21. Fibres and Yarns for Carpets

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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
- 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
- Outline the yarn requirements and characteristics for the various types of tufted and woven carpets

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

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 characterised in various ways, for example:

- The pile fibres, eg 100% wool, 100% nylon, 80% wool/20% nylon, etc
- Method of manufacture : (a) woven – Axminster, Wilton, 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 principal reference for this lecture is the reference text by Crawshaw (Crawshaw, 2002).

The Wools of New Zealand Technical Information Bulletins on carpet yarns, which are suggested as readings, are also very useful references for this lecture.

21.1 Introduction to 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.

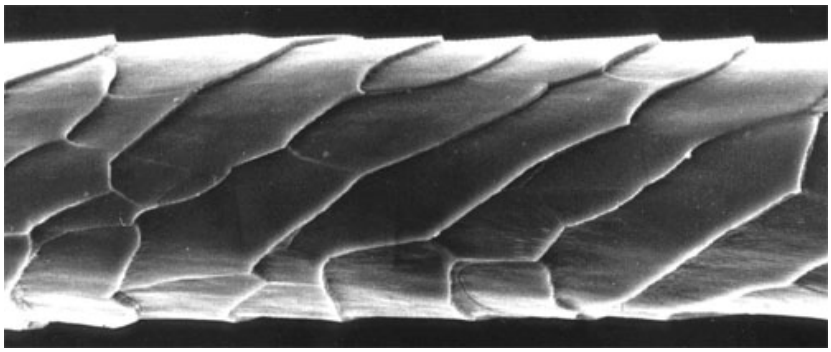
Wool - its structure and properties

Wool has been used from the earliest history of carpet construction 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.

Of all the textile fibres, wool is by far the most complex. Wool consists of a protein named ***keratin***, which has an intricate structure of long-chain molecules.

There are many *cross-linkages* (or chemical bonds) between the long, coiled chains, and this structure is largely responsible for the outstanding elastic properties of wool, its strength and durability. The unique surface scales (the *cuticle*), which cover the fibres (Figure 21.1), and the wavelike crimp shape give wool its special characteristics. Of all the carpet fibres wool has by far the highest capacity to absorb moisture.

Figure 21.1 Wool fibre showing the external scales (cuticle). Photograph supplied by E. Wood, courtesy Canesis Network Ltd.



Wool has a number of properties that make it very desirable as a carpet fibre:

Moisture absorption

A major advantage of wool is its ability to absorb up to 30% by weight of water vapour without the wool feeling wet. Wool products are therefore a buffer to changes in the ambient atmospheric conditions. For example, wool carpets and furnishings readily absorb moisture produced by human occupation in the home.

Soiling and cleaning

Compared with most other fibres, wool has a high resistance to soiling, but it is also easy to clean. The water-repellent surface of the fibre allows time for spills to be wiped up before they cause permanent staining. The overlapping scales of the fibres trap soil particles in the upper region of a carpet pile so that they are readily removed by vacuum cleaning.

Flexible behaviour

Wool is probably the most resilient fibre in common use, being capable of bending thousands of times without suffering permanent damage or deformation. An example is the recovery of a wool carpet pile after countless foot impacts. The resilience and elasticity of wool fibres compensate for their relatively low tensile strength, and thus give them more durability than might be expected.

Abrasion resistance

Wool is moderately abrasion-resistant, and blending a proportion of nylon (often 20%) with wool increases the wear life of a carpet.

Odour absorption

With the millions of fibres present in a carpet, the large total surface area and the sites within the fibres where odour molecules can become attached enable a wool carpet to improve indoor air quality.

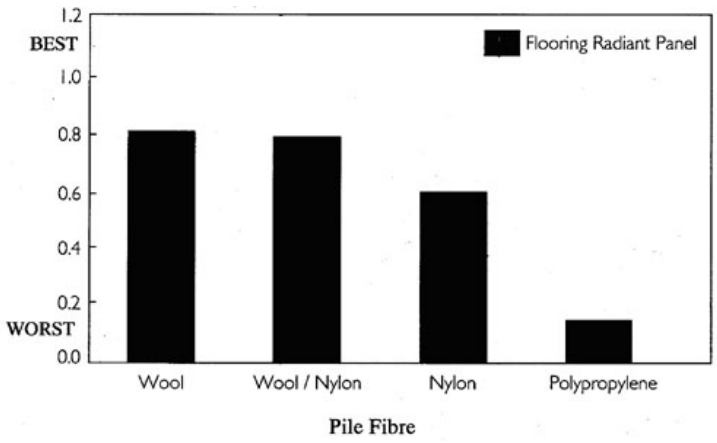
Setting

The same principles used in the permanent setting of human hair (ie, the application of heat, moisture, special chemicals) apply when it is required to retain the twist in yarns that are destined for cut-pile carpets. These treatments are generally required to preserve the initial appearance of the product during use.

Flammability

Because of wool's insulating properties it offers a high level of protection to heat and fire. It is difficult to ignite (see Figure 21.2), or to sustain burning. Unlike most synthetic fibres, wool does not melt and its ash is non-sticking, thus burn marks can be readily brushed away on carpets etc. Wools superior flame-resist properties can be further enhanced through treatment with zirconium salts. In addition, wool contributes less to smoke or toxic gas formation than other carpet fibres.

Figure 21.2 Relative amounts of energy required to ignite carpets composed of various fibres. Source: Wools of New Zealand.



Static electricity

If the moisture content is low, high levels of electric charge may build up on the wool fibre during processing, or on a wool product in use. Static electricity has a detrimental effect on processing performance, and moisture is usually added before processing to minimise static effects. Anti-static agents may be applied to wool products, especially to carpets in situations where static electricity may be a shocking problem. However, under normal humidity conditions where wool contains a significant amount of moisture, static electricity is much less evident than in products made of synthetic fibres.

Man-made 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.

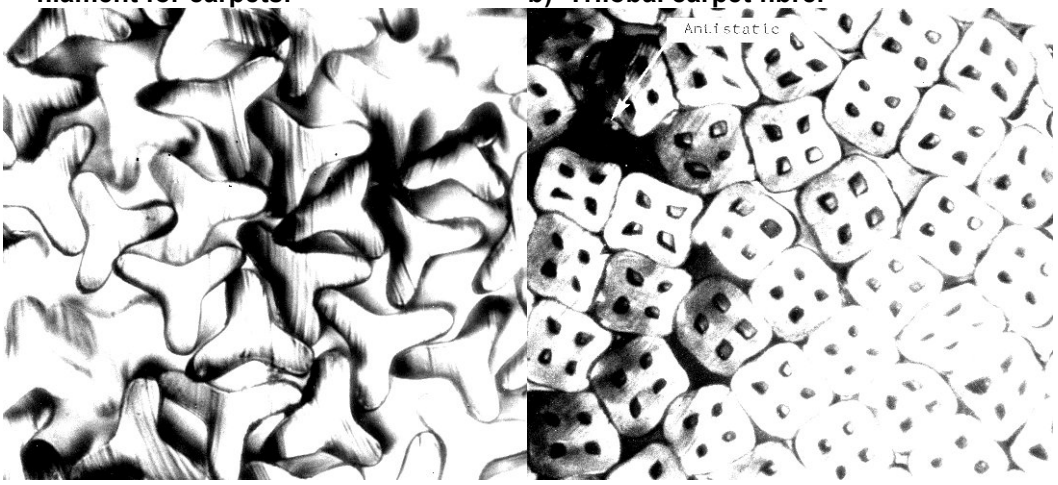
Synthetic fibres are made from polymers built up from simple molecules. Using raw materials from the petrochemical industry, the fibres are extruded by forcing a thick mixture of chemicals in a hot melted state through microscopic holes in a device resembling a shower rose, called a *spinneret*. The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

A fortuitous laboratory 'accident' led to the development of nylon, the first truly synthetic fibre, by Dr Wallace Carothers at Du Pont during the period 1927-38. Nylon (or polyamide fibre) is composed of long-chain molecules joined together by amide linkages. Because several methods of making polyamide fibres were found, each varying slightly in constitution and properties, a generic name 'nylon' was coined. The two common types of nylon in use for carpet yarns are Nylon 66 and Nylon 6. Figure 21.3 shows the two main cross-sections available with typical nylon carpet fibres.

Figure 21.3 Source: Wool Research of New Zealand.

a) Square cross-section, continuous filament for carpets. **b) Trilobal carpet fibre.**



Nylon 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 21.1 compares the strengths and weaknesses of the three main carpet fibres: wool, nylon and polypropylene.

Table 21.1 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

21.2 Carpet wool production

Wools suitable for carpets are generally coarse, ie, with a mean fibre diameter > 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 manufacture. For more information on the selection and blending of suitable wools for carpets, see the downloadable technical information.

Traditionally, wool used in manufactured carpet was spun on the woollen system to be woven into Axminster and Wilton styles. The growth in recent decades in carpet tufting, and in semiworsted spinning for face-to-face weaving has placed more demands on yarn quality and strength. This growth has stimulated increased attention on the need to accurately specify wool carpet blends.

A significant amount of New Zealand wool also goes into hand-made carpets and rugs in India, Nepal and other Asian countries. New Zealand crossbred wools are often blended with local wools to improve the quality of the yarns. NZ wools also provide a degree of lustre which is beneficial for dyeing and carpet finishing.

Carpet wool sheep were introduced to Australia in the 1970s. They are mostly run in the high-rainfall wool growing areas of Tasmania, Victoria and New South Wales. However, the carpet wool sector is a very small proportion of the Australian clip, and is much smaller than the amount of wool that is suitable of carpets which is grown in New Zealand. Hence Australia is net important of carpet wool and carpet yarn, mostly from New Zealand.

The United Kingdom is also a significant producer of carpet wools, some of which is exported. This wool is mostly Scottish Blackface, which is favoured by carpet manufacturers because of its unique characteristics.

Other countries such as China and India produce considerable amounts of wool which are suitable for carpets, particularly the hand made types. However, this wool is not exported but is consumed internally. Because of the inferior quality of the indigenous wools, they are mostly blended with good quality 'carrier' wools (as produced by New Zealand) to produce yarns of acceptable quality.

Wool types for carpets

Tufted carpets

The types of wool used for tufted carpets may be classified into three main groups. These are used in differing proportions in blends, depending on the quality (which controls the price) 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, a less of these poorer wool types must be used.

While recovered wool may be used as a minority component in some carpets to cheapen the blend, this practice is not permitted by Wools of New Zealand or the Woolmark Company, for quality reasons.

Axminster carpets

For Axminster carpets, the principal wool requirements are for price, spinning performance and carpet performance. An average low price can best be met by using three classes of blend which are required for the different colour components of a patterned carpet design:

- white, to be used for white and pale coloured yarns
- yellow, for dyeing to medium and deep colours
- grey, for dyeing to heavy shades.

Economies can also be achieved by incorporating a proportion of short fibre into the blend. This must not be too short or in too high proportion, however. Excessively short fibre is not as cheap to use as its first cost indicates, because of lower carding yields, reduced spinning performance and high fibre loss during carpet manufacture. In addition, a high content of short fibre can lead to excessive fibre shedding from the carpet during the early stages of wear.

Good performance in carding and spinning can be achieved by using wool of good length and a crimpy component to provide cohesion to the fibre web and slubbings. Good performance in carpet wear requires the wool to be sound, free from bacteriological or chemical damage, and of high fibre diameter, medullation and crimp to provide resistance to compression by the foot.

These requirements lead to blends of medium bulk second shear wool and longer oddments, often with medullated wool to provide a crisp handle. For economy, stained wools may be used in yellow Axminster blends, but wools yellowed by bacteriological attack should be avoided. Wools contaminated by pigmented or stained fibres or brand marks may be used in grey Axminster blends.

Wilton carpets

The principal requirements for yarns for Wilton (or wireloom) weaving are for uniform dyeability and low kemp content, so that heavily medullated wools (which tend to contain kemp and which appear lighter in colour when dyed together with solid wools) should be kept to a minimum. It is not essential to have a majority component of expensive, long, sound wools.

Table 21.2 gives examples of carpet blends produced from 100% New Zealand wool. Note that, in terms of wool quality, the Axminster and tufted loop pile blends use the highest proportions of inferior wools while the face-to-face woven and cut-pile tufted carpets have the highest demand for wools of superior quality.

Table 21.2 Wool blends for different carpet types. Source: Wood, 2006.

Yarn manufacturing system	Carpet type		Wool components Mainstream	Filler	Specialty
Woollen	Woven	Axminster	30%	50%	20%
		Wilton	45%	35%	20%
	Tufted	Loop pile	30%	55%	15%
		Cut pile	65%	20%	15%
		High twist	45%	40%	15%
Semiworsted	Woven	Face-to-face	80%	-	20%
	Tufted	Loop pile	50%	40%	10%
		Cut pile	60%	25%	15%
		High twist	60%	35%	5%

Table 21.3 gives examples of typical objective specifications for a range of carpet blends. Note the types of carpet which:

- require the finest wools
- can use inferior colour wools
- require the longest wools
- require the most bulky wools
- have the highest levels of medullated fibre.

Table 21.3 Typical objective specifications for carpet blends. Source: Wood, 2006.

Carpet blend	Diameter (μm)	VM (%)	Colour Y	Colour Y-Z	Barbe (mm)	Bulk (cm^3/g)	Medullation (%)
Woollen - tufted	36	0.3	60.0	5.0	78	21	8
White Axminster	39	0.3	62.0	3.5	72	23	17
Yellow Axminster	36	0.5	57.0	8.1	67	23	17
Woollen Wilton	36	0.3	60.0	4.0	83	21	12
Semiworsted tufted	35	0.2	60.0	4.0	108	20	8
S-W face-to-face	33	0.2	60.0	4.0	105	20	5

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 the tufted carpet sector, staple fibre yarns tend to be used in the heavier weights of carpets. This section will concentrate on staple fibre yarns for carpets, principally those made from wool.

Carpet yarn specification

Yarn count

The yarn count is a measure of the yarn *linear density*, ie, its mass per unit length. A yarn with a high count will generally be thicker than a yarn with a low count, provided the twist levels are similar and the fibres have similar levels of bulk. The count of carpet yarns is mostly measured in grams per kilometre (or tex).

Yarn ply

Yarns can be tufted as a single strand (a singles yarn (Figure 21.4)), or with two or more strands of yarn twisted together (a plied or folded yarn) (Figure 21.5). The yarn ply is the number of strands that have been twisted together. Two strands twisted together form a two ply yarn (the most common yarn for carpets while three strands together is a three ply yarn.

Figure 21.4 Singles yarn for carpet (woollen spun).
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.

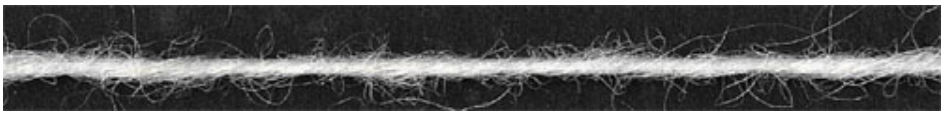
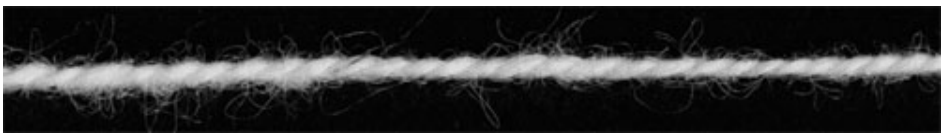


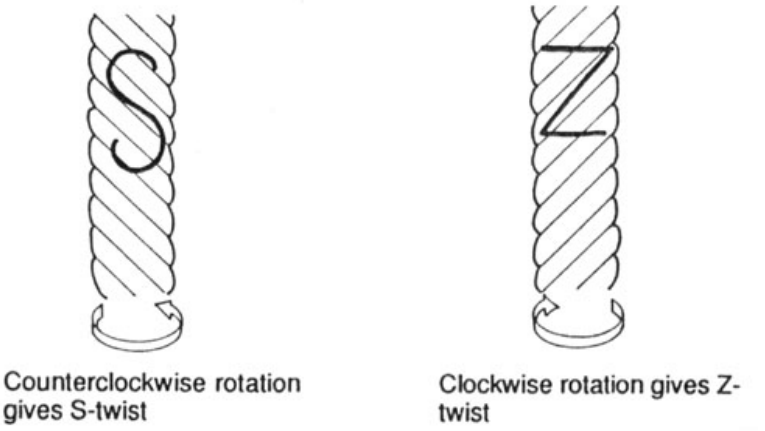
Figure 21.5 folded carpet yarn (woollen spun).
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.



Yarn twist

When yarn is formed from a strand of fibres, twist is inserted at spinning. Twist is used to hold the fibres together and to give the strand enough strength and cohesion to resist in subsequent processes (or in use). Twist has a major influence in the strength of a yarn and therefore the weaving or tufting efficiency. Twist also influences the appearance of the pile in the finished carpet. Figure 21.6 shows the two possible directions of twist (S and Z).

Figure 21.6 Directions of twist inserted in spinning. Source: Wood, 2006.



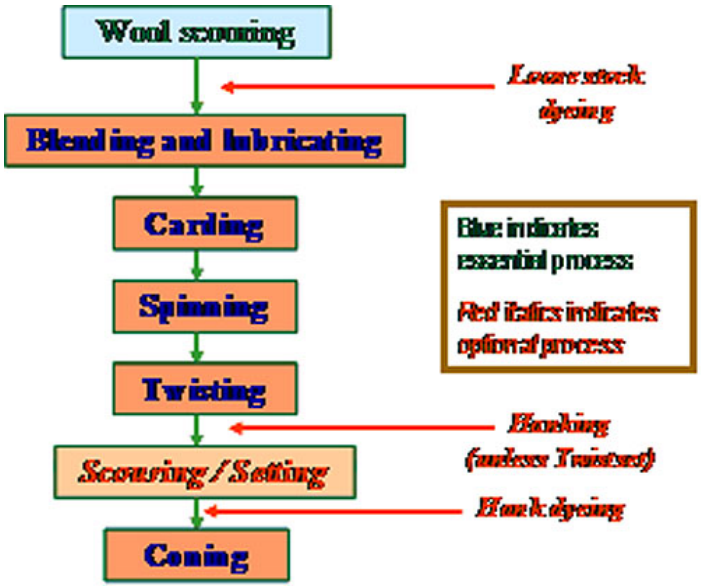
The yarn twist measures the amount of twist in a length of the yarn (normally expressed in turns per metre). If a two-fold yarn is used, it is necessary to specify the twist levels (1) for the singles yarns, and (2) for the twisted combination. To give the yarn stability, the directions of the singles and folding twist are in opposite directions (Figure 21.7). In this case the twist is described as S on Z. In tufting S on Z or Z on S are not equivalent, as tufting machines are set up to handle one direction better than the other.

Figure 21.7 Opposing directions of singles and folding twist in a two fold yarn (S on Z). Source: Wood, 2006.

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 (eg, R140 tex/3) simply 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 (Figure 21.8).

Figure 21.8 Woollen spinning route. Source: Wood, 2006.



The woollen process for carpet yarns has two variations – conventional (oil) spinning and dry spinning.

- In conventional spinning around 3-5% of processing lubricant is applied before carding and this is later removed by scouring the yarn. If the residual lubricant is not removed, soiling problems are likely in the yarn and carpet. Setting to stabilise the yarn twist is generally carried out in conjunction with scouring or yarn dyeing
- Dry spinning uses a smaller amount of processing lubricant (0.5 – 1%) and there is no scouring step. The dry spinning process is only practicable if processing is undertaken in an atmosphere of 75% relative humidity and 20^{o}C, high standards of cleanliness in the mill are maintained and if the blend is comprised of clean, good length wool.

Although the woollen system has fewer processing steps, semiworsted machinery is more productive in medium and fine counts of yarn. The semiworsted route is similar to dry woollen spinning in that no wet processing step is included. The relative conversion costs move in favour of semiworsted as the yarn counts become finer. However the semiworsted system requires raw material with a high mean fibre length and minimum 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 wools that give the desired properties in the carpet. The blend may include a proportion of cheaper, shorter wools.

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 tom provide 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 Axminster or Wilton carpets.

Yarn setting

Where a yarn is to be made into a cut-pile carpet, it is necessary to stabilise the twist in the yarn as part of the finishing treatment. An acceptable level of twist set is essential for clarity of texture and good texture retention in the carpet. Good setting can be achieved by:

a) chemical setting, where the yarn is immersed in a solution of sodium metabisulphite in a tape scour or Twistset machine and is usually carried out in conjunction with yarn scouring, or
b) boil setting of the yarn in a dye vessel.

An insect-resist agent can also be applied at these stages.

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 carpet may be printed.

- 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.

Yarns for tufting

When pile yarn is tufted into carpet, it has to pass through the eye of the needle and over a looper, and any faults and joints in the yarn could obstruct its passage and cause a stoppage. The yarn must also pass easily between reed fingers without being jammed. Although much has been done to alleviate these problems through improved design of tufting needles, an important requirement for wool tufting yarns is freedom from large knots and joints and minimal content of large faults such as thick places.

Furthermore, even a fault-free yarn is subjected to relatively high tension (typically around 500 grams force (gf) or 5 Newtons) as the needle eye with its yarn penetrates the backing fabric. Although the mean yarn strength is normally much greater than this, account should be taken of the statistical variability of strength, and there should be no weak places in the yarn breaking at less than 500 gf. A discrepancy between the geometry of the tufting system and the yarn delivered introduces a requirement for extensibility; otherwise the previously formed loop is robbed of some yarn, with an adverse effect on carpet quality. Tufting yarns, therefore, have special requirements for strength, extensibility and regularity. On a loop-pile machine, the rows of loops are dropped off a metal finger called a ‘looper’ at each needle stroke, whereas the loops formed for cut-pile carpets accumulate and have to slide along a hook before being cut. The demands for strength on yarn for cut-pile tufting are therefore higher.

Equally as important as the ability to tuft efficiently is the influence of yarn on carpet styling. Although patterning mechanisms for tufting machines and carpet printing systems are evolving, a high proportion of wool tufted carpets still rely on texture for their styling. This means that a wide range of counts of yarn is needed for the available gauge range in tufting machines. Different yarns are needed for cut-pile and loop-pile carpets, wool blends may range from the refined to the rugged, and various yarn constructions are used. Yarn finishing is a variable too, and the ‘engineering’ of a yarn must take into account the different carpet manufacturing and dyeing routes.

The main spinning routes for tufting yarns are woollen and semiworsted. Over most of the count range used for tufted carpets, the yarn properties rather than cost considerations govern the choice between woollen and semiworsted spinning. Woollen spinning gives the spinner a wider fibre choice than semiworsted spinning, hence woollen yarns are more easily engineered to have the required characteristics for the desired carpet texture and price. However, the finer machine gauges (eg 1/10 inch), with the associated finer yarns, favour semiworsted yarns economically since the output of a woollen card depends largely on the linear density of the slubbings delivered and the production of finer yarns by this route is less efficient.

Semiworsted yarns are characterised by a more parallel arrangement of long fibres than a typical woollen spun yarn. This route provides strong, regular yarns with few joints, hence promoting good tufting efficiency. The parallel fibre configuration also tends to provide a compact and lustrous appearance. On the other hand, woollen-spun yarns have a more random fibre orientation and are usually more bulky with low lustre. The differences in bulk and lustre can be minimised by using crimpy wools as a major component in semiworsted carpet yarn blends.

Fibre crimp also has a dramatic effect on twist setting of semiworsted yarns. Without highly crimped wools, semiworsted yarns virtually cannot be set. Spinning at a low tension (ie, with light travellers) assists the setting of semiworsted yarns since a greater torque (favouring set) arises at twisting. Woollen yarns, which have a high degree of fibre entanglement and are amenable to setting, are usually chosen when tuft definition in cut-pile carpets is required.

In general, a trend towards coarse gauge tufting favours woollen 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.

At carpet finishing, good equipment and technique must be used to achieve good latex penetration when the carpet is tufted from semiworsted yarns. The random fibre configuration of a woollen yarn ensures that fibres mostly contact the latex at the yarn surface. Latexing just the surface of semiworsted yarns can allow the core of parallel fibres to be too readily withdrawn from the tuft, leading to excessive fibre shedding from a carpet in wear.

A wide range of 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. Table 21.4 summarises typical yarn specifications for some tufted types and illustrates the diversity of yarns used in tufting. The tensile properties of a yarn are:

a) the breaking load (ie, the force at which a stressed yarn eventually breaks)
b) the breaking extension or elongation (the percentage increase in length at the point the yarn breaks).

Table 21.4 Production and properties of typical tufting yarns. Source: Wood, 2006.

Tufted product	Processing route	Yarn construction	Finished yarn tensile properties
Woollen-spun heather yarn for velour carpet	Stock dye Woollen spun Scour/chemical set	Count: R 480 tex/2 Singles twist:: 185 tpm S Folding twist: 130 tpm Z	Breaking strength: 1.5 kgf Breaking extension: 10.0%
High twist yarn for frisé carpet	Stock dye Woollen spun Scour/chemical set	Count: R 520 tex/2 Singles twist:: 196-210 tpm S Folding twist: 305 tpm Z	Breaking strength: 2.2 kgf Breaking extension: 11.0%
Yarn for heavy gauge loop pile	Stock dye Woollen-spun Scour	Count: R1960 tex/2 Singles twist:: 95 tpm Z Folding twist: 55 tpm S	Breaking strength: 7.3 kgf Breaking extension: 19.3%
Semiworsted yarn for patterned loop pile contract carpet	Stock dye Semiworsted spun No yarn finishing	Count: R440 tex/2 Singles twist:: 180 Z Folding twist:: 120 S	Breaking strength: 3.2 kgf Breaking extension: 16.0%
Saxony yarn for winch dyeing	Woollen-spun Twistset	Count: R690 tex/3 Singles twist:: 195-200 tpm S Folding twist :175-180 tpm Z	Breaking strength: 2.4 kgf Breaking extension: 10.2%

Yarns for Axminster weaving

Axminster carpet constructions remain widely popular for multi-coloured patterned styles of residential and contract carpets. Although Axminster machinery could be used for producing plain carpets, it is less effective for this purpose than tufting or Wilton weaving.

The most commonly used yarn counts fall within a fairly narrow range, centred around 620 tex. Two-ply yarns are usually used, although some companies prefer to use the more expensive three-ply yarns.

At such counts, the woollen spinning system is a cost effective yarn conversion system which can accommodate a proportion of relatively short, cheap wools. A high proportion of Axminster carpet yarns are spun from blends of 80% wool and 20% nylon. Most Axminster carpets are made from woollen-spun yarns. Some high-quality Axminster carpets have a lustrous appearance achieved by using worsted yarns in counts such as R620 tex/2/2

Axminster yarns are usually dyed in hank (skein) form, and the twist of the yarn is set in the dyebath. No separate twist setting process is required.

The principal requirements for Axminster yarns are:

- low cost (to compensate for the relatively high cost of carpet conversion; and high percentage waste in spool Axminster manufacture)
- cohesive structure (to ensure the grippers take all plies of the yarn)
- levelness of count and colour (especially in designs with large areas of one colour)
- good bulk or covering power (but not such high bulk as to press the tufts together, precluding inter-tuft shadows)
- resilient carpet texture
- good carpet performance in use (minimal fibre shedding, low rate of pile wear, good retention of appearance).

As no great stresses are imposed on the yarn during manufacture, the requirements for good physical properties such as strength and elongation are not stringent, except as they contribute to carpet performance.

The counts used in typical Axminster carpets are:

Two-ply: R620 tex/2 to R520 tex/2
Three-ply: R780 tex/3 to R620 tex/2.

Axminster yarns generally have a relatively low level of twist, around 80 tpm singles twist and 55 tpm folding twist. Folding twist levels are set to balance the spinning twist and minimise the tendency to snarl. For two-ply yarns this means that the level of folding twist should be about 70% of the singles twist.

Yarns for Wilton (or wire loom) weaving

Wilton carpet is traditionally expected to have a more refined, less rugged, appearance than Axminster carpet. The tufts in cut-pile styles are expected to be well defined. The requirements for yarn strength and extensibility are not as demanding as for tufting yarns.

Woollen spinning is most appropriate for the coarser counts of Wilton yarns while very fine qualities use yarns spun on the semiworsted system. Intermediate qualities may be woven from woollen or semiworsted yarns. Frisé carpets are woven from woollen-spun yarns because semiworsted yarns do not cockle satisfactorily to give the desired pile texture.

Table 21.5 gives typical woollen spun yarn specifications for common types of Wilton carpet.

Table 21.5 Typical woollen spun yarns for Wilton carpets. Source: Wood, 2006.

Yarn type	Count	Singles twist (tpm)	Folding twist (tpm)	Breaking strength (kgf)	Breaking extension (%)
Conventional	R 625 tex/2	165 Z	120 S	> 2.5	15 – 18
Conventional	R 450 tex/2	245 Z	130-135 S	>1.8	15 – 20
Hard twist	R520 tex/2	185 – 190 Z	330 – 340 S	>2.0	>10

Readings

The following readings are available on CD

The following Wools of New Zealand Technical Information Bulletins, which have been prepared for carpet yarn manufacturers, are relevant to this lecture

1. Chemical Treatments
2. Heather Tweed and Effect Yarns
3. Selection and Blending of Wool for Carpet Manufacture
4. Semiworsted Spinning
5. Spinning of Wool Carpet Yarns
6. Twist Setting of Wool Carpet Yarn
7. Woollen Spinning
8. Yarn Bonding Technology
9. Yarn Scouring
10. Yarns for Axminster Weaving
11. Yarns for Face-to-face Weaving
12. Yarns for Tufted Carpets
13. Yarns for Wire-Wilton Weaving

Activities

Available on WebCT

Multi-Choice Questions

Submit answers via WebCT

Useful Web Links

Available on WebCT

Assignment Questions

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

Summary

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.

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

- The pile fibres, eg 100% wool, 100% nylon, 80% wool/20% nylon, etc.
- Method of manufacture : (a) woven – Axminster, Wilton, 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 twist and 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.

This lecture examines the requirements for carpet fibres – resilience, durability, cleanability, flammability, dyeability, etc. For wool carpets the ability to blend various wool types, often in conjunction with a proportion of man-made fibres to achieve the required performance economically is very important.

The yarn requirements are also crucial – count, twist and twist stabilisation in particular, to create the diversity evident from the list above. The various types of carpet construction have different requirements in these respects.

References

Cottle, D.J., 1991, Sheep Breeds, Chapter 2 in *Australian Sheep and Wool Handbook*, editor D. J. Cottle, WRONZ, ISBN 0 909605 60 2.

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)