13. Wool Carpet Manufacture

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Learning objective

On completion of this topic you should be able to:

- List the key attributes of an ideal carpet fibre
- Briefly outline the properties of wool that make it a good fibre for carpets
- Compare the advantages and disadvantages of wool with the other major carpet fibres
- Describe the wool components of a typical carpet yarn blend
- Outline the raw material requirements for the various types of tufted and woven carpets
- Describe the main route by which wool carpet yarn is produced
- Briefly discuss the colouration options for carpets
- Explain the purpose of yarn setting and how it is carried out
- Define the terms used to describe the constructions of tufted 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
- Briefly outline the methods of making Axminster, Wilton and face-to-face woven carpets
- Discuss 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

Wool, nylon, polypropylene, yarn blend, mainstream wools, speciality carpet wools, filler wools, woollen route, semiworsted route, dry spinning, yarn, tufting, weaving, Axminster, Wilton, face-to-face carpet, loose stock dyeing, hank dyeing, setting, yarn count, twist (singles and folding), yarn tensile properties Carpet construction parameters, hand-knotting, hand-tufting, machine tufting, loop pile, cut pile, patterning mechanisms, finishing, Wilton weaving, face-to-face weaving, Axminster weaving, finishing, backcoating

Introduction to the topic

A carpet is a textile floor covering that combines an attractive appearance with warmth, and comfort for standing, walking or reclining on. Carpets bring many diverse benefits to homes and public spaces. For example, they

- add colour, texture and interest to interiors
- absorb noise to create a quieter, less distracting workplace
- insulate against heat loss and provide a warmer, softer surface to the touch
- are slip-resistant and absorb energy, reducing breakage of falling objects and injuries when people stumble.

The top layer of the carpet, which is subjected to foot traffic, is called the pile. It composed of millions of yarn segments, arranged in a compact formation as short loops or upright tufts.

Today's carpets come in a huge range of combinations of constructions, textures, colours and patterns. A carpet pile may be described in various ways, for example, in terms of:

- The pile fibres, eg 100% wool, 100% nylon, 80% wool 20% nylon, etc
- Method of manufacture : (a) woven – Axminster, Wilton, hand-knotted etc; (b) tufted

- The general pile construction: loop pile or cut-pile, and combinations of these two types
- Pile texture: eg, frieze, plush and velvet (cut pile types which differ in their levels of tuft definition)
- Pile colour and colour variation (design): plain shade, berber/heather or patterned
- Pile construction: tuft or loop spacings along and across the carpet, pile mass density, pile height and pile thickness
- Carpets suitable for good performance in heavy, medium and light foot traffic situations.

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 hand-knotted wool pile.

Wool has always been 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 main methods of making wool (and wool rich) carpets and rugs: hand-knotting, weaving and tufting (Figure 13.1). In hand-knotted and woven carpets the base fabric is formed and the pile yarn integrated at the same time, while in tufted carpets the pile yarn is inserted into a pre-formed fabric by needles.

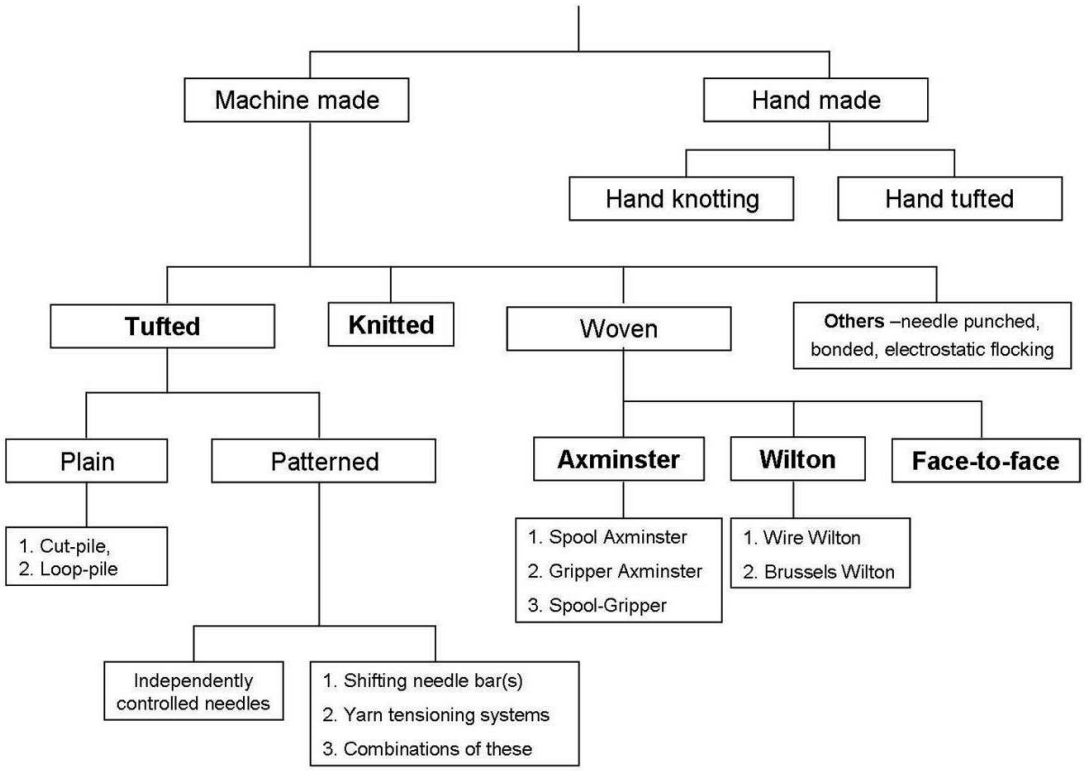

Figure 13.1 Methods of making wool carpets

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.

A comprehensive review paper covers recent developments in textile floor coverings, including fibres, manufacturing methods, design trends and performance (Crawshaw, 2003). The principal reference for this topic is the book by Crawshaw (Crawshaw, 2002).

13.1 Carpet fibres

The quality of a carpet depends largely on the properties of the fibres from which it is made. The ideal carpet fibre should have the following physical and chemical properties:

- Whiteness or near whiteness
- Easily dyed but fast to light, water, shampooing
- Adequate strength
- Good abrasion resistance
- Good resilience and resistance to compression
- Resistance to soiling and easily cleaned
- Unaffected by drycleaning solvents
- Flame resistant and unaffected by heat to be expected during service
- Not easily wetted and if wetted not requiring a prolonged period to dry
- Warm to handle
- Insect proof or easily rendered insect proof
- Low relative density to give good coverage per unit mass of fibre
- A moisture regain which is relatively high, and not so low as to cause a build up of static electricity when walked on
- Resistance to atmospheric influences and to the action of light.

The principal fibres used in modern commercial carpet manufacture are wool, nylon, acrylic, polypropylene and polyester. These fibres display the above features to varying extents. Man-made fibres are used in over 80% of carpets made today because of their consistency of supply, price stability, uniformity of quality and the durability that they impart to carpets.

Wool in carpets

Wool has a number a positive attributes that enable it to remain popular as a carpet fibre, especially at the top end of the market. These include:

1. Its ability to absorb up to 30% by weight of water vapour, providing a buffer to changing ambient conditions;
2. Odour absorption which improves indoor air quality;
3. A high resistance to soiling and easy cleaning;
4. High flexibility which enables the fibre to bend thousands of times without suffer permanent damage or deformation;
5. Yarns which are readily set so that the twist can be retained;
6. Relatively low flammability giving good protection from fire;
7. Low static charge accumulation under normal atmospheric conditions

Wool has been used from the earliest history of carpets because the early rug makers were nomadic sheep herders. Since then rug making has been associated with the technology of the wool industry and this tradition has provided the benchmark by which other fibres are compared.

Wools suitable for carpets are generally coarse, ie, with a mean fibre diameter greater than 34 micron. Over 65% of New Zealand wool is coarser than 34 micron, so that carpets are the most important end-use. New Zealand crossbred wools (33-37 microns) have an established reputation for high processing efficiency, they contribute to superior yarn strength and have an excellent base colour for dyeing to light shades. These wools therefore comprise many carpet yarn blends around the world. New Zealand wools compensate for the deficiencies of local or inferior wool types, which are also often included in woollen blends. Consequently, New Zealand is the dominant global supplier of quality wools suitable for carpet manufacturing.

The types of wool used in carpets may be classified into three main groups, termed general purpose, specialty and filler wools. These are used in differing proportions in blends, depending on the quality and type of carpet to be made.

(1) General purpose (mainstream) wools

These wools are used because of their good colour, strength, ease of spinning and good wearing properties. They also have the ability to carry inferior quality "filler" wools through manufacture. Examples are New Zealand crossbred fleece and second shear body wool, mostly obtained from the Romney and the closely-related breeds, the Coopworth and Perendale.

These wools can be further divided into two groups – lustre wools (which have a shiny appearance) and high bulk wools (which have a springy handle). The percentages of these two groups can be varied according to the effect required in the finished product. Lustrous wools are not generally favoured for most types of machine-made carpets because they tend to produce low bulk (lean) yarns, and the lustre can exacerbate the inevitable change in appearance of a carpet as it wears on the floor.

(2) Specialty carpet wools

The wools are sought for the special properties with respect to appearance and handle that they impart to a carpet. Examples are Drysdale, very coarse Romney crutchings and British wools such as Scottish Blackface. These wools tend to have higher levels of medullation than the general purpose wools. The presence of medullation gives a desirable crisp handle.

The main producers of specialty carpet wool in Australia are the Drysdale, Tukidale, Elliotdale and Carpetmaster breeds (Cottle, 1991), (Kajons, 1991). All except the Elliotdale were developed in New Zealand.

(3) Filler wools

These wools tend to be short, discoloured, generally of inferior style and are used simply because of their cheapness. Examples of suitable New Zealand wools are locks, second pieces, second crutchings, bellies, dag wool and stained wool. However, the ability to use these cheaper wools is often dictated by the style of carpet. Where a pale shade is required, less of these poorer wool types must be used.

Man-made carpet fibres

During the twentieth century there was a search for low-cost carpet fibres that could match the properties and performance of wool. These man-made fibres are of two types, *regenerated* fibres and *synthetic* fibres.

Regenerated fibres have the same fundamental chemical constitution as the raw material, although in a different physical form. For example, viscose rayon is manufactured from the cellulose in wood pulp.

Synthetic fibres are made from polymers built up from simple molecules. Using raw materials from the petrochemical industry, the fibres are extruded by forcing a thick mixture of chemicals in a hot melted state through microscopic holes in a device resembling a shower rose, called a *spinneret*. The emerging thin filaments are solidified and twisted together to form a yarn.

Synthetic fibres can be 'engineered' to exhibit special qualities for specific purposes in the end product. They can be manufactured in a range of denier sizes (ie diameters) and are available as continuous filament or as staple fibre. Heat setting or *texturizing* introduces artificial crimp. Many fibres are spun in different shapes of cross-section and may have a bright or matt finish.

Dull finishes are obtained by incorporating white pigments such as titanium dioxide into the melt prior to extrusion, or by inserting tiny voids within the fibre to scatter light. Coating fibres with a fluorocarbon film helps to prevent soil and stains adhering to the surface, and stains from spreading.

Nylon (or polyamide) weighs less than any other carpet fibre, hence a lower mass of this fibre is necessary in carpet construction. The nylon fibre absorbs very little moisture. Extra resilience and cover in carpets is provided by heat-set crimping of the nylon, attempting to imitate the superior resilience of wool.

Polypropylene is the newest of the carpet fibres. Polypropylene polymers form a filament that has a similar strength to nylon. The chains of simple hydrocarbon molecules are in an orderly arrangement.

Table 13.1 compares the strengths and weaknesses of the three main carpet fibres: wool, nylon and polypropylene.

Table 13.1 Comparison of major carpet fibres. Source: Wood, 2006.

Fibre	Assets	Drawbacks
Wool	Best soiling resistance Good cleanability Good texture retention Flame resistant, self- extinguishing More resilient than acrylic, polyester or polypropylene Good thermal insulation Moisture buffering indoors	Most expensive fibre Higher intrinsic variability than synthetics Not as resistant to abrasion as synthetics Static level high under low humidity conditions Not all stains can be removed
Nylon	Most durable, hard wearing, versatile Maintains its appearance, but not quite able to match wool Performs well at low pile weights Good texture retention Good cleanability in soil-hiding forms	Higher soiling propensity than wool Static level very high Will fuse and melt with heat Poor colourfastness Susceptible to degradation in sunlight
Polypropylene	Very durable, hard wearing Excellent stain removal Low static level Fade resistant Solution dyed fibre very colour fast	Poor texture retention Poor resilience Susceptible to soiling, oil-based stains Limited colours, poor dyeability Low melting point - melts and fuses with heat Scarred by frictional heat Limited resistance to organic solvents

13.2 Yarns for carpets

The carpet industry uses both continuous filament and staple fibre (ie, spun) yarns as pile materials. While filament yarns are more widely used in tufted carpets, staple fibre yarns tend to be used in the heavier weights of carpets. This section focuses on staple fibre yarns for carpets, principally those made from wool.

Processing routes for carpet yarns

Staple fibre yarns for carpets are produced mostly on the semiworsted and woollen systems. The worsted system is used for some fine weaving yarns only because it is difficult to spin such fine yarns from an uncombed sliver. Generally, synthetic fibre yarns are spun on the semiworsted system and most wool yarns are spun on the woollen system

Although the woollen system has fewer processing steps, semiworsted machinery is more productive in producing yarns of medium and fine counts. The relative conversion costs move in favour of semiworsted as the yarn counts become finer, however the semiworsted system requires raw materials with a high mean fibre length and strength, and minimal short fibre content. On the other hand, the woollen system is more flexible in its raw material requirements, and the manufacturer is free to blend diverse types of wool that in combination give the desired properties in the carpet.

A trend towards coarse gauge tufting favours woollen spun yarns whereas semiworsted yarns are favoured for the finer gauges. Indeed, the normally compact nature of semiworsted yarns may be used to advantage to obtain particularly dense, high quality, fine constructions of carpet, both cut-pile and loop-pile.

Woollen yarns are generally bulkier than semiworsted yarns; however the use of highly crimped wool and synthetic fibres provides similarly bulky yarns on both systems. The woollen system can easily be used to introduce nep, flame, slub or other coloured effects to produce fancy yarns.

The tufted and woven methods for making wool carpets have different requirements in terms of yarn specification and quality. In general, standards for raw material selection, spinning quality and yarn finishing need to be higher for tufting yarns than yarns for woven carpets.

Yarn setting

Where a wool yarn is to be made into a cut-pile carpet, it is necessary to stabilise the twist in the yarn. An acceptable level of twist set is essential for clarity of texture and good texture retention in the carpet. Setting of wool involves rearranging the disulphide bonds in stretched, bent or twisted fibres to reduce the level of stress. Good yarn setting can be achieved by a number of methods:

a) chemical setting, where the yarn is immersed in a solution of sodium metabisulphite,

b) boil setting of the yarn (in hand form) in a dye vessel, or

c) steam setting in an autoclave, in batch or a continuous line (Superba system)

Another method of stabilising the twist in wool carpet yarns and to produce the desired pile texture in cut-pile constructions is to include a low-melt synthetic fibre such as polyester as a component in the blend. The melt-bonding fibres, which are typically added to the yarn blend at around 10% level, adhere to each other when heated and form a lattice structure inside the yarn.

Colouration

Wool for carpets may be dyed in the form of loose stock, hanks, yarn packages or carpet. Alternatively, a white (greige) carpet may be printed by spray or padding techniques.

- Stock dyeing is mostly used for plain colours and where large quantities of a particular colour are required. Subsequent blending eliminates any effects of unlevel dyeing

- Hank dyeing is preferable where relatively small amounts of yarn of a particular colour are required. The advantage here is that the process also relaxes and bulks the yarn and introduces a high level of twist set. An insect-resist agent may also be applied at this stage
- Package dyeing has advantages in terms of water and energy usage, and ease of control. However, packaged yarn is not free to relax so that package-dyed yarn is leaner than hank-dyed yarn
- For carpet dyeing (winch or continuous) or printing a well-set yarn is required to withstand the severe mechanical action under hot, wet conditions.

13.3 Hand-made carpet manufacture

Hand-knotting is carried out on a simple loom as shown in Figure 13.2.

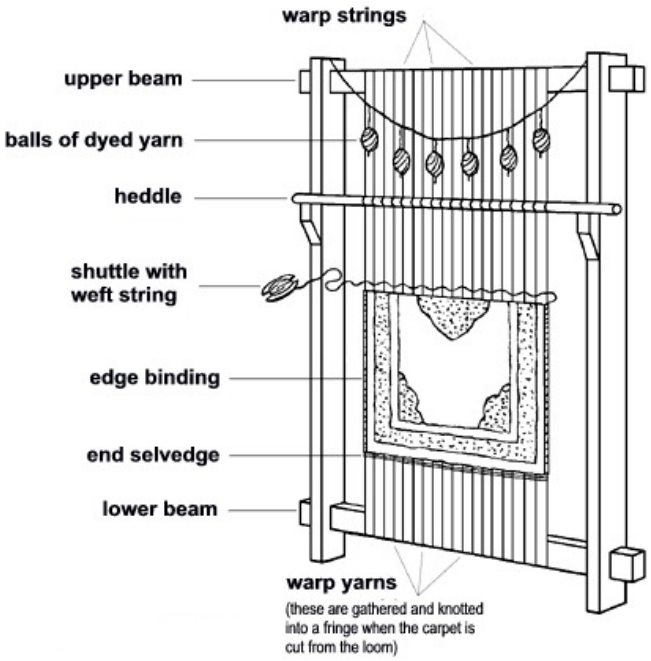

Figure 13.2 Loom for hand-knotting carpets. Source: Wood, 2006.

Figure 13.3 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.

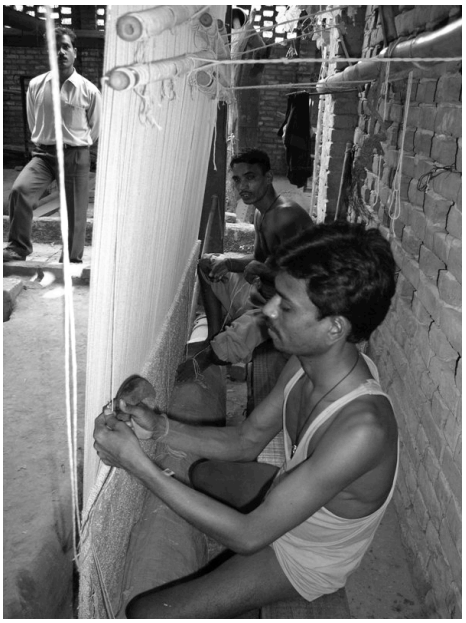

Figure 13.3 Hand-knotted carpet loom operator. Photograph supplied by E J Wood.

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 13.4) or a Turkish knot (Figure 13.5).

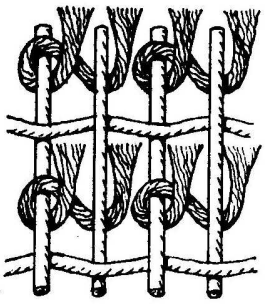

Figure 13.4 Persian knot for hand knotted carpet. Source: Wood, 2006.

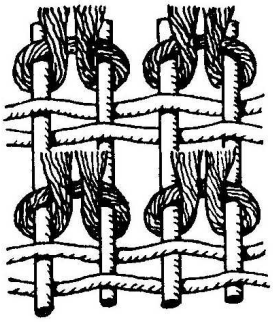

Figure 13.5 Turkish knot for hand knotted carpet. Source: Wood, 2006.

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 and brushed to cleanse them and to improve the uniformity of pile lay. Often the washing process is boosted by chemical solutions to increase the lustre, soften the colours and generally impart an antique appearance.

Gun tufting is another method of making carpets and rugs by hand, and it is virtually dedicated to wool. A single, hollow needle inserts a tuft of a specific colour anywhere in the carpet, to produce artistic wool hangings or spectacular rug designs for luxury locations. Both mechanised and manual tufting guns are used. Using clippers to carve the pile along the boundary between adjacent pattern elements, the rug design is highlighted.

13.4 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, Georgia, and the technique was soon improved for making broadloom (ie, wall-to-wall) carpets.

In the past 60 years the increase in the tufting of carpets has been phenomenal and it is now the dominant method of making carpets, including wool. 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.

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.

A wide range of wool carpet styles can be made by the tufting process, from the finer yarns for velour and hard-twist types, to the very coarse count yarns in some loop pile products. While the patterning options are more restricted than with woven carpets, attractive geometric designs can be produced.

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 13.6).

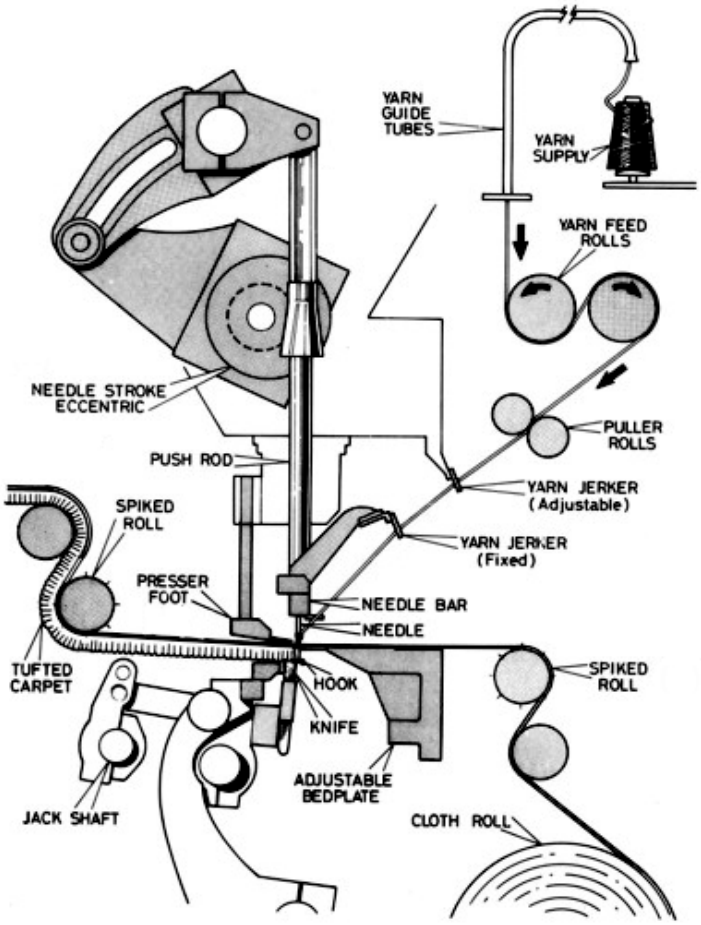

Figure 13.6 Tufting machine mechanism. Source: Cobble Blackburn Ltd.

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 13.7).

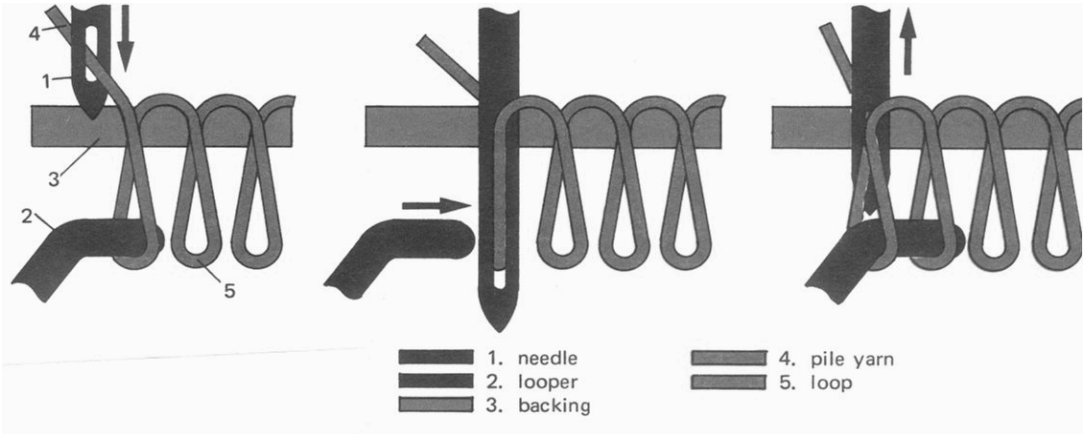

Figure 13.7 Formation of a loop pile carpet. Source: Wools of New Zealand.

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 13.8. Note the different looper shapes and directions in Figures 13.7 and 13.8.

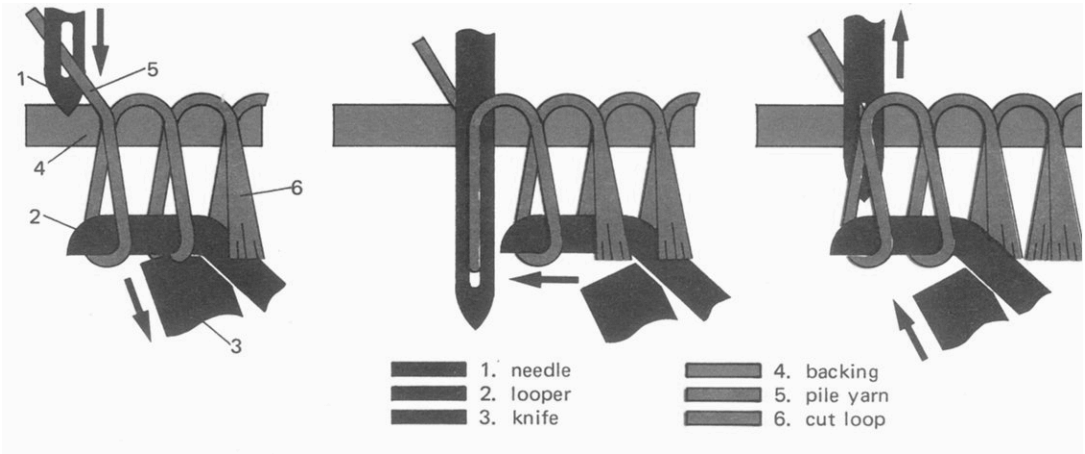

Figure 13.8 Formation of a cut pile carpet. Source: Wools of New Zealand.

Typical machine gauges are 5/32", 1/8" and 1/10", and stitch rates can be as high as 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

Yarn 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. A yarn under higher tension will tend to produce a lower loop than when the tension is reduced.

A number of alternative mechanisms are available to control and vary yarn tension, and hence vary the pile height. Figure 13.9 shows one relatively simple type of yarn tensioning system where varying tensions applied to the yarns by eccentric disks as they rotate cause alternately high and short loops to bed formed. The angular positions of the disks can be altered to produce a range of high/low pattern effects.

More sophisticated patterning systems use sets of computer-controlled rollers running at different speeds to vary the tension in individual yarns.

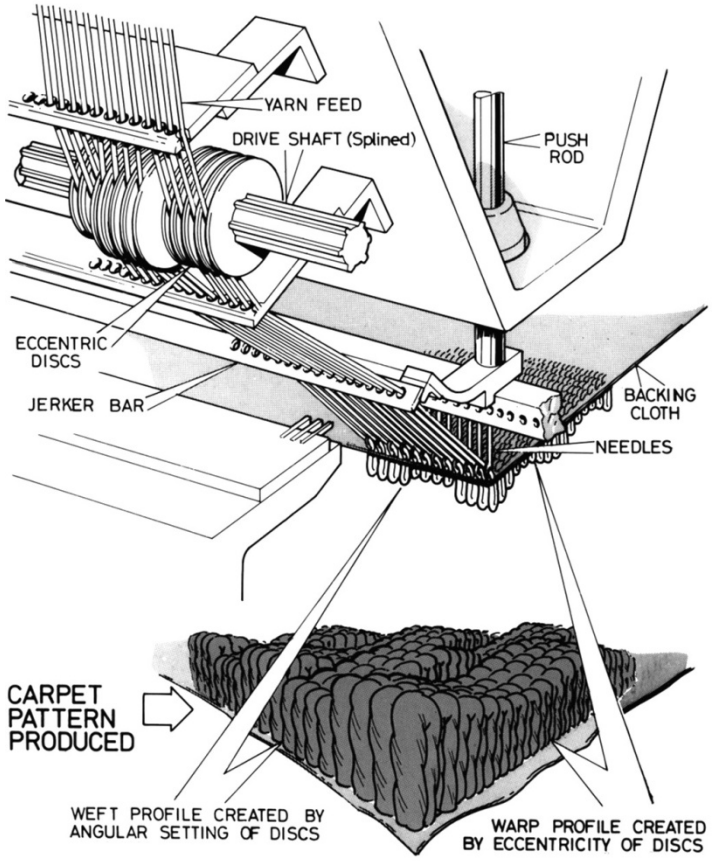

Figure 13.9 Eccentric cam yarn tensioning system for producing variable height loops. Source: Cobble Blackburn Ltd.

Sliding needlebar

Using one or two needlebars that can slide back and forth sideways, 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. Figure 13.10 shows the top and reverse sides of a tufted carpet, showing the zig-zag displacement of the tufts produced by a sliding needlebar.

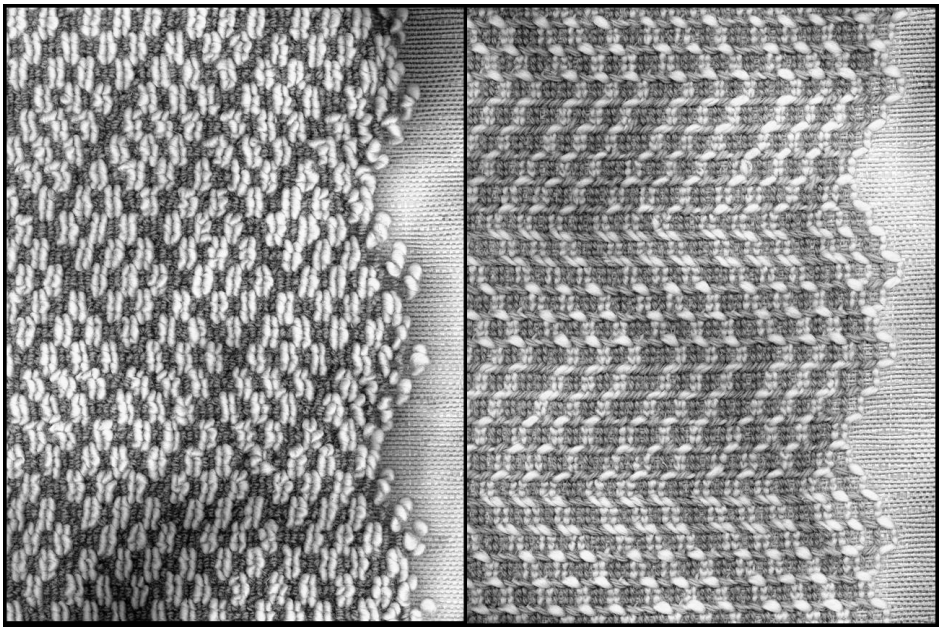

Figure 13.10 Pile produced by a sliding needlebar

More complex patterns can be achieved by combining the two mechanisms (ie, by varying the yarn tension in conjunction with sideways shifts in the positions of the needles).

Individually controlled needles

A single needle bar machine with **individually controlled needles** allows the overtufting of a precise cut-pile pattern into a base carpet fabric that has been produced by a conventional tufting machine. Each individual needle can be activated or deactivated by a computer pattern selection system. This method is used to introduce a coloured motif into an otherwise plain carpet

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 has a thin coating of synthetic latex 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 in an oven. This process is called *backcoating* (Figure 13.11).

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. This treatment can also be used on high-low loop piles to produce cut-loop textures.

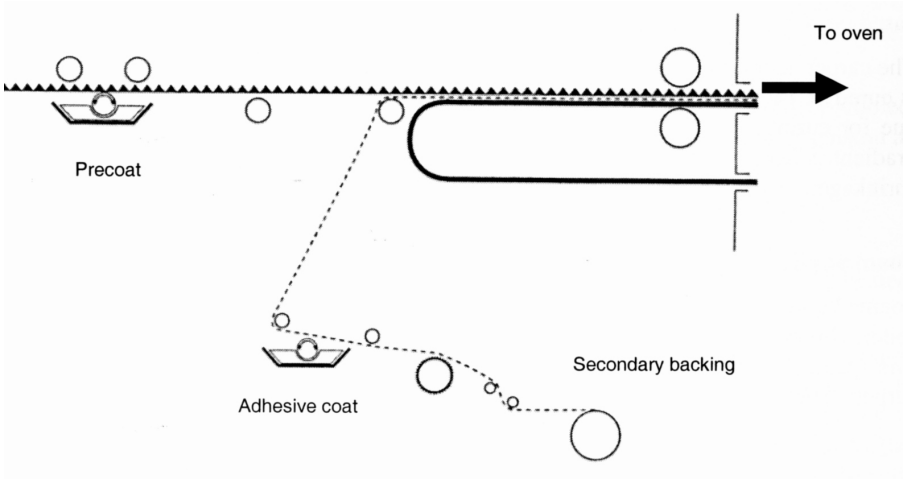

Figure 13.11 Kiss-coating method of applying a secondary backing to a tufted carpet

13.5 Carpet weaving methods

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

In woven carpet, the entire structure of pile and backing is assembled simultaneously. Fine threads run the width of the loom (the *weft* threads) and across the loom (the *warp* threads). Individual tufts are cut to length and inserted in the loom between the weft and warp threads to form the pile. The warp and weft threads are tightened, locking the tufts into place 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.

Axminster weaving

Axminster weaving emulates the hand-knotting method of forming a carpet, with tufts of individually-coloured yarns being incorporated in the backing as it is woven. However, the tufts are inserted around the weft rather than around the warp as in hand-knotting. The advantages are of the Axminster method 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 (for 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

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

In the spool-based methods the pile yarns of the various colours are wound onto spools in the sequence that the colours will appear across the width of the carpet. 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 13.12 shows the structure of a typical Axminster carpet. This is a 3-shot structure, meaning three weft insertions per row of tufts formed.

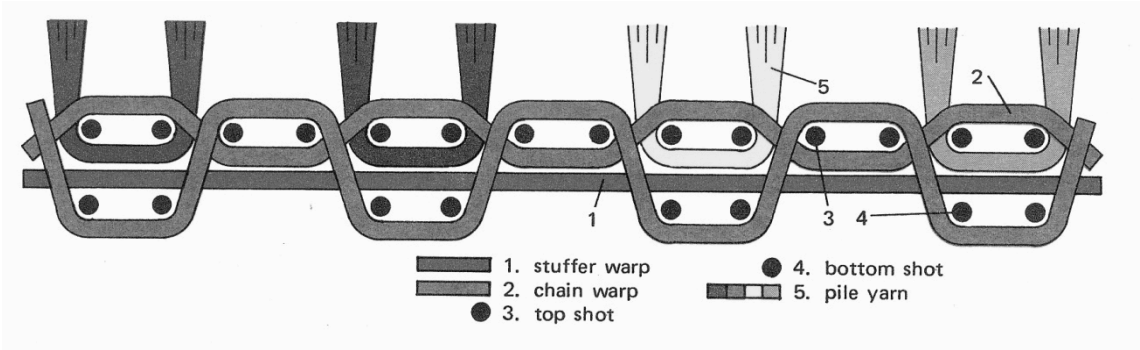

Figure 13.12 Axminster weave structure (3 shot Corinthian weave).
Source: Wools of New Zealand.

Gripper Axminster looms use a Jacquard mechanism to select the correct coloured yarn for each row of the carpet and bring them into line. Then up come the 'grippers' like a row of birds' beaks to pull out the required length of yarn for each tuft. At this instant a knife comes down to cut off this length and the grippers swing down pushing the tufts into the backcloth as it is woven. Each row of pile is inserted in this way throughout the carpet. The tuft insertion process is shown in Figure 13.13.

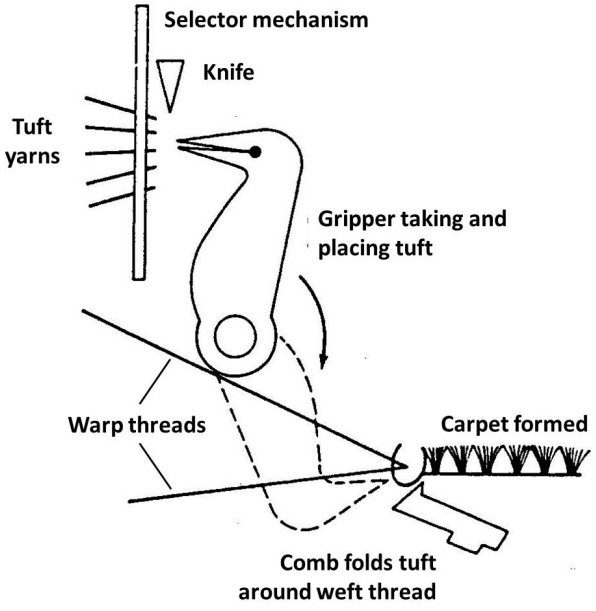

Figure 13.13 Tuft insertion process in Gripper Axminster carpet weaving

Wilton weaving

Wilton weaving is a versatile method 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.

There are three main methods of weaving a Wilton carpet: plain Wilton, Multiframe Wilton and Face-to-face Wilton.

Plain Wilton

These are carpets of one colour, each row of pile being formed over a wire, which is withdrawn later in the weaving sequence. If the wire has a knife attached, it will cut the pile during the withdrawal of the knife, giving a Wilton carpet. If the pile is not cut during the withdrawal of the knife, a loop pile is formed and the carpet is called a Brussels.

Multiframe Wilton

These carpets have two to five colours in their patterning. They are usually made with a cut pile, although combinations of cut and uncut pile can be made.

Figure 13.14 shows how wire after wire is woven into the fabric, to be subsequently withdrawn. One set of pile yarns (frames) is raised to form each crosswise row in the pile while the remaining three yarns are 'dead' in the backing.

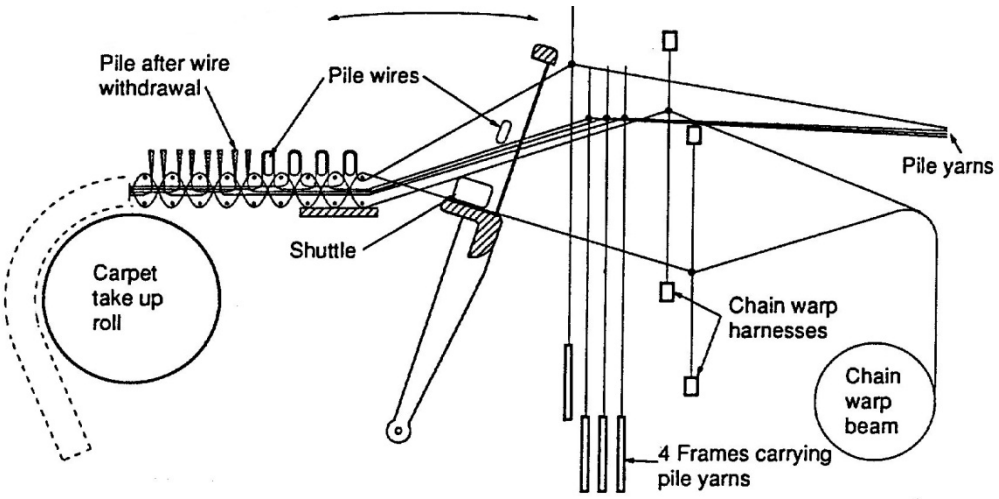

Figure 13.14 Wilton mechanism (4-frame loom). Source: Wood, 2006.

Figure 13.15 shows the construction of a 5 frame, three shot Wilton carpet. Each of the five colours 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 but adds to the cost of production.

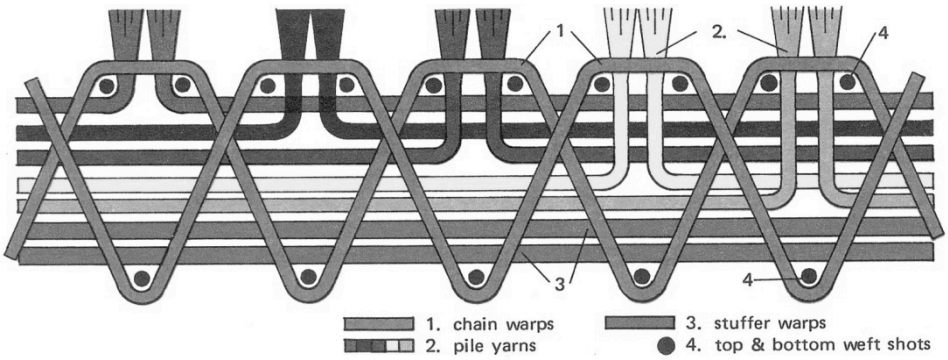

Figure 13.15 Wilton weave structure (5 frame, 3 shot). Source: Wools of New Zealand.

Face-to-face Wilton

Two carpets are produced with the same amount of dead yarn as one wire-loom carpet, so the yarn costs are lower. Two fabrics are woven simultaneously, 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 that are mirror images of each other.

Figure 13.16 shows a face-to-face weave structure before the carpets are separated. Many other structures are possible.

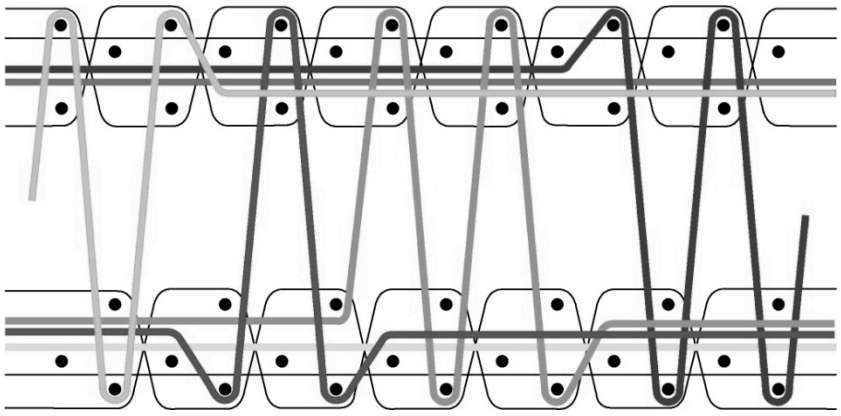

Figure 13.16 A face-to-face weave structure. Source: Michel Van de Wiele NV.

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.

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' where a line of loops is inadvertently pulled out. 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, and carving to accentuate design areas in a gun tufted rugs is also common.

Table 13.2 is a summary of all carpet types.

Table 13.2 Summary of carpet types

Type/description	Special characteristics
TUFTING	
1000 – 2000 rows of pile yarn are simultaneously stitched through carrier fabric (woven or nonwoven primary backing)	Most popular method for carpet manufacture (> 90%) Variety of textures achieved with varying colours, pile height variation , 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 Multilevel loop	All loops of same height from row to row A patterning attachment which varies yarn tension 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 to form finished product	Most often used in commercial locations Heavy, firm hand, high durability
Wilton Carpet made on Wilton (or wire) loom Loop (Brussels) or cut pile Level surface or multilevel	Capable of intricate patterning, styling and colouration versatility Withstands intense traffic so mostly used in busy commercial locations, also rugs Durable, dense, bends all ways
Face-to-face Two carpets woven simultaneously, then separated	The fastest method of weaving a carpet
Axminster Carpet made on Axminster loom (3 types) Cut pile only, mostly single level	Offers wide range of colours and designs 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 the web learning management system

1. *Patterning Techniques for Tufted Carpets* by E J Wood

Summary

The history of carpets is entwined with the history of human civilization, and rugs and carpets have been prized possessions through the ages. Wool has always been 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.

A carpet combines an attractive appearance with warmth, and comfort for standing, walking or reclining and they bring many diverse benefits to homes and public spaces. The top layer of the carpet, which is subjected to foot traffic, is called the pile. It composed of millions of yarn segments, arranged in a compact formation as short loops or upright tufts. Because the demand to perform for the long term in high-traffic locations, important requirements are placed on the fibres and yarns that make up the carpet pile. Carpets come in a huge range of combinations of constructions, textures, colours and patterns.

Three main methods of making wool (and wool rich) carpets and rugs are available: hand-knotting, weaving and tufting. In hand-knotted and woven carpets the base fabric is formed and the pile yarn integrated at the same time, while in tufted carpets the pile yarn is inserted into a pre-formed fabric by needles. All types of carpets require finishing treatments after tufting or weaving to make the products ready for sale.

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

Kajons, A., 1991, Speciality Wool Production Part 2, Chapter 19 in *Australian Sheep and Wool Handbook*, editor D. J. Cottle, WRONZ, ISBN 0 909605 60 2.

Wools of New Zealand Technical Information Bulletins (available as downloadable documents). www.woolsnz.com:

- Yarns for Axminster Weaving
- Yarns for Face-to-face Weaving
- Yarns for Tufted Carpets
- Yarns for Wire-Wilton Weaving

Wool Research of New Zealand. Images supplied courtesy of WRONZ now Canesis Network 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 (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)
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
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)