

SHOE INDUSTRY CERTIFICATE COURSE



TEXTILES AND SYNTHETIC MATERIALS*



* This document has been produced without formal editing



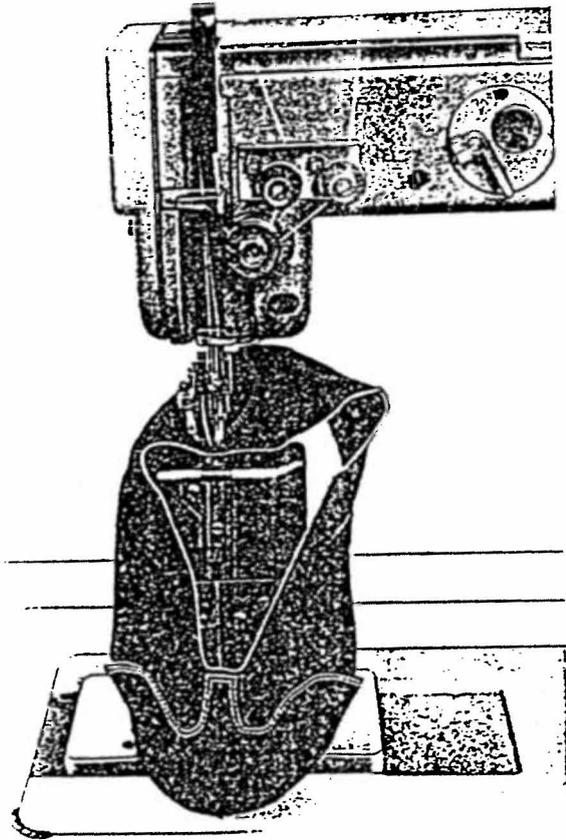
This learning element was developed by the UNIDO Leather Unit's staff, its experts and the consultants of the Clothing and Footwear Institute (UK) for the project US/PHI/85/109 and is a part of a complete Footwear Industry Certificate course. The material is made available to other UNIDO projects and may be used by UNIDO experts as training aid and given, fully or partly, as hand-out for students and trainees.

The complete Certificate Course includes the following learning elements:

Certificate course

- Feet and last
- Basic design
- Pattern cutting
- Upper clicking
- Closing
- Making
- Textiles and synthetic materials
- Elastomers and plastomers
- Purchasing and storing
- Quality determination and control
- Elements of physics
- General management
- Production management
- Industrial Law
- Industrial accountancy
- Electricity and applied mechanics
- Economics
- SI metric system of measurement
- Marketing
- Mathematics
- Elements of chemistry

FOOTWEAR AND LEATHERGOODS INDUSTRY CENTER
STAFF DEVELOPMENT PROGRAM



TEXTILES

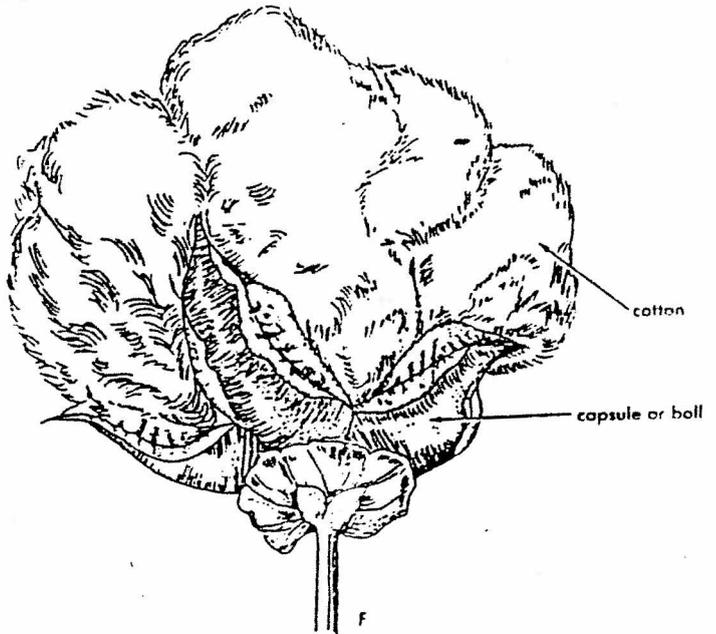


TABLE OF CONTENTS

Page

INTRODUCTION

I. THREADS AND FIBERS

A. Thread Production

1. Spun Threads

1.1 Yarn Twist

1.2 Ply and Cord

1.3 Thread Twist

2. Continuous Filament Threads

3. Blended Threads

B. Classification of Sewing Threads

1. Cotton

2. Linen

3. Polyamide Threads

4. Polyester Threads

C. Thread Characteristics and Properties

1. Strength

2. Stretch or Extensibility

3. Elasticity

4. Loop Strength

5. Seam Strength

6. Shrinkage

7. Resistance to deteriorating Influences

8. Ease in Manufacture

D. Shoe Factory Considerations in the Choice and Use of Threads

1. Thread Choice

2. Causes of Seam Failure

E. Yarn Count Systems

II. FABRICS

A. Woven Fabrics

1. Structure of Woven Fabrics

- 1.1 Warping
- 1.2 Weft Preparation
- 1.3 Weaving
- 1.4 Quality of Woven Fabrics

2. Finishing of Woven Fabrics

3. Uses of Woven Fabrics in Footwear

- 3.1 Linings
- 3.2 Interlinings
- 3.3 Backers
- 3.4 Localised Stiffenings and Reinforcements
- 3.5 Footwear Uppers

4. Selection of Woven Fabrics

- 4.1 General Features
- 4.2 Requirements for Vamp Lining

B. Knitted Fabrics

1. Weft Knitting
2. Warp Knitting

C. Non-woven Fabrics

1. Felts
2. Bonded Fiber Fabrics
 - 2.1 Web Formation
 - 2.2 Web and Fibrous Web Consolidation

D. Laminated Fabrics

1. Adhesive Bonding
2. Foam Lamination
3. Film Lamination

E. Coated Fabrics

1. PVC Coated Fabrics
2. PVC Coating
3. PU Coated Fabrics
4. Properties of Coated Fabrics

F. Poromerics

1. Definition
2. Common Features
3. Structure
4. Advantages and Disadvantages

G. Braids

Annex 1. New Developments in H.F. Techniques

Annex 2. High Frequency Radiations

T E X T I L E S

Textiles are :

- fibrous materials twisted, corded, split or extruded in filaments,
- cloths made of filaments, fibers, threads or yarns assembled by weaving or knitting (texere, texture) or agglomerated as non-woven.

The main uses of textiles in the footwear industry are :

- joining or attaching materials for :
 - sewing, stitching, fancy stitching,
 - reinforcing,
 - attaching of trims, buckles, buttons, etc.
 - sole attaching.
- lining material for vamp and backer linings, interlinings, reinforcement, stiffeners
- upper material,
- support for coatings
- support for impregnation (toepuffs, counterforts, etc)
- felt materials and non-woven

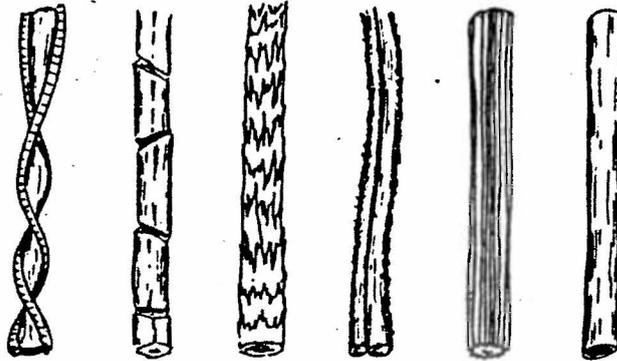
I. THREADS AND FIBRES

A. Thread Production

Threads are made from fibres long enough to be assembled.

There are three types of fibres :

- natural fibres from vegetable or animal origine usually assembled by spinning e.g. cotton, flax, jute, wool hair or regenerated fibers.
- artificial fibres deriving from natural substances such as cellulose (Viscose, acetates) or minerals (asbest or glass)
- synthetic fibres completely man-made from polyamids, polyesters, polyacrylics, polypropylene, polyvinylics.



Cotton

Flax

Wool

Silk

synthetic

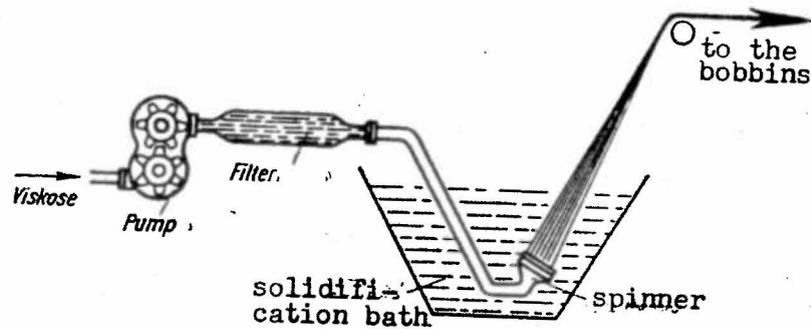
1. Spun Threads

Most conventional threads are composed of fibers which are "spun" together into yarns, and these yarns are then twisted together to form threads.

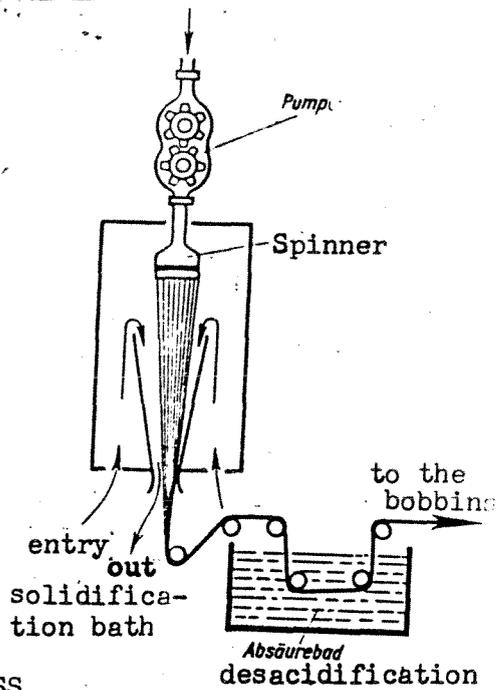
The fibres of cotton and linen have to be straightened and laid in parallel formation in long "rovings" which are then twisted in the spinning operation to form yarn.

Synthetic filaments are treated in the same way or are commonly spun into yarn as they are extruded from the spinnerets. In that case filament and yarn formation are simultaneous.

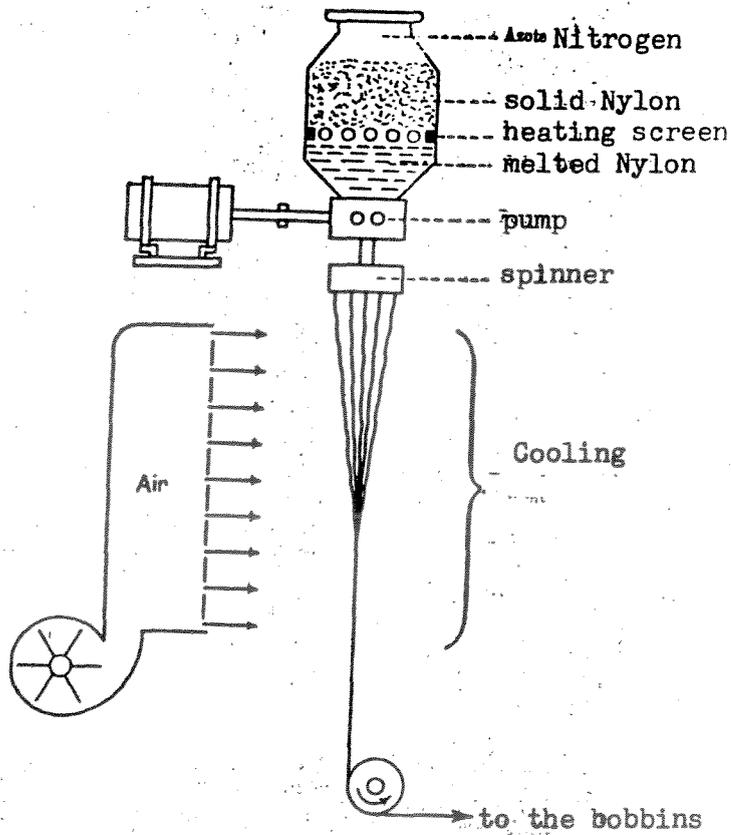
Artificial and synthetic fibres are produced by solvent (wet), melt or draw process.



WET PROCESS



DRAW PROCESS



NYLON MELT PROCESS

1.1. Yarn twist

The fibres are twisted in yarn formation in order to give strength to the yarn. If untwisted they would easily slide apart. Without twist, a conventional thread could not be controlled in sewing. The individual plies would separate and most probably fray and break.

Therefore twist is required essentially to hold the plies together and give the thread substance, strength and flexibility.

The more the twist the greater the strength up to a point where brittleness occurs. There is thus a maximum number of turns per unit of length.

Twist may be in either direction, clockwise or counter clockwise. It is convenient to refer to S twist and Z twist, the direction of twist corresponding with the middle part of the letter as shown in the figure.



Z

S

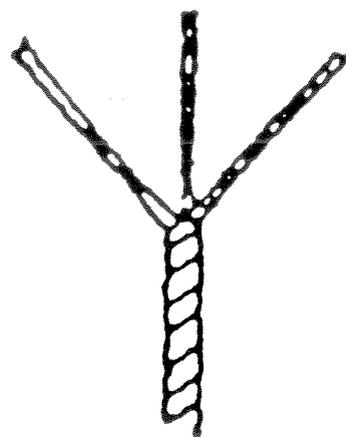
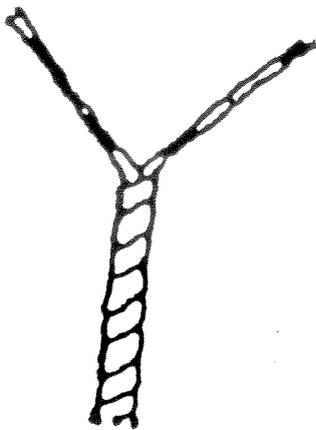


Most threads today are made with a left or Z twist because this is suitable for most sewing machines. There are, however, certain machines which generally perform better with a right or S-twist. Direction of twist in no way affects the strength of the thread but it could seriously upset its performance were it is used on a machine for which it was not suited.

If the twist cannot be easily seen, as in fine threads, it is possible to distinguish it as Z-twist if the yarn is untwisted by a clockwise turn and vice versa.

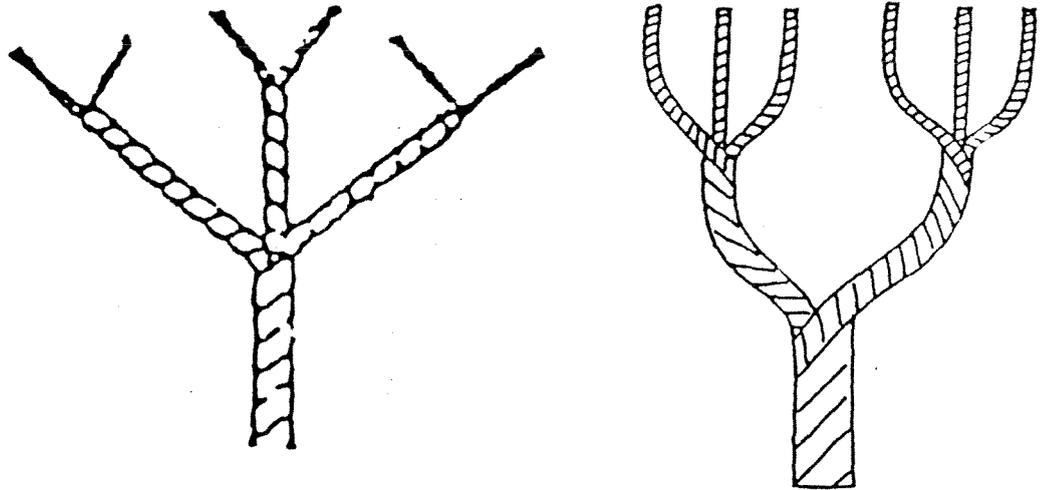
1.2. Ply and Cord

Threads are initially produced in 2 or 3 ply construction, which means two or three spun yards are twisted together into two or three ply thread.



Subsequent winding and twisting operations are involved in converting these plied threads into the heavier 4 cord, 6 cord or 9 cord (cabled) thread.

The construction of a 6 cord thread for instance may be one of the two diagrams below.



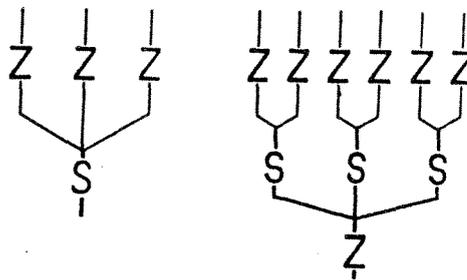
Synthetic threads are produced in 1, 2, 3, or 4 ply construction on the same principle.

10 cord threads are seldom used in footwear. (men heavy work shoes)

The size of the yarn can vary, so that, one 6 cord thread may be thicker than another 6 cord thread.

1.3. Thread twist

From the figure below it will be seen that the direction of yarn twist is always opposite to that of ply twist, and in cabled thread, the plies and thread are twisted in opposite directions. This is necessary for the components of the thread to "bed" together, and ensures that the thread holds together without unravelling.



As with yarn twist, an increased amount of twist gives increased strength because the threads become more compact. Twisting beyond a certain point, however, should be avoided as "twist liveliness" results, causing loops, knots and snarling while sewing.

Twist is also associated with stretch, increased stretch.

A Thread with 4 twists per centimeter will have more stretch than one with 3 twists/centimeter.

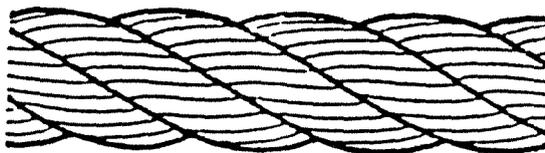
2. Continuous Filament Threads

Synthetic threads can be made in continuous filament, monofilament or multifilament, with or without looper thread, and in spun from staple spun similar to the cotton system.

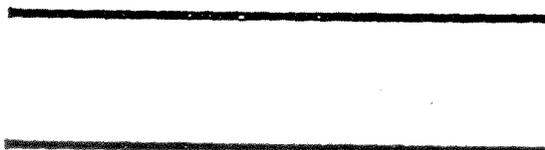
In appearance such threads are usually smooth and lustrous, giving a neat, cleancut stitch which compares favourable with silk.

They are claimed to have the highest strength-weight relationship of any thread, thus enabling finer stitching and to be used mainly on high fashion shoes.

Continuous Filament



Monofilament



The major disadvantages of continuous filament threads are:

- breakages occurs during high speed machining due to the generation of heat in the thread.
- Synthetic fibres are thermoplastic, they soften and melt under heat and such threads must be lubricated or machine speeds reduced to avoid difficulties. Recent developments, such as "teflon" coated needles to reduce friction, have however reduced improved matters.

- the surface of these threads is very smooth and slippery, and unsecured thread ends are very likely to slip and the stitching may loosen.

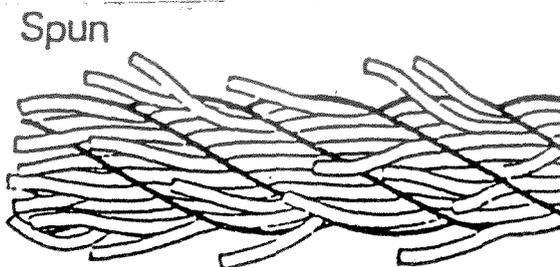
3. Blended threads or core-spun threads

Blended thread may be made from two or more continuous filaments, around each of which has been spun a sheath of cotton (usually) by the process known as "core spinning".

These threads may then be used to construct more complex threads in the same way as by the more conventional process.

The purpose of the outer covering is to prevent fusion against hot needles, and the cotton content also helps fill the needles holes, and makes the thread less slippery. The cotton content may vary from 12 to 30 %.

Blended threads are strong, due to their continuous filament content but are more expensive due to the increased processing involved. They are widely used for heel-seams, where strength is very important, and are particularly suited to machines having automatic thread-cutting devices.



B. Classification of Sewing Threads

Sewing threads currently being used in the footwear industry can be classified into five types :

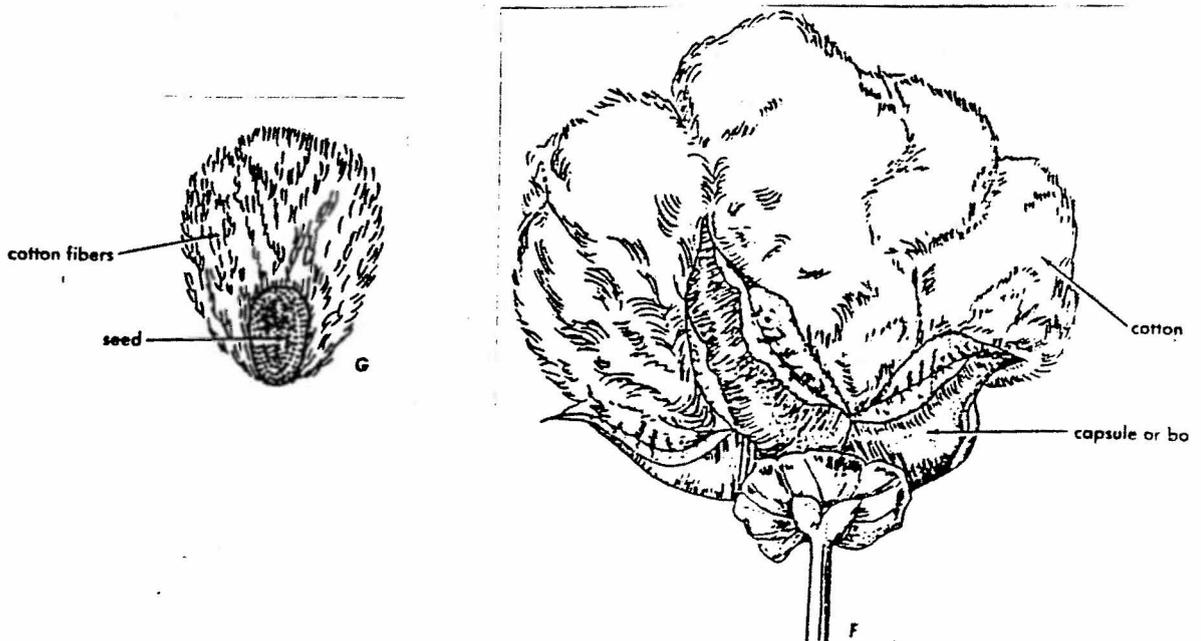
- | | |
|----------------------------|----------------------------|
| - Cotton) | } natural vegetable fibres |
| - Linen) | |
| - Polyamids (Nylon 6, 6)) | } man-made fibres |
| - Polyester (Terylene)) | |
| - Blended (core-spun) | mixed fibres |

1. Cotton

Cotton fibres enclose the seed of the cotton plant within a pod or boll. At the stage when the boll has burst, the fibres are collected. They are subsequently freed from seeds and later from impurities such as pieces of leaf and stem, dirt and dust.

Very short fibres which are present are separated, to be classed as cotton lint or "linters". Only the longer fibres are used in the manufacture of cotton goods. The greater number of these vary in length between 2 and 4 cm, but some are as short as 1 cm, some as long as 5 cm

An average diameter is 0.03 mm



The quality of a cotton fiber is mainly determined by its length (some Sea Island cotton S & I average 5 cm, poorer Indian cotton averages 2 cm in length). The longer fiber is usually finer, and the finer fibers are more twisted so that with these fibers it is possible to make threads of high relative strength.

A basic factor determining the quality of a cotton thread is the quality of the fibers from which the thread is made.

As cotton is a form of cellulose, it is deteriorated by acids but not by the action of alkalis.

In its dried form, the cotton fiber, after the seed boll has burst, is flat and ribbon like, it is also twisted.

Cotton threads are usually produced in three types : soft, mercerised and glace.

Soft threads receive no special finishing treatment other than the normal lubrication.

Mercerised Cotton in the yarn or cloth form is frequently given a treatment finishing known as mercerising, which consists of immersion in a strong solution of sodium hydroxide (NaOH Caustic Soda) which is subsequently washed out whilst the material is kept stretched.

The chief advantage of mercerising treatment is a much higher lustre, but there is also an increase in strength and a better affinity for dyes. Another effect is to restore the cylindrical shape which the fibers had before they were dried out. A mercerised cotton fiber is no longer flat and ribbonlike, its cross section is round instead of flattened.

Glace cotton threads are soft threads which pass through a final polishing. This gives them extra strength, increases their resistance to abrasion and makes them especially suitable for demanding applications such as stitching leathers.

Threads can also be "gassed" or "singed" to remove surface hair thus providing a smoother appearance.

Special finishes can be applied to make the threads rainproof, rotproof or mildewproof.

Cotton closing threads have been very largely replaced by synthetic or blended threads which are in many ways superior. In fact, the main reason for the retention of cotton thread (also fabrics) is the price advantage.

2. Linen

Linen fibers, also called flax fibers, are coming from the flax plant. As cotton, linen fibers are of vegetable origine and consist of cellulose they come from the stem of the plant and are classed as "bast" fibers. The flax plant grows in countries with a high rainfull and a moderate climate (Ireland, Belgium, some parts of Russia).

The treatment to separate the fibers is long and costly. It is a rotting process accelerated by temperature and enzymes. Hence, linen cost much more than cotton.

The linen fibers are very long, between 25 cm and one meter. The flax fiber, however, is more truly a fiber bundle, made up, like leather fibers, of very fine fibers or fibrils ranging from about 1 cm to nearly 7 cm in length. Thus a cross section of a linen fiber bundle under high magnification will show that it is made up of many fibers, and that these are seen to be many sided cross section.

Since the linen fiber is largely cellulose, it is resistant to alkalis and can be destroyed by acids. However, linen is not often mercerised because it has a higher luster than cotton.

Linen threads are stronger than cotton threads and extremely durable, they are very expensive and only used for special purposes.

3. Polyamide Threads

Polyamides (see lecture on Plastomeres) are raw materials for thread production.

Since polyamide fibers, like other synthetic fibres, are produced by extruding the material whilst in the liquid state through fine jets to form solid fibres, the fibers are perfectly round and uniform in cross-section. Consequently it is possible to identify synthetic fibers by their uniform cylindrical appearance when viewed through the microscope.

Polyamides have very largely displaced cotton as a closing thread. This is owing to its superior strength, its high resistance to abrasion, its ability to withstand chemical attack (particularly by alkalis) and its complete resistance to fungal growth.

It has only one significant disadvantage, that, it is thermoplastic, it softens and even melts at elevated temperature.

Synthetic threads are also more stretchy than natural fiber threads, with an extension at break reaching 30 % compared with a stretch of less than 10 % on the natural fiber threads.

Polyamid threads are available in :

- Continuous filament mainly in bonded form,
- Textured thread
Texturing is a process whereby certain properties are imparted into a flat, untreated synthetic filament yard. There are various methods of texturing, namely, false twisting, Air jet, etc. Textured yarns are soft and bulky, have improved absorbancy, durability and pull resistance, they also feature good stretch and recovery properties.
- Monofilament is a continuous filament yarn consisting of a single filament (direct extrusion). The shrinkage factor and the fact that monofilament threads tends to produce stiffer seams limit its use to specialised application.
- Spun is mainly used for knitwear but also for many high stretch applications. It eliminates the danger of cracked seams because extra-elasticity permit seams to stretch as far as the fabric and relax to their former length every time.

4. Polyester Threads

The behavior of polyester thread is very similar to that of polyamid, but it has an improved resistance to acids and will deteriorate to a lesser extent after prolonged exposure to sunlight.

Polyester threads are available in :

- continuous filament
- multifilament single ply
- spun
- core-spun thread

This is a polyester/cotton spun thread. During manufacture cotton and continuous filament polyester are brought together at spinning so that the cotton forms a covering around the polyester. The resultant core-spun yarn is then twisted to form 2, 3 or 4 plied thread. It is an integration of polyester and cotton combining the properties of both. As the synthetic content is greater than the cotton, core-spun thread assumes the properties of 100% polyester thread with regard to strength, resistance to abrasion and chemicals. The cotton cover improves sewability and protects the polyester core against needle heat.

C. Thread Characteristics and Properties

1. Strength

Strength depends chiefly on :

- 1.1. The type of fiber (cotton, linen, polyester, polyamid)
- 1.2. The quality of fibre (first grade cotton or third grade)
- 1.3. The twist in the yarn
- 1.4. The number of yarns, taking also into account the size of the yarns.
- 1.5. The twisting of the yarns when forming the thread.
- 1.6. The finishing process (wax or dressing etc.)
- 1.7. The humidity of the atmosphere in the case of natural fibres.

The strength increases in more humid atmosphere.

Strength is measured by tensile strength or breaking strength This is the load at which the thread breaks expressed in newtons.

2. Stretch or Extensibility

Stretch depends on natural stretch in the fibers and on the degree of twist in the yarn and in the thread.

Stretch must be present in shoe threads because shoe seams must accommodate themselves to variable stresses along their length when uppers are moulded by lasting strains to the curves of the last, and when the footwear is flexed in walking, also when shoes are drawn off the last.

On the other hand there must not be too much stretch, causing either mechanical difficulty in removing the excess amount, or, if it is not removed, this will give seams which do not hold the parts together with sufficient firmness.

The elongation or extensibility is the amount by which a thread is extended at breaking point, expressed as a percentage of its original length.

3. Elasticity

Elasticity is that property of a thread by which it recovers (or tends to recover) its original length immediately after removal of any load causing extension.

Elasticity must be allied with stretch, and although extensible, a good thread should contract again after being stretched thus restoring tightness of the seam.

4. Loop Strength

The loop strength is the load required to break a length of thread which is looped through another thread of the same length.

The loop strength ratio is the ratio of the loop strength to the single thread strength.

5. Seam Strength

The seam strength is the load required to rupture a seam prepared under standard conditions.

6. Shrinkage

Is the amount by which a thread freely contracts after washing and drying under standard conditions expressed as a percentage of the original length. This is not applicable to footwear threads.

7. Resistance to deteriorating Influences

A good thread must withstand the action of the bacteria, moulds and fungi arising out of foot perspiration and other causes. If the shoe is to be exposed to other severe conditions in wear, such as exposure to acids, special properties may be required in the threads used.

8. Ease in Manufacturing

Lastly, but by no means least, a thread must perform satisfactorily in the sewing or stitching machine for which it is intended and production should not be interrupted by frequent thread breakages or allowed down because machine speed cannot be maintained.

D. Shoe Factory Considerations in the Choice and Use
of Threads

1. Thread Choice

Breaking Strength, Stretch, Elasticity, Resistance to deteriorating influences and ease in manufacture are the properties that influence thread choice for various uses.

The first three properties are satisfied to the greatest overall degree by the synthetic threads, as good or better than silk (no more in use) in strength and elasticity, but, unlike silk and the other natural fibers, completely resistant to the attacks of bacteria, moulds, fungi and insect pests, and very high resistant to the action of acids (except polyamids), alkalis and organic solvents.

Their operational values may be lower than with silk, they may soften as a result of frictional heat.

In the selection of threads, cost also plays a part, and for some purposes, cotton threads are cheaper and of adequate strength.

For sole stitching, only a small degree of extensibility is required, and the seam should not "give" a great deal under the strains of flexing. If it does, movement may arise between the parts, and this would quickly break the stitches. Linen has less extensibility than cotton, and this, with its greater strength and durability, determines its selection for sole stitching.

The welt sewing thread is more exposed to deteriorating influences from perspiration etc., and threads of synthetic fibres are being used especially as the high elasticity of these threads seems sufficient to restore tightness to the welt seam after stretch through flexing.

The resistance of natural fiber threads to rotting can be increased by treatment with fungicides and rot-proof linen threads are available

for welt sewing. As the effect of perspiration in both acid and alkaline at various stages, none of the natural fibres, including silk, are immune to perspiration attack unless specifically treated.

2. Causes of Seam Failure

Tensile strength, smoothness, stretch, elasticity and resistance to deteriorating influences affect the durability of a thread and therefore the durability of the thread seam.

However, the breakdown of a thread seam may be due to factors other than the inherent qualities of the thread.

The most common faults in seams are :

- 2.1. Undue strain on the seam through uneven contraction or expansion of the joined components. This occurs for instance with the welt seam, through shrinkage of the innersole due to the effect of perspiration.

- 2.2. Chafing or abrasive wear on the thread due to inadequate or unbalanced tensions. With loose tensions in an upper closing lapped or running-round seam, there is not only "play" between the parts to put an undue strain on the thread, but the loops on the surface are more exposed to abrasive wear.

- 2.3. Thread size, needle-size, needle point and stitch length must correctly chosen for the material which is being stitched. Thread size and stitch length must be suited to the material. Where a large needle is used, stitch-spacing must be greater to prevent weakening of the material, and the thread diameter must match the needle.

As a rule, square, rectangular, traingular needle points should be avoided in sttiching footwear materials, except for some fancy stitches.

- 2.4. Weakening of the thread by abrasive surfaces in the needle eye or at other points in the passage of the thread through the machine.
- 2.5. Weakening of upper closing threads through failure to counteract the heating effects of high machine speeds, by thread lubrication.
- 2.6. Inadequate waxing of sole stitching and welt sewing threads, affecting their lubrication and their firm setting in the holes made for them.

E. Yarn Count Systems

Yarn Count is an indication of the relationship between the length and weight of any yarn.

Several count systems exist falling into one of two types :

- fixed weight or
- fixed length

Fixed weight systems show the number of length units in a given weight of yarn.

The International Metric Count gives the number length units per unit of mass, number of meters per kilogram
or number of kilometers per kilogram
or number of meter per gram

(the yarns becomes finer as the count numbers increase)

Fixed length systems show the weight of a given length.

The SI Metric Unit is the mass per unit of length (meter)

$$1 \text{ tex} = 10^{-6} \frac{\text{kg}}{\text{m}} \qquad 1 \text{ decitex dtex} = \frac{\text{decigrams}}{\text{km}} \qquad \frac{\text{g}}{10 \text{ km}}$$

or grams per kilometer

or milligrams per meter.

(the yarns become heavier as the count numbers increase)

(*)

(*) Traditional Counts are still in use e.g.

Cotton Count = number of hanks of 840 yards per lb.

Linen Count = number of hanks of 300 yards per lb.

Denier Count for silk natural and synthetic = weight in g//9000 m

Dram silk count = weight in dram per 1000 yards

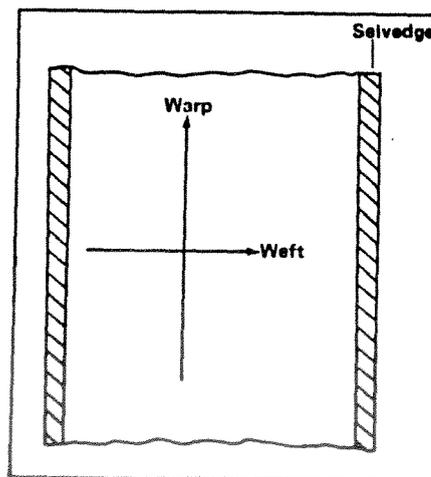
II. FABRICS

A. WOVEN FABRICS

1. The Structure of Woven Fabrics

Woven fabrics are made of yarns or threads interweave, those running in the length of the material, i.e., parallel to the selfedge, are known as WARP yarns, and those running across the material are known as WEFT yarns.

Woven fabrics consist, thus, of two sets of threads, warp and weft, which interlace at angles wherein the alternate warp threads are lifted so the weft thread can be inserted.



The warp threads, also called "ends", run lengthways; the weft threads or "picks", run at right angles.

The width of a fabric is limited to certain conventional sizes. Its borders are called "selfedges" which are usually woven in a stronger structure than the body of the fabric.

The selfedge retains the weft thread and takes the considerable

strain to which the edge of a fabric is subjected during weaving and especially during finishing operations.

Preparatory operations of the threads are necessary to ensure that they can be interlaced at right angles.

These include :

1.1. Warping

The warp yarns are aligned parallel to each other with the aid of a device known as a comb and are then wound onto the warp beam.

Before beaming, the warp threads or yarns have to be treated.

Indeed, the weaving action is fast and with the continuous rubbing of yarns against each other and against various parts of the loom such as the shuttle or pick, it is essential that the surfaces of the warp threads are as smooth as possible. This is achieved by "sizing" which protects them against damage and prevents them from causing damage to themselves.

Usually the warp yarns are impregnated with starch or dextrin mixed with fats. Mineral substances are used to ensure that the starch-treated yarns remain sufficiently pliable for weaving.

Synthetic "sizing" based on various adhesive systems is now also used to replace starch.

After sizing, the warp yarns are dried and beamed. The beams are combined to form the weaver's beam used on the loom during weaving.

1.2. Weft Preparation

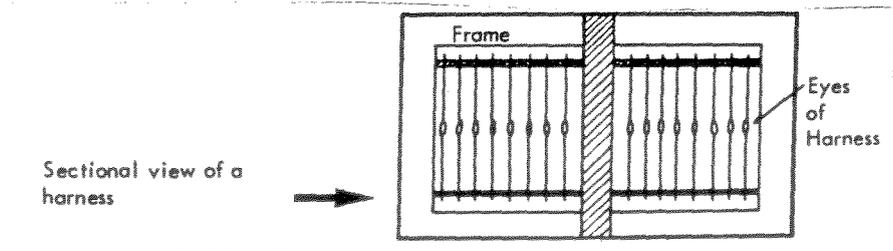
Weft yarns need relatively little preparation and are usually wound from large bobbins to small bobbins (cops or pirns, hence the name of the operation 'pirning'). Those small bobbins fit into the shuttle.

This operation can be done either away from the loom in another department or at the loom with an automatic winding unit.

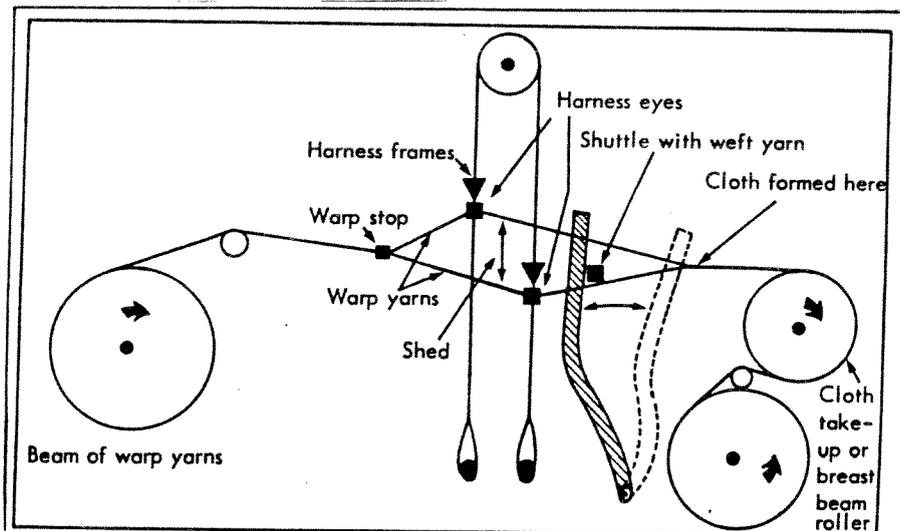
1.3. Weaving

The principle of weaving has changed a little through the ages. It consists of the interlacing of warp and weft yarns crossing each other approximately at right angles.

Prior to weaving, warp yarns are individually drawn through eyes in fine steel wires suspended from the loom shafts or harnesses. Each one carries a number of steel wires or cords with a central eye through which a warp yarn is treated to enable its movement to be controlled during weaving.



During weaving, the harnesses are raised and lowered alternately causing the warp yarns to open and form a "shed" which is the space between the two sets of warp yarns.



Shedding is the first mechanical step in weaving.

When the aperture or shed is at its greatest, the shuttle carrying the weft yarn is driven at very high speed through the shed formed by the warp yarns. The harness motion is then reversed - the top warp yarns change places with the bottom yarns - and the shuttle is driven back through the new opening.

The harness motion and flight of the shuttle occur in quick and continuous succession. This is known as "picking" and one single passage of the shuttle is called a "pick".

Weaving is generally a fast operation, e.g. 180 picks per minute. The preparation and setting up of a loom is known as "loom tuning" and is a highly skilled operation. This operation can be done by hand or by automatic threading and tying-in machines.

1.4. Quality of a woven fabric

The quality of a woven fabric depends mainly

- on the nature and strength of the yarns of which it is composed, and,
- on the manner in which those yarns are interwoven.

1.4.1. nature of the yarns.

The yarns and threads composing fabrics are of :

- natural
- artificial (regenerated natural materials) or
- synthetic origine

Aside from the materials used for making, sewing and stitching threads, other materials can be used for footwear fabrics, such as :

- wool : used for slipper material such as camelhair cloth (usually mixed with cotton)
- vegetable fibers : abaca, waterlilies, etc.
- silk : some ladies high fashion shoes
- cellulose acetates: rayon, viscose
- polyvinyllic fibers
- polyacrylonitrile fibers
- polymethylenic fibers

1.4.2. Yarn factor

The factors which determine the strength of the yarns have been covered by the lecture on threads. The main ones are :

- Degree of twist

A greater amount of twist not only increased tensile strength, but also makes the yarn more compact, thus giving a greater firmness and resistance to abrasive wear. A cloth made of tight twist yarn gives better wear. It lacks the softness and fullness which go with low-twist yarn.

- Direction of twist

The direction of twist in weaving threads is only varied depending on machine requirements. In yarns for fabrics, it has an effect on the feel and appearance of the fabric.

The twist of warp and weft yarns may be in the same direction, or in opposite directions. The latter is the more common arrangement.

When warp and weft yarns are in opposite directions, the yarns do not bed into each other so readily and the result is a cloth with more fullness.

If warp and weft yarns have the same twist direction, they merge more closely and a thinner fabric with a flatter surface is the result.

When the yarns are two-ply, if the folding twist is in the opposite direction to the yarn twist, a soft yarn which beds easily into the fabric is produced; whilst if the twist is in the same direction, a harder yarn is produced.

1.4.3. The Weave Factors

The two weave factors which affects the strength and the appearance of a fabric are the closeness of weave and the weave pattern.

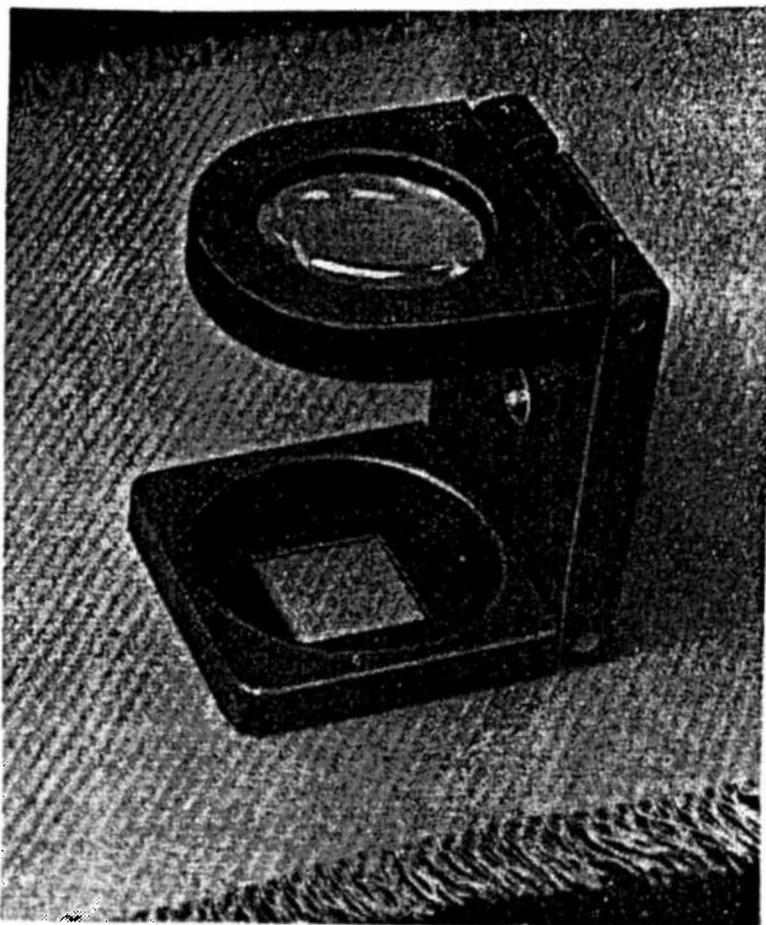
The Closeness of Weave or Fabric Count

The closeness of weave is indicated by the FABRIC COUNT, which is the number of warp threads (ends) to the centimeter, and the number of weft threads (picks) to the centimeter.

Thus a fabric with a count of 20 ends and 16 picks is a closer, heavier and stronger fabric than one with 18 ends and 14 picks.

The ends and picks are commonly counted in the cloth by using a "counting glass" which contains a magnifying lens mounted in correct focus over a frame with one cm aperture.

If either warp or weft threads are 2-ply or folded yarns, then the count will be double.



In a simpler way, to count is to mark off a centimeter on a small sample and to remove the yarns one by one whilst counting them.

The mass and strength of a cloth will also depend on the yarn size.

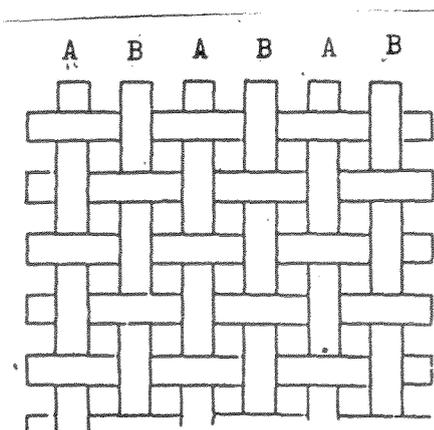
The Weave Pattern

There are many weave patterns, the main kinds are :

- Plain weave or calico in which the yarn passes alternately over and under the warp yarn.

Suppose that the warp threads are marked a b a b a b the b threads are first raised for the passage of the shuttle thread then the a threads, then the b threads again, and so on, we get the "over one and under one pattern".

This weave is used mainly for cotton vamp lining materials. The plain weave gives the best balance of strength and stretch in warp and weft direction.



PLAIN

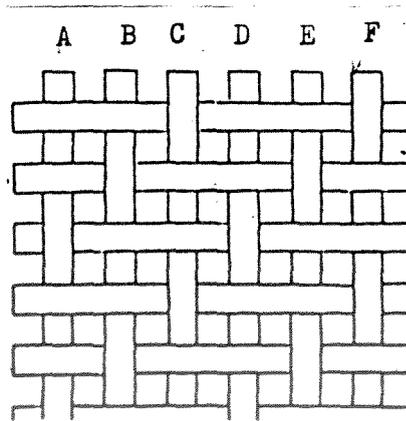
Another advantage is that it has the greatest number of "weave crimps" (up and down deflections) in both directions. This allows more "give" to the lasting strains before the yarns undergo tensile strain.

The only disadvantage of plain weave is that it gives an unattractive surface appearance.

It is to create a more attractive appearance, that all the other weave patterns have been introduced.

- Twill weave (duck or serge)

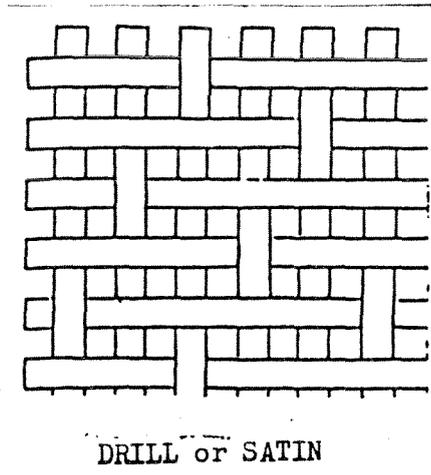
The yarns go over two and under two, but in a "staggered" manner, e.g. if one weft thread goes over warp threads a and b, it goes then under c and over d and f and so on.



TWILL or SERGE

- Drill Weave (satin)

One of the yarns goes alternately over one other and under three or four warp yarns producing a diagonal line.



Almost infinite variety of effects can be produced by :

- varying the weave pattern
- varying the relative number of warp and weft yarns to the centimeter
- varying the relative size and kind of warp and weft yarns.

2. Finishing of woven fabrics

The appearance of fabrics is of course affected by finishing processes such as bleaching, dyeing, printing mostly applied on the loom cloth. These are complex and specialized treatments, but we shall confine ourselves to certain processes which affect the serviceability of fabrics used in the shoe industry.

2.1. Treatment of yarns before weaving.

The greatest strain in the weaving process falls on the warp yarns, and these are strengthened by :

- 2.1.1. bonding the surface of the fibers to reduce friction, using adhesives such as fermented starch.
- 2.1.2. softening the yarn to improve its flexibility by use of tallow, soap, etc.
- 2.1.3. increasing the moisture intake by use of a deliquescent such as glycerine.

The presence of these materials increases the risk of mildew and mould formation, and this is counteracted by use of an antiseptic such as zinc chloride. The presence of a mineral salt may lead to spue formation on the vamp.

Starch like substances may also lead to stain formation on the vamps, especially on aniline leathers.

Some finishing preparations may attack metallic parts, such as buckles or zippers.

- 2.2. Fabrics, namely linings, are improved to a limited extent by the addition of stiffening agents, chiefly forms of starch. Such stiffening makes the material easier to handle and to cut, and gives it more "body".

It is also used to mask an inferior open weave, especially with the addition of China clay mixed with the starch. At the same time, the weight of the fabric is increased, and since cotton lining materials are partly designated by mass (grams per square meter) a false impression is given if the weight is due to "fillers".

3. Uses of woven fabrics in footwear

3.1. Lining ; mainly vamp lining in cotton.

3.2. Interlinings

These are normally sandwiched between lining and upper to give "body" to the upper. They are most of the time cotton material with one or both faces wire-brushed to form a nap.

Such interlining materials are sometimes stuck to the main lining material, and marketed as "combined" lining. Starch adhesives may be used. Some interlinings are combined with non-woven or with artificial or synthetic fabrics.

3.3. Backers

These in general are used to reinforce and minimize stretch in the material to which they are attached.

Swansdown material, usually used for interlining, may be classed as a backer when it is stuck to the upper, mainly with latex.

Another type of backer, known as "acme", is stuck to the upper by the application of heated iron or by hot plating. They are also called "thermoplastic" backers and have generally a cotton base with a coating of gutta-percha (*), or a mixture of rubber and paraffine wax, or with

(*) gutta-percha : latex containing more natural resins and with lower rubber content (from Payena or Percha tree Malaysia)

polyvinyllic or acrylic resins, the coating providing adhesion when heat is applied.

Cleaners or other liquids which dissolve rubber and gutta-percha must be used with care on uppers with these backings. It should also be noted that these iron-backers create impermeability, making the shoe uncomfortable. With loose grain leathers they increase the wrinkles in the grain of the uppers. Spot or strip adhesion are to be preferred.

Elasticised backers are used to increase elasticity in vamp or instep areas of the upper, allowing a close fit without discomfort.

As they are commonly visible in the shoe, the elasticised part of the upper being unlined, gives an attractive appearance by the incorporation of artificial fibers with the cotton yarns. The weft yarn has a rubber core to provide the required elasticity.

3.4. Localised Stiffenings and Reinforcements

The chief components put in footwear for a stiffening effect are toe puffs and stiffeners or counters.

Some of them are woven fabrics, but can also be non-woven, leather, leather-fibers and non-fibrous thermoplastic materials.

A commonly used type of toe puff is a cotton fabric impregnated with pyroxylin (*) known as "celastic type". There are also fabrics, mainly cotton, impregnated with natural or synthetic thermoplastic resins.

With pyroxylin types, the base material is often a felted material, but with the resin puff the base is most of the time a cotton fabric.

Counters are mostly of fibre-board (Leather or cellulose), but there are also fabrics impregnated with resins.

In impregnated puff and stiffener materials, the impregnant is the most important item.

Stiffening parts other than impregnated fabrics are used as side linings or to stiffen tongues, tabs or bows. They are sometimes cut from a fabric known as "buckram", which is a heavily stiffened combination of two cotton cloths, one of coarse and one of finer weave.

Important reinforcement materials in footwear are tape, ribbons or strips. They are used for localized reinforcement in hidden positions to reinforce seams and the top line of quarters, or in exposed positions to bind edges.

Tapes are mostly of cotton with or without artificial fibers (rayon woven with the cotton to give a more attractive appearance). Tapes are also entirely of synthetic fibers : polyamide or polyester.

Increased strength and tightness is given to the tapes by the feature that they are woven as tapes with a selveedge on both sides.

"Cut Tapes", which are cut from wide material are sometimes used for seam reinforcement where less strength is required and binding tapes are sometimes cut tapes which are cut "on the bias", i.e. diagonally to warp and weft directions, with a view to easy accomodation to pronounced curves.

(*) Pyroxylin or collodion is a partially nitrated cellulose, with two nitrate groups NO_2 per cell glucose unit.

In the selection of reinforcement tapes, two important and combined properties have to be taken into account :

- a) The strength. It is obvious that the reinforcing tape must be stronger than the reinforced material, but at the same time,
- b) The stretch or elongation must be the same or lower than that of the reinforced material.

Tapes are also used for forming the rib on the attached rib type of innersole. Those tapes are heavy weight cotton fabrics.

3.5. Footwear uppers

A wide range of fabrics are used for footwear uppers, not only on slippers and athletic or sport footwear, but also on casual and even on high fashion shoes.

Nearly all fibers, natural, artificial or synthetic, can be used in the weaving of fabrics for uppers. For the time being, the most used are cotton, cellulose, polyamides and polyesters.

Beside a wide variety of weave pattern and combinations, there are also infinite possibilities of changing the appearance by dyeing, impregnation and finishing.

The technology of making uppers in woven fabrics may seem similar to that applied for leather uppers, in fact, it is quite different in :

- cutting
- binding of parts
- lasting

In addition to mechanical properties, such as tensile strength and elongation, tear resistance, bursting, abrasion, etc., fastness and stability properties are very important, namely :

- light fastness and ageing resistance
- water and solvent fastness
- heat resistance and stability
- flame resistance

As many woven materials are absorbent or more easily penetrated by liquids, they can act as a wick and transport through migration dyestuffs or other substances from one component to the other. They can also loose some water soluble finishing products.

The need for care in the use of organic solvents applies with greater force to fabric uppers, e.g. cellulose acetates (rayon, viscose) fabrics or acetate containing fabrics are sensitive to deterioration by organic solvents.

4. Selection of Woven Fabrics

4.1. General Features

The following general features will determine the nature, strength and appearance of a woven fabric.

- 4.1.1. the quality of the fiber
- 4.1.2. the amount of twist in the yarn
- 4.1.3. the size of "count" of the warp and weft yarns
- 4.1.4. the ply of the warp and weft yarn (single, two-fold or three-fold)
- 4.1.5. the direction of twist in warp and weft yarn or thread

- 4.1.6. the "count" of the fabric, i.e. its compactness as shown by the ends and picks per centimeter
- 4.1.7. the relative strength of warp and weft yarn
- 4.1.8. the weave pattern
- 4.1.9. the type of finish, e.g. bleached, dyed, tinted, printed etc.

4.2. Requirements of a vamp lining

4.2.1. The purpose of a vamp lining

- to present a smooth surface to the foot, particularly by covering seams and joins in the upper and the edges of the toe puff
- to give body to the upper in the vamp region
- to assist in absorbing moisture from the foot
- to improve the appearance of the inside of the shoe
- to reinforce an upper material which is intrinsically weak.

4.2.2. Manufacturing and wear requirements

- the lining has to be cut from rolls of material with maximum economy
- it is subject to pulling strains, separately or with the outside
- it has to undergo the strains of flexing in the vamp area and to resist wear by abrasion with the foot

- it has to undergo attacks from perspiration in a position where drying out is not rapid
- if uppers are mulled or humidified, the lining has to go through a dampening and drying-out process

4.2.3. Special requirements for cotton linings

Cotton at present, has the best combination of properties to give a good lining and at comparatively low price.

The following special requirements are to be noted :

- since the lining is so much exposed to the attack of perspiration, and remains for some time in damp state, conducive to bacteria and mould cultivation, its life is prolonged if it is rot-proofed
- stiffening and dressing materials must not be such, or in such quantity, as to cause spue formation on the vamp
- strength and stretch in warp and weft directions should preferably be balanced
- since the lining is commonly pulled with the outside it should have as much stretch as the upper otherwise it may break (min. recommended 10 to 15 %)

Stretchiness above that of the leather is however not desirable, unless it is removed by separate pincering it is likely to cause wrinkling and bagginess in wear

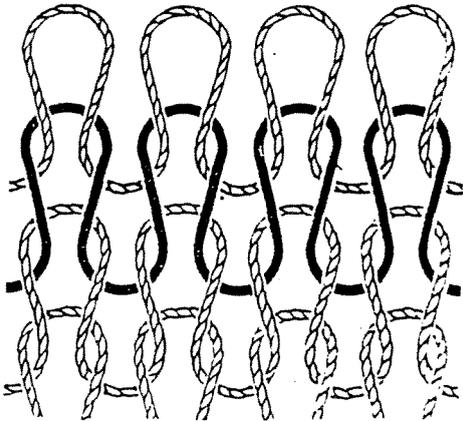
- non-shrinking, non-curling cotton fabric should be chosen, especially if the uppers are to be mulled.

B. Knitted Fabrics

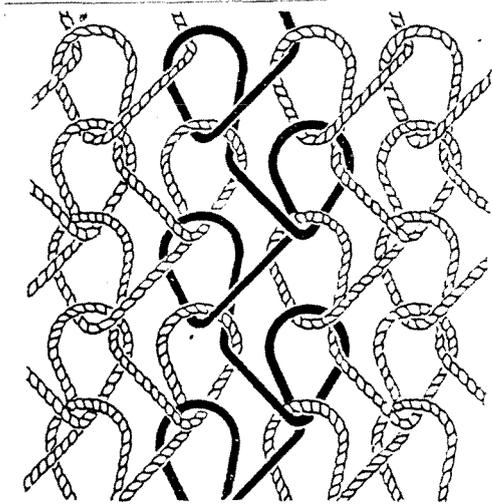
Knitted fabrics consist of a series of interlaced loops.

There are two main categories of machine knitting :

- weft knitting
- warp knitting



weft knitting



warp knitting

1. Weft Knitting

In weft knitting, the loops are formed, as in hand knitting, by the fabric being made - one loop at a time - as the yarn travels across.

Each new row of loops hangs on the previous row of loops in the fabric.

Each horizontal row of loops is known as a "course" and each vertical line of loops is known as a "wale".

Weft knitted fabrics are liable to ladder if one loop is broken.

Whereas hand weft-knitting uses one needle to form loops and transfer them and the other to hold the transferred loop, modern weft knitting machines use rows containing a large number of needles to achieve high production rates. The size of the needle depends largely upon the yarns it is required to knit.

Each needle is hooked so that initially, straight yarn can be drawn into loops which are then pulled through existing loops in the fabric.

To allow their passage through old loops, the hooks of the needles must be closed in some way; otherwise, they would bind with the old loops rather than slide through them.

There are many types of weft knitting machines, namely the circular type machine which knit continuously by rotation, similar to the stocking knitting machine, and the flat-bed machines similar to the domestic hand-flat knitting machines.

There are two basic types of weft knit structure : plain and rib.

- 1.1. Plain weft knitted is a fairly elastic fabric which tends to curl. Its face and reverse sides are different in appearance. It is also known as "jersey".

The fabric is produced at a fast rate on only one set of needles by either circular or flat-bed machines. It is used for sweaters, underwear and sometimes as support for cheap coated fabrics.

- 1.2. Rib weft knitted is a fabric in which the alternate waves are intermeshed in opposite directions.

The fabric looks the same on both sides and it does not curl.

It is about half the width of a similar plain-knit fabric produced on the same machine.

Rib fabrics are heavier and a little more expensive.

Interlock (double jersey) fabrics consist of two rib fabrics knitted together by means of two yarns which knit alternately on the face and back. They are reversible and have similar smooth appearance on each side. They do not curl, are firmer and less stretchy than most weft-knitted fabrics.

2. Warp Knitting

Whereas weft knitting depends upon the formation of loops laterally formed as the yarn travels horizontally, warp knitting forms stitches or chains of loops in each yarn in the warp direction. Warp knitted fabrics are sometimes called "tricot".

The success of the warp knitting method of fabric production is due to the post-war development of continuous filaments, polyamides, polyesters and regenerated cellulose acetates. It has largely replaced the traditional methods of lace knitting in the production of lace, net and elastic net.

The three main warp knit structures are : Tricot, Locknit and Satin.

2.1. Tricot

Tricot, the simplest fabric, is made from two sets of warp threads. There are two threads on each needle and each set makes a similar movement.

Tricot is used for lingerie, blouses and dresses and for linings laminated to other fabrics. Its chief characteristics are soft "textured", good drape, and elasticity.

Tricot is a term often applied to many other types of warp-knitted fabrics, most of which are used with foam or other fabrics to give combined upper materials or lining.

2.2. Locknit

Locknit is a structure using two guide bars. One guide bar moves across two needles as the other moves in the opposite direction but over only one needle space.

Two threads are knitted on each needle, but while each stitch consists of a double loop, only one is visible on the face of the fabric.

The back of the fabric is characterized by crossing laps of yarn. This ensures a firm and stable structure.

Locknit is a very important war-knit fabric because of its smooth face and good resistance to laddering. Stripes and other designs can be easily incorporate by the use of colored yarns.

Locknit fabrics are laminated with foam to produce linings used in slipper and general footwear.

2.3. Satin

Warp-knitted satin fabrics are produced in a way similar to locknit fabrics. Instead of the guide bars traversing the threads over two needles before it is knitted together much longer floats are produced on the "back" of the fabric by a traverse over four needle spaces.

The lapping movement of the guide bars can be compared with that of the locknit method. The "back" of the fabric, therefore, has a very smooth surface and good lustre.

Satin can be brushed or raised to produce the familiar nap of fabrics used in slippers.

C. Non-woven Fabrics

Fibres can be converted directly into fabrics, by-passing the yarn stage for economic reasons.

Fibers can be interlocked in a web or matts or fleeces having to some extent, cohesion.

Non-woven materials are widely used, mainly as base fabrics for coatings.

1. Felts

Traditional felts can only be made from wool or animal hair fibers which have unique frictional properties.

Animal fibers have scales on their surface which interlock when rubbed together.

If a mass of wool fibers is mechanically "tumbled", especially in hot and wet conditions, each fiber tends to move in one direction through the mass and the whole mass of fibers becomes entangled.

All felt, or non-woven fabric, achieves its strength and other critical physical properties by a random entanglement of fibres instead of a regular interlacing of threads.

A felt can be conveniently cut in any direction without fraying or unravelling because of its compact fiber arrangement.

As a result of the compaction process, the felts produced are generally very stiff and heavy, with little draping or shaping properties.

2. Bonded fiber fabrics

Bonded fiber fabrics, can be made from staple fibers of all types, however, the most used fibers are now synthetic ones.

There are two important stages in the manufacture of bonded fabrics :

- web formation and
- web-fiber consolidation.

2.1. Web Formation

The production of webs can be achieved by any of the following dry or wet process techniques :

2.1.1. A number of layers or web produced on the carding machine, are superimposed according to the thickness required.

This is the least expensive method of production but the final bonded structure is very weak. This non-woven is unsuitable for footwear.

2.1.2. Layers of card web are superimposed by cross-laying or angle-laying. The web of fibers is fed on to a lattice which moves backwards and forwards across a second lattice at right angles to the first. The web is thus laid down in a series of folds. The number of overlappings of the folds may be varied so as to alter the weight of the fabric.

2.1.3. The fibers are blown in a fast air stream from which they are sucked on to and collected in the form of a web. This is the best method because the fibers are random-laid thus eliminating the directional properties of the fabric.

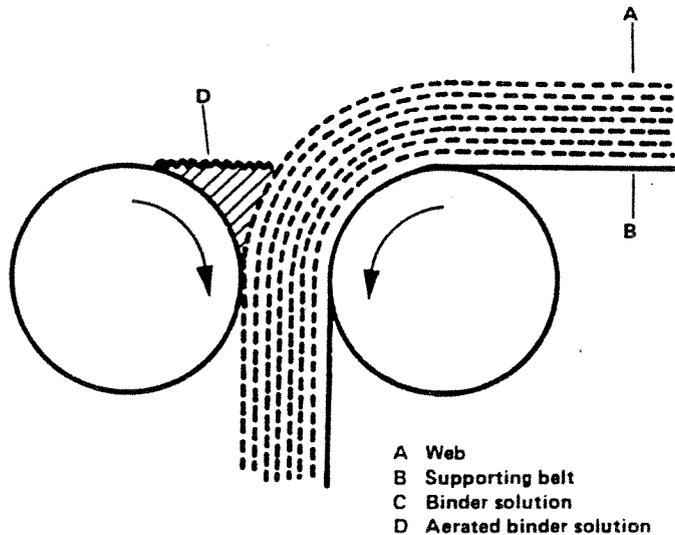
2.1.4. There is also a wet method of producing webs, it is based on paper making principles.

Firstly, the fibers are dispersed in water and then a web is formed by the settling of the fibers on a moving perforated screen through which water drains.

This process has a very high speed of production but the product as such is not suitable for footwear because it resembles paper in both appearance and properties.

A patented system of Freudenberg, Weinheim, West Germany, avoids compacting the web which occurs in the normal roller method. In that system the binder is in the form of a coagulated foam.

FREUDENBERG SYSTEM



2.2.2. Thermoplastic fibers

An alternative to the application of adhesive is the use of low melting point thermoplastic fibers which can be softened by heat with or without the action of plasticizers, which caused to bond with one another under pressure.

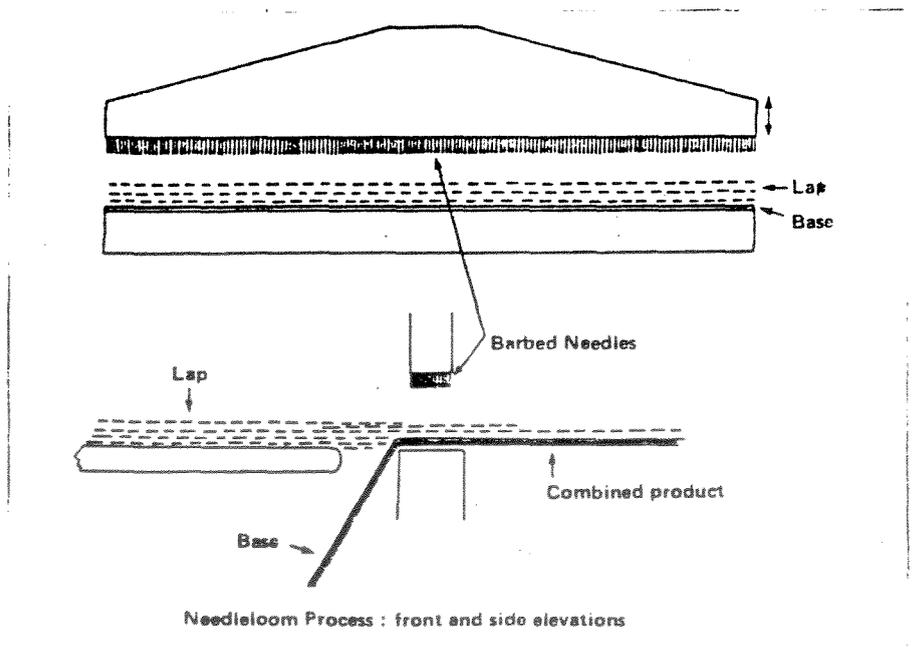
This method can be used to produce fabrics composed of 100 % synthetic fibers or to combine natural regenerated fibers in various blends.

Fabrics made in this way are generally rather dense and papery, though often very tough and durable.

2.2.3. Needle fabrics

For over a century, needle looms have been used to make thick felts of jute, cotton, coarse hair for carpet underlay, padding and other inexpensive products.

By this method, a thick web is subjected to repeated punching by needles so that the fibers are forced through the fiber mass and gradually become entangled. A coarse woven scrim is often used as the base of the fabric. Some of the fibers making up the bulk of the material then get forced through the scrim, and the web becomes locked in.



Needle punching

Non-woven coherent fabrics can be made by causing the fibers of webs to become interlocked. The deep entanglement of the fibers provides a strong material.

The technique of needle punching is shown in the figure.

As a needle descends through the fiber mass, it carries with it fibres trapped and caught by the barb. The needle then emerges leaving fibers entangled in the batt or web. It is the fibers from the web itself which hold the batt together.

Generally, needle bonded non-wovens are used as substrates for synthetic lining materials. The early poromerics were based on needled substrates.

D. Laminated Fabrics

One of the earliest types of laminated (or combined) textile was the double texture rainwear material (mackintosh). This was made by simply combining two woven fabrics using a solution of rubber in naphta.

This method has been widely used for the production of shoe upper materials.

The reasons for combining two or more fabrics, and for binding fabrics to foam, for shoe upper materials are both technical and economical.

They include :

- reduction of cost by providing an inexpensive base to give the more expensive top fabric the required weight, thickness, grip and stiffness,

- the use of cloths for footwear for which they were not originally intended. For instance, a raffia braid can be bonded to a more substantial base. When suitably finished, the laminated cloth can be used for shoe uppers,
- improvement of dimensional stability. If the face fabric is easily distorted, bonding it to a firmer ground fabric will help to stabilize it and make it usable as a shoe upper material,
- economising of linings. A fabric which is already lined eliminates the cutting out and stitching of a separate lining. Usually woven cotton or nylon tricot is used as the backing fabric,
- an attractive color contrast can be obtained by combining a cloth of high color and open structure with a neutral colored lining,
- general foot comfort can be improved by added thickness and where cotton or similar fibers are used, increased absorbance of foot moisture,
- adding aesthetic appeal to the inside of the shoe.

There are three basic methods of laminating or combining face fabrics to other types of textiles or non textile substrates :

- adhesive bonding
- foam lamination
- film lamination

1. Adhesive bonding (solvent or aqueous dispersions)

This is the most widely used method for bonding two fabrics.

A compounded rubber latex is applied by knife to one of the fabrics being bonded. The other fabric is then fed together with the latexed cloth through the pressure rollers of a simple calendar and on to a drying drum for curing. Next, they go to the take-up roll.

Wet or aqueous based adhesive bonding with water-based dispersions of acrylic co-polymers, and some solvent based solutions of polyurethanes or polyester are used for laminating textiles for upper materials. The adhesive is applied to the underside of one or both fabrics by back coating and then fed together through the pressure rollers or a calendar and cured over a drying drum or hot hair curing oven.

2. Foam Lamination

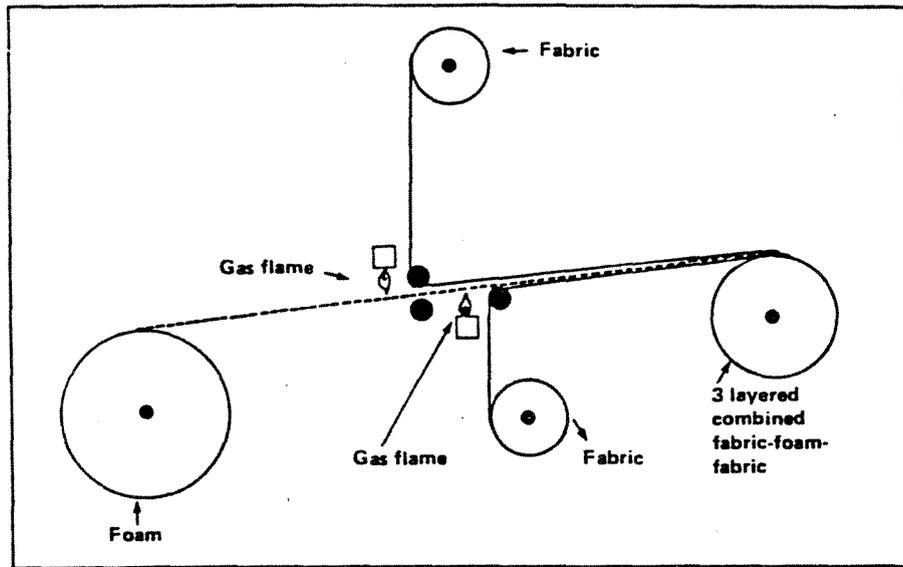
Foam/fabric combinations were developed primarily for the clothing industry. They are now widely used as linings in shoes.

Usually the foam is a polyurethane. Polyurethane foam has a physical cellular structure which traps 92 % of its weight by air. It is therefore very light in weight and as a shoe lining material adds insulation to the foot.

Foams of varying thickness and different degrees of insulation can be combined in different ways.

PU foam can be used to bond two fabrics such as fabric/foam/fabric or in single fabric/foam lamination.

The process includes taking a foam and feeding it through two banks of gas flame at a speed which melts the surface and makes it tacky.



Foam laminating

The tacky foam is then continuously fed between and combined with two fabrics. The three layers are brought in contact by passing them between light pressure rollers.

3. Film Lamination

Any fabric can be laminated with a film, usually PVC, sometimes a polyurethane film.

Like for foam lamination, the two layers are brought together by passing them between pressure rollers. The junction between film and substrate is realized by an adhesive layer. This adhesive can be applied straight before combination or applied and dried on the backside of the film and then protected by a silicone paper.

There is also a transfer technique in which the liquid filmogene material is sprayed on a silicone paper or rubber, with eventual embossing, and then dried and transferred on to the substrate.

(see Annex 1)

Such lamination can also be applied onto leather.

Some covering films are thin metal containing paper reinforced with polyester (aluminium, gold, silver, bronze), or dyed (aniline) or pigmented polyester/papers.

Reptile patterns can be printed on the polyester/paper.

The application technique is simple.

A dispersion of acrylic resin is sprayed onto the leather.

After drying the leather and the paper are ironed in a press at a temperature of 85-90°C and under a pressure of 50 to 100 atmospheres during 5 seconds.

The resulting finish is very glossy, has elasticity and a good rub resistance.

E. Coated Fabrics

The most common type of synthetic upper and lining materials being used at present consist of a fabric coated with a polymeric pigmented compound. Such materials are relatively inexpensive.

The substrate or the backers may be : woven, knitted, non-woven or leather splits.

The coating is the result of an application of liquid polyvinylchloride sometimes polyurethane and when dried the coating can be compact, expanded, microporous, coagulated or flocked.

1. PVC coated fabrics

1.1. Woven Substrates

A wide range of weaves may be used. The differences in weave pattern will affect the appearance and the stretch characteristics of the material.

The backers may be of cotton, regenerated or synthetic fibers, or mixed cotton/synthetic.

Raised or swansdown flannel type backers are also used and some quarter lining materials have rubberized fabric backings to give them a plump full feel and to improve adhesion to stiffeners.

Although woven fabric backers provide a strong, flexible base, and provide a degree of absorption for foot perspiration, the woven cotton backer is frequently too tight in the warp direction (7 to 8 % breaking stretch) and looser in the weft direction (25-30 % breaking stretch). A more balanced stretch is desirable and warp breaking stretch should be 15 to 20 % and certainly not below 10 %. Too tight warp leads to breakages during lasting, or persistence of longitudinal creases. More stretchy synthetic backers, instead of cotton, improve this property in plastic coated fabrics.

1.2. Knitted backers

These are used mainly in conjunction with cellular PVC coatings. The resulting material is soft and stretchy. Lasting behavior is improved, but shape-retention may be impaired. Such materials are mainly used in slippers and soft casuals.

1.3. Non-woven substrates

These may be in the form of felts or bonded fabrics. The latter are more common and a wide variety of materials can be produced depending on the fibers used, and the type and quantity of binder. Some very good backers can be made in this way, they can be skived, have a good appearance and leatherlike stretch properties in all directions. Good bonded fabrics are, however, expensive.

2. PVC Coating

2.1. Basic Production Method

PVC Coatings are made by enduction of a vinyl paste.

The vinyl paste consists of two essential components :

- the vinyl paste resin, and
- the plasticiser, which is generally a colorless liquid.

There is no volatile solvent present.

The ratio of plasticiser to paste resin, and the type of plasticiser and resin used determine the viscosity of the paste.

On heating a single paste, the plasticiser is gradually absorbed by the resin particles until at a temperature between 65° and 100°C, depending upon the type and amount of plasticiser used.

On further heating to temperatures in excess of 170°C, the mass begins to soften, and the resin and plasticiser melt and fuse together.

INFLUENCE OF THE PLASTICISER ON THE PROPERTIES OF POLYVINYLCHLORIDE

	Octyl- benzyl adipate	Tricresyl phosphate	Diphenyl cresyl phosphate	Diphenyl octyl phosphate	Trioctyl phosphate	Dibutyl phtalate	Benzyl butyl phtalate	Sulfonic Ester	Poly-adi pates	Mixture 1/1 padipate ABN ABN
	1. 60 parts of PVC and 40 parts of plasticiser									
Tensile ₂ stren. N/cm ²	1550	2100	2150	1600	1400	1700	2000	1850	1700	2250
Elongate at break %	355	215	260	315	320	340	300	310	210	215
Tear Resist. N/cm W	440	480	570	400	430	460	510	530	480	900
Shore Hardness A	70	76	75	70	75	67	80	75	80	95
Cold resist. °C	-60	-15	-15	-40	-60	-40	-25	-35	-30	-25
	2. 72 parts of PVC and 28 parts of plasticiser									
Cold resist. °C	-40	+5	0	-30	-60	-30	-10	-20	-30	-15

When this fused or "gelled" material is cooled, it will have good strength and elasticity, if the type of plasticiser and the ratio on plasticiser/resin are well selected (see Table).

Some plasticisers have polar groups (carboxyls) which can link to the vinyl, some also can improve the cold crack resistance.

It is also essential to reach high temperatures in the fusing of the two components.

During high temperature heating there is a tendency for the PVC to decompose by a process of oxydation and loss of hydrochloric acid. Small quantities of stabilisers (e.g. diphenylthio-ureum) are added to reduce this decomposition.

Pigments are added to produce suitable colors. These pigments must be fast to light, to heat and to migration.

Fillers may be added to modify the properties of the paste and to reduce the cost. Too much filler in a paste leads to very poor flex life.

When the paste is applied to a fabric, it is fused again under infra-red and rolled, embossed or ironed. Printing with engraved rollers is also possible.

2.2. Types of PVC Coatings

The PVC coating can be either :

2.2.1 Compact

Such coating is used for upholstery, handbags, and low-priced footwear. The pasty PVC is enducted on a substrate and cured.

After curing, it can be embossed, plated or printed to a variety of surface finishes.

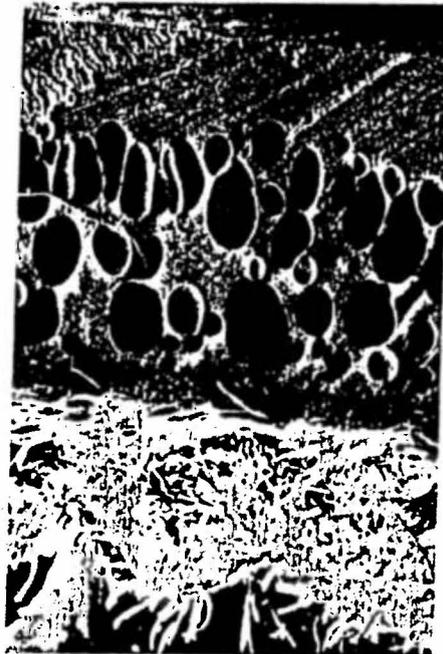
The thickness of the coating is relatively high, 0.3 mm. Below that thickness there is a tendency of marking from the substrate and the material becomes too weak.

PVC compact coated fabrics are generally unpopular for footwear because of their impermeable nature.

2.2.2 Expanded PVC

These materials have two coating layers : one ground layer which is expanded and a top layer in compact PVC. They are also water vapour impermeable but have a better handle and feel than compact PVC.

Another advantage is that the stitches bed down more easily.



Expanded PVC

2.2.3 Microporous PVC

These consist of a very fine sponge-structured PVC coating with very small pores which interconnect and therefore make the coating permeable.

Some of these materials have a very thin skin through which the underlying cells occasionally break. The structure of this particular material may be quite complex, but the material is absorbant and permeable yet waterproof.

Another class of material for linings has fine open cells which give a suede appearance, and such materials are also absorbant and permeable. This type is made by a process in which salts and starch are mixed into the PVC paste before coating, and when subsequently washed out, what is left is the fine porous structure.

Most of the PVC sheet materials can be classified in terms of the backers and coatings.

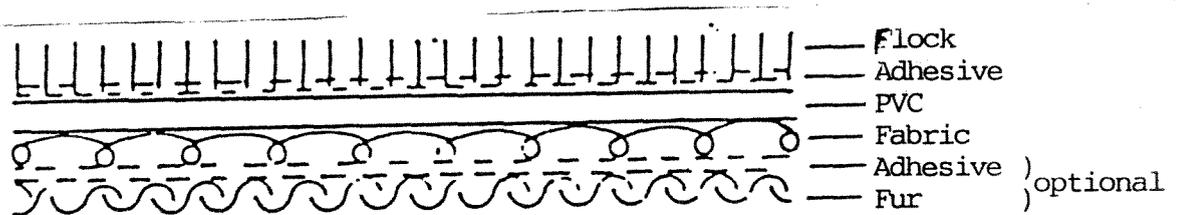
Some combinations will be more common than others : solid PVC is most common on a woven backer, expanded coatings usually have knitted backs, and the microporous types are likely to be on bonded fibres. Other combinations are, however, frequently found.

2.2.4 Flocked PVC Fabrics

PVC coated fabrics are also found in the flock-finished or suede material.

Some of these have a PVC coating which is microporous while others are embossed to give a matt finish.

Other types of suede effects are obtained by short fibers of any polyamides embedded in the PVC coating. While the coating is still wet, the polyamide or cellulose acetate fibers are laid through an electrostatic field to give the suede appearance.



STRUCTURE OF A FLOCKED FABRIC

Polyamide flock generally has better abrasion resistance than cellulose acetate flock but all polyamide flocks are not equally good, probably due to the differences in fiber length, thickness and closeness of packing.

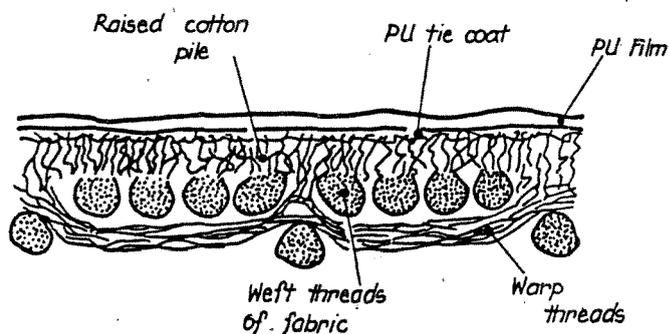
Many of the flocked fabrics for uppers are on knitted substrate and for linings on non-woven.

All coated fabrics have a tear resistance which is lower than that of the substrate. If the coating is superficial, there is risk of delamination, if the coating penetrates, the tear resistance can drop up to 50% of the initial resistance of the substrate fabric.

3. Polyurethane Coated Fabrics

Like for PVC coated fabrics, a PU coating can be applied to different kind of substrate : woven, knitted or non-woven.

The main difference between PU coating and PVC coating lies in the thickness of the top layer. PU coatings are thinner than PVC ones, and the PU coated fabric is more elastic with a better hand and appearance.



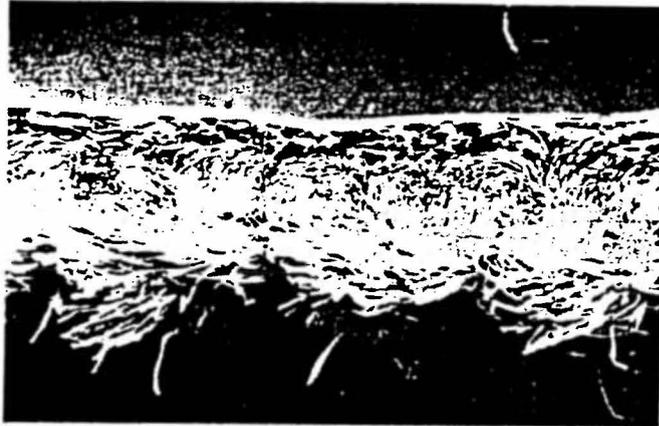
Cross section of PUCF

As the PU layer is thinner the fabric backer has to be raised or swansdown to prevent the weave of the substrate from making an impression through the PU surface and to give at the same time a full and spongy feel to the material.

Some PU coated fabrics have two top layers one in PU foam and the other as a film.

Materials with PU coating were originally designed for use on handbags and in garments. They had initially some undesirable features as shoe upper material. The main disadvantage was the ease with which the PU film separated from the backer. Some PU coated fabrics are still very sensitive to hydrolysis and have a low scuffing resistance in wear.

Some fabrics have a double coating, PVC for the ground layer and PU for the top layer.



: Eduction PU.

Recent processes, sometimes called "transfer process" are as follows:

- a) A solution of a pigmented PU top-film is coated on a plain or embossed release paper. The solvent is removed to give a film about 0.05 mm thick.
- b) A PU adhesive coating is then spread to the PU film, which is still on the release paper.
- c) The combined adhesive/pigmented top-film is laminated to a pile fabric between rollers, and the assembly, which still includes the release paper is passed through an oven to remove the adhesive solvents and consolidate the bond between the PU film and the pile of the fabric.
- d) After cooling, the PU coated fabric (PUCF) is removed from the release paper, and both are made into rolls. The release paper is re-used and the PUCF goes on to a finishing stage if required.

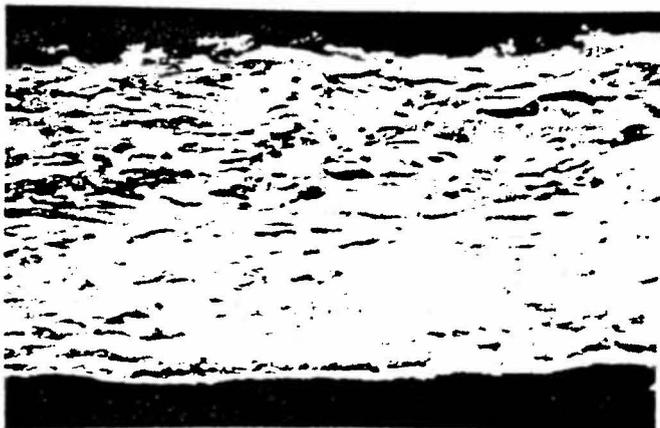
- e) If a high gloss release paper has been used, the PUCF will be ready for delivery.

If special finish effects are required, the material can be processed by finish spraying or in a photogravure roller printer.

Other recent innovations are :

a) The coagulated PU coated fabrics

These are based on the impregnation of a plain or raise woven cotton fabric with the PU dissolved either in an organic solvent or in water. The coagulation technique allows the formation of a porous structure which has some permeability making them convenient for footwear and garment. As shown in the figures, the porous structure of the water medium coagulation is different from that of the organic solvent medium.



Coagulated PU

solvent coagulated



water coagulated



b) The foam PU coated fabrics

Made by transfer coating of the thin solid PU film with PU foam interlayer to a plain woven or non-woven fabric.

4. Properties of Coated fabrics

Leather possesses a very good balance of stretch, plasticity and elasticity.

Coated fabrics, on the other hand, vary greatly in those properties. Generally, they tend to show stretch characteristics which are governed by the weave of their backing fabrics, and they are frequently too tight in the warp direction.

Some attempt to overcome this and to give a more balanced stretch has been made by using non-woven or bonded-fibre types of substrates or also knitted fabrics. There are also possibilities to use reinforcement to control the stretch of the surface layer.

Materials having the same characteristics in all direction are called "isotropics".

Woven fabrics are "anisotropic" according to the weaving, the type of yarn and eventually the reinforcement. They have usually their maximum stretch in the diagonal direction.

Knitted fabrics are less anisotropic and many non-woven are isotropic. The balance "elasticity/plasticity" of coated fabrics is also different from that of leather. The degree of set is generally good but the heat setting of most of the coated fabrics requires longer time or higher temperatures (up to 160°C). This is important, as well for synthetic materials for uppers as for linings.

Synthetic materials are often quoted by the "Modulus of elasticity" which is the ratio of the deformation of a material to the stress producing that deformation.

$$\text{Modulus of elasticity} = \frac{\text{strain}}{\text{stress}}$$

Low modulus materials are those which require a low force to extend them and vice versa.

A low modulus, but high elastic material, will deform easily in wear and will be comfortable and its elasticity will allow it to regain its shape when removed from the foot. If it is not elastic, however, it will deform in wear and lose its shape permanently.

A high modulus material may show a good deal of shape retention, but will not give so easily to the foot. Fitting of the shoe becomes more critical and can be uncomfortable.

There are no problems in cutting coated materials, this can be done with cutting dies, or modern techniques as water-jet or laser. The edges of materials with a non-woven substrate are better than those with a weave of knitted material.

Materials with non-woven substrate may be split or skived.

Stitching must be adapted to each type of coated material, namely the type of thread, the feed mechanism and the number of stitches per centimeter. The shape of the needles is important, triangular needles can cut the threads of woven substrate and make always a beginning of tear in the coating. The recommended stitch length is 3 to 4 mm. Any type of rivet should also be avoided in junction of coated materials. Rivets are always a beginning of tear.

The behavior of coated materials with adhesives is very complex and will depend mainly from the nature of the coating and from the resistance of the material to delamination.

F. Poromerics

1. Definition

A poromeric material used in footwear :

A man-made material generally similar in nature and appearance to leather, with a comparable permeability to water vapor.

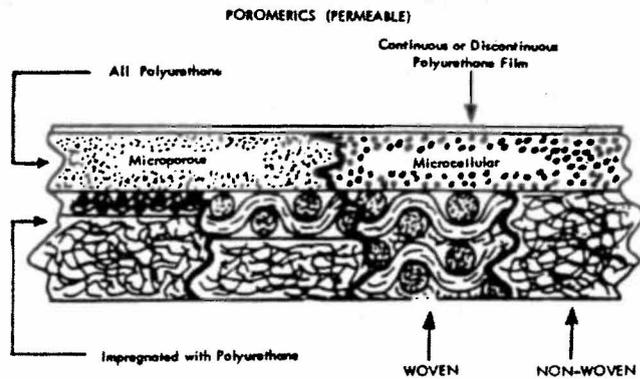
Poromerics come far close to the structure and performance of Leather than coated fabrics do.

2. Common Features of Poromerics

The common features of poromerics are that they have a fibrous backer, a porous structure, and a surface coating, usually of polyurethane, which is also porous.

This porosity may be achieved either mechanically by minute holes, or chemically by "chemi-sorption"

Despite these common features, however, there is a great deal of variation in structure and physical properties amongst the poromerics, and they should not be considered as a single type of material for manufacturing purposes.



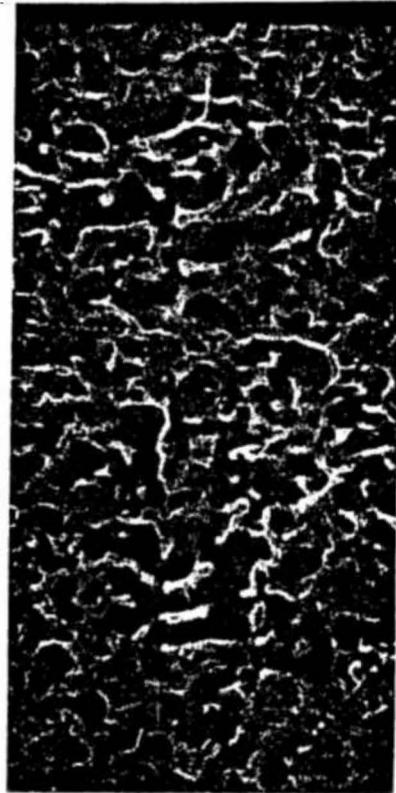
... Diagrammatic section of various poromerics

Although the poromerics mostly have a fibre layer or layers (except PORVAIR*) they differ fundamentally from leather, for leather fibres have no binder to hold them together whereas the poromerics have their fiber layers literally "glued" together. It is this property, of course, which gives leather, its high permeability and absorbency, and because of the many air spaces around the fibers, its superior insulating qualities as well.

Mag x 40



Mag x 250



Photomicrograph of a cross section of PORVAIR

-
- (*) PORVAIR is permeable but non-fibrous, it is a continuous sheet material having non-laminar structure consisting of interconnected microscopic cells in a matrix of polyurethane elastomer.

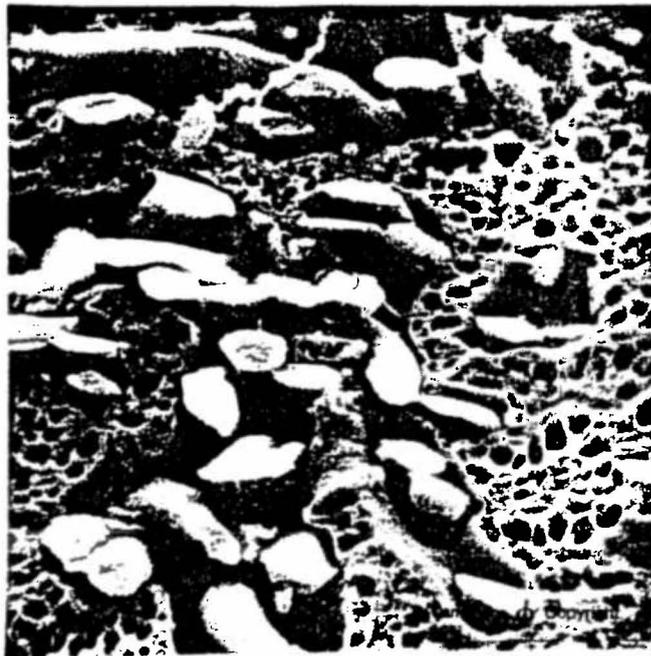
3. Structure of Poromerics

Most of poromerics have some sort of fibrous backing, and this will vary both in fiber type and density.

Various polymer fibers, for example polyester, polyamid, polypropylene, are used in the fabric substrate. The incorporation of leather has and still is being tried. Some good results were obtained in France and Czeschoslovakia, but the materials are too expensive to be commercialised.

The synthetic resin binder will also vary in type and structure, but is usually a foam, which may be intimately bonded to the fibers, or may be only partially bonded, and partially free from the fibers.

The structure of this foam will, of course, affect the stretch, the flexibility and feel of the materials.



Photomicrograph of fibrous structure of Clarino (magnification 550)
fibers are apparent in the foam structure

On top of this fibrous layer comes a microporous polyurethane layer containing no fibers, and a finer porous structure.

Finally the top surface is usually a very thin coating of polyurethane, which can have very good flex and abrasion resistance.

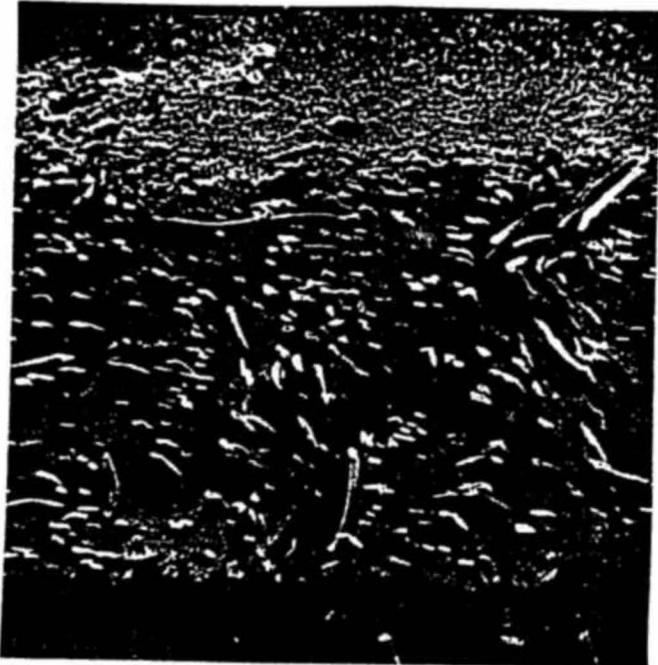


Fig. 1. Photomicrograph of the poromeric 'Clarino' taken at 45° to cross-section



Fig. 2. Substrate layer in the poromeric 'Xylee' showing the polyurethane binder around the fibres
Magnification 500

4. Advantages and disadvantages of Poromerics

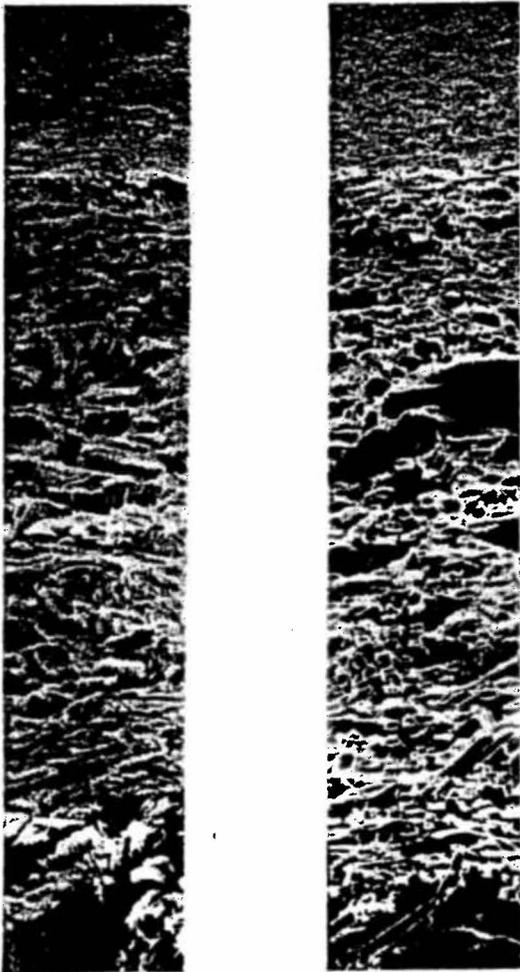
The main advantage of poromerics is their cutting value due to the shape and the homogeneity of the material.

In addition, they have an attractive finish which is generally "easy care" and they adapt themselves to modern techniques such as laser or water-jet cutting, embossing and welding, HF transfer.

They are also much closer to leather in structure, permeability to water vapour and performances in wear.

Because of differences in their structure and production process each poromerics needs an adoption of the footwear manufacturing techniques, chiefly in the heat setting. Some poromerics show the "orange peel" effect in the stretched areas during lasting.

Many poromerics are sensitive to hydrolysis and can be attacked by human perspiration. As a result of this degradation, the microporous layer loses its elasticity and flexibility eventually becoming brittle.



*Photomicrograph pictures showing structure of calf leather on the left and 'Corfam Leo' on the right
Magnification 165-170*



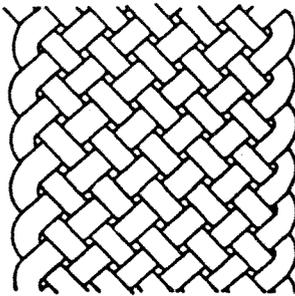
Poromeric shoe upper showing damaged area in close-up



Cross-section of material from a degraded shoe showing cracks appearing within microporous layer

E. Braids

Producing braids consists of interlacing three or more yarns diagonally in such a way that each strand passes alternately over and under one or more of the others.



Braids are in two types:

- flat braids in the form of a flat strip or tape ranging from 5 mm to 50 mm wide, and
- round braids, which are tubular

In a regular braid, each strand passes alternately over and under two of the opposite strands, showing two complete double ribs or lines of herringbone shape.

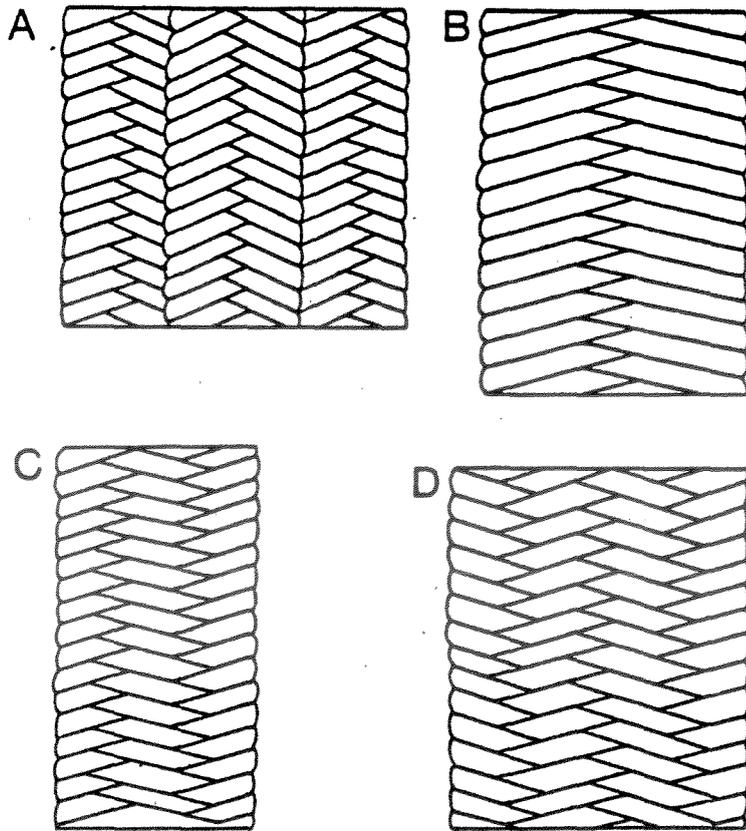
Flat braids are known by the number of lines which they contain.

Braiding machines have two plates between which a train of gears operate. The gears have flanges or lugs to engage the bottom and end of the bobbin carriers which carry the yarn. The top plate constructed with a separate path to guide the bobbin carriers.

Above the braiding table, rollers draw the finished braid through the machine at constant speed to ensure a uniform braid.

A variety of materials is used for making braids : cotton, wool, worsted, mohair, silk, linnen, hemp, jute, tinsel. Also, metal threads, straw and various synthetic threads as such or coated.

The footwear industry uses braids extensively in the form of shoe laces, top line tapes, trimmings for platform covers and strappings for many types of footwear.



Different types of braid : (A) Vienna braid, (B) Soutache braid, (C) President braid and (D) Square braid.

The diagonal course of the yarn normally makes braids fairly stretchy along the length with a corresponding contraction in width.

This means that braids are not recommended for reinforcement for which woven top line tapes should be used. Woven narrow fabrics are compact and can withstand higher stresses than braids.

Knitted narrow fabrics have a lower modulus than braids but are still too stretchy for reinforcements.

NEW DEVELOPMENTS IN HIGH FREQUENCY TECHNIQUES

High frequency (HF) techniques are applied in footwear manufacture since more than 20 years, particularly in welding, embossing, bonding of man made materials and PVC flow moulding.

The HF techniques is well mastered and many footwear manufacturers are using it with success.

A recent development of HF radiation is the application by transfer of a finish layer onto crust leather.

Crust leather being tanned and fatliquored presents all the characteristics of finished leather (suppleness, strength, etc.) except for the color and finish. The dyes and finishing chemicals are laid on a silicone release paper and then "transferred" onto the leather.

The junction between the leather and the finish film is performed in an HF field. The HF waves are not producing heat, they only bring into motion the molecules of some substances, here the molecules of the finish film. It is the collision of the adjacent molecules which generates heat and allows binding between leather and finish film, without overheating or burning the materials. The heat is happening only at the point where the molecules collide and occurs only during the radiation time which is very short.

The transfer of finish film on leather could be done with a heating press, but in that case heat is conducted by the hot plate and the materials are overheated which results in change of the color or shade. Also overheating the leather will make it to become hard and brittle. On the other hand presses and heating plates are expensive and energy consuming.

The silicone release paper is cheap and can be reutilized. Silicone rubber moulds can also be used, they are easy to produce and can be reutilized many times.

Transfer technique can be applied on pieces of leather (cut parts of footwear or leathersgoods) allowing the producers of manufactured goods to reduce their stock of finished leather and to decide at the last minute the grains and colours to be used.

Advantages of the HF transfer technique are:

1. smaller and cheaper equipment than conventional presses and tannery finishing machines.
2. savings of energy.
3. great versatility of the moulds and release paper giving a wide range of grain appearance, embossing and colors.
4. savings of finishing chemicals as only the usable parts of leather are treated.
5. fast production on the spot.
6. standardization and reduction of the leather stock in the warehouse, no remaining colors or grains.
7. lower price of crust leather.

The price of silicone paper is about ¥5 per square foot.

The HF transfer technique is patented as well as the machine for the application of the finishing products by a French company.

ANNEX 2

HIGH FREQUENCY RADIATIONS

High Frequency wave heating differs fundamentally from radiant and conducted heat.

The HF waves go through a material.

When a material is placed in an electric field the molecules of that material try to orientate themselves in the direction of the field. If the applied field is rapidly alternating in direction, the molecules will be rapidly swung, first in one direction and then in the other.

Collision with adjacent molecules will occur and frictional heat will be generated. As the molecules exist in uniform density throughout the material, the heat will be equal throughout the material.

In the HF field the temperature of the material raises uniformly throughout its substance so there is no waiting for the center to heat. Therefore very rapid and uniform heating is possible without burning.

Generating of HF Current

HF waves are generated in a similar way to radio waves (*).

The generator is working in the same way as a radio transmitter.

The generator consists of three main parts :

- Transformer : This raises the main voltage to a high value,
- Rectifier : This changes the alternating current to a direct current,
- Oscillator Valve : This valve is arranged in the circuit to stop and start the current, millions of times per second.

The rapid stopping and starting of the current through the valve causes an alternating HF current.

The generator can be coupled to any two electrodes and to establish an HF field.

Uses of HF in Footwear

1. Welding : Fusing together of two pieces of material
2. Cut/welding : The components are automatically cut out after welding. The resulting edge is neater in appearance than the conventional press-cut edge.
3. Embossing : Any pattern can be embossed onto materials that react to HF.
4. Bonding : HF can also be used on hot melt, even to bond leather to leather. PU adhesives can also be reactivated by HF.
5. Applique welding : Two contrasting materials are used for this method. The drop on the machine is controlled so that the top material is pushed just below the surface of the base material and welded in that position. As soon as the material is taken out of the machine, the excess top material is torn off. This is sometimes known as "tear-seal" welding.
6. Compression skiving: Poromerics can be reduce by collapsing the cellular structure under HF and pressure. This produce consistent identical skives and the material in this area increases in strength.
7. Flow moulding : A mould is made from a model component using silicone rubber, which is unaffected by HF. The mould is placed in the HF machine and into it is placed a blank castor component, usually PVC. When HF is applied the material flows into the rubber mould taking onto itself the shape and surface characteristics of the original model including any stitching.

