22. Wool Carpet Manufacture

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Learning objectives

By the end of this lecture, you should be able to:

- Define the terms used to describe the constructions of tufted and woven carpets
- Explain the hand-knotting method of making a carpet
- Describe the tufting method of making a carpet, including the machine features required to produce loop pile and cut pile constructions
- Outline the features of Axminster, Wilton and face-to-face woven carpets
- Compare the advantages and disadvantages of the various production methods for machine-made wool carpets, including construction, production rate, and patterning options

Key terms and concepts

Carpet construction parameters, hand-knotting, hand-tufting, machine tufting, loop pile, cut pile, patterning mechanisms, finishing, Wilton weaving, face-to-face weaving, Axminster weaving (spool, gripper, spool gripper methods).

Introduction to topic

The history of carpets is entwined with the history of human civilization, and rugs and carpets have been prized possessions through the ages. Carpet weaving is believed to have originated in southern Persia about 4000 years ago. The oldest existing carpet, the Pazyryk carpet, which is believed to be 2400 years old, has a knotted wool pile.

Rugs were listed as valued chattels in the literature of Persia in the 6th century. They were probably coarse fabrics flat-woven on a loom in much the same way that other plain textiles were made. Hand-knotted rugs were created later, possibly by nomad tribes of Turkestan or the Caucasus. The weaving of hand-knotted rugs spread throughout the Orient, and Persia became the predominant centre of manufacture. Oriental rugs were carried to Europe by the Saracen conquerors of Spain and by the returning Crusaders. The Spanish were the first Europeans to make hand-tied pile rugs. In the tapestry-weaving centre of Aubusson, France, flat-woven rugs were made. Aubussons were known for their floral patterns in pastels. Deep-pile rugs, first made in Paris in the 17th century, were called savonneries, after the abandoned soap works that housed the carpet factory.

Wool has remained the mainstream fibre for hand-knotted carpets and rugs and it was natural that, when mechanical weaving of carpets was introduced in the early 19th Century, wool was adopted as the pile material.

Today there are three principal methods of making wool (and wool rich) carpets and rugs: knotting, weaving and tufting. Hand-knotting of rugs is mostly carried out in countries where labour costs are low, such as India, China, Nepal and countries of the Middle East. Needle-punching is also an important process for manufacturing textile floor coverings, but little wool is used in this sector.

Over the past 50 years tufting has become the dominant method of carpet manufacture. While it cannot offer the huge flexibility in design that is available in machine weaving, the patterning scope is increasing as a result of technological innovation.

The share of the global market for wall-to-wall woven carpets has as the same time declined in relative terms, but a significant quantity of wool is used in this sector, and it continues to be the major fibre for quality machine-made rugs. Woven products have retained their importance for the contract carpet market and upper segments of the residential market. Improved weaving technologies have contributed to this, as well as the ongoing popularity of wool in prestige locations.

This lecture examines the various technologies that are used to make wool carpets today, from the simple hand-knotting loom to the highly sophisticated face-to-face weaving loom. The principal reference for this lecture is the comprehensive reference text by Crawshaw (Crawshaw, 2002). In addition, the Wools of New Zealand Technical Information Bulletins on carpet manufacturing methods, which are suggested as readings, are also very useful references for this lecture.

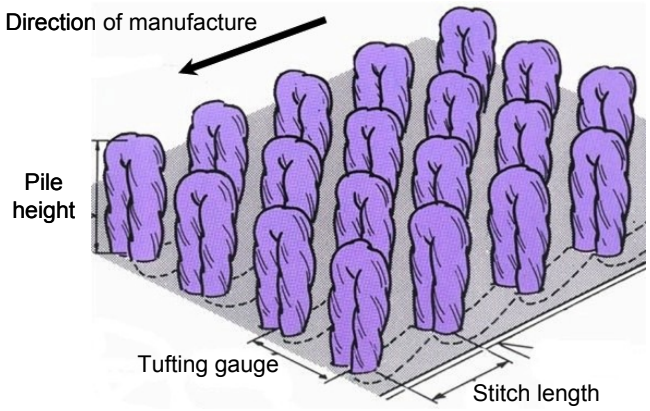
A comprehensive review paper covers recent developments in textile floor coverings, including fibres, manufacturing methods, design trends and performance (Crawshaw, 2003).

A summary of machine-made carpet types is contained in a table at the end of these lecture notes.

22.1 Carpet construction terminology

In order to understand the manufacture of carpets it is important to become familiar with a number of technical terms. This first group of terms is associated with carpet construction (Figure 22.1).

Figure 22.1 Carpet construction parameters. Source: Wood, 2006.



Carpet width

Body carpet (or narrow loom) is a plain or unbordered carpet in piece form, usually made in 70 cm or 91 cm widths for making up into larger areas by seaming or other edge-to-edge joining. Broadloom refers to carpets made 1.83 metres (6 ft) wide or more, usually 3.66 metres (12 ft) in Australia and New Zealand. European producers commonly make 4 metre and 5 metre wide broadloom widths.

Pile height

This is the length of a cut tuft or one leg of a loop from its tip to the point where it enters the carpet backing. Short tufts, which tend to remain upright, look and wear better than long tufts, which tend to bend and lie over.

It is necessary to distinguish between pile height and pile thickness. Pile thickness is the thickness of the pile layer measured vertically, and unless the tufts are vertical this will be less than the pile height. Pile thickness is the parameter that is usually monitored during the wear life of a carpet or a carpet sample under test.

Total pile weight

This is the weight in grams of all the pile yarn (including pile yarn woven into the backing) per square metre.

The weight of pile that can be shorn off above the backing, called the effective or **shorn pile weight**, is a measurement used in assessing carpet performance.

Stitch length

The stitch length is the length of yarn in one full stitch in a cut-pile carpet. The stitch length is generally measured by withdrawing the yarn used to form a number of stitches (say 5 or 10), and measuring this length. It is the measured length divided by the number of stitches withdrawn.

Pile or tuft density

The tuft density is a measure of the tufts per unit area. The tuft density is governed by the *gauge* and *stitch rate* in tufted carpets (or the *pitch* and *beat-up* in woven carpets). The tuft density measures the degree of compactness of the pile.

22.2 Tufting terminology

Stitch rate

Stitch rows are tufted along the warp direction of the carpet. The distance between stitches put in by the same needle is known as the stitch rate, and is usually expressed as the number either as the number of stitches per inch (2.54 cm) or per 10 cm. This distance between the stitches is controlled by the speed at which the backing fabric is fed through the machine. The faster the speed, the greater the distance between the stitches, provided the tufting rate is constant.

The stitch rate can be readily altered by the operator.

Tufting gauge

The tufting gauge of a machine is fixed - it is the distance between adjacent needles across the width of the tufting machine. To alter the gauge, you need to change the needle bar on which the needles are held.

In general, coarser yarns are tufted with a coarse gauge and long stitch length. The gauge makes a big difference to the surface appearance and wearing properties of a carpet. It is generally expressed in Imperial units. For example, $^{1}/_{8}$ gauge is 8 rows/inch and $^{5}/_{32}$ is 6.4 rows/inch. Using metrics, a 4 mm gauge construction is looser and more suitable for domestic use than a 2.5 mm gauge, which has a dense, tight pile suitable for commercial use.

22.3 Carpet weaving terminology

Woven carpets are constructed from the following four sets of threads.

1. Chain warp ends

These run the length of the carpet and interlace with the weft. One pair of chain warp ends is between each row of pile tufts.

2. Stuffer warp ends

These run the length of the carpet but do not interlace with any other threads. They are called "dead" ends and run between the weft. Usually, one, two, or three stuffer ends are used to each pair of chain ends. Lower grade carpets may have no stuffer ends at all.

"Dead" is the term used when the thread or yarn is not seen in the finished carpet face. "Dead" ends can be included in the backing but not seen in the face of the carpet.

3. Pile warp ends
These form the face of the carpet and interlace with the chain warp and the weft. One row of pile tufts is between each pair of chain ends.

In Wilton and Brussels carpets, with two or more differently coloured pile ends, a "dead" pile end can lie next to the stuffer ends when the pile end is not seen on the carpet face. In plain-coloured Wilton and in multicoloured Axminster carpets, no "dead" pile ends exist. The ends always show on the face of the carpet.

4. Shots or picks
These are the weft threads that usually form the primary backing of the woven carpet. Fibres used for the threads are jute, cotton or polypropylene. The threads are often called backing yarns.

Pitch or sett (equivalent to the gauge in tufting)

This is the number of pile tufts per 2.54 cm (1 inch) across the carpet in the loom in the direction of the weft. In Axminster manufacture, an 8 pitch means eight tufts per 2.54 cm (inch). Common pitches for spool Axminster carpets are 7, 9, and 9.5 and for gripper Axminster are 6, 7, 8, and 9. In Wilton and Brussels carpet manufacture, the pitch is often expressed as the number of tufts per 70 cm (27 inches) of width, usually between 176 and 256 (6.5 to 9.5 pile tufts per 2.54 cm).

The pitch of a Wilton loom can be doubled up so that other qualities of carpet can be woven in the same loom. For mechanical reasons, the pitch of Axminster looms cannot be changed.

Beatup (equivalent to stitch rate in tufting)

This is the number of rows of pile tufts per 2.54 cm (1 inch) along the length of the carpet. In general, the beatup for Axminster is from 4 to 12 and, for Wilton and Brussels, about 6 to 13. Beatup takes its name from the third primary motion of the weaving cycle performed by the loom. The beatup motion in carpet looms can be repeated for each row of tufts, to make a denser pile carpet.

Jacquard

A jacquard is a mechanism for patterning. Today electronic jacquards are mostly used but the original system was based on a series of punched cards. These control the sequence of yarn selection on the loom and provide the 'intelligence' by which the pattern is introduced. In the case of the more traditional mechanical punched card systems the presence (or lack) or a hole in the card determines the correct yarn selection at the weaving point.

22.4 Hand-knotted carpet manufacture

Hand-knotting is carried out on a simple loom as shown in Figure 22.2.

Figure 22.2 Loom for hand-knotting carpets. Source: Wood, 2006.

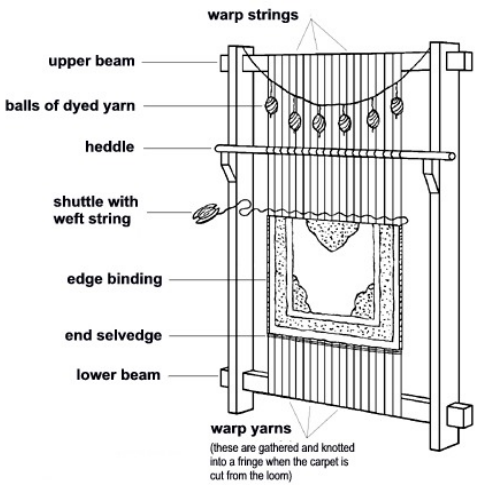


Figure 22.3 shows a worker at a hand-knotting carpet loom in India. Notice the knife is his right hand for cutting the yarn ends when the knot has been tied.

Figure 22.3 Hand-knotted carpet loom operator. Photograph supplied by E. Wood.

A hand-woven fabric is the foundation of the carpet, while the pile is produced by introducing knots of another material such as wool yarn. The weaver will weave a strip of perhaps 150mm of foundation fabric, and then insert the first row of knots on the warp threads. They will be either a Persian knot (Figure 22.4) or a Turkish knot (Figure 22.5).

Figure 22.4 Persian knot for hand knotted carpet. Source: Wood, 2006.

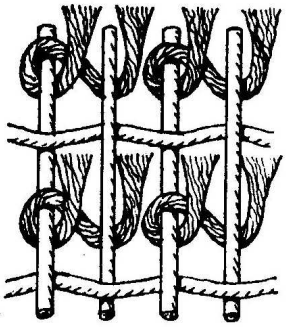
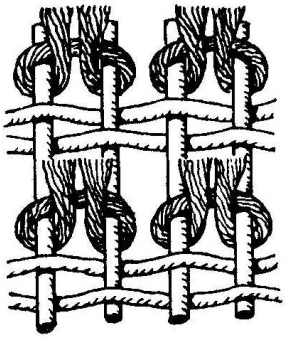


Figure 22.5 Turkish knot for hand knotted carpet. Source: Wood, 2006.



The knots of pile yarn are tied in by the weaver, who brings forward a back warp-thread level with the next front thread and knots the pile yarn around them.

The knots are pulled tight and the yarn ends are cut to the length needed.

After each row or part of a row of knots is tied, two weft yarns are inserted:

1. through the shed formed between the front and back halves of the warp, and then
2. through the reverse shed formed by temporarily pulling forward the back half of the warp.

The teeth of a heavy comb or beater are passed between the warp ends to beat down the weft yarns into place and make the knots firm.

The nature of a knot and its insertion ensures that the tuft lies at a very acute angle to the *back* (or the *lie* of the pile as it is called). Because each tuft is quite separate from the next, the weaver has an unlimited field, both in the choice of pattern that may be produced, and in the number of colours that can be used.

In hand-made carpets, the key objective has been to cram as many pile tufts as close as possible together to give a luxurious pile. This is why these carpets have always had such a great reputation for luxury and quality. By contrast, however, in woven carpets made by modern looms, the utmost economy of pile yarn is often required because of its high cost. Consequently there is lower density of tufts by comparison.

As a finishing treatment, hand-knotted carpets are usually vigorously washed in water to cleanse them and to improve the uniformity of pile lay (Figure 22.6). Often the washing process is boosted by chemical solutions to increase the lustre, soften the colours and generally impart an antique appearance.

Figure 22.6 Washing of hand-knotted carpet in Indian carpet mill. Photograph supplied by E. Wood.

Gun tufting is another method of making carpets and rugs by hand, and it is virtually dedicated to wool (Figure 22.7). A single, hollow needle can insert a tuft of any colour anywhere in the carpet. Hence, this technique may be used to make artistic wool hangings or spectacular rug designs for luxury locations.

Figure 22.7 Mechanised hollow needle tufting gun. Source: Wools of New Zealand.

A manual method of inserting tufts is also used in developing countries (Figure 22.8).

Figure 22.8 Hand tufting in an Indian carpet mill. Photograph supplied by E. Wood.

22.5 Tufted carpets

Carpet tufting originated from the tufted bedspread (candlewick) industry in the USA in the 1920s. Crude tufted rugs began to be made by machine around the outbreak of World War 2 around Dalton, and the technique was soon improved for making broadloom (wall-to-wall) carpets.

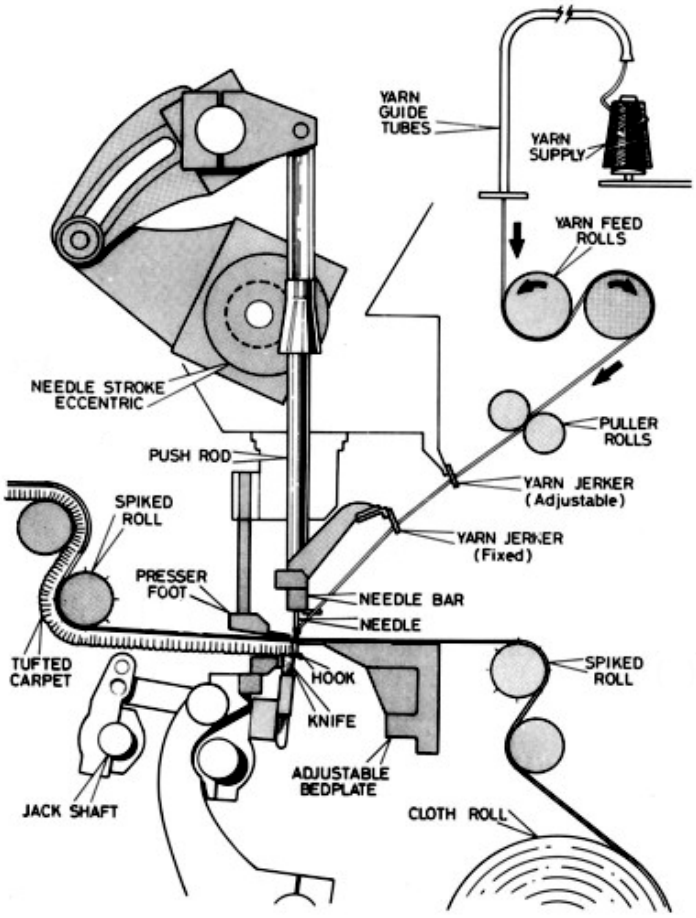
In the past 50 years the increase in the tufting of carpets has been phenomenal and today it is the dominant method of making carpets, using both man-made fibres and wool. The Dalton area can arguably claim to be the carpet manufacturing capital of the world. Factors in the growth of tufting of carpets include the steadily increasing range of cheap, synthetic fibres for carpets, a succession of innovative machinery developments and increased consumer affluence in the developed countries. Cobble Blackburn Ltd is the leading manufacturer of tufting machinery.

Tufting is a much more productive process than weaving by machine loom, particularly for plain carpet, but it is not as versatile in terms of patterning. As the complexity of a tufting pattern increases, the production rate becomes slower, but is still faster than weaving.

The tufting mechanism

Tufted carpets are formed by stitching loops of pile yarn from a *needle bar* carrying 1000-2000 needles into a pre-woven (or spunbonded) primary backing fabric. The needles oscillate up and down in unison, much like the action of a sewing machine needle and each is threaded with its own supply of yarn (Figure 22.9). A cutting mechanism is integrated with the loopers when a cut pile carpet is required.

Figure 22.9 Tufting machine mechanism. Source: Cobble Blackburn Ltd.

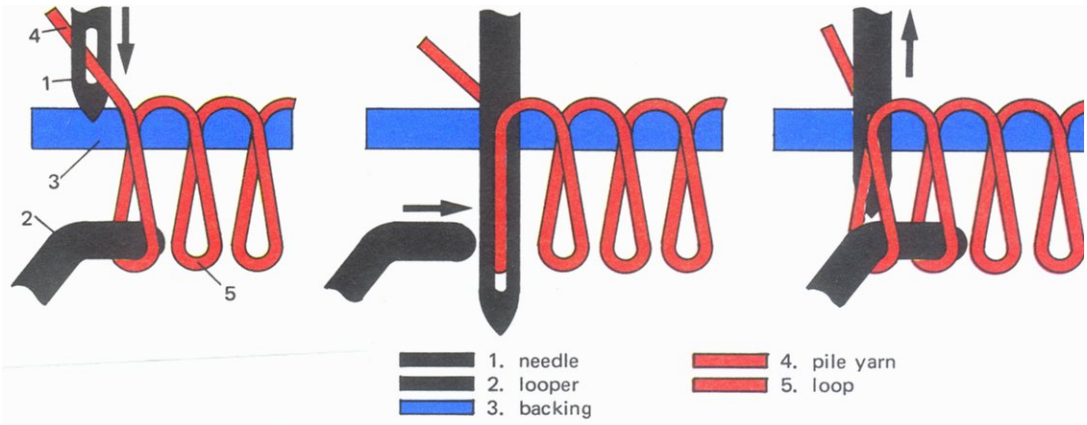


For the loop pile tufting cycle, the sequence of steps is as follows:

1. The pile yarn is fed from a creel or a beam
2. The positively driven feed rollers deliver to the needle the correct length of yarn to form the loop
3. The needle bar carrying the needle is given a vertical reciprocating motion by means of an eccentric shaft
4. On insertion of the needle through the backing cloth, the looper passes between the yarn and the needle, forming a loop as the needle rises
5. Once the needle bar is lifted clear, the backing fabric is moved forward by the spiked intake roller.

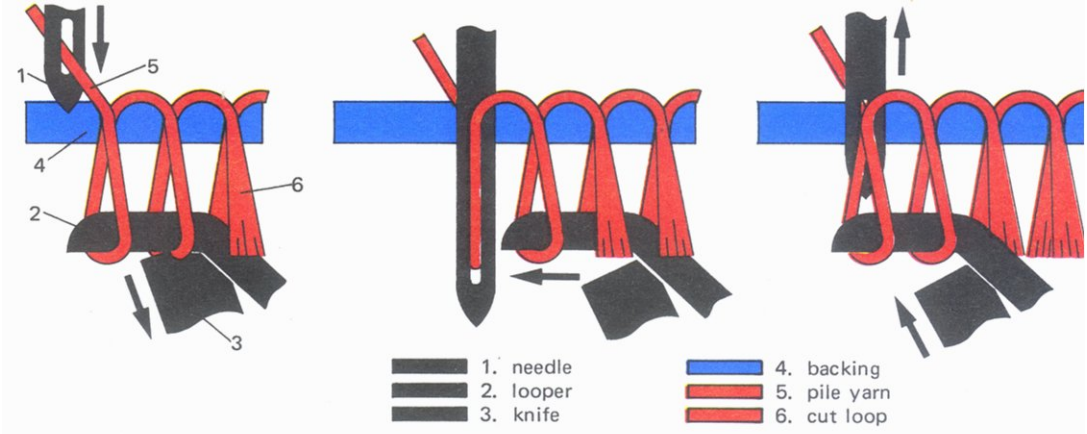
The looper approaches the fabric from the rear, allowing the loops to slide off after they are formed (see Figure 22.10).

Figure 22.10 Formation of a loop pile carpet. Source: Wools of New Zealand.



If cut pile carpet is being made, the loops are captured by the looper hook and a knife cuts each loop in turn, as shown in Figure 22.11. Note the different looper shapes and directions in Figures 22.10 and 22.11.

Figure 22.11 Formation of a cut pile carpet. Source: Wools of New Zealand.



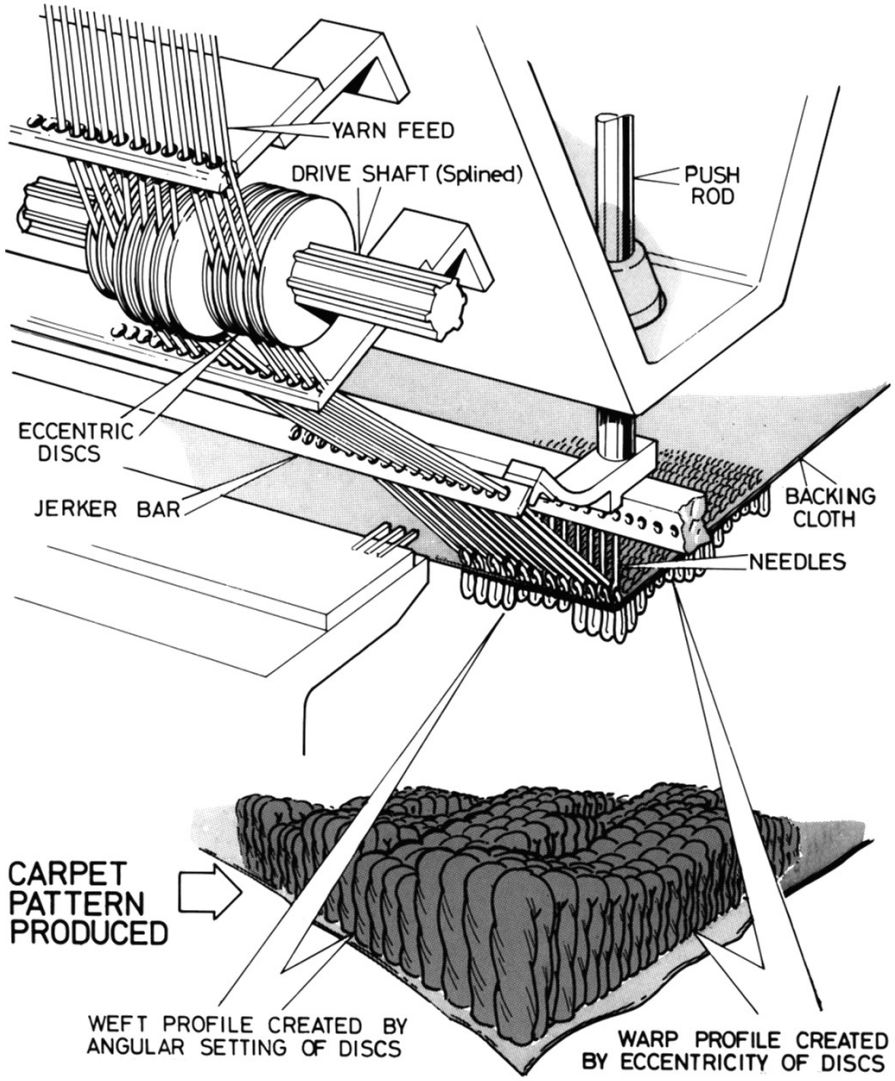
Typical machine gauges are 5/32", 1/8" and 1/10", and stitch rates can be as high as 16 per inch (or 6 stitches per cm) on fine gauge tufting machines. Pile heights vary typically between 3.5mm and 10mm for carpets destined for commercial locations.

Patterning of tufted carpets

Many wool carpets are manufactured without using a patterning mechanism, so that product variety is provided by the pile texture, in which yarn engineering plays a major part.

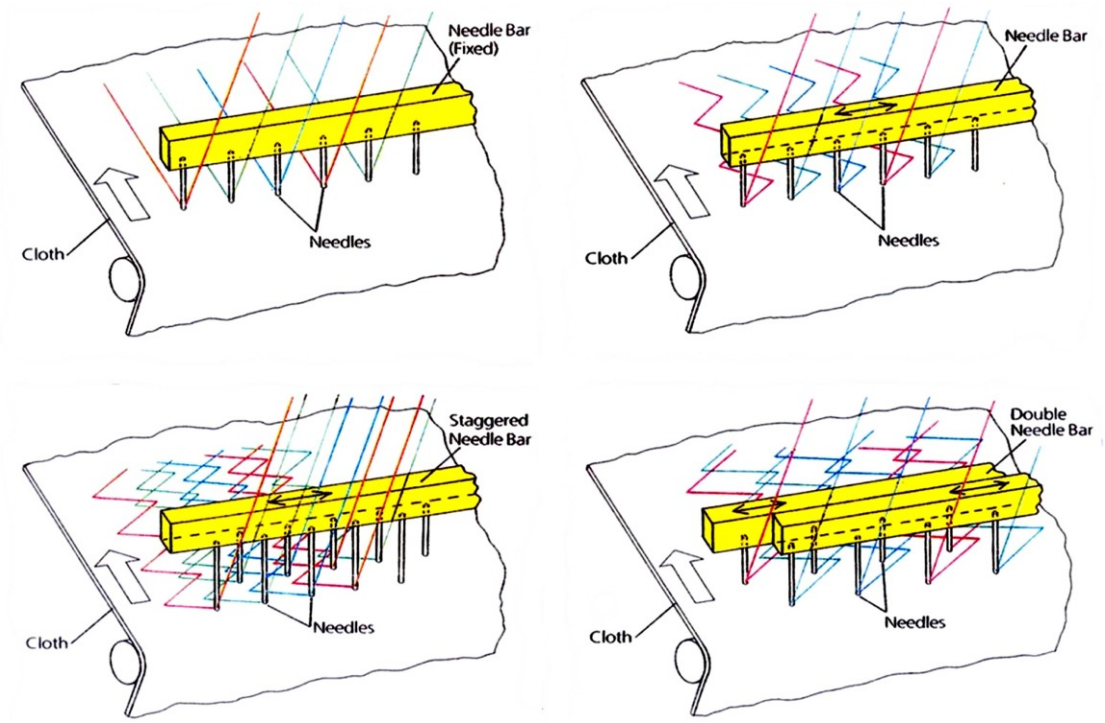
- The three principal techniques for mechanical patterning in tufting are yarn tensioning, cross-over tufting and independently-controlled needles (ICN): **Tensioning systems** can be used to produce sculptured carpets composed of high and low loops, and the colours in a low loop can be buried under high loops of a different colour to produce two-colour designs. Figure 22.12 shows one relatively simple type of yarn tensioning system where eccentric disks introduce alternately high and short loops as they rotate. The angular positions of the disks can be altered to produce a range of high/low pattern effects.

Figure 22.12 Eccentric cam yarn tensioning system for producing variable height loops. Source: Cobble Blackburn Ltd.



- Using one or two needlebars that can slide laterally under the control of stepping motors, and with different colours of pile yarn fed to the correct needles, the colours in a carpet can be transposed to create simple geometric designs. More elaborate effects can be achieved by combining the two mechanisms (varying tension plus sideways shift). Figure 22.13 shows different needle bar actions to produce zig-zag shifts in yarn position in the primary backing
- A single needle bar machine with **individually controlled needles** allows the overtufting of a precise cut-pile pattern into a base fabric that has been produced by a conventional tufting machine. Each individual needle can be activated or deactivated by a computer pattern selection system.

Figure 22.13 Sliding needle bar systems for patterning. Source: Wools of New Zealand.



It is in the area of patterning mechanisms that the most impressive advances are being made in carpet tufting technology today. The most sophisticated systems combine tensioning devices with cross-over tufting mechanisms.

Finishing of tufted carpets

The tufted cloth, whether it is loop pile or cut pile, has a synthetic latex coating applied to the primary backing, and a secondary backing material of woven jute fabric or another fabric is then attached. The latex is cured by heating. This process is called *backcoating*.

The main functions of the secondary backing are to anchor the tufts (or loops) and to give the carpet dimensional stability. In some cases a foam backing, which acts as a cheap underlay, may be applied. For locations where an impervious backing is required, such as in hospitals, a more rigid polymer backcoat such as polyurethane is applied. The so-called *unitary* backed carpets have no separate secondary backing but a thick coating of latex is applied. These are only suitable for direct stick installations where the carpet is glued to the floor.

The two ends produced in a cut-pile carpet differ in slightly in length due to the cutting action. A light *shearing* (or cropping) treatment is usually given to trim cut pile tufts to produce a smooth uniform surface.

22.6 Woven carpets

Weaving is the traditional method of making carpet. Woven carpet is often referred to as either Axminster or Wilton – these are types of weaving looms. Carpet-weaving industries developed in Brussels, Belgium, and, in the 1700s, in Wilton, Axminster, and Kidderminster, England. The French inventor Joseph-Marie Jacquard devised the mechanism for figured weaving in 1800 and it was first used in Wilton.

The first carpet factory in the United States was founded in 1791 in Philadelphia by W.P. Sprague, and the second, in Worcester, Mass., in 1804. Erastus Brigham Bigelow revolutionized the industry when, in 1841 in Lowell, Mass., he introduced the first power loom. Bigelow used steam to power an ingrain (flat-weave) loom. Later he perfected a power loom to make a Brussels, or looped-pile, woven carpet. The Axminster power loom was developed in 1876 by Halcyon Skinner, based on an idea by Alexander Smith.

In woven carpet, the entire structure of pile and backing is assembled simultaneously in a single operation. Fine threads run the width of the loom (the *weft* threads) and down the face of the loom (the *warp* threads). Individual tufts are cut to length and inserted in the loom between the weft and warp threads. These threads are tightened, locking the tufts into place. Both Axminster and Wilton carpets have a light adhesive coating applied to complete the carpet. Unlike a tufted carpet, which is a sandwich of the pile, primary backing and secondary backing, a woven carpet is an integrated fabric from front to back.

Wilton (or wire loom) weaving

Wilton weaving is a versatile system which can be used to create many different pile textures. Carpets manufactured in this way are particularly suited to contract use because of the ability to achieve low, dense piles with a high product weight and firm handle. Wire loom weaving also provides the opportunity to produce carpets in cut, loop or cut and loop constructions, with a variety of textures and up to six colours (frames). However, for reasons of cost, two or three colours are more usual.

Figure 22.14 shows the construction of a 5 frame, three shot Wilton carpet. Each colour in the pile is a frame, while the number of weft yarns associated with each pile loop (before cutting) determines the shot of the carpet (in this case 3). This carpet also has two stuffer warps. Notice the large amount of yarn that resides in the backing – this is called "dead yarn" because it does not contribute significantly to the performance of the pile.

Figure 22.14 Wilton weave structure (5 frame, 3 shot). Source: Wools of New Zealand.

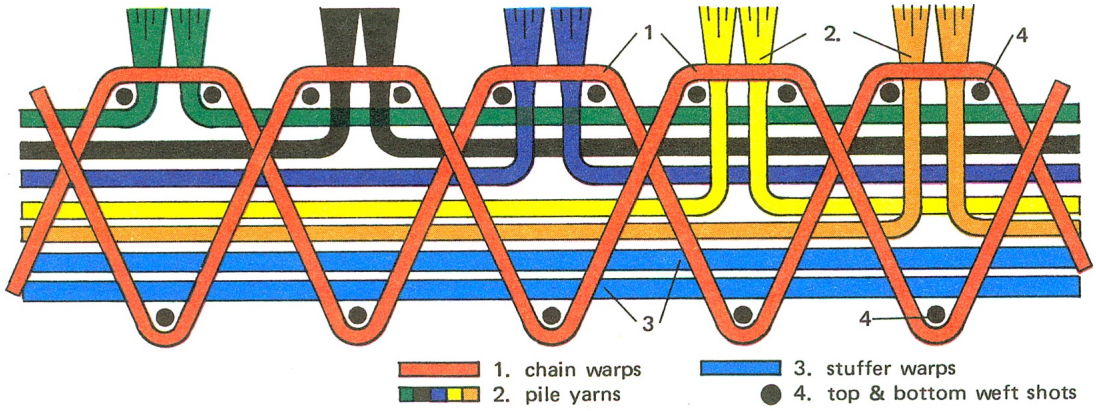
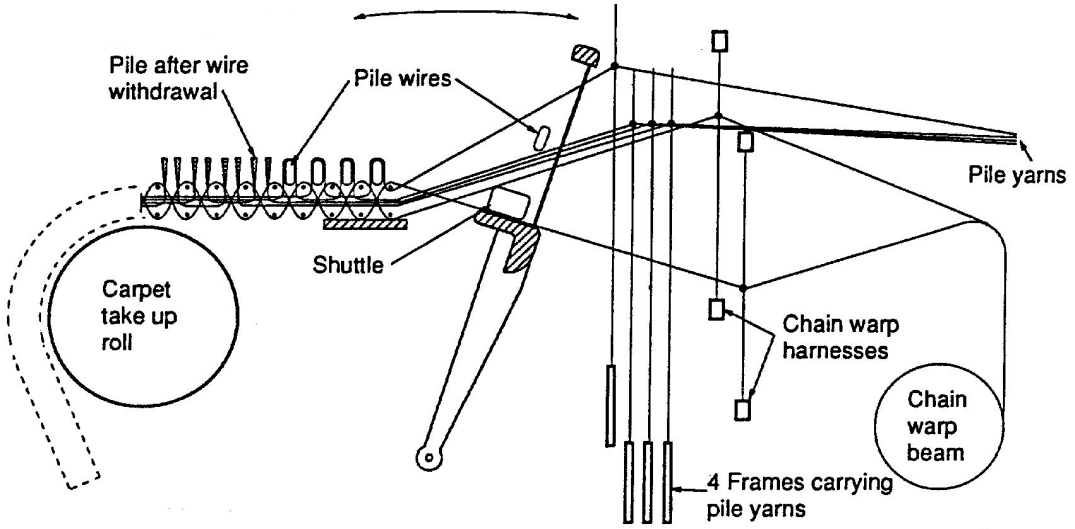


Figure 22.15 shows how wire after wire is woven into the fabric, to be withdrawn later. One set of the pile yarns (frames) is raised to form each crosswise row in the pile, while the remaining three are "dead" in the backing.

Figure 22.15 Wilton mechanism (4 frame loom). Source: Wood, 2006.



Good quality Wilton carpets are woven with five or six frames, which limit the range of colours in a pattern to six. Because of the high density of tufts in the pile they are durable and hardwearing. Because they produce cut pile carpets with a very level surface only minimal cropping or shearing is required. They are back-coated to improve tuft bind.

Multi-colour (ie, multi-frame) Wilton weaving is controlled by a jacquard mechanism which selects the correct yarns drawn from packages on a creel across the width of the machine. The yarns selected by the jacquard are raised and laid across a wire; those not required for that row of the pattern are not raised and become 'buried' beneath the surface pile in the backing of the carpet. These buried yarns give the carpet its weight and dimensional stability. The shuttle contain the weft backing yarn then whips across, interlacing the warp backing yarns and binds the pile into place. By now, other wires have been laid across the width of the machine and a new yarn selection has taken place by the jacquard.

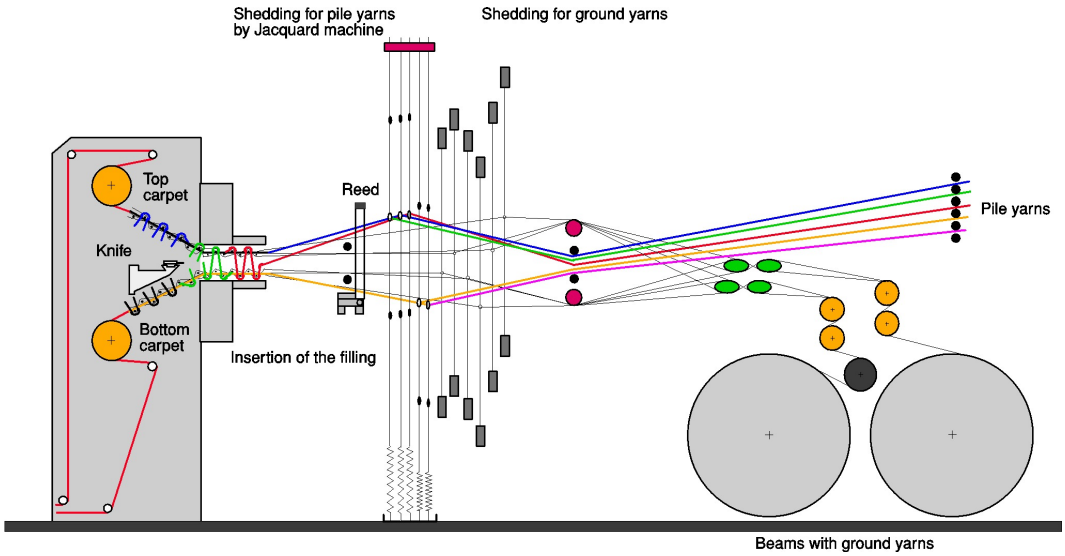
There may be 20 – 50 wires in a set, and in due course those inserted at the beginning of the cycle begin to withdraw, ready for re-insertion during the next sequence. If the carpet is a cut pile construction the end of each wire is fitted with a blade which cuts the loops as it is withdrawn. In a loop pile construction (*Brussels Wilton*) the wires are oval in cross-section without a blade at the end.

The Wilton method involves high material costs because yarns not appearing in the design are still present in the carpet as "dead" pile. The production rate of face-to-face weaving is higher than that of wire loom weaving, and this has lead to a trend towards face-to-face weaving.

Face-to-face weaving

The face-to-face system produces two carpets with the same amount of dead yarn as one wire-loom carpet, so material costs are lower. Two fabrics are woven; one above the other and pile warps are interlaced between the two, forming a 'sandwich'. The pile warps are cut by a knife, which separates the fabrics, to give two carpets (Figure 22.16).

Figure 22.16 Face-to-face weaving loom. Source: Michel Van de Wiele NV.

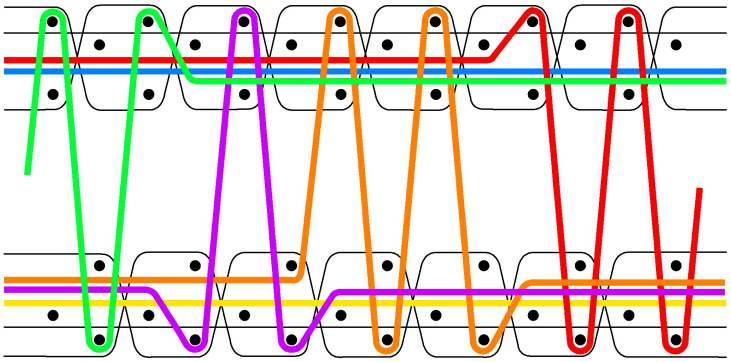


Elaborate designs are often made by the face-to-face process. The different colours of the pile yarns, which are controlled by a jacquard mechanism, create the design of the carpet. Up to 14 colours can be used and only one colour is making the pile at any time – the remaining colours are incorporated in the backing of the carpet as 'dead pile'.

It is the most productive method available for making woven carpets. It is particularly useful for producing rugs from fine pile yarns to traditional hand-made or modern designs.

Figure 22.17 shows a face-to-face weave structure. Many other structures are possible.

Figure 22.17 A face-to-face weave structure. Source: Michel Van de Wiele NV.



Axminster weaving

The general advantages of the Axminster method as a carpet manufacturing process are:

- Almost unlimited possibilities for colour and design
- High proportion of effective pile (no 'dead' pile or buried loops as with Wilton carpets)
- Wide variety of constructions, but only in cut pile
- Highly suitable for wool (ease of cutting)
- Patterns of textures as well as colours can be produced, with the possibility of using pile yarns of different counts or twist levels
- Simplicity of mechanism and ease of maintenance
- Ability to change carpet qualities very quickly
- Good quality backing

Despite the superior economics and efficiency of tufting, the above advantages have been responsible for Axminster carpets retaining a significant share of the global carpet market.

Three different techniques are available for weaving Axminster carpets, and these depend on the operating principles of the loom. They are known as:

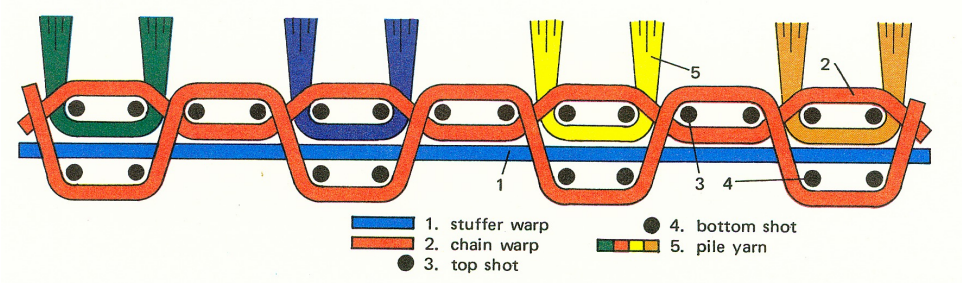
1. Spool weaving
2. Spool-gripper weaving
3. Gripper-jacquard weaving

Spool Axminster is still used today but because these looms are no longer manufactured the technique is becoming less common. In Spool Axminster carpet weaving the tufts are positioned between the ground warp threads **before** being cut from the length of pile yarn.

In Gripper Axminster carpet weaving the tufts are positioned between the ground warp threads **after** being cut from the length of pile yarn. The Gripper method is the more versatile than Spool Axminster method, and this has been enhanced by the introduction of electronic jacquards to control the colour selection. These are favoured in mills where relatively short production runs are required.

Figure 22.18 shows the structure of a typical Axminster carpet (3-shot) Note that in Axminster weaves, shots are double (two threads per shot). The term *shot* refers to the number of weft insertions of the backing per row of tufts across the carpet.

igure 22.18 Axminster weave structure (3 shot Corinthian weave). Source: Wools of New Zealand.



Two types of weave are made by the Axminster process. The *Kardax* weave takes the pile yarn through to the back of the carpet so the design is visible, as in hand-knotted carpets. This weave is usually used when weaving rugs to resemble hand-knotted carpets. A firm backing structure and tuft bind is achieved so that it is not necessary to backsize the carpet.

The ability to see the back is irrelevant for broadloom carpets for wall-to-wall installation, so a *Corinthian* weave is used, which is slightly more economical in pile yarn usage. A 'ridgeback' effect is produced and the carpet flexes easily in the weft direction. Sizing or latexing is usually carried out to make the backing firmer and to improve the tuft bind.

Spool Axminster

The first stage in Spool Axminster weaving involves spool setting, the winding of the coloured yarns on to spools. Operators working from the pattern design place packages of dyed yarn on to a table in the order in which they are to appear in one row across the carpet. The yarns pass through a reed, and a measured amount is wound on to a spool.

For example, depending on how many spools are used, 10-12 metres could be required for 500 metres of carpet with a tuft length of 2 cm. Each spool is numbered to correspond to its place in the design.

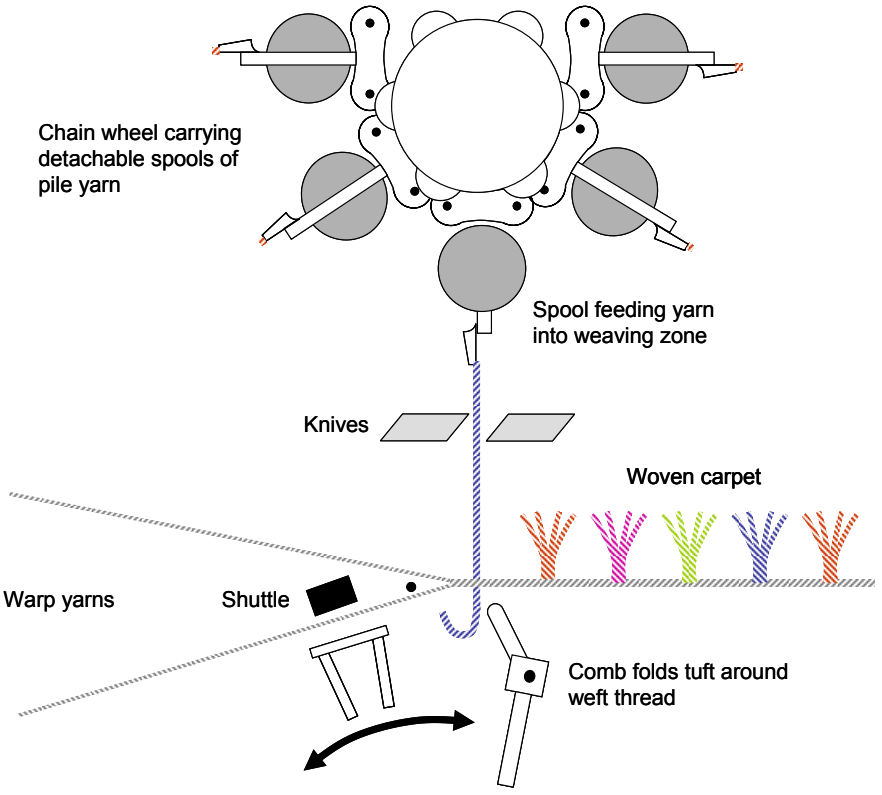
After setting, the full spools go to the threading machine, which pulls the yarn ends through the tubes on the spools. These tubes guide the yarn ends to the tuft weaving area. The tufts are positioned between the ground warp threads before being cut from the pile yarns wound on the spools.

When the tuft is placed, a comb turns the tuft round the weft shot and holds it in place until a further shot is inserted to bind the tuft into the carpet. When the tuft has been placed the spool forming the next row of the pattern is brought into position, as so on.

The labour intensive nature and relatively slow production of the spool Axminster process has caused this method to be mostly replaced by the gripper methods. Few looms of this type are still in use today.

Figure 22.19 shows the spool Axminster weaving process.

Figure 22.19 Spool Axminster mechanism. Source: Wood, 2006.

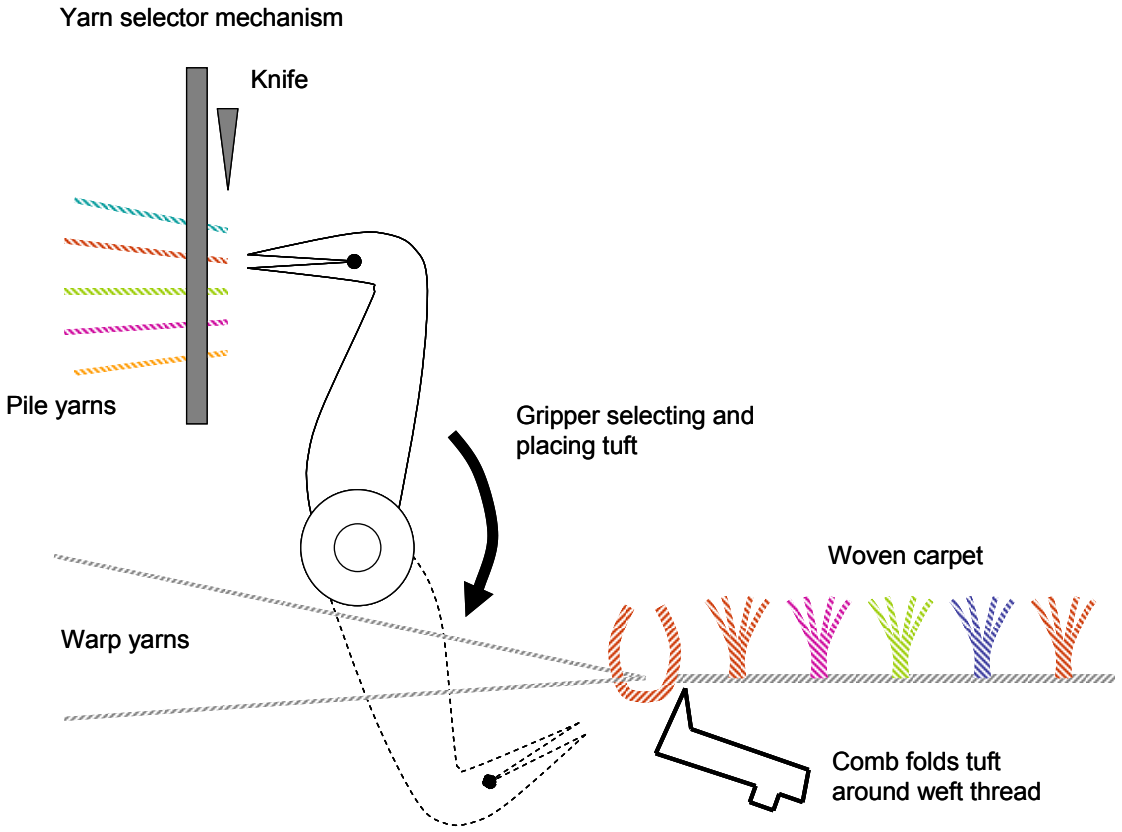


Gripper-Jacquard Axminster weaving

The Gripper-Jacquard Axminster method differs from the traditional spool Axminster carpet weaving in not requiring spool setting; hence it is more economical.

The loom has a series of beak-like 'grippers', one for each tuft across the width of the carpet being woven (Figure 22.20). The yarns are fed to a selection mechanism from a creel, which holds the packages of yarns in a sequence determined by the design. A selector mechanism, controlled by an electronic Jacquard device, chooses the tuft for each beak on each row.

Figure 22.20 Gripper Axminster mechanism. Source: Wood, 2006.



The jacquard device operates as follows: the presence (or absence) of a hole in the punched card (or the action of a solenoid in the case of an electronic jacquard in modern machines) determines, for every tuft across the machine, which colour should be presented by the yarn carrier to the gripper mechanism. As one, all of the grippers reach forward, the jaws open, and an end of yarn is gripped from the yarn carrier. The jaws close on the yarn and the grippers begin to rock backwards, withdrawing the yarns as they move. Once the required length of yarn has been withdrawn for a given tuft length, a blade operates across the loom, cutting the yarns into individual tufts. The gripper mechanism then continues to rock backwards to the weft insertion point, at which time the shuttle is whipped across the loom. This binds one end of the tuft in place as the weft interlaces with the *chains* and *stuffer* yarns of the warp. The grippers then begin to return forward, placing the other leg of the tufts in position to be bound by another shot of the weft. The jaws finally open to release the tuft and move to grip the next end of yarn as presented by the yarn carrier.

Spool-Gripper Axminster weaving

In Spool-Gripper Axminster weaving, the yarns for presentation to the grippers are wound on spools. The spools are held by a *fret* or frame that extends across the width of the loom. The frets are suspended by a chain from a gantry above the loom. For a pattern that repeats over, say, 100 rows, there will be 100 frets (or a multiple of 100).

Spools are wound with the required sequence of colours as required by the pattern, in the same manner as for Spool Axminster weaving. The chain brings the frets of spools to the weaving position ready for selection by the grippers. The weaving sequence is then similar to that of a Gripper-Jacquard loom; the ends of yarns protruding from the spools are each selected by a separate gripper which rocks back and implants the tuft at the weaving point.

After the first row of tufts has been inserted and the grippers begin to move up to select the next series of tufts for the next row in the design, the chain brings a new fret of spools to the gripper position. And so the cycle continues.

Spool-Gripper weaving is faster than Gripper-Jacquard weaving because in the former the distance travelled by the gripper is shorter and the delay necessary for the jacquard mechanism to operate is avoided.

Finishing of woven carpets

Woven carpets do not require a secondary backing to be applied. However, a thin coating of latex, called *backcoating* is applied to the back of the carpet to remove all creases and folds from a woven carpet, improve tuft bind, promote good dimensional stability and prevent broadloom carpets from fraying when they are cut for installation. In loop-pile carpets the tuft bind must be particularly strong to prevent 'laddering'. The application of steam in this process causes the tufts to bulk and give improved pile cover and handle.

Cut pile woven carpets and rugs require shearing to produce a smooth even surface. Hand-made rugs may be shorn by machines that are passed by hand over the carpet (Figure 22.21), and carving to accentuate design areas in a gun tufted rugs is also common.

Figure 22.21 Finishing of a hand made carpet in an Indian mill, Photograph supplied by E. Wood.

Summary of carpet types

Type/description	Special characteristics
TUFTING	
600 – 2000 rows of pile yarn are simultaneously stitched through carrier fabric (primary backing)	Most popular method for carpet manufacture (> 90%)
	Textural flexibility achieved with varying colours, surface textures, using various types of yarn etc.
Cut pile Carpet pile surface with all of the yarn tufts of the same height	Patterned effects created using different yarn colours
	Geometric designs created with shifting needle bar attachment
Loop pile	
Level loop	All loops of same height from row to row
Multilevel loop	A patterning attachment is used to achieve different pile heights in a pattern repeat
Cut and Loop	
A combination of cut and loop pile	Varying levels of pile height and pile textures create interest
WEAVING	
Coloured pile yarns and backing yarns woven simultaneously into finished product	Most often used in commercial locations
	Heavy, firm hand, high durability
Wilton	
Carpet made on Wilton (or wire) loom	Capable of intricate patterning, styling and colouration versatility
Loop (Brussels) or cut pile	Withstands intense traffic so mostly used in busy commercial locations, also rugs
Level surface or multilevel	Durable, dense, bends all ways
Face-to-face	
Two carpets are woven simultaneously	The fastest method of weaving a carpet
Axminster	
Carpet made on Axminster loom (3 types)	Offers wide range of colours and patterns
Cut pile only, mostly single level	Withstands heavy traffic
	Durable, ends only in one direction
KNITTING *	
Warp-knitted yarn fabricated on face and back simultaneously. Pile, backing and stitching yarns are looped together by three sets of needles	Similar to woven carpet but less stiff
	Mostly solid colours
	Quality depends on amount of pile yarn and strength of attachment of the face, chain and backing yarns
NEEDLEPUNCHING *	
Web of fibres moves through machine. Barbed felting needles penetrate and entangle fibres into durable felt-like fabrics	Usually made from solution-dyed polypropylene
	Diverse range of designs
	Only used in glue-down situations
BONDING *	
Yarns are implanted into vinyl or thermoplastic coated backing	Often dye-cut for modules (tiles)
	Cut-pile produced by slitting two parallel sheets of face-to-face carpet

Readings

The following readings are available on CD:

1. Meade, W.J. Recent progress in carpet technology. Warren Meade, Research Leader, Physics and Consumer Products Division. Wool Research Organisation of New Zealand (Inc) courtesy Canesis Network Ltd., Christchurch, New Zealand.
2. Wood, E.J. Patterning techniques for Tufted Carpets. Canesis Network Ltd., Christchurch, New Zealand.
3. Wools of New Zealand, Carpet Technical Information Bulletins.

- Broadloom tufting
- Axminster weaving
- Wilton weaving
- Carpet finishing
- Backcoating technology

Activities

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Submit answers via WebCT

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Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCt

Summary

The history of carpets is entwined with the history of human civilization, and rugs and carpets have been prized possessions through the ages. Today there are three principal methods of making wool (and wool rich) carpets and rugs: knotting, weaving and tufting. Hand-knotting of rugs is mostly carried out in countries where labour costs are low, such as India, China, Nepal and countries of the Middle East.

Over the past 50 years tufting has become the dominant method of carpet manufacture. While it cannot offer the huge flexibility in design that is available in machine weaving, the patterning scope is increasing as a result of technological innovation.

The share of the global market for wall-to-wall woven carpets has as the same time declined in relative terms, but a significant quantity of wool is used in this sector, and it continues to be the major fibre for quality machine-made rugs. Woven products have retained their importance for the contract carpet market and upper segments of the residential market. Improved weaving technologies have contributed to this, as well as the ongoing popularity of wool in prestige locations.

This lecture examines the various machines that are used to make the diverse range of wool carpets available today, from the simple hand-knotting loom to the highly sophisticated face-to-face weaving loom.

References

Cobble Blackburn Ltd. 'An Introduction to Tufting'. Published by Cobble Blackburn Ltd., Blackburn, United Kingdom.

Crawshaw, G.H., 2002, iCarpet Manufacture, *WRONZ, ISBN 0-908974-25-6*

Crawshaw, G.H., 2003, Textile Floorcoverings Updated, Textile Progress, volume 34, No. 34, The Textile Institute, ISBAN 1870372573

Michel van de Wiele, NV. Images supplied by G. Crawshaw, author of 'Carpet Manufacture', by Mich van de Wiele NV., Belgium.

Wools of New Zealand. Images supplied courtesy of Wools of New Zealand Ltd., Christchurch, New Zealand.

Glossary of terms

Abrasion resistance	The ability of carpet pile fibres to resist dulling or wear through the abrasive action of foot traffic
Antimicrobial carpet	Carpet chemically treated to reduce the growth of bacteria, fungi, mould and mildew
Antistatic	The ability of a carpet to dissipate an electric charge before it reaches the threshold of human sensitivity
Appearance retention	The ability of a carpet to keep its original appearance (ie, texture, colour) in use
Axminster	A method of making a carpet where individual tufts are inserted during weaving in a pre-arranged colour sequence. The four types of Axminster weaving are spool, gripper, spool gripper, chenille.
Backcoating	A carpet finishing process which involves the application of a secondary backing, foam backing or a thin coating of latex, depending on the type of carpet or rug
Backing	Materials (fabrics or yarns) comprising the back of a carpet as opposed to the carpet pile or face. This includes the primary backing, secondary backing and backing formed in making a woven carpet
Beam	A large cylinder onto which carpet yarns are wound prior to feeding into a carpet loom or tufting machine
Beck (or winch) dyeing	Dyeing of tufted greige (undyed white) carpet as a continuous loop in a large vat of dye liquor
Berber	A type of wool carpet made from thick yarns in natural colours (ie, undyed) containing colour effect material (neps, flecks or flames)
Blend	A mixture of two or more fibres (or wool types)
Broadloom	A term for carpets produced in widths exceeding 2 metres (6 feet)
Brussels carpet	A woven loop pile carpet produced by the Wilton method
Chemical setting	Stabilising the twist in a wool yarn by immersion in a hot solution of sodium metabisulphite
Colourfastness	The ability of the pile fibres to resist fading and discolouration by the action of light, wet cleaning or other agents
Continuous dyeing	Dyeing of carpet (greige) while it travels continuously through machinery and dye flows evenly onto its surface yarn
Continuous filament	An unbroken strand of synthetic fibre such as nylon – formed by extrusion of a molten polymer through spinneret holes
Creel	The rack or frame next to a tufting machine which holds the cones of pile yarn that feed into the needles of the machine and enables the cones to unwind smoothly without tangling
Creeling	The operation of place yarn packages on a creel
Cropping (or shearing)	A finishing process that trims the surface fibres of a carpet pile to produce a smooth even surface

Cushion (or underlay)	Material placed under a carpet (or attached to it) to provide softness and adequate support when walked upon
Cut pile	A pile surface created by cutting the loops of yarns formed in a tufted or woven carpet
Cut and loop pile	A carpet in which the face is a combination of cut ends of pile yarns and loops
Dead yarns	The pile yarn in a Wilton carpet that remains hidden in the backing structure when not forming a pile tuft (or loop)
Delamination	A form of deterioration of a tufted carpet in which the primary backing separates from the secondary backing
Dimensional stability	The ability of a carpet to retain its original size and shape once installed. A secondary backing helps this.
Durability	The ability of a carpet to resist wear over a long period.
Face-to-face weaving	A carpet weaving process where two base fabrics connected by pile yarns are woven simultaneously. The yarns are then cut to produce two carpets that are mirror images of each other
Finishing (carpet)	The processing of carpets after tufting or weaving, including application of secondary backing, application of foam backing, steaming, soil resist treatments, shearing and brushing
Finishing (carpet yarn)	The final step for a carpet yarn, involving scouring, setting and the application other treatments such as insect resist agents
Fluffing (or shedding)	The accumulation of loose short fibre fragments on the surface of a cut pile carpet early in its wear life
Frames	Racks at the back of a Wilton loom holding spools from which yarns are fed into the loom. Each frame holds a separate colour.
Frieze (or frisé or hard twist)	A yarn that has been very tightly twisted and well set to give a rough texture to a carpet pile
Fuzzing	A hairy effect on a carpet surface caused by fibres working loose
Gauge	The number of ends of surface yarn across a tufted carpet, usually measured in ends per inch (ie, 1/8 gauge = 8 ends/inch). Also, the distance between the needle points.
Greige fabric	A ‘grey’ undyed fabric
Grinning	Visibility of the carpet backing between adjacent rows of tufts. This fault has several possible causes, including too low pile weight
Heather	A subtle multicoloured effect produced by intermingling yarns or spinning different coloured fibres together. Berber and tweed are similar types of yarn and are generally 100% wool.
Heat setting	A process for stabilising the twist in thermoplastic carpet yarns such as nylon
Hexapod Tumbler Tester	A rotatable drum (300 mm diameter) for subject carpet samples to simulated foot traffic. The samples line the inside wall of the drum. It uses a heavy metal tumbler with 6 protruding studs to impact with the carpet as the drum rotates for a specified number of revolutions.
Hook	A component in a cut-pile tufting machine which catches a loop as it is formed and holds it while the knife cuts it.

Indoor air quality	A term used to describe the quality of air breathed by the occupants of a building
Insect-resist treatment	A fibre or yarn treatment on wool to prevent attach by moth larvae and beetles
Jacquard	A device for a carpet weaving loom that produces a pattern from coloured yarns. In old versions the information was carried on punched cards; today computers control the jacquard mechanism.
Jerker bar	Part of a tufting machine comprising a moveable guide (eyeboard) through which the pile yarns are threaded. It controls tension on the pile yarns on their path to the tufting needles.
Jute	A natural (plant) fibre that is used in backing in woven carpets, or woven into fabric to become secondary backing in tufted carpets. Now gradually being replaced by fibreglass and polypropylene.
Latex	A water emulsion of synthetic rubber, natural rubber or other polymer. In carpets latex is used for laminating secondary backings to tufted carpet and backcoating woven carpets and rugs
Level loop	A carpet construction in which the yarn on the face of the carpet forms a loop anchored into the carpet back. The pile loops have the same height, making a smooth, level surface
Looper	The finger on which the loops are formed in a tufting machine, to produce a loop pile carpet.
Loop pile	A carpet pile surface where the face yarns remain continual loops, connected together beneath the backing fabric
Lustre	Brightness (or reflectivity) of fibres, yarns and fabrics. Synthetic fibres are produced in various lustre classifications
Matting	Severe pile crush combined with entanglement of fibres and tufts
Mending	Hand repair of carpet after tufting and weaving to replace missing tufts, remove knots and loose ends, etc.
Nap	Carpet or rug pile surface; the direction of the pile
Needle	An eyed needle that inserts yarns into primary backing to form tufts
Needle bar	This holds the tufting needles and reciprocates up and down to produce the tufting action
Nonwoven	A fabric manufactured directly from fibres or filaments, or from a web of fibres, without the need for weaving, knitting or tufting
Nylon (or polyamide)	A petrochemical-based fibre invented in 1938 by DuPont in USA. There are two basic types: nylon 6 and nylon 6,6. It is produced in bulked continuous filament and staple fibre.
Olefin (or polypropylene)	A fibre (or sheet or film) made from a by-product of the petroleum industry. Available as either bulked continuous filament or staple fibre. In carpets has a lower life expectancy than nylon.
Package dyeing	The yarn is wound on perforated tubes and the packages are dyed by passing dye liquor through the packages under pressure.
Pattern	Artistic decorative design of the surface of a carpet. It may be printed, woven with coloured yarns or sculptured in multiple pile heights.
Piece dyed	Carpet dyed by immersion in an aqueous dye bath

Pile crush	Loss of pile thickness by compressing and intermingling of tufts caused by traffic and heavy furniture. It may be irreversible if the pile has inadequate resilience
Pile (face or nap)	The visible surface of a carpet consisting of yarns in a loop and/or cut configuration
Pile height	The length of a cut tuft, (or one leg of a loop), measured from its tip to the point where it enters the carpet backing
Pile (or tuft) density	The number of tufts per unit area
Pile thickness	The vertical distance from the carpet backing to the pile surface
Pilling	A condition of the carpet surface in which fibres from different tufts become entangled with wear to form small knots of fibre. The pills are anchored to the pile.
Pitch	In a woven carpet, it is the number of ends of yarn in 27 inches of width
Plied yarn	A yarn composed of two more single yarns twisted together; the most common form of yarn used in carpets.
Plush (or velour)	A smooth cut pile carpet, with a lower and more dense pile than a Saxony carpet. Each individual yarn end is less distinguishable than in a Saxony
Ply	A measure of the number of individual yarns twisted together to produce the finished yarn
Primary backing	The fabric into which the loops of yarn are inserted in tufting; mostly woven or nonwoven polypropylene.
Printed carpet	Carpet having a coloured pattern applied after finishing. Several different techniques are used, including jet injection, rotary screen and flatbed screen printing
Puckering	An installation defect in carpet seams in which one side is longer than the adjoining carpet edge. The excess gathers into wrinkles at the seam
Reed	Part of a carpet weaving loom consisting of thin strips of metal with spaces between then through which the warp yarns pass. The motion of the reed pushes fill yarn tightly into the fabric.
Resilience	The ability of a carpet pile to return to its original thickness after a compressive load has been momentarily applied
Rows or wires	In a woven carpet, this is the number of pile yarn tufts per running inch lengthwise. Analogous to stitches per inch in tufted carpets.
Rug	Carpet cut into room or area dimensions and laid loose.
Saxony	A cut pile carpet with well-set surface yarns that are even across the surface. The tufts are longer, placed more densely and have better tuft definition than in a plush carpet
Sculptured	Any carpet pattern formed from high and low pile areas, such as high-low loop and cut and loop
Seam	In carpet installation, the line formed by joining the edge of two pieces of carpet by various techniques – tape, hand sewing, etc.
Secondary backing	The fabric attached to the primary backing of a tufted carpet, usually with a latex adhesive

Shading (or pile reversal or watermarking)	An apparent colour difference between areas of the same carpet resulting from a random difference in pile lay direction. It arises from differences between the cut end lustre and side lustre of fibres.
Shag	A carpet texture characterised by very long pile tufts laid over in random directions so that the sides of the yarn form the traffic surface.
Shearing	See Cropping
Shifting needle bar (or sliding needle bar)	A patterning attachment for tufting machine involving a mechanism for moving one or two needle bars back and forth sideways to produce a zig-zag pattern
Shot	A weaving term for fill yarn, the yarn inserted at right angles to the warp across the fabric width. In woven carpet it is the number of picks of fill yarn per row of pile tufts.
Soil resist treatment	Application of a fluorochemical finish that gives low surface energy properties to carpet pile fibres. This inhibits wetting by oil and water based materials, and inhibits the attachment of soil
Sprouting	Emergence of long pile tufts above the normal pile surface. They can be removed by cutting with scissors before or after installation
Stain-resist treatment	Chemical treatment to minimise stains from food and drink colours
Static shock	Discharge of electric charge from a carpet to a person to ground (eg a doorknob). Shoe friction against the pile fibres causes the static charge to accumulate and various finishes can be applied to dissipate this charge before it builds to the human sensitivity threshold
Stitch length	Total length of yarn from which a tuft is made. It equals twice the pile height plus the associated backstitch behind the primary backing.
Stitches	Stitches per inch – the number of yarn tufts per running inch of a single tuft row in a tufted carpet
Stock dyeing	Loose staple fibres are dyed in a vat, before being blended, carded and spun into yarn
Streak	Any lengthwise narrow visible defect in a carpet. It may arise from soiling, a colour difference (dye shade) or texture difference (yarn twist or bulk)
Stripe	A more continuous form of streak
Stuffer	A backing yarn in woven carpet. Stuffers are normally warp yarns that increase weight, strength, handle, stiffness and stability.
Texture	Visual and tactile surface characteristics of a carpet pile, including high-low and cut-loop patterning, yarn twist, pile orientation.
Tip definition	Visible individual cut ends in a carpet surface
Tip shearing	Shearing off tufted high loops in the finishing process to create a cut/uncut texture
Total weight	The weight per square metre of the total carpet pile, primary and secondary backings and coatings.
Traffic	The passing back and forth of persons over a given carpet surface area
Tuft bind	The force required to pull out a tuft from a carpet surface
Tufting	A method of carpet manufacture in which surface yarns are sewn through a primary backing material

Turns per metre (tpm)	The number of times two or more yarns have been plied together in a one metre length
Twist	The number of turns in a yarn per unit length (ie, turns per metre). Twist direction may be left handed or right handed (Z or S twist).
Unitary carpet	Carpet used for glue-down installations that has an application of latex back coating to increase tuft bind performance properties without the addition of a secondary backing
Velvet texture	A smooth surface texture with individual tufts not visible, on a dense plush carpet
Vettermann Drum Tester	A rotatable drum tester for subjected carpet samples to simulated traffic wear. It uses a steel ball with 14 rubber studs rolling randomly inside the drum for a specified number of revolutions.
Warp	A weaving term for the yarns in woven fabrics and carpets that run lengthwise. They are usually delivered to the loom from a beam. Woven carpets usually have three sets of warp yarns, on separate beams (pile warp, stuffer warp and chain warp)
Weaving	A fabric formation process used for manufacturing carpet in which yarns are interlaced to form cloth. The loom interlaces lengthwise (warp) and widthwise (filling) yarns
Weft	Yarns which run widthwise in a woven carpet, interlacing with various warp yarns
Wilton	A type of woven carpet produced by a jacquard mechanism which uses a computer programme to select yarn colour. The carpets may have patterned or multilevel surfaces
Wires	Parts of carpet weaving looms composed of metal rods or blades on which the pile tufts are formed. Round wires form loop pile and flat, sharp wires form cut pile textures.
Woollen spinning	A spinning method which produces relatively bulky, hairy yarns suitable for carpets. Commonly used with wool.
Woven backing	The primary or secondary backing fabric used in carpet tufting.
Woven carpet	Carpet produced by a loom. Slower, more expensive and labour-intensive than tufting
Yarn count (or linear density)	The mass per unit length in a yarn (ie, tex = grams per km)