Chapter II Overview of sewing process related topics

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1. Sewing machines

It is surprising how diversified and packed with mechanical and electronic high-technology industrial sewing machines are nowadays. Nevertheless, all of the basic mechanisms of stitch formation remain similar to the ones created during the second half of the 19th century. To present the measurable and controllable variables involved in this process, a brief insight into the principle of machine operation is presented in this chapter.

1.1. Principles of operation

A sewing machine is a machine able to interlace threads through or around textile or other types of materials. This **stitch formation process** is based on the following three functions:

a) Crossing the fabric carrying the needle thread to the reverse side of the fabric;

b) Interlacing the needle thread(s) with the remaining ones (or with itself in one-thread stitch types);

c) Feeding and removing the material.

1.1.1. Stitch and seam type classification

Stitch formation is the actual process by which threads are interlaced in or around a material resulting in a *stitch*. When a stitch is used with a defined geometry for material layer positioning, a *seam* is formed. Stitch and seam types are classified in specific international and national standards [4][5][6][7][8][9].

Seams perform many different functions, and all of the standards regarding their classification are quite extensive. Figure II- 1 shows examples of seams and their representation, classified according to the British Standard 3870 [9].

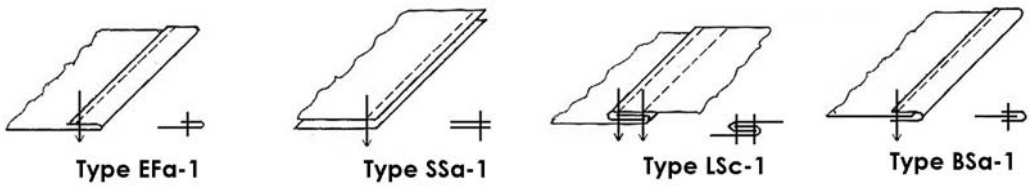


Figure II- 1: Seam examples, 3D and 2D representation, classified according to [9]

Stitch types are chosen for a seam depending on the functional or aesthetical requirements of the seam. All of the referenced standards are very similar in the way stitch types are classified. According to the Portuguese standard [4], for instance, 6 classes are defined, namely:

- Class 100 - Simple chainstitch
- Class 200- Manual stitches (stitches normally performed by hand)
- Class 300- Lockstitch
- Class 400- Double Chainstitch

- Class 500- Overedge or overlock[1] stitches
- Class 600 - Interlock or covering stitches

Within each of these classes, two supplementary digits define variants. A one-needle, two-thread double chainstitch is, for instance, referred to as stitch type 401.

Classes 100 and 300 to 600 are the bulk of stitch types used industrially. They can be roughly divided considering two basic stitch formation processes:

- Lockstitch (class 300)
- Chainstitch (classes 100, 400, 500 and 600).

The fundamental difference between lockstitch and chainstitch types is that, in the first one, the threads are interlaced, whilst in the second case the loops formed by the threads are interlaced. Figure II- 2 illustrates this difference.



Figure II- 2: Interlacing of threads (lockstitch) vs interlacing of loops (chainstitch)

This principle of interlacing is the first factor determining a set of properties that will assign typical application areas to each stitch type.

Other geometrical and functional differences between the stitches determine the division of the chainstitches among themselves. A detailed study of these is beyond the scope of this work, and can be found in [1][2][3].

In this work, an overlock machine in a three-thread, one-needle configuration has been used. This configuration produces a stitch of type 504 or 505 (depending on thread tension adjustment).

The stitch formation process for this stitch type will be presented next.

1.1.2. Stitch Formation

The overedge, or overlock stitches, class 500, are also widely used in the industry. Their most particular feature is the fact that the seams are formed around the edge of the fabrics, instead of just on the top and bottom of the fabric plies[2]. A

[1] Although the term “overedge” is used in the standards, this stitch type is usually referred to as “overlock”, a designation adopted by some sewing machine manufacturers.

[2] The word “overedge” finds its origin in the fact that the threads are guided “over the edge” of the fabric in this stitch type.

knife cuts the edge of the fabric as the stitch is formed, so that a constant distance is kept between the seam line and the edge (seam *width* or *margin*).

This formation principle has a decisive effect on the shape of the machine. Considering that stitch formation happens on the edge of the fabric, no material has to pass on one of the needle's sides. The material is thus fed along its borders. In other machines, the seam can be produced anywhere on the fabric. They are therefore built with an arm, allowing material to pass on both sides of the needle. Figure II- 3 illustrates this difference.

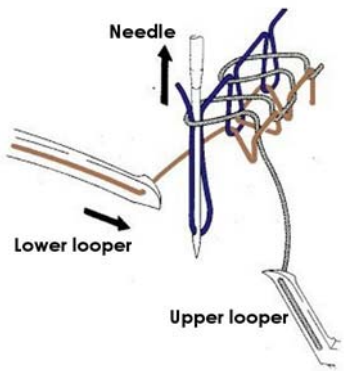


Figure II- 3: The shape of an overlock machine shape compared to a lockstitch with a regular arm

This shape allows the mechanisms for material feeding, needle and other stitch formation elements movement to be much more compact. As a result, overlock machines are able to achieve sewing speeds up to 10000 stitches per minute (spm), being the fastest of all machines.

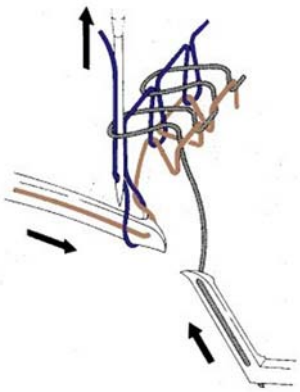
Class 500 stitches possess the ability of not only joining materials, but simultaneously supplying an edge finishing that is important in many situations. In effect, some variations of stitches in this class are used exclusively to produce edge finishing on single fabric layers, an operation called *serging*.

The stitch formation cycle for the overlock stitch can be observed in Figure II- 4.



1. Initial Situation

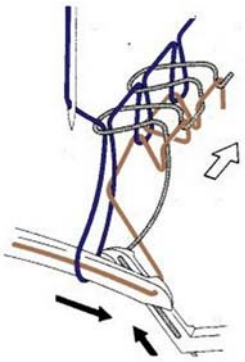
The needle has penetrated into the fabric and starts its ascending movement. A loop of the needle thread is formed. The lower looper is moving from the leftmost position to the right.



2. Lower looper thread interlacing

The lower looper passes through the needle thread loop, holding it.

The upper looper is moving from its rightmost and lowest position up and to the left.

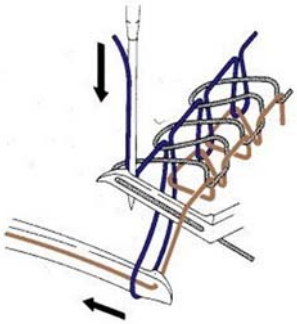


3. Upper looper interlacing and material feeding

The material is moved forwards to achieve the required stitch length.

Upper and lower loopers cross. The lower looper passes through the thread triangle formed by the needle and lower looper threads.

The needle is at its topmost position.

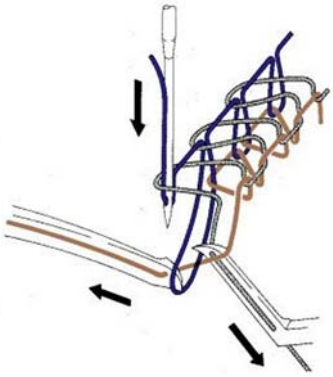


4. Needle thread interlacing

The needle has started to descend and penetrates the thread triangle formed by the upper and lower looper threads.

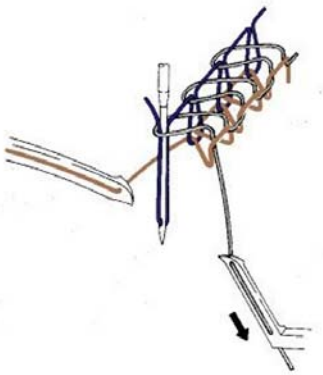
The upper looper is at its topmost position.

The lower looper has started to move to the left.



5. Release of the interlaced loops

Both loopers are moving away from the needle, letting the interlaced loops slip off.



6. Stitch tightening

The thread in excess is pulled and the stitch tightens around the fabric.

Figure II- 4: Stitch formation cycle for overlock stitch type 504 (Source:[10])

Figure II- 5 shows the schematic representation for the 504 stitch, and the final appearance of a seam produced.

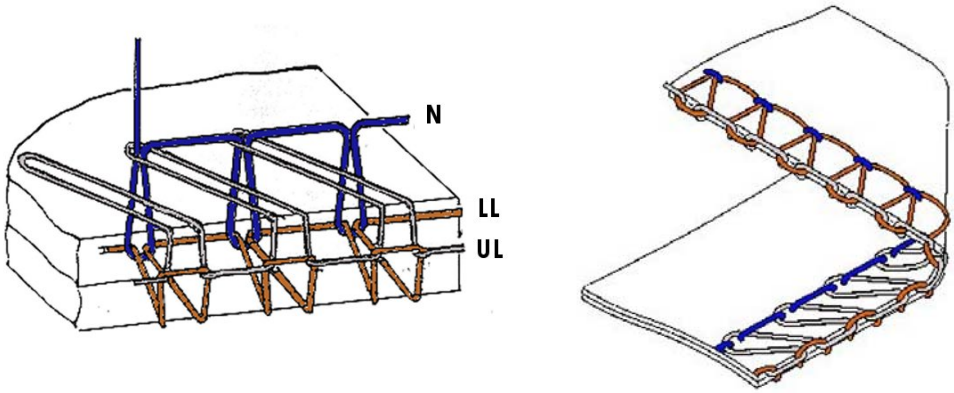


Figure II- 5: Schematic representation and final appearance of the 504 stitch (N: Needle - LL: Lower Looper - UL: Upper looper threads)

The complexity of the class 500 stitches is noticeable. Working around the edge of the fabric, these stitches acquire a third dimension even when using just one needle.

It is also possible to verify that this is a variant of a chainstitch, in the sense that loops are interlaced, instead of threads. A practical consequence of this fact is that chainstitches can *run back* when the threads are pulled from the end to the beginning of the seam, meaning that the stitch formation process can be inverted and the seam unravelled.

As all chainstitches, the overlock stitches possess high elasticity, making them adequate for seaming extensible materials. This stitch is frequently combined with double chain stitch type 401 to improve its strength and to avoid seam grinning, one of the most common faults of this stitch.

Overlock machines are fast and do not use special thread storage and delivery devices (bobbins), which means that they can be fed continuously with standard thread packages.

This stitch also presents some disadvantages. It consumes a great amount of thread, having a higher volume, and therefore being much more exposed to wear than other stitches. The fact that it runs back under certain conditions makes it less durable.

An interesting variation of the 504 stitch is the 505 stitch. Essentially, the difference results from the tensions that are applied to the threads during stitch formation. Figure II- 6 shows the diagram of the 505 stitch:

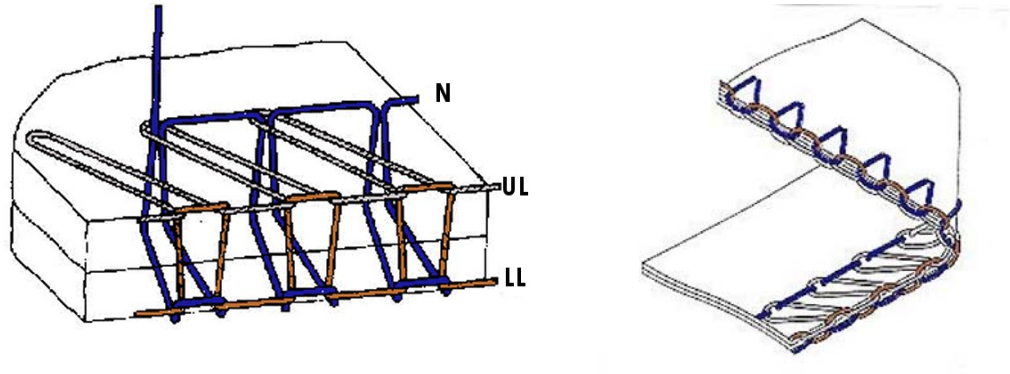


Figure II- 6: Schematic representation and final appearance of the 505 stitch (N: Needle - LL: Lower Looper - UL: Upper looper threads)

The basic difference to the 504 stitch is the modified balance of the thread tensions. The links between threads appear repositioned, in a way that puts two of the three links on the edge of the fabric. This results in more thread being present on the edge of the fabric, protecting it to abrasion more efficiently. This type of stitch is therefore used for edge finishing. It has, however, lost its suitability for joining the materials. The link between needle and lower looper thread, that holds the two fabric plies together in the 504 stitch, has moved to the edge of the fabric.

1.2. Machine subsystems

Although needle penetration, thread interlacing and material feeding are all functions involved in the **stitch formation process**, they will be considered as three separate subsystems, leading to three independent fields of study. In the context of this work, thread interlacing will be studied within the subsystem termed as **stitch formation**, and the other two functions as the **needle penetration** and **material feeding** subsystems. A brief overview of the relevant issues in each of these three subsystems will be given next.

1.2.1. Stitch formation

The study of stitch formation involves the analysis of thread tensions, thread consumption measurement, their monitoring and adjustment. This has to be done bearing in mind that the feeding and needle systems are also part of the stitch formation process; some adjustments of the feeding system and of the needle bar trajectory have an influence on the stitch formation process. However, these settings are kept constant throughout the study, and only the adjustment of thread tensions and the behaviour of measured thread consumption are examined. Thread tension is the variable that most directly influences stitch formation; it has to be adjusted every time the material or seam objective is changed.

To apply tension on the threads, sewing machines are equipped with tensioning devices called *Tensioners* (Figure II- 7). These are composed by two metal rings, compressed by a spring. The thread passes between these rings and acquires tension as it is pulled through.

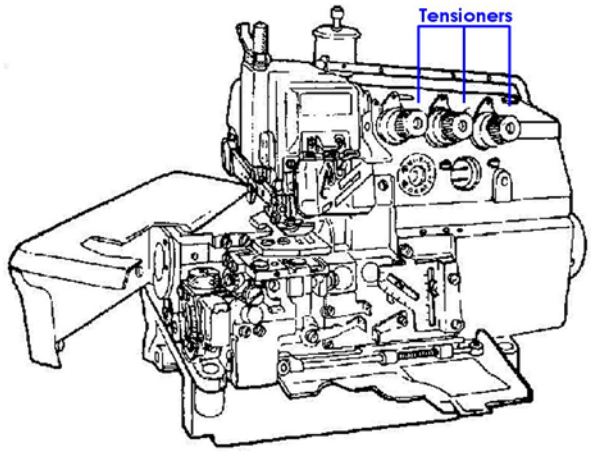


Figure II- 7: Tensioners on an overlock machine

The first objective in adjusting thread tensions is to assure that the resulting stitch is geometrically correct for the stitch type considered. This is important to achieve the stitch's optimal functional properties. The correct geometry for a stitch is achieved by properly balancing the thread tensions.

The overall value of tension is also fundamental, and depends largely on the material being sewn and on the purpose of the seam.

Excessive thread tension causes the seam to loose elasticity, which can be critical when sewing extensible materials. It is also one of the causes for seam *puckering*, especially in lightweight materials. Puckering is an effect in which the material shrinks at the seam line, becoming undulated. Seam puckering is one of the most difficult quality problems to solve. Figure II- 8 shows an example of this defect.



Figure II- 8: Seam Pucker Example

Lack of tension, on the other hand, often compromises the function of the seam. This is particularly true on seams used for joining materials. A lack of thread tension will not allow the threads to hold the material layers together: *seam grinning* will occur when they are pulled apart.

Other defects occurring in everyday use of sewing machines are *skipped stitches* and localized stitch distortion.

A *skipped stitch* occurs when one or more of the interlacings that are normally formed during a stitch cycle do not take place. This can happen due to a great number of reasons, namely thread tension misadjustment. A skipped stitch

represents a weak point in a seam, is aesthetically unpleasant and the seam is susceptible to unravel from this interruption of the chain.

Distorted stitches appear as a small number of stitches in which the geometry or the thread tension has momentarily changed. They can also represent a seam weak point, as distorted stitches may loose strength and/or elasticity due to the tension variation that originated them.

Figure II- 9 shows examples of a skipped stitch and a stitch distortion

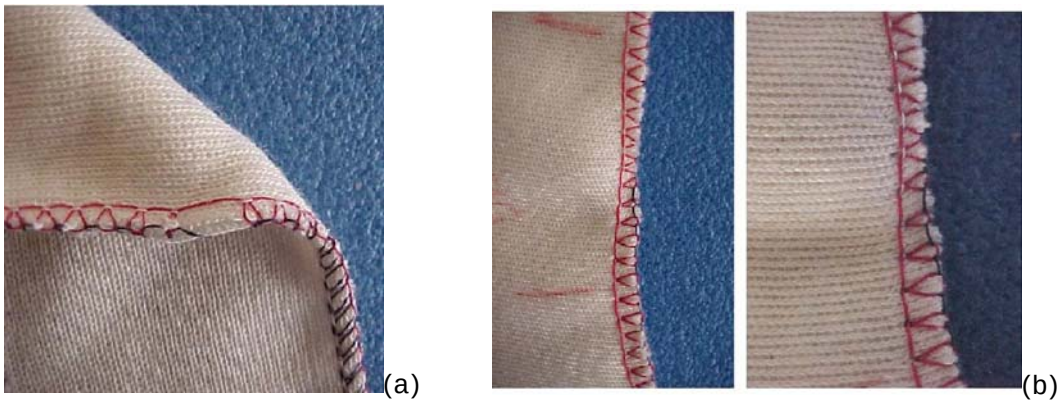

(a) (b)

Figure II- 9: Skipped stitch (a) and stitch distortion (b) examples

1.2.2. Material feeding

The feeding system is responsible for providing movement to the material being sewn.

Industrial sewing machines use a wide range of feeding systems. Basically, a sewing machine feeding system is composed of a presser-foot, a throat plate and a feed-dog. A short description and analysis of basic systems is presented.

The drop feed is the simplest feeding system. Figure II- 10 shows the components and the principle of operation of the drop feed system.

The throat plate is devised with slots to allow the needle to penetrate into the fabric and the feed-dog to emerge from underneath.

The feed-dog has an elliptical movement. When the needle withdraws from the fabric, the feed-dog emerges, pushes the fabric layers against the presser foot and backwards, making them advance.

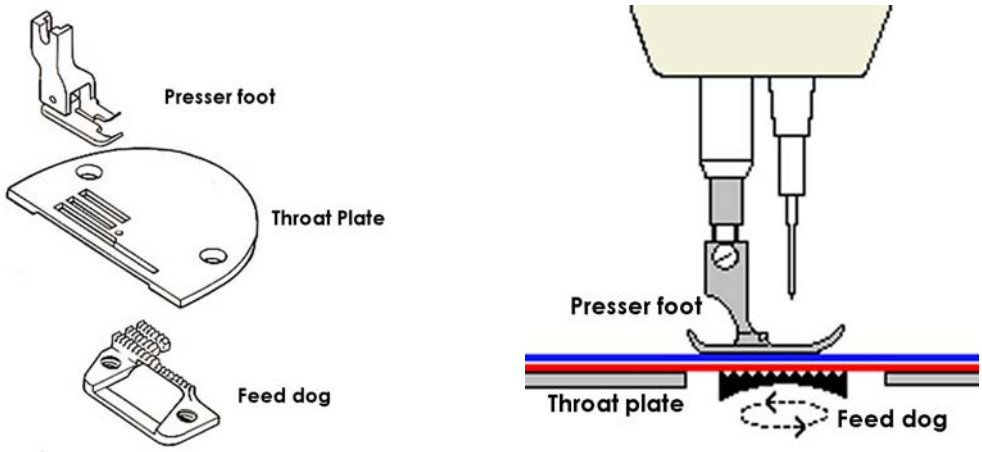


Figure II- 10: Basic components and principle of operation of a simple drop feed system

The horizontal projection of the ellipse determines the stitch length. This horizontal amplitude of movement can be mechanically adjusted to vary stitch length. The stitch length measured on the seam will equal this nominal regulation if the following two conditions are met:

- The presser foot maintains a constant contact with the fabric throughout the stitch cycle;
- No slip occurs between the fabric layers and the feed-dog.

To assure these conditions as fully as possible, the presser foot is equipped with a helical spring to apply the required force, being its pre-tension adjustable.

This simple mechanical system has revealed inefficient in some situations. In high-speed or highly variable speed situations, variations of the resulting stitch length are observable. These variations may be considered as defects beyond defined tolerances, and should be avoided.

Stitch length irregularity results from loss of fabric control during the process. The spring-hinged system is not able to maintain contact between presser foot and fabric. This effect is known as *presser foot bouncing.*

Normally, thinner fabrics are more troublesome than the thicker ones, because decreasing fabric thickness/mass reduces damping and oscillation is more likely to occur.

To overcome these situations, presser-foot spring pre-tension is increased, but excess of force applied to the fabric can cause other problems.

Extensible materials, of which knitted fabrics are the best example, are difficult to be fed by a simple drop feed system. These fabrics tend to be stretched as they are pushed against the presser foot. The stitch is then formed with the fabric under extension, and the resulting seam will present loose stitches, an obvious reduction of stitch length, and often heavy undulation of the fabric at the seam line. For these fabrics, differential bottom feed, shown in Figure II- 11, is used.

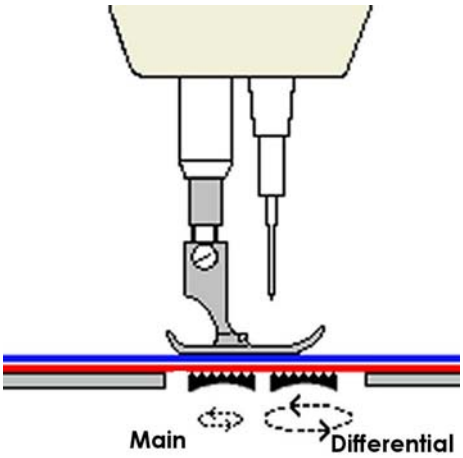


Figure II- 11: Differential bottom feed system

In this system, two feed-dogs are used. Although working synchronized, the feeding amplitude ratio between the main and the differential feed-dog can be varied. The range of feeding ratio available on a machine is specified as shown by the following example:

$$FeedingRatio \rightarrow 1:1{,}4 - 1:0{,}7$$

In this case, the ratio ranges from positive (differential feed-dog feeding 40% more) to negative (differential feed-dog feeding 30% less).

In a positive feeding ratio, the differential feed-dog has a wider movement than the main feed-dog, resulting in the fabric being gathered at the needle-overfeed.

In some operations this gathering effect is produced on purpose. It can be used, for example, to shape 2-dimensional components to a 3-D shape[1] or to create other effects.

A positive feeding ratio has, however, another very important application. When correctly adjusted, it can compensate the stretch imposed to extensible materials during feeding. This allows the stitch to be formed with the fabric tension-free, avoiding the problems associated with a simple drop feed. Virtually all sewing machines used in knitted fabrics are equipped with at least a positive differential feeding system.

The negative feeding ratio adjustment is used to stretch the fabric during stitching- underfeed. This can be used to produce some special effects, but has also another important application.

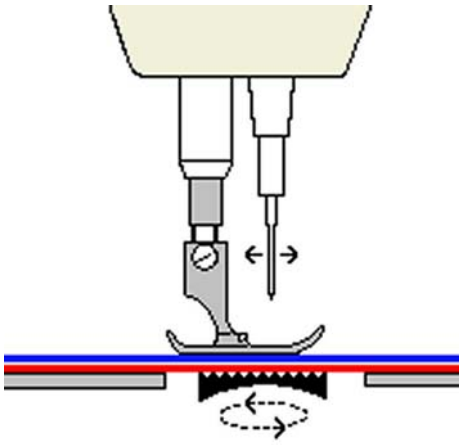
Fine woven fabrics, with low extensibility, tend to pucker in the finished seam due to the residual sewing thread tensions. The negative differential feed can be used to stretch the fabric, so that, after sewing, it relaxes in the same proportion as the threads.

In both cases – negative and positive feed – the feeding system is adjusted so that the extension level applied to the fabric enables an even seam to be produced.

[1] The sewing process is, in fact, the process in the apparel industry in which 2-dimensional components are shaped to a 3-dimensional garment.

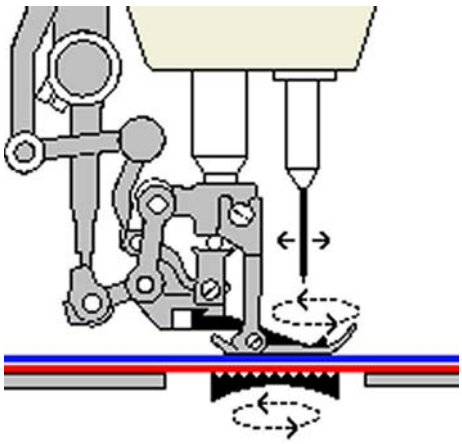
When thicker materials, higher number of plies or slippery fabrics are sewn, other feeding systems are often used. Although bottom-feed systems are adequate for most of the sewing conditions they can, even under optimal conditions, fail to avoid the slip between fabric layers during feeding. This results from the fact that only the bottom layer is in contact with an active part of the feeding system.

The *compound* feeding system uses the needle as an auxiliary feeding element. Adding a presser foot as a feeding element various combinations are obtained, as shown in Figure II- 12.



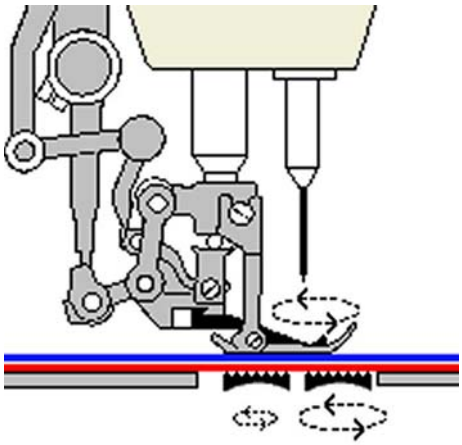
Compound feed

Uses the needle to aid in the feeding movement. With this system, feeding occurs when the needle is inside the material, as opposed to the simple drop feed. This system is used to eliminate ply-shift.



Unison feed

In this case, the presser foot is mechanically designed to impart feed by itself. Combined with the needle and the bottom feed-dog, this is an excellent feeding system for heavy materials or a high number of material plies.



Bottom differential and variable top feed

This rather complex system combines a differential bottom feed with the presser foot. It is possible to vary not only the differential feed ratio, but also the feeding ratio between top and bottom feed. This allows complex adjustments to introduce special effects selectively in the upper and/or lower fabric ply, to compensate for differences between materials plies, or to produce complex 3-D shaping.

Figure II- 12: Several combinations of feeding elements

Although more complex feeding systems greatly increase feeding efficiency of the machines, the problems of insufficient fabric control pointed out for a simple drop feed system appear in these systems as well. The study of the dynamics of the fabric feeding, especially at high speeds, is important and expected to be highly important.

1.2.3. Needle penetration

The stitch formation process depends on carrying a thread through the fabric so that it can be interlaced with itself or with other threads. This is a requirement for all stitch types, and all of them use a needle to fulfil this task.

The needle is inserted into the needle-bar, which has a linear oscillating movement, synchronized with the other stitch formation elements.

Ideally, the needle should penetrate and withdraw from the fabric without causing any damage or deformation to the structure. A seam in which these conditions are not satisfied will most certainly result in a non-quality product. Moreover, the functionality of the seam may be compromised; damage inflicted on the fabric will result in weak points of the seam.

A trouble-free needle penetration depends not only on the needle selection but also on fabric properties. The fabric should withstand the needle penetration without yarn breakage, it should be able to accommodate the needle and the thread in its structure without distortion, and it should be able to recover from needle penetration without affecting seam appearance. The needles should be correctly chosen; needle tip and diameter are fundamental characteristics to avoid problems.

There are basically three parameters to distinguish needles:

- The needle system: A set of dimensional and geometrical parameters that define a needle to be used with a specific type of machine;
- The needle size: Diameter of the needle shaft, expressed in the metric system in [mm x 100] (example: a Nm90-Needle has a 0,9 mm shaft diameter);
- The needle point: Shape and finishing of the needle point, adapted to each type of material.

Figure II- 13 shows the typical configuration of a sewing needle and its most important features.

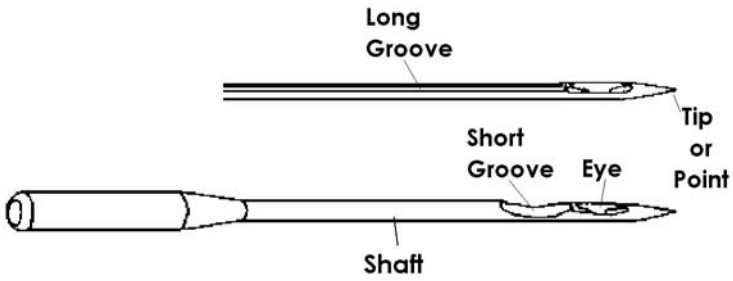


Figure II- 13: Typical sewing machine needle

The long groove is the space in which the thread runs through the needle to the needle eye, and provides protection for the thread when the needle penetrates into the fabric.

The short groove is placed on the exact spot where loop formation occurs This allows the hook or looper to be closer to the needle, making the pick-up of the needle thread loop more reliable, thus avoiding skipped stitches.

The point is the first element to contact the fabric, and should produce space for the penetration to take place. Depending on the nature of the material being sewn, the means by which this space is created can be twofold:

- Cutting the material;
- Pushing yarns apart.

This distinction results in the first classification of needle points.

Cutting points are used in materials like leather or plastics, in which the material has to be cut so that thread can be passed through it. Several shapes exist for cutting points. The shape of the cut produced on the material influences largely the aesthetical effect of the seam. Figure II- 14 shows some of the tips available.

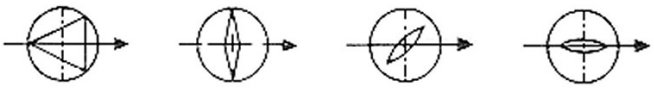


Figure II- 14: Cutting point examples. From left to right: Triangular, diamond, right cut, pearl. Arrow shows threading direction

In woven or knitted fabrics, as in the majority of textile structures, cloth points are used. Their function is to push the yarns apart in order to make penetration possible. It is very important, in this case, that the material is not cut or otherwise damaged. A broken yarn on a fabric represents a weak point on its structure and thus a defective seam.

Needles with a cloth point are also available in a great assortment. They can, however, be grouped in two main variants, round-point or ball-points. Figure II- 15 shows these two variants. Many special points exist for specific applications.

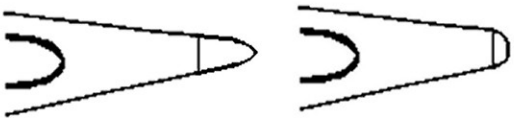


Figure II- 15: Cloth points. Normal or round point (left) and ball point (right)

Of these variants, the rounded point is the most commonly used, and it is adequate for most of the cases.

Ball points were developed to enhance the slippage of the yarns over the needle tip, minimizing the penetration of the needle through the yarn.

However, in some cases, due to a lack of mobility of the yarns in the fabric's structure, and/or due to the friction between the needle tip and the yarn, the needle tip penetrates through the yarn. In this situation, the ball point is more likely to cause a yarn breakage than the round point.

In round and ball points, thinner and thicker points can be found, regardless of needle size. The choice is based on the material being sewn.

Needle size depends mainly on the thread size used, because the needle eye and the long groove's dimensions have to be matched with the thread. Otherwise loop formation may be more difficult and stitch formation is compromised.

However, a thick needle is more likely to produce damage to the fabric than a thin one. Frequently, the thread is downsized to allow the use of a thinner needle. Possible damage produced includes not only broken yarns, as shown in Figure II-16, but also structural deformation of the fabric resulting in seam pucker.

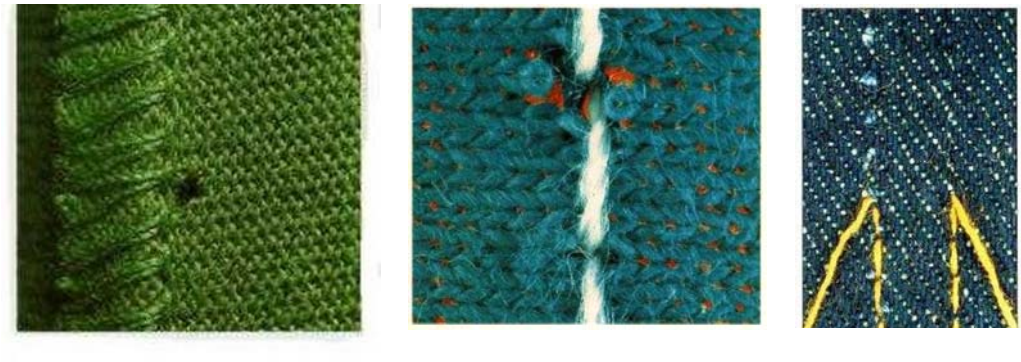


Figure II- 16: Examples of defects produced by wrong needle choice or defective needles

2. References

[1] Araújo, M.D., Tecnologia do Vestuário, Lisbon: Fundação Calouste Gulbenkian,1996

[2] Carr,H.,Latham,B., The Technology of Clothing Manufacture, Oxford: BSP Professional Books, 1989

[3] Chuter, A.J., Introduction to Clothing Production Management, Oxford: BSP Professional Books, 1990

[4] Standard: NP- 3801/1991, Têxteis. Tipos de Pontos de Costura. Classificação e Terminologia.

[5] Standard: NP 3800/1991, Têxteis. Tipos de Costuras.

[6] Standard: ISO 4915, 1991-08. Textiles. Stitch types. Classification and terminology.

[7] Standard: ISO 4916, 1991-09. Textiles. Seam types. Classification and terminology.

[8] Standard: BS 3870 Part 1: Stitches and seams. Classification and terminology of stitch types.

[9] Standard: BS 3870 Part 2: Stitches and seams. Classification and terminology of seam types

[10] The Fundamentals of Overlock Sewing Machines, Pegasus Sewing Machine Mfg. Co, Osaka, Japan. 1989