2 various colour shade and value from natural dye stuff.

2. Equipment

2.1 Equipment : hand knitting and domestic knitting machine

Figure 161 Raw material to produce knitted fabric

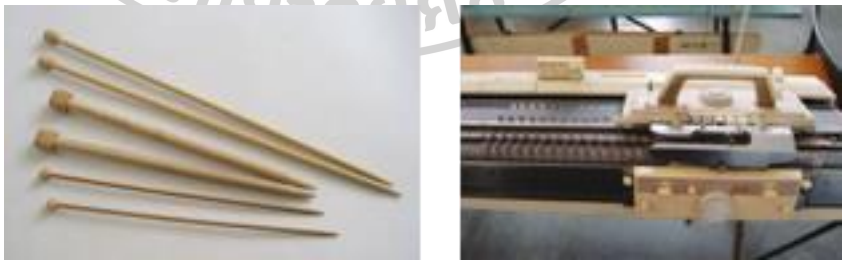


Figure 162 Hand needle (left) and domestic knitting machine (right)

Art relationship

The design process was use of yarn properties to be a key point to create knitted fabric, the purpose was to present its value.

In the case of art, material formation can be explain by two theories: Clive Bell's art as form and John Dewey's art as experience.

For the formal, the form in this case is concerned in two folds. The first fold is the researcher's innovation to make the finer of special quality, its strength, flexibility, elasticity and colour is the outcome of the experiment. As the yarn or fibre processed through the treatment it is possible that the best material to make design, a design of knit fabric, simple or more complex structure can be made. As explained, a piece of art work, according to Clive bell, the complex form is consisted of simple form. Knitted fabric of specific design quality can be success fully made only when it is made of the small unit, the yarn of finer processed, treated by special experiment based on researcher's innovation. Therefore, size and other qualities of yarn or fibre making a form. And their organisation into more complex form, the knitted fabric give the outcome, a ready designed art work.

The point view of John Dewey is how a piece of art made: need to know the material and need to master the technique. Knowing the material, in this case, the researcher has spent years doing experiment. The researcher has acquired skill through the experimentation so well, whether what can be done in each case of yarn and fibre. It is the experience that enable researcher to innovate and improve the fibber to its specific quality, for its strength, elasticity, flexibility, dye and colour quality as well as strength and thickness. As the finer, making the form of smaller unit of form is made possible, the trial of doing design, by knitting or other technique, artistic experiment will guide the researcher to construct the complex form, By this means, a design of the more complex structures is made possible because it is made of the finer innovated to have specific quality based on various experiment and treatment.

Inspiration

The knitted fabric inspiration from Siam fighting fish. The Siam fighting fish have multi colour: strip, marble, glister, shade, and value . The shape and form was straight, curve, circle, semi-circle, and wave. When fish expand its tail it show a texture: Layer, thick, thin, and transparence. Moreover, fish foam and water movement makes beautiful translucent bubble and watermarks. Consequently, it is obvious to transform yarn into knitted fabric and express the its yarn quality to make the desired fabric.

The design was separated into two colour group, first was red and blue. The mood board will be use to visually explain over all idea of design as follows:

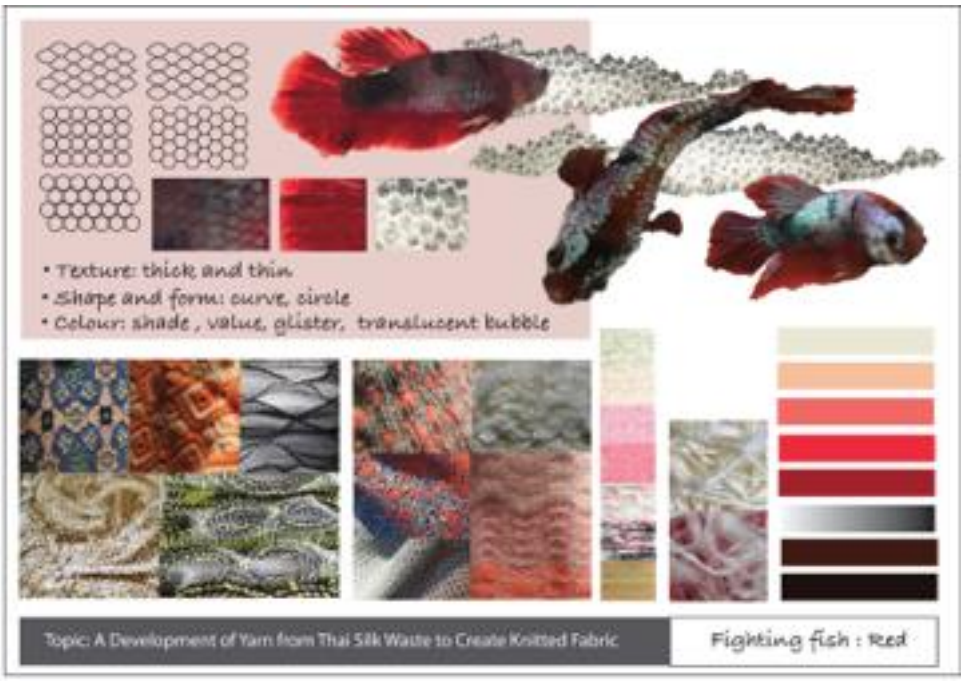


Figure 163 The mood board “Fighting fish: Red”

Figure 164 The mood board “Fighting fish: Blue”

Production

The production began from expand characteristics of inspiration: Siam fighting fish. The obvious finding were line, shape, form, texture and colour. The fish body have a straight, curved, and wave lines. The shape and form were circle, triangle, ellipse, and wave. Texture were thick, thin, layer, uneven, glitter, fish foam feel like light and fuzzy bubble. There were multi colour founding such as red, blue, green, violet, black, and white. Most of all were red and blue shade, therefor, the design selected both colour theme. The colour consist of hue, shade and value, moreover, fish scale was produced to make glister colour and fish foam translucent colour. The colour appear in small and big strip, fin and tail shape, and small dot like marble.

The characteristics of Thai fighting fish was a guild line to design yarn from Thai cocoon waste, selected pattern and technique to transform yarn into the pieces of knitted fabrics as following:

To explain an overall view, making Translucent bubble, Pink fish's tail, See through curve, Fuzzy fish scale, Fish's tail pleat, Fish's tail traveling curve, Fish fin waver, Ellipse fish's tail, Marble fish fin #1, Marble fish's fin#2, and Fuzzy fish's tail will be key art form of researcher's work detail will be later explained.

Figure 165 Knitted fabric from Thai silk waste yarn.

From this point the researcher will explained each of them as following:

Design 1 Translucent bubble

The first design was inspired from fish foam. A small translucent bubble looks gently and softly. The researcher applied roving and pile stitch loop to knit by domestic machine. The product present raw material and fabric properties: thick, light weight, puffy, and softly touch.

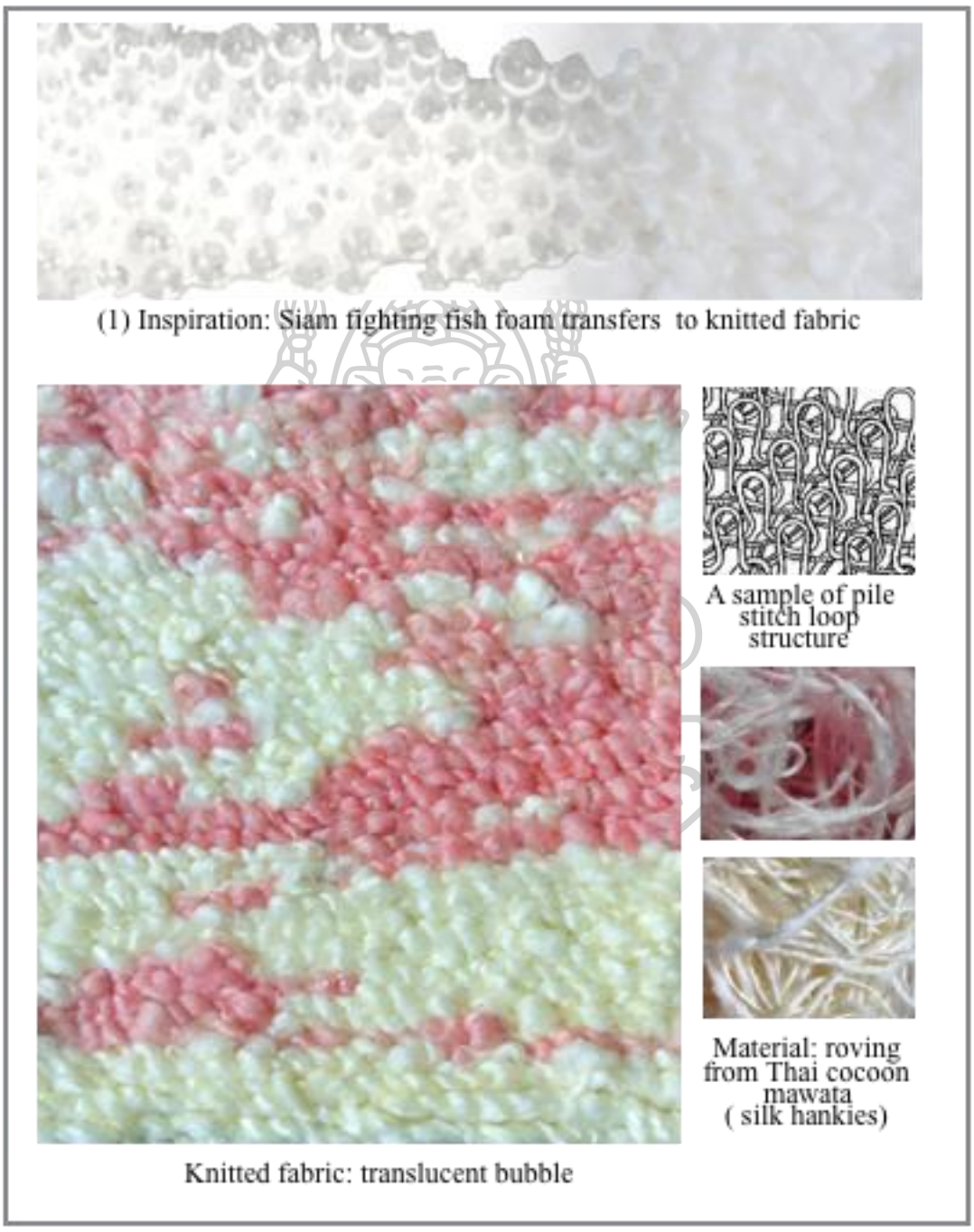


Figure 166 Knitted fabric from Thai silk waste yarn: design 1

Design 2 Pink fish's tail

Inspiration of pink fish's tail, the uneven texture looks like multilayer surface and value of colour. The design represents by knitting different yarn by single jersey structure done a hand needle tool and domestic machine. This fabric present raw material and fabric properties: Thick and thin, uneven texture, and light weight.

Figure 167 Knitted fabric from Thai silk waste yarn: design 2

Design 3 See through curve

Another inspiration of fish scale, fish body colour contrast with pearl colour of fish scale produce a colourful curve line occured, represented by knitting single yarn into single jersey structure and increase-decrease or hole stitch technique on a domestic machine. Moreover, metal yarn was used for knitting insert between curve line to reflect fish scale appearance and clearly express to curve line colour presenting raw material properties: flexibility and strength ability.

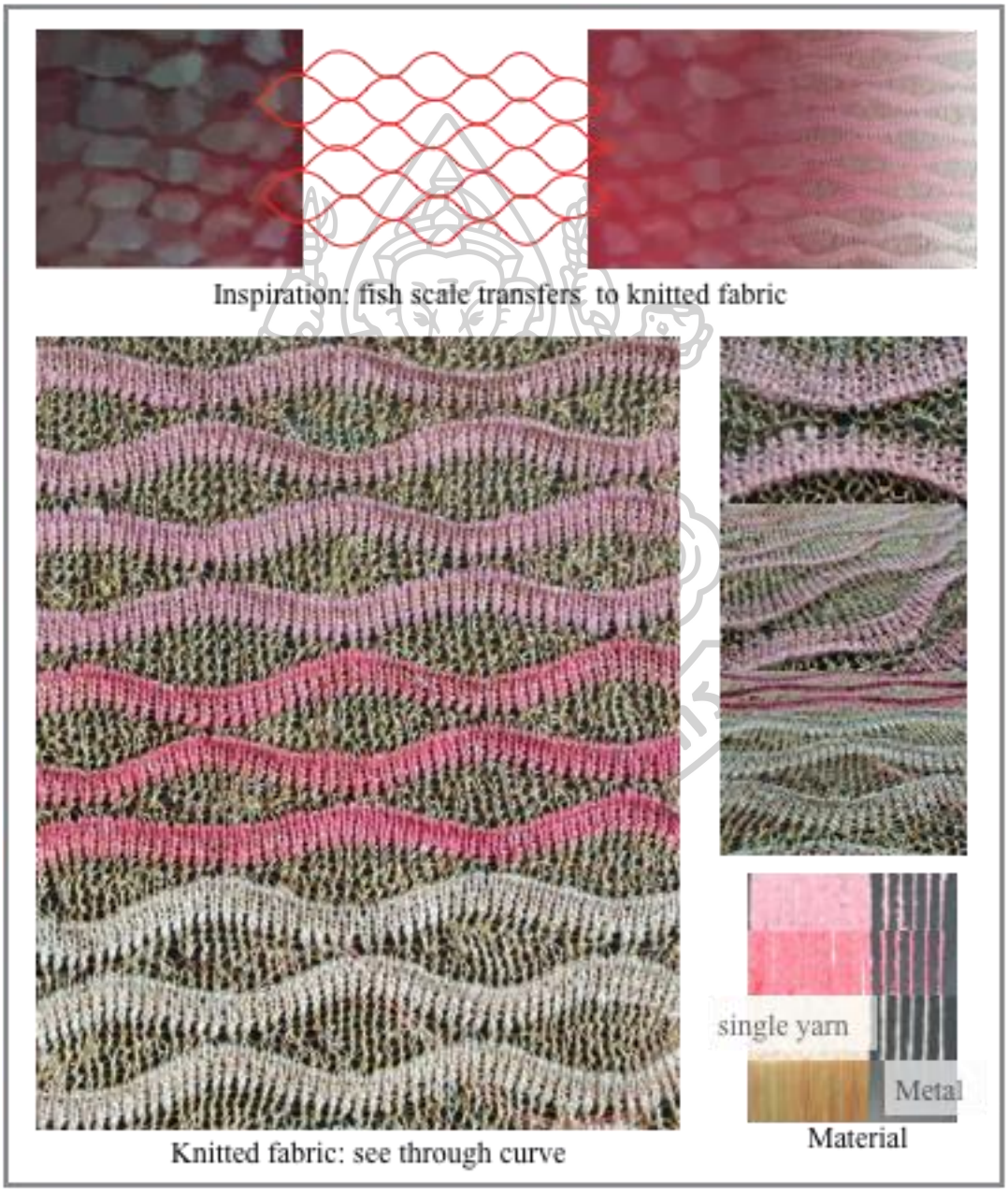


Figure 168 Knitted fabric from Thai silk waste yarn: design 3

Design 4 Fuzzy fish scale

Also from the same source of inspired design as in design three. The curve line of fish scale transfer to hexagon, represented by knitting different yarn using jacquard technique (punch card) on a domestic machine. A core yarn used to make hexagon line and shape, fancy yarn produces fuzzy pattern that looks like uneven fish skin. This fabric present raw material and fabric properties: uneven surface, and light weight.

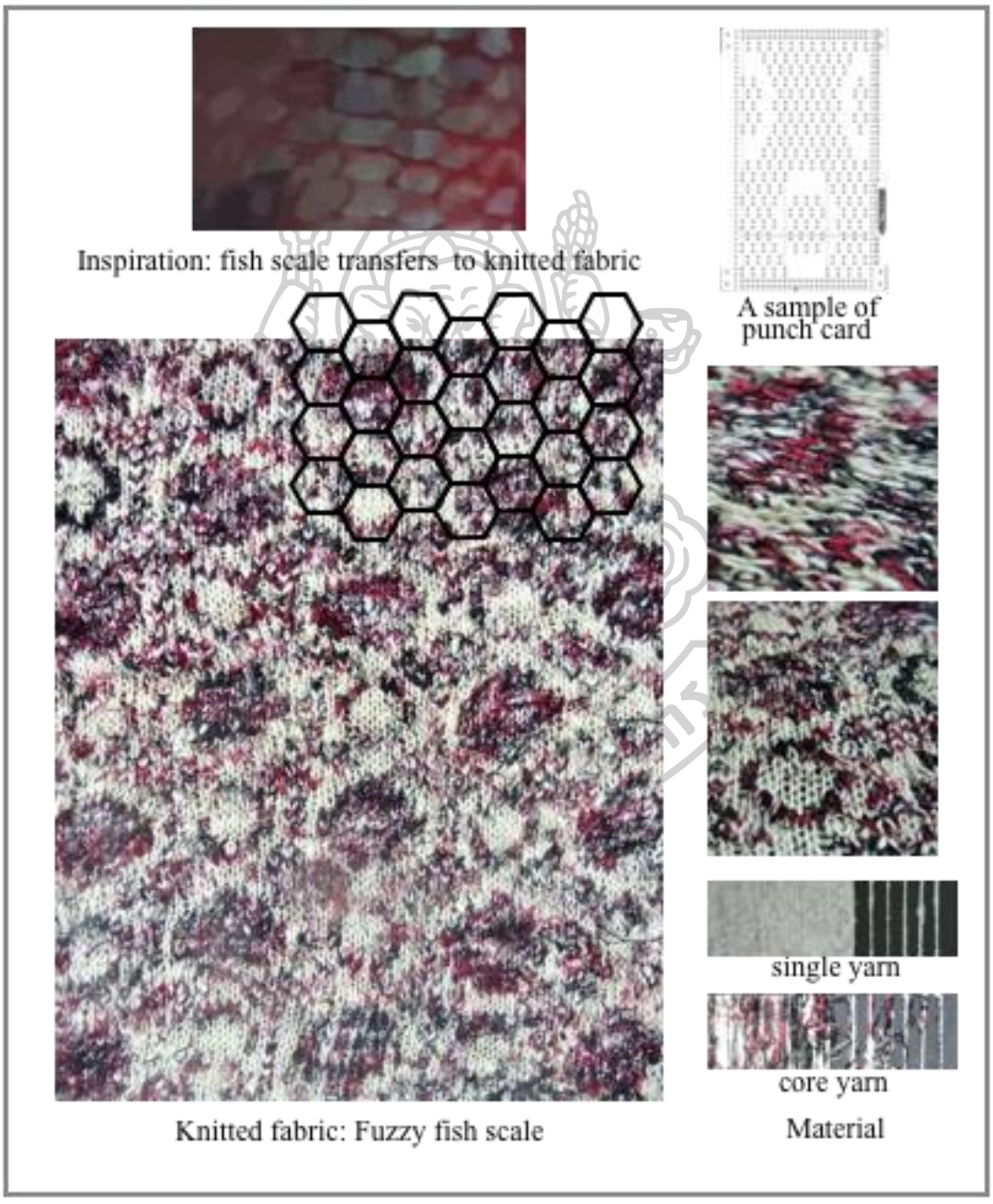


Figure 169 Knitted fabric from Thai silk waste yarn: design 4

Design 5 Fish's tail pleat

Application of inspiration of fish's tail, the pleat looks like multilayer surface and colour shade and value. The design communicate an idea by knitting single yarn into multi-strip line colour and used a lifting technique on a domestic machine. This fabric present raw material and fabric properties: Thick and thin, uneven texture, three dimensional, and light weight.

Figure 170 Knitted fabric from Thai silk waste yarn: design 5

Design 6 Fish's tail traveling curve

Being inspired of fish's tail movement, fish movement and expansion its tail making a curve line and different surface qualities: thick and thin. The design represents by knitting ladder structure (float stitch) using a domestic machine. This fabric present raw material and fabric properties: thick and thin, light weigh, flexibility and endurance.

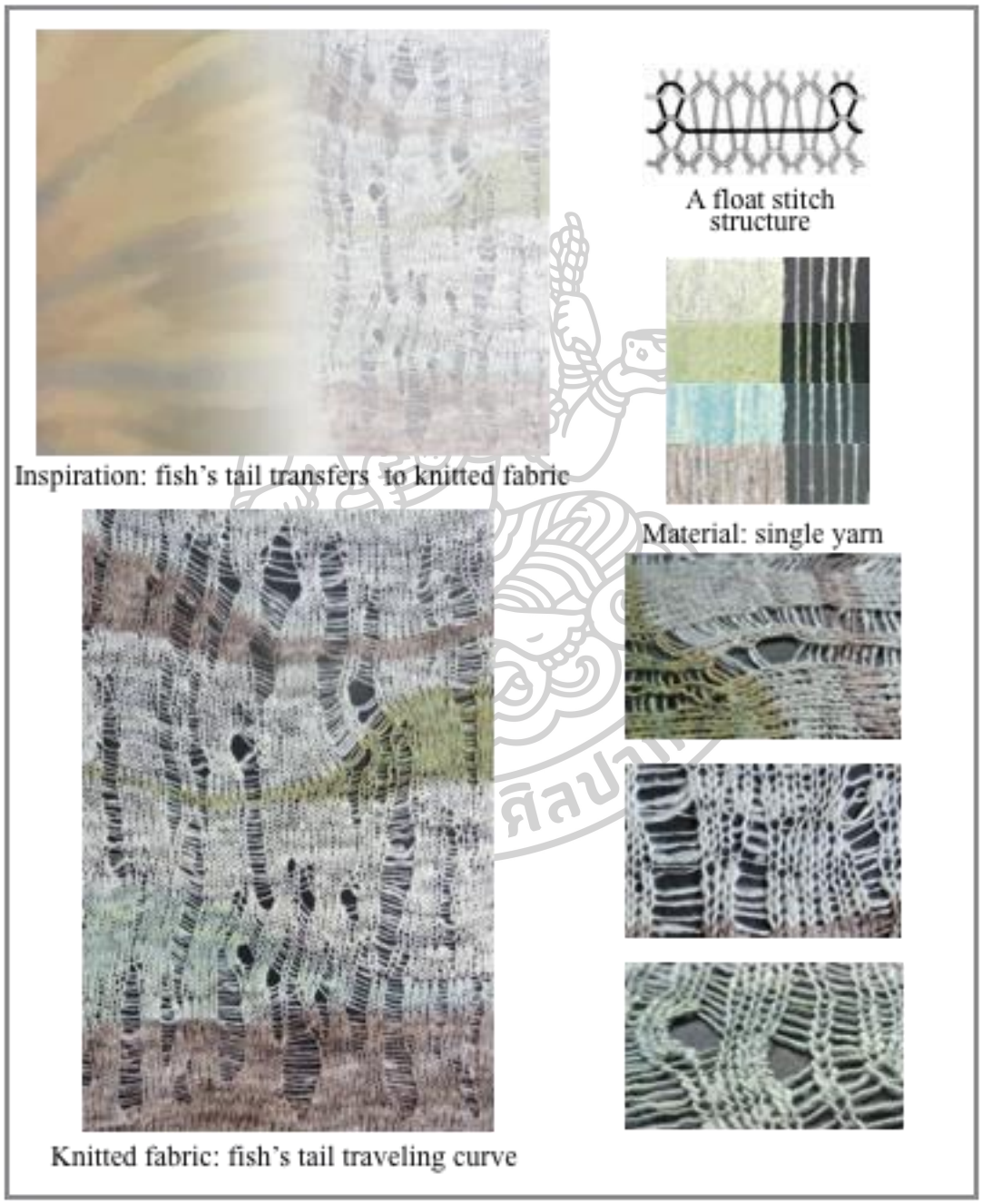


Figure 171 Knitted fabric from Thai silk waste yarn: design 6

Design 7 Fish fin waver

An inspiration of fish fin, when fish move, its make vibration and twisting, at the same time the movement look like a fuzzy spiral. Partial knitting technique using a domestic machine making this fabric to show raw material and fabric properties: thin, light weight, flexibility and durability.

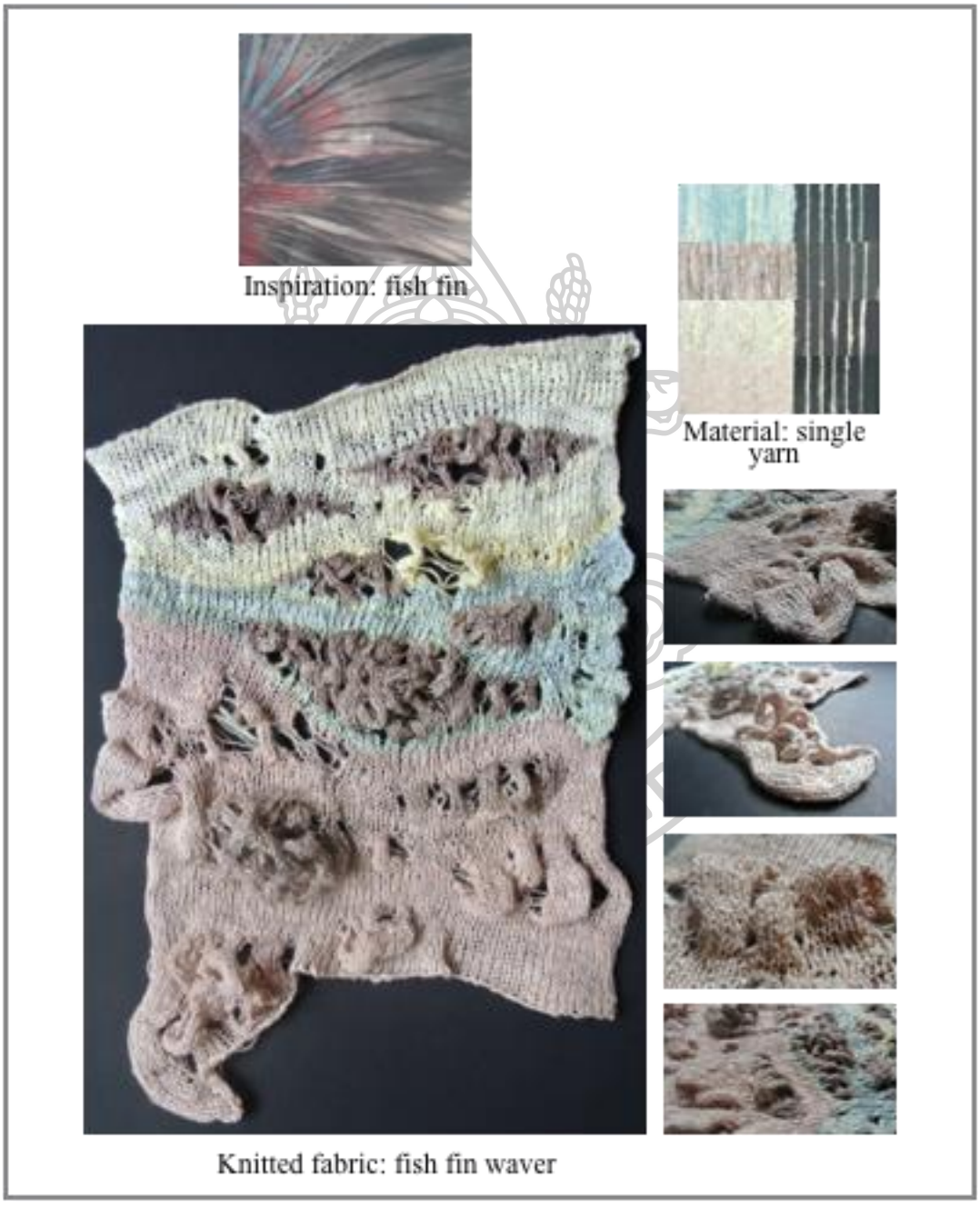


Figure 172 Knitted fabric from Thai silk waste yarn: design 7

Design 8 Ellipse fish's tail

The third inspiration of fish's tail, many colour, texture and pattern on fish's tail. The researcher used straight line, curve line applied to produce a new pattern and knitting by a domestic machine to make a single jersey structure and increasing and decreasing (hole stitch technique), presenting raw material and fabric properties: thin, three-dimensional, light weigh, elasticity and strength ability.

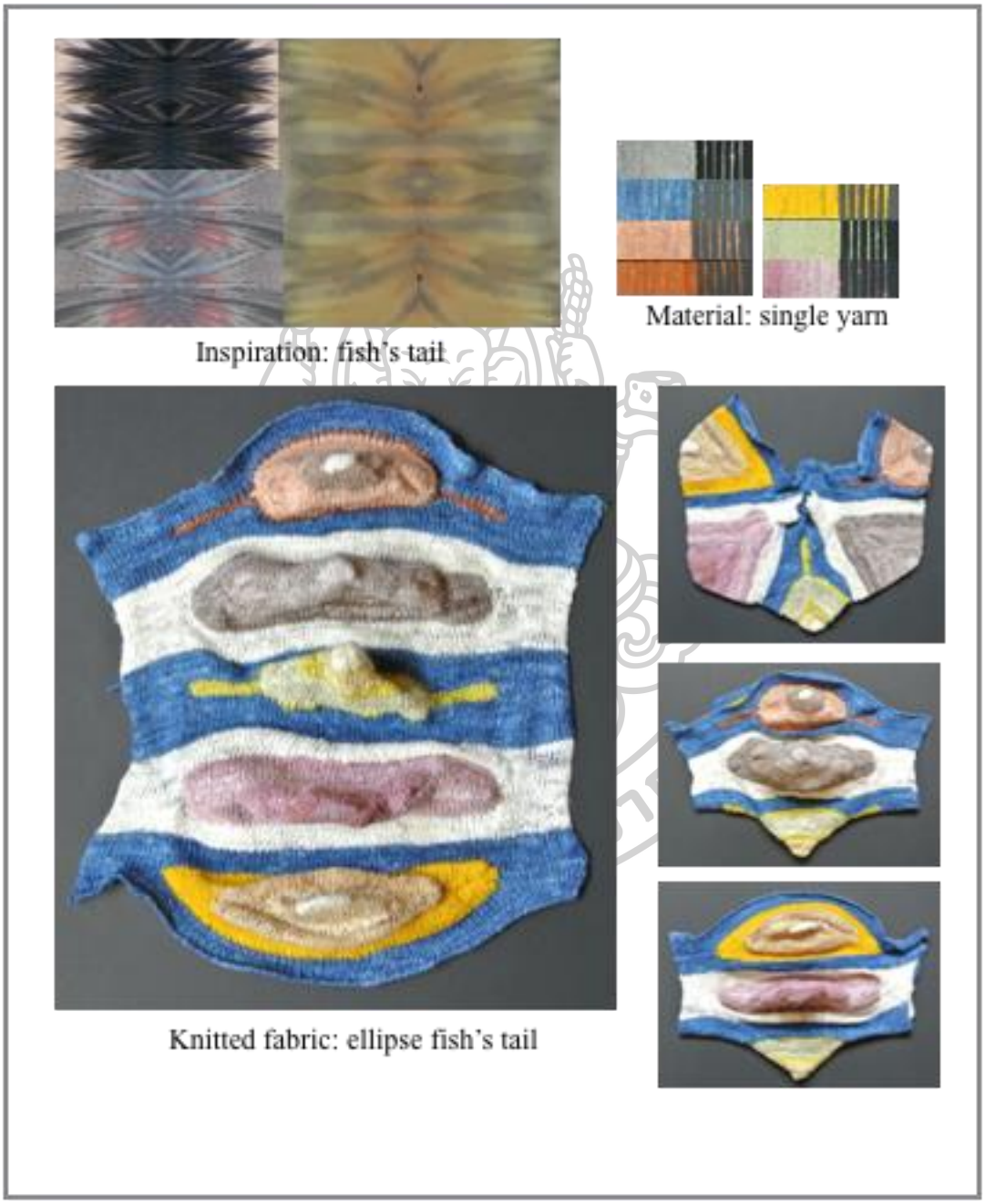


Figure 173 Knitted fabric from Thai silk waste yarn: design 8

Design 9 Marble fish fin #1

The second inspiration of fish fin, texture and pattern on Siam fighting fish: marble pattern and colour represented by knitting different yarn into cable structure and application of hand needle tool and domestic machine presenting raw material and fabric properties: thick and thin, uneven texture, light weigh, flexibility and durability.

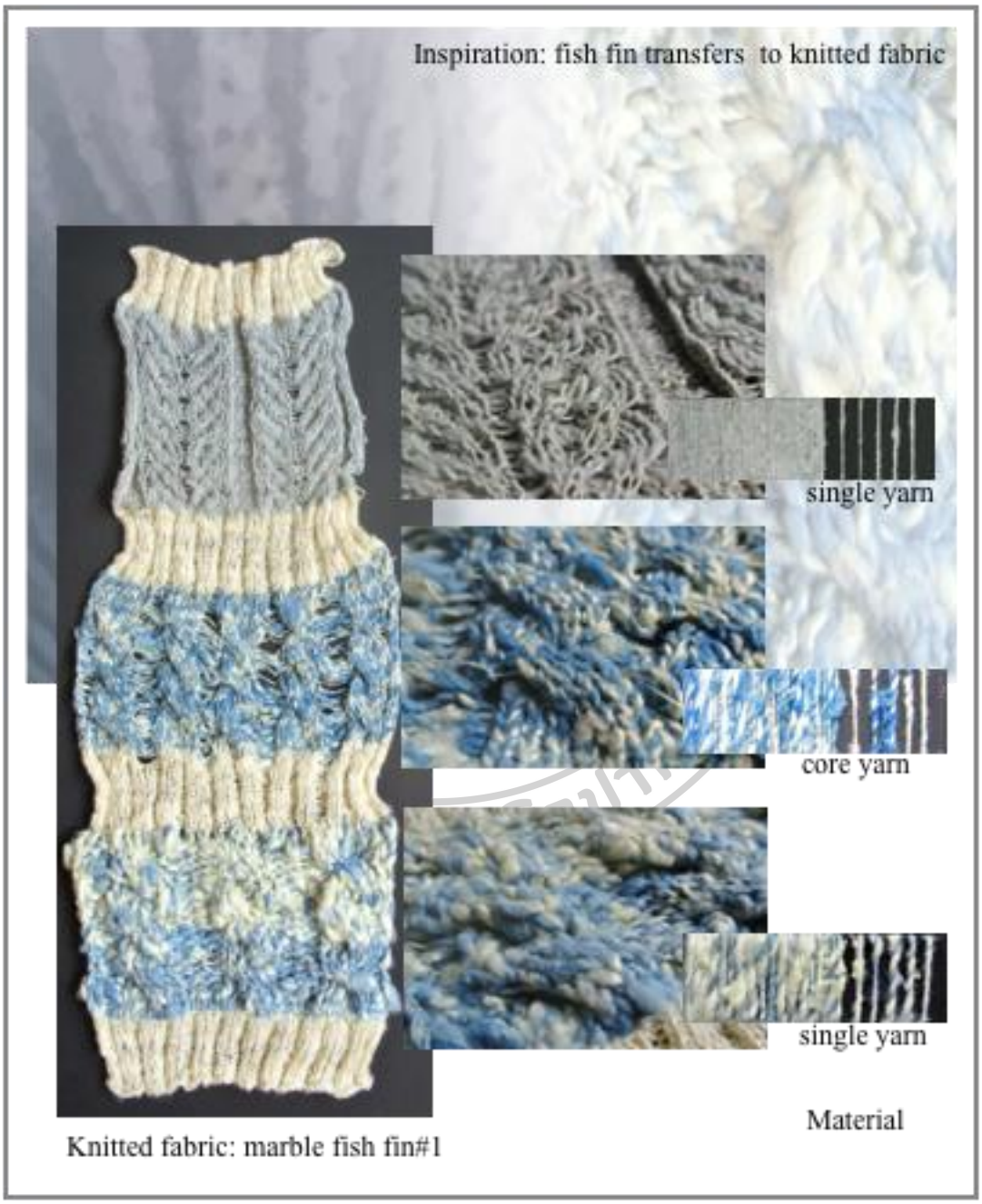


Figure 174 Knitted fabric from Thai silk waste yarn: design 9

Design 10 Marble fish's fin#2

The other theme of fish fin, new pattern rearranged by reducing motif and colour of fish natural fin structure. The design represents by knitting single yarn into strip pattern used a punch card and hole stitch technique on a domestic machine. This fabric present raw material and fabric properties: thin, uneven texture, light weigh, flexibility and strength ability.

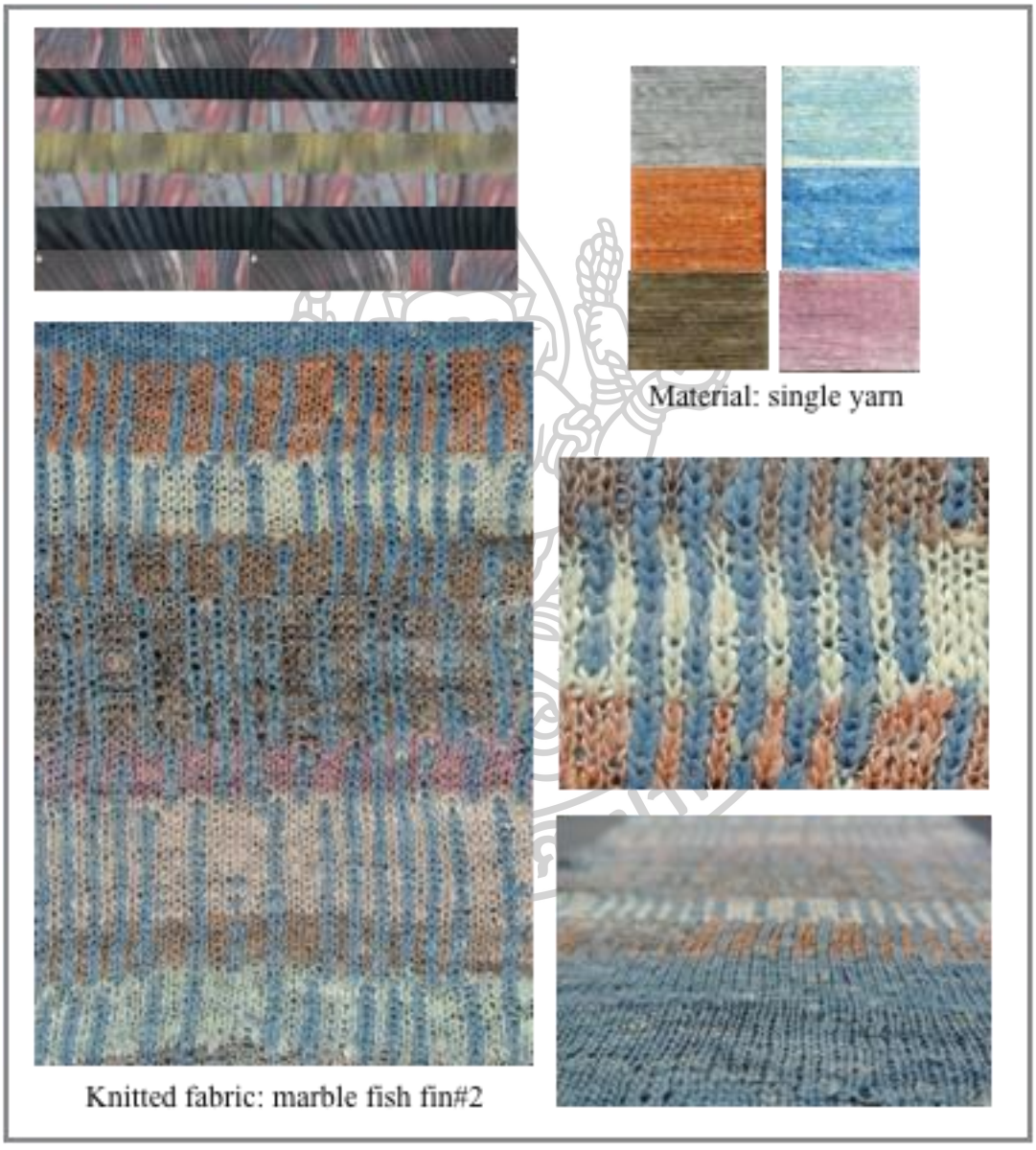


Figure 175 Knitted fabric from Thai silk waste yarn: design 10

Design 11 Fuzzy fish's tail

This final piece of design is accomplished as an integration of various dimensions of fish's tail anatomy. The piece depicting a fuzzy fish's tail structure by mixing raw material and application of knitting technique and work on a domestic machine presenting raw material and fabric properties: thin, uneven texture, softly touch, and light weigh.

Figure 176 Knitted fabric from Thai silk waste yarn: design 11

Conclusion

From all these eleven design, the design process shows a potentiality of Thai cocoons waste yarn and knitted fabric as follows:

1. physical properties

1.1 The yarn from Thai cocoon waste in form of roving, single yarn, plied yarn, and core yarn can be applied into knitted fabric by both hand needle tool and domestic machine. A yarn can be created into various knitted fabric types: standard and applied structure, it can produce the extraordinary structure that reflex to a strength and flexibility of yarn.

1.2 The yarn can be create knitted fabric in flat form and three-dimensional as well. A different yarn type and colour can be knitted to create new pattern and texture.

1.3 The knitted fabric was both smooth and uneven surface. Knitted fabric from roving was thick and softly touch. While knitted fabric from single yarn was thin as see-through fabric. However, both fabrics were remaining Thai silk properties: light weight and shiny.

1.4 In the case of flexible, all design of knitted fabrics were good flexible and restorative ability.

2. Artistic properties

2.1 A raw materail: mawata (silk hankies) can be produce yarn in different size and texture, that can be use to create more surface and texture.

2.2 Thai natural dyed applied on mawata, roving and yarn produce a lot of shade and value yarn, that was a result of more beautiful workpiece.

The conclusion explains that a yarn from Thai cocoon waste was remaining Thai silk properties: sticky substance, light weight, and shiny. A unique character: smooth and uneven surface, thick and thin, strength and flexibility, and can be created into various shape, form, and pattern.

Chapter 5
Conclusions and Recommendation

The aim of the research is to develop yarn from Thai silk waste to create knitted fabric. The reason for using Thai silk waste as raw materials to study is because it is a local material that has a unique character such as being gummy, sticky and shiny. Therefore, its waste is much too valuable to throw away. Moreover, value can be added to Thai silk waste. It can be done by knitted fabric properties: more flexible and able to produce in flat, seamless, and three-dimensions. In addition, the environment-friendly design concept are used as a study framework guideline.

The focus of this study is "practice based research and pure practice". The methodology consists of two parts. The first part relates to the collection of information regarding Thai silk waste and its benefits. The second part concerns the experiment in order to determine a method and list of equipment for the production of knitted fabric through a craft and industrial process. The steps of the process relate to fibre preparation, spinning, dyeing, knitting, and fabric testing. The result of an experiment will be transformed into knitted fabric to present the artistic value of the waste through textures, colours, structures and patterns. The conclusion of this research is as following:

Literature review analysis

Silk is a natural fibre made of silkworm. It is the only natural fibre which exists as a continuous filament. Silk has been regarded as a highly valued textile fibre. Its qualities of strength, elasticity, softness, absorbency, affinity for dyes and adaptability to various forms of twisting continue to meet various applications. The silk industry produces solid waste; the waste is divided into three parts: blaze and unreelable cocoons, reelable waste and throwsters waste. Generally, silk waste is used for making the yarn we know as spun silk. The best grades of spun silk yarn are used as filling or weft in several varieties of silk fabrics, both plain and twill, and in pile goods such as velvets. A considerable amount is also used in the production of embroidery and knitting silks. Lower grades of spun-silk yarn are used in making ribbons and silk cords, while the cheapest grades are used to make knitted goods and coarser silk or silk-mixed fabrics.

In the case of Thai silk, the Thai cocoon species has a particular property, it is a small and slim shape, but it is durable in the environment as well. Filament silk yarn is terrific and has unique physical characteristics never seen in another silk. Its cross-section is triangular shaped making beautiful light refraction. The strongest Thai silk ever found is the yellow silk type which consisted of 18 kinds of amino acid. The percentage of the amino acid is over 34.5 higher than those of other countries. All of this is a result of the unique characteristics of Thai silk. It is quite a gummy, sticky and shiny.

The Thai silk industry produces a significant amount of solid waste which can be classified into three types: incomplete cocoons, broken silk yarn, and silk fabric waste. The detail among the three types are as follows:

1. Incomplete cocoons: the imperfect cocoons which cannot be reeled commercially. Examples are double cocoons, feeble cocoons, pierced cocoons, piques, and rates.

2. Broken silk yarn: the waste product from reeling, winding, throwing, and weaving.

3. Silk fabric waste: the waste produced in apparel industries, and decorative product industries

Businesses reuse this waste for items such as fashion accessories and decorative products. For example, the cocoons are usually used to create decorative products such as lamp shades and artificial flowers. Fabric from spun silk has been a frequent choice for home textiles such as upholstery and pillowcases. Spun silk fancy yarn is also used in fashion fields on hats, scarve and bags. Also, silk fibre is used to make a thread and bio-composite in the medical field.

The Experiment conclusion

The purpose of experiment is to find a solution to produce yarn from Thai silk waste. The information from literature review was the analysis using an experiment framework to find the method for utilizing Thai silk waste. The process was divided into two parts, with operations in both the academic laboratory and the field

1. A result of the first experiment

The first experiment was tried out to prepare fibre, spun, dyed and knitted into a piece of fabric from three types of Thai silk waste: cocoons, broken silk yarn and waste from silk fabric. The first experiment consists of fibre preparation, spinning, dyeing and knitting. The result of the first experiment are as follows:

1.1 Fibre preparation

There were two methods to prepare the fibre: hand preparation and machine preparation. The incomplete cocoons can prepare fibre by both hand and machine. While the broken silk yarn and fabric silk waste can be prepared by machine only.

1.2 Yarn spinning process

There were two methods to spinning: hand spinning and machine spinning. Fibre from incomplete cocoons, broken silk yarn and fabric silk waste can be spun by hand. Whereas machine spinning could not complete to 100 percent the silk waste fibre, it worked with a blend of cotton 50:50 before feeding the fibre to spin.

1.3 Knitting process

There were three types of equipment used to produce knitted fabric: hand needle knitting, domestic machine and automatic knitting machine. The knitted fabric by hand knitting needle No. 12 gave an uneven surface, soft in touch and medium flexibility. The domestic machine: single bed gauge 5 produced a smooth surface, medium flexibility and was soft in touch. In the case of V-bed gauge 7, it could not complete knitting the fabric, the yarn was broken during the knitting process. The automatic knitting machine: Shima seike SES.122 / multi gauge could knit only blend yarn (cocoon fibre: cotton/ 50:50). The fabric result was a smooth visual surface, but not soft in touch and less flexible.

1.4 Dyeing process

Natural dyestuff was used to colour the yarn and the piece of fabric made from the incomplete cocoon. The yarn dye absorbed the colour better than piece dye.

2. A result of the second experiment

The result from the first experiment was used to be the guideline to develop the advantageous material and a method which followed an environmentally friendly design concept. The incomplete cocoons were selected to be a material for the second experiment. The crafting process began from preparing fibre by mawata process: expand degumming cocoon on the wood frame and hang to be dried, hand spun by traditional Thai spinning tool, natural-dyed and knitted fabric by hand and domestic machine, the result presented below:

2.1 Fibre preparation

2.1.1 Equipment

There should a new frame designed because of the Thai cocoons physicality. A suitable frame for the Thai cocoon was 10 centimetres squared and made from hardwood. A plastic tray was used to avoid rusting because water was used in the process. A frame design was made that allowed for adjusting a size and that was easy to store and carry.

2.1.2 Fibre preparation

Thai degumming cocoon was stretched into a gossamer film on a frame of about ten sheets overlaid to be mawata (silk hankies), this is a raw material to make roving for spinning.

2.2 Spinning process

The traditional Thai spinning can spin various types of yarn, there were single yarn, ply yarn and core yarn. A yarn count from single yarn was number 8 of the indirect system. In addition, yarn testing by Standard : ASTM D5035 Standard Test Method of Breaking Strength and Elongation of Textile. The results of the testing indicate the yarn has fastness and is highly flexible and therefore suitable for products that require high flexibility.

2.3 Dyeing process

Natural dyestuff was available locally in Thailand such as lac, gardenia dulcet bark, mangosteen leaf, golden shower pod, indigo, turmeric and coffee ground. These produced light and dark colors and can add more shade and value by mordants such as ferric oxide, alum and tamarind. The material forms to dye were mawata, roving and yarn. Dyeing methods were drop, dip, immersion and free style dyeing. One or more colour can be dyed on one piece which allows for extraordinary colour creation.

2.4 Knitting process

There are two methods used, hand knitting needle and domestic machine.

2.4.1 The raw material “mawata” can be used to knit in various forms. Firstly was roving, it produces thick, lightweight and soft touch fabric. Secondly was yarn, it produces thin and lightweight fabric.

2.4.2 The handspun yarn can be knitted flat form in various patterns such as single jersey, pointelle, laddle, cable and pile loop. In the case of dimension form by lifting, increase-decrease technique and jacquard it was easy to

knit. Although the surface was uneven, the fabric was soft in touch, thin and lightweight.

2.5 Knitted fabric testing

A sample knitted fabric to test was produced by domestic gauge 5.5, tension 3, single yarn number 8 and knitted into 10 square centimeter. Each testing used three pieces of the sample. Busting fabric testing, the results of the testing indicate that the fabric is highly flexible and strong and suitable for producing products that require high flexibility and strength. Elasticity testing, the results shown fabric elasticity is related to the knitted fabric properties, the sample had high elasticity and good restorative ability. This indicates that it is suitable for products that require high flexibility

The design conclusion

The objective of the design process was to present properties and the artistic value of yarn from Thai silk waste trough knitted fabric. This process found more potential in Thai cocoons waste yarn and knitted fabric.

1. Thai cocoon waste transfer into mawata (silk hankies) can produce yarn in different sizes and textures, that can be used to create more surface and texture. Thai natural dyed applied on mawata, roving and yarn produces a lot of shade and value yarn, that was a resulting in a more beautiful workpiece

2. Knitted fabric have a unique characteristic: smooth and uneven surface, thick and thin, strength and flexibility, and can be created into various shapes, forms, and patterns. In the case of Thai silk properties, it was remaining sticky, light weight, and shiny.

The research conclusion

1. The utility of yarn and knitted fabric from Thai cocoon waste

A yarn from Thai cocoon was retaining Thai silk properties: sticky, light weight, and shiny. A knitted fabric from Thai silk waste yarn has a unique character: smooth and uneven surface, thick and thin, strength and flexibility, and can be created into various shapes, forms, and patterns.

All of this corresponds to textile products specific requirements explained by Thomas Gries, Dieter Veit and Burkhard Wulfhorsr, there are the aesthetic properties: handle, optical appearance and look, cooler and luster, and physical properties: strength, elongation, wrinkle resistance (2015, 18). That suggests the benefit of knitted fabric from this research can be used for daily lift products such as the something around us: garments and home textiles. That relates to J. Wilson, (2011: 3-4) the designer reminds us that knitted products are a part of everyday life as well as lifestyle. He describes knitting as one of the textile products that produces fabrics like no other and these fabrics have many functions: The clothing or apparel, specialised fabrics, interior textiles, industrial textiles, and consumer textiles.

2. The environment friendly design relation

The environment-friendly design concept was used as study framework guideline. The concept of environment-friendly design is called “Eco-Design” and is also known as “Economic & Ecological Design”. A definition of EcoDesign is Environment-friendly design and Sustainable Design is the harmony of technology,

procedure and aesthetics. The principle of EcoDesign are Reduce, Reuse, Recycle and Repair, it's applied on all stages of production.

From the concept of environment- friendly design, researchers recycled Thai silk waste into yarn, reducing energy by craft process. In the case of environmental protection the colouring process was done by natural dyed-stuff. The detail of this process are explained in chapter three and four.

Moreover, this research corresponds to eco knitted fabric design that Uraiwan Paradee (Pitimaneeyakul) explains: Knitted fabric design process should reduce material, energy and wastage. Knitted fabric should be designed under re-usability or recycle, recycle and up-cycle concept, and knitted fabric production should minimise it's environmental impact. The alteration, derived from this research

Recommendation

1. The researchers found that the Thai silk waste is much too valuable to be thrown away. Thus, It should be studied and developed in order to obtain more advantages from Thai silk waste.

2. The development of Thai silk waste utilization should be done together by both craft and industry fields. Both systems can be create innovation: the craft side can develop innovation from folk wisdom, and industry can develop through modern technology. They can aim for the same goal which is to reduce environmental problems.

However, the researcher suggests that the development should focus on the local people and villagers. Such as Thailand's sufficiency folk wisdom. They can develop designs and produce in a way that corresponds to the environmentally friendly concept.

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