Wood: Materials for Furniture

The furniture industry has relied heavily on wood and wood-based materials throughout history. Furniture has evolved from simple utilitarian objects made to support people and inanimate objects to articles that are designed and built with both functional and aesthetic characteristics and intended for display as well as utility. The origin and development of furniture can be traced to an innate human desire to provide for comfort and convenience as well as to display wealth, social and political status, or power. Furniture is made from many materials, from rattan to precious metals, but from the earliest recorded history to the present, the dominant material chosen for constructing furniture is wood (see *Wood: History of Use*). Wood furniture was present in the ancient cultures of China, Egypt, and Greece. Historic research indicates that early Egyptian furniture was constructed from the indigenous woods of acacia, almond, fig, palm, tamarisk, willow, and poplar and also from exotic woods of ebony, cedar, ash, beech, oak, yew, elm, and cypress. Although much of this early furniture has not survived, the dry climate of the Egyptian pyramids has provided numerous examples of ancient wooden furniture (Morley 1999, pp. 14–16).

The reasons for selecting wood as a preferred material for furniture are much the same now as they were thousands of years ago. Wood excels in performance, manufacturing, and appearance characteristics. From the consumer's point of view, wood has a pleasing appearance, is warm to the touch, and is strong and durable. From a manufacturer's point of view, wood has many positive attributes: a favorable strength-to-weight ratio; easily worked with a wide variety of tools to make artistic and functional shapes; easier to join to other pieces of wood or other materials than most other structural materials; can be readily finished with varnishes, paints, and similar materials to enhance or modify its natural appearance; common and available near population and manufacturing centers; and a renewable resource.

Wood continues to be the overwhelming choice of customers, who often identify the most important attributes to be reliability, environment friendliness, pleasing appearance, and good value (Pakarinen 1999). Evidence suggests that the wood industry has an opportunity to capture the environmentally informed consumer by providing certified wood that is produced according to accepted standards of environmentally sustainable management; the customer's perception of environmental impacts is beginning to influence the manufacturer's choice of materials (Stevens *et al.* 1998).

1. Style and Design

The style, or general appearance of furniture during a period of time, changes over the course of history. Style reflects the priorities of the culture at the time. The furniture of early civilizations reflected the desire of the privileged and ruling classes to display their power, wealth, or zealous aspirations. From the beginning, furniture style was influenced by architectural style. Ample evidence exists indicating that Egyptian architectural ornamentation was applied to ancient Egyptian furniture and changes in Greek architecture were reflected in Greek furniture styles. Beginning in the late nineteenth century, architects began having a direct influence in the design of furniture, attributable to their desire to furnish buildings in harmony with the overall design of a structure. The common element among all of these styles is the use of wood.

The elements of design incorporate both style and structural integrity. Design has evolved from the subjective trial-and-error approach of the artist to one of using engineering principles to choose materials and design elements based on the mechanical properties of the materials (Eckelman 1978). Although engineering design of furniture is practiced in many modern furniture-manufacturing facilities, much of the world's furniture is still designed and built the intuitive way and by full-scale testing of prototypes. There is growing interest in developing better analytical methods to help the furniture designer optimize the production of a cost efficient and safe product (Smardzewski 1998).

The desire to create different or new appearances in furniture style led to the use of different manufacturing methods and materials. Examples of methods and materials include the invention of veneering and inlay, frame and panel construction, bending techniques, and the use of plywood and composite materials. Although ancient Egyptians invented many of these techniques, they needed to be modified and improved to be compatible with the economic and technical demands of the industrial age. In the modern style, nonwood materials such as metals and plastics were often chosen by designers to achieve the desired look. Although these nonwood materials have made significant inroads into furniture manufacturing, the bulk of the furniture made today is still made from wood or wood-based materials. In the USA, pine (*Pinus* spp.), maple (*Acer* spp.), and cherry (*Prunus* spp.) were the preferred furniture materials through the nineteenth century, giving way to a strong preference for oak (*Quercus* spp.) fueled by the styles of the late nineteenth-century arts and crafts movement. Oak remains the species most used for furniture in the USA.

2. Material Properties

The elements important in the selection of materials for furniture manufacturing can be defined by the material properties. The fundamental wood characteristics of anatomical structure and density are highly correlated to the physical and mechanical properties that affect performance, manufacturing, and appearance characteristics important for furniture materials. Wood continues to be a favorite furniture material because it excels in most of the manufacturer's and consumer's selection criteria described above as desirable attributes, and it is readily available and cost-competitive with other possible materials.

2.1 Performance Characteristics

How well a particular wood performs in any product is in large part a function of the wood density (see *Wood: Density*). Density is a good predictor for strength and stiffness, two mechanical properties that are very important considerations for furniture (see *Wood: Strength and Stiffness*). Because all furniture is designed to carry a load, it is necessary to choose wood that has the necessary strength and stiffness to perform the intended task, be it to support a person or a heavy load of books. Wood in the density range 400–800 $kg\,m^{-3}$ (oven dry mass, green volume basis) is preferred (Webster *et al.* 1984). Lower density woods have inferior strength and stiffness properties and manufacturing characteristics. Higher density woods are often undesirable because they are more costly to process and they may yield a piece of furniture heavier than desired by the customer.

Dimensional stability, or the ability to maintain a desired dimension during normal exposure to fluctuations in relative humidity, is a very important performance consideration in furniture design and construction (see *Wood: Dimensional Change from Moisture*). Density is highly correlated with dimensional stability. Therefore, high-density woods are generally less dimensionally stable than low-density woods. However, if the wood is properly dried to its target moisture content, dimensional stability is usually adequate for most furniture uses. Difficulty is encountered when furniture is exposed to warm, humid climates. In this situation it is wise to use materials with similar dimensional change characteristics in the same piece and to design the furniture to allow for movement of the wood (Wadso 1995). Woods with a tangential shrinkage greater than 10%, a radial shrinkage greater than 6%, or a tangential to radial shrinkage ratio greater than 2.5 are likely to present problems during normal use. Special design techniques are required if high-shrinkage woods are used (Hoadley 1980).

Durability is a measure of the natural resistance of wood to biological degradation (see *Wood Products: Decay During Use*). This property is not an important consideration for interior-use furniture. It is, however, an important performance criterion for outdoor-use furniture. Species with a high degree of durability such as redwood, cedar, and teak are ideal choices for outdoor furniture because of their high degree of durability.

2.2 Appearance Characteristics

The appearance is often of primary importance when choosing furniture woods for items where the wood surface is readily visible. The appearance characteristics are not important for the secondary woods (those not visible) used in solid wood or upholstered furniture. For furniture that has exposed wood, the color, texture, and figure (grain pattern) of the wood determine the aesthetic quality of the item (see *Wood: Macroscopic Anatomy*). Color is determined by the chemical composition of the extractive component of wood. Texture is directly related to the structure and distribution of anatomical features such as wood rays, annual rings, and hardwood vessels. Figure is a reflection of the orientation of these anatomical features to the aspect of the wood surface. In general, hardwoods have more desirable color, texture, and figure than softwoods because of the more complex anatomical structure found in hardwoods. The highest value furniture woods, such as rosewood and walnut, are often those with unusual and striking figure and/or color.

2.3 Manufacturing Characteristics

Important considerations in choosing furniture woods are the machining, joining, and finishing characteristics of the wood. Density also has a significant impact on these characteristics. Low-density woods often exhibit poor machining and finishing qualities. High-density woods cause increased wear of cutting tools. Also, since density is a measure of the amount of cell wall substance in a given volume of wood, it is highly correlated to permeability. Permeability has a slight effect on gluing and finishing characteristics but not enough to affect material selection.

Many attempts to describe the numerous major and minor wood species of the world in terms of machining, joining, and finishing characteristics have been reported (Davis 1962, Webster *et al.* 1984). Machining characteristics are controlled by the density and texture of wood, and can be described by the quality of the surface formed by cutting tools. Joining refers to the ability to connect two or more pieces of wood together mechanically (e.g., mortise and tenon joints) or by adhesion. Since connections depend heavily on the quality of the surface, woods with good

machining characteristics typically join well (see *Wood: Surface Properties and Adhesion*). Exceptions are woods having densities greater than $700\,kg\,m^{-3}$ or those with unusual extractives causing oily or resinous surfaces that interfere with the chemical and physical bonding. Generally, high-density, fine-textured woods have the best machining and finishing qualities but are more time consuming and costly to process.

3. Wood and Wood-based Materials

Furniture is constructed from a wide variety of wood and wood-based materials. Solid wood is the primary form used, but veneer, plywood, and composite panels are also routinely used (Table 1). Some manufacturers also use engineered products such as laminated veneer lumber and parallel strand lumber.

3.1 Solid Wood

By far, the most common species used for furniture are hardwoods in solid wood form. Compared to softwoods, the higher density hardwoods have superior furniture manufacturing characteristics such as better machining and finishing, and higher strength. In addition, hardwoods often have more interesting color and figure. In a survey of 140 woods with an acceptable combination of characteristics for a wide variety of furniture uses, only 16 were softwoods (Webster *et al.* 1984). Some of the most desired species for making fine furniture are listed in Table 2. In addition to these premier furniture woods many other species are commonly used. Woods with less favorable furniture characteristics and consequently lower value (e.g., yellow poplar) are usually used for hidden wood components, such as internal frames, upholstered furniture, or cabinet backs. Of the $135 \times 10^6\,m^3$ of wood used in the USA in 1990, 30% was red oak (*Quercus* spp.), 16% was white oak (*Quercus* spp.), and 11% was yellow poplar (*Liriodendron tulipifera*) (Forbes *et al.* 1993).

In some regions of the world, interest in a noncommercial species often develops to the point of having a significant impact on regional furniture production. Two examples are rubberwood (*Hevea brasiliensis*) in Malaysia and red alder (*Alnus rubra*) in the Pacific Northwest region of the USA. Rubberwood has become the major species fueling the Taiwan export furniture industry. Red alder, once considered a weed species in the Douglas-fir forests of the US Pacific Northwest, is now a major raw material for the California, Oregon, and Washington furniture industry. Other noncommercial species such as tanoak (*Lithocarpus densiflorus*) and madrone (*Arbutus menziesii*) in the western USA and woods from urban areas are also being used for furniture in local and niche markets (Shelly 1997).

Table 1
Major wood household furniture construction types used in 1989 based on sales estimates.

Construction material or type	Percentage of total
Solid hardwood	44.7
Non-wood laminate over composite material	25.9
Hardwood veneer over composite material	11.3
Solid softwood	8.4
Hardwood veneer over solid wood	5.5
Other construction types	4.2

Source: Meyer *et al.* (1992).

3.2 Wood-based Materials

The use of thin pieces of decorative veneer glued to a substrate wood of inferior quality is an ancient technique. It is an early example of maximizing the value of a highly prized species or a specific log that has exceptional appearance characteristics. Veneers are sawn, peeled, or sliced (usually sliced) to a variety of commercial standard sizes. Although much of the low-to-medium value furniture produced may use vinyl or other polymer materials as face laminates, high-grade hardwood veneers are the laminate choice for high-value furniture (see *Wood: Materials for Veneers and Panels*).

All of the wood industry composite materials are used in furniture manufacturing, including plywood, oriented strandboard (OSB), medium-density fiberboard (MDF), hardboard, and even plastic–wood fiber composites (see *Wood: Materials for Veneers and Panels*, *Wood: Nonstructural Panel Processes*). These composite products are most often used for hidden components of furniture or the substrate for a decorative veneer or laminate material. In furniture uses, composite materials have the advantage over solid wood of being cheaper and providing better dimensional stability in the interior environment. However, when exposed to long-term loading situations or radical moisture environments, composite materials are more susceptible to strength degradation than solid wood (see *Wood: Creep and Creep Rupture*). Creep and fatigue behavior, the measures of material response to long-term loading, are important considerations when using composites in furniture (Bao *et al.* 1996).

Laminated veneer lumber (LVL), a relatively new structural material, is actually very similar to the molded, curved plywood laminates developed in the furniture industry in the mid-twentieth century. The use of LVL for nonexposed furniture parts and frames is gradually increasing. LVL has all the advantages of composites, such as a lower cost than solid wood, plus it has the distinction of providing a solid wood appearance. Other engineered wood materials such as parallel strand lumber are also used in furniture manufacturing but the total market share of engineered wood materials is very small compared to the other wood and wood-based materials (see *Lumber:*

Table 2
Some species highly rated for furniture use because of an excellent combination of wood properties and manufacturing characteristics.

Species	Region of origin	Density[a] ($kg\,m^{-3}$)
Beech (*Fagus sylvatica*)	Europe	600–640
Canalete (*Cordia gerascanthus*)	Central/South America	440–520
Caviuna (*Machaerium* spp.)	Central/South America	650–750
Cherry (*Prunus avium*)[b]	Europe	500–680
Cherry, black (*Prunus serotina*)	North America	470
Cocobolo (*Dalbergia retusa*)	Central/South America	880–980
Ebony, Ceylon (*Diospyros ebenum*)	Southeast Asia	600–800
Idigbo (*Terminalia ivorensis*)[b]	Africa	430
Iroko (*Chlorophora excelsa*)[b]	Africa	550
Mahogany (*Khaya* spp.)[b]	Africa	440–650
Mahogany, Honduras (*Swietenia macrophylla*)[b]	Central/South America	440–680
Makore (*Tieghemella heckelii*)[b]	Africa	550
Maple, hard (*Acer saccharum*)[b]	North America	490–560
Muninga (*Pterocarpus angolensis*)	Africa	590
Oak (*Quercus robur* and *Q. petraea*)	Europe	600–640
Oak, red (*Quercus* spp.)	North America	520–610
Oak, white (*Quercus* spp.)	North America	570–640
Padauk (*Pterocarpus* spp.)[b]	Southeast Asia	520–750
Peroba (*Aspidosperma* spp.)[b]	Central/South America	700–800
Primavera (*Cybistax donnell-smithii*)	Central/South America	400
Rosewood, Brazilian (*Dalbergia nigra*)	Central/South America	750–880
Rosewood, Honduras (*Dalbergia stevensonii*)	Central/South America	620–730
Rosewood, Indian (*Dalbergia latifolia*)	Southeast Asia	700
Sapele (*Entandrophragma cylindricum*)	Africa	550
Trebol (*Platymiscium* spp.)	Central/South America	730–940
Walnut, African (*Lovoa trichiliodes*)[b]	Africa	450
Walnut, black (*Juglans nigra*)[b]	North America	510

Sources: Anon (1999), Chudnoff (1984), Farmer (1972).
a Expressed on an oven dry mass and green volume basis. b Identified by Webster *et al.* (1984) as having exceptional furniture-manufacturing characteristics.

Laminated Veneer).

Comparing volume consumption of various materials is difficult because the data for composite panels are reported in surface area for a variety of sizes. However, a comparison can be made of calculated equivalent volumes, based on the most common thickness for representative composite types (Table 3). Hardwood lumber is clearly the preferred material with $5.72 \times 10^6\,m^3$ of consumption or 52% of the total volume of wood and wood-based materials used. Particleboard at 20% and softwood lumber at 18% of the totals complete the top three materials by volume. The remaining composite materials (OSB, plywood, MDF, and hardboard) make up only 10% of consumption.

4. Furniture Industry

The USA is the largest furniture-consuming market in the world and the leading importer of furniture. About 26% of the wholesale furniture sales in the USA are of imported items. The leading exporters of furniture are Taiwan, Indonesia, and Europe (Ratnasingam and Reid 1996). In terms of value, Taiwan exports more than three times that of the second largest Asian producer, Indonesia. The Pacific Rim producers made their surge into furniture exports by specializing in the low- to medium-quality, knockdown furniture that can be produced at low cost and easily shipped to Europe and the USA. This trend has increased with the rapid expansion of ready-to-assemble (RTA) furniture. RTA sales range from 40% to 75% of the furniture market in much of Europe and about 12% of the market share in the USA.

As the market share of RTA furniture continues to increase, the consumption of composite materials, especially particleboard, is expected to grow more than other materials. The proportion of solid wood, particleboard, MDF, and wood veneers used is expected to increase and the use of softwood lumber, plywood, and OSB will be likely to decrease (Sinclair *et al.* 1990). It is unclear how much impact nonwood materials will have on the future manufacturing of furniture, but one thing is clear—wood has remained the favored material for furniture for more than 3000

Table 3
Consumption of wood and wood-based materials by USA furniture manufacturers in 1990.

Material	Volume by defined basis ($\times 10^6$)	Equivalent volume ($\times 10^6\,m^3$)	Percent of total volume
Hardwood	2425 board feet	5.72	52
Softwood	839 board feet	1.98	18
Particleboard	1259 square feet, 3/4 inch basis	2.23	20
MDF	248 square feet, 3/4 inch basis	0.44	4
Hardboard	125 square feet, 1/8 inch basis	0.04	0.3
OSB and plywood	318 square feet, 7/8 inch basis	0.66	6

Source: Meyer *et al*. (1992).

years and it is unlikely that it will be removed from its dominant position in the future.

See also: Wood: Future Availability; Wood: Lumber and Other Solid Wood Processes

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