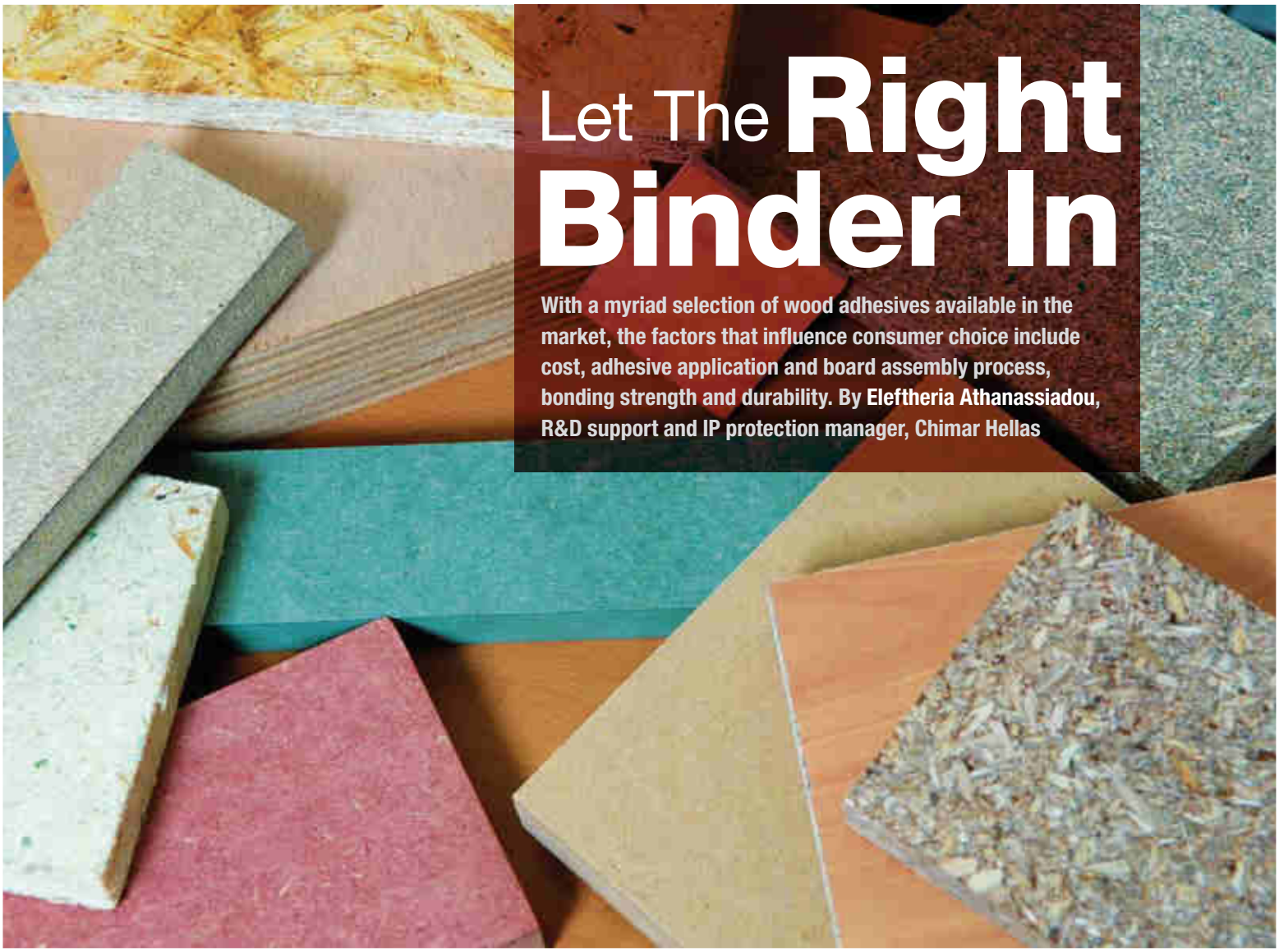

Let The Right Binder In

With a myriad selection of wood adhesives available in the market, the factors that influence consumer choice include cost, adhesive application and board assembly process, bonding strength and durability. By Eleftheria Athanassiadou, R&D support and IP protection manager, Chimar Hellas

The adhesive in wood panel applications bonds together pieces of wood, in the form of particles, fibres, veneers or strands, to form a wood-adhesive matrix. The strength of the product depends on an efficient distribution of the adhesive on the wood substrate. The wood-adhesive matrices are then formed into mats and pressed under heat into the final product.

This type of process requires an adhesive that does not react immediately at room temperature (premature cure), but is heat-activated during the pressing operation. In addition, since the wood surfaces are brought close together, gap filling is not an important issue, but over penetration is.

However for plywood, the surfaces are not uniformly brought in such close contact, requiring the adhesive to remain on the surface. Light coloured adhesives are important for some applications, but many of these products have their surfaces covered by other materials. Most of the adhesives used in wood bonding have formaldehyde as a co-monomer, generating concern about formaldehyde emissions. Given the weight of adhesive (2–10 percent) compared to the product weight, cost is an important issue.

Formaldehyde Binders

Thermosetting formaldehyde-based resins are the main binders used in current industrial production of wood-based panels. They are derived by the condensation polymerisation of formaldehyde (F) with either urea (U), melamine (M), phenol (P), resorcinol (R) or a combination of these monomers.

Straight urea-formaldehyde (UF), melamine-formaldehyde (MF), phenol-formaldehyde (PF), resorcinol-formaldehyde (RF) resins and combinations like UMF, MUF, MUPF, PUF and PRF are readily available. They are produced via reaction of

monomers to form aqueous suspensions of oligomers.

The final setting of the polymers is affected through the application of heat and pressure during the hot-pressing step of board manufacture. The co-reactant or combination of co-reactants used with formaldehyde is selected depending on the cost, production conditions, and expected performance of the target panel product.

The issue of formaldehyde release from composite wood panels is mainly related to the use of UF resins as bonding adhesives for their production. UF polymers are contributing to the panel formaldehyde emission by their low resistance to hydrolysis and the presence of free non-reacted formaldehyde.

The formaldehyde re-classification by the International Agency for Research on Cancer of the World Health Organization (WHO) as 'carcinogenic to humans (Group 1)' and the reduced emission limits for panel products that were established henceforth have driven the resin industry in the development of low formaldehyde release UF resin systems, with or without the addition of melamine.

At the moment, the available amino resin systems can meet even the most stringent prevailing formaldehyde emission standards for composite panel products, without deterioration in the panel performance or significant modification of the operating conditions of the panel industry, or the need to employ other types of binders.

Formaldehyde-based resins providing panels with formaldehyde emission values at the level of natural wood are offered in the market. The prevailing emission standards and limits are well below the levels of concern for formaldehyde.

Urea-formaldehyde (UF), along with melamine-formaldehyde (MF) and melamine-urea-formaldehyde (MUF) are the most important amino resins. They are generally sold in aqueous suspension

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Cost is a big factor in the selection of a suitable adhesive.

form with content of active matter in the range of 50-70 percent (on a weight basis). Their curing is enhanced with the addition of an acid catalyst.

UF resins are light in colour, fast curing, hard and abrasion resistant, and provide excellent dimensional stability, good flame resistance and a 'clear glue line' (point at which the wood element and adhesive meet in an adhesive binding).

UF resins compete with other formaldehyde resins with regard to its end-use applications due to their lowest production cost. However, they are less moisture and abrasion resistant than melamine-formaldehyde (MF) and phenol-formaldehyde (PF) resins.

UF resins are generally used in applications requiring dimensional stability, but with only moderate exposure to heat or moisture, such as particleboard or medium density fibreboard (MDF) for furniture or cabinet making. They are also used in the production of panels for building and construction applications, such as interior grade particleboard and plywood.

Melamine-formaldehyde (MF) resins are similar in chemical behaviour and properties to UF resins. In addition, MF resins are tougher, more thermally stable, and are more moisture and chemically resistant than UF resins.

They are most commonly used as adhesives in the production of exterior grade plywood, curved plywood and marine grade plywood, as well as in the production of structural panels (plywood and oriented strand board (OSB)) for interior applications. Another significant use is for impregnating paper sheets used as the backing in making decorative laminates. The resins for paper impregnation are different in many respects (such as degree of polymerisation, addition of copolymerising additives and viscosity).

The limitation of the MF adhesives is their high cost due to the cost of the melamine. This has led to the use of copolymer resins MUF (with high level of melamine) or UMF (low melamine level) with many of the performance attributes of the MF resins, but at a lower cost. The MUF adhesives can replace other adhesives that are used for some exterior applications.

Phenol-formaldehyde (PF) resins are the first synthetic polymers that were developed and address a wide variety of applications. There are two classes of phenolic resins: resoles and novolacs.

The resoles are used in most wood adhesive applications. They are produced under alkaline conditions and are cured under the application of heat. Resole PF resins offer comparable strength and dimensional stability to UF resins, but have higher moisture and chemical resistance than either UF or MF resins.

For this reason they are the adhesives of choice for structural and exterior grade wood panels (mainly plywood and OSB). They are also used for the impregnation of Kraft paper to produce industrial and decorative laminates via high pressure lamination (HPL).

The main limitation of PF resins is their deep red colour which leads to dark coloured panels. Their high cost together with long curing times, also limit their widespread use in wood bonding applications. A common additive for PF resins is urea, to reduce the cost and to provide improved flow properties.

Resorcinol-formaldehyde (RF) resins have the advantage over PF resins by being curable at room temperature. Like the phenol-formaldehyde resins, these adhesives form very durable bonds. They are resistant to both bond failure and to degradation. They possess the combination of adhesive properties and moisture resistance needed for exterior grade structural panels.

Their main drawback is the high cost of the resorcinol which limits their use to specialty applications. To lower the cost, but maintain the room temperature curing properties, phenol-resorcinol-formaldehyde (PRF) adhesives were developed. PRF adhesives are widely used in wood lamination and finger jointing.

Other Types Of Adhesives

Isocyanate adhesives have shown increasing use in wood bonding applications due to their high reactivity and bonding efficiency irrespective of the presence of high moisture/water levels.

Their most common representative in wood panel applications is the polymeric diphenylmethane diisocyanate (pMDI) binders. They are used in the production of OSB and are possible substitutes for PF resins in plywood production. There are also isocyanate adhesives which are technically feasible for particleboard and MDF production.

Besides high cost, the limitations of pMDI binders are their tendency to stick to press platens and their toxicity due to the presence of free isocyanate groups. Both stickiness and safety issues have been addressed in the modern wood-based panel industry, but still pMDI binders represent a low share in adhesives for the global panel market.

Another quality of pMDI-bonded panels is low formaldehyde release. However, the conventional route to producing MDI involves the use of formaldehyde.

Hybrid UF/pMDI and PF/pMDI adhesives for wood panels have been recently introduced to the market for upgrading the existing adhesives technology and performance, and for solving the problem of free isocyanate groups.

Brendan C

100 percent soybean adhesives do not have sufficient dry and wet strength for application in wood panel manufacturing.

Water borne epoxy resins and copolymers are examined for their use as potential substitute adhesives for wood-based panels. They are water resistant, have low creep, and are dimensionally stable. Besides their high material cost, they are toxic and have longer curing times than UF resins, thus limiting the productivity of the wood panel production process.

Water borne polyvinyl acetate (PVA) and polyethylene-vinyl acetate (EVA) dispersions are mainly used for wood bonding in furniture construction and could be potentially used for particleboard and MDF production. They possess good dry strength characteristics but are limited by their poorer performance under moderately high temperatures and humid conditions.

Bio-Based Adhesives

Since ancient times, adhesives from plants and animals have been used for several gluing applications including the gluing of wood. In the early 1900s, bio-based adhesives were used in the manufacturing of cost effective wood products for replacing solid wood, thus leading to the expansion of the wood products industry.

After the 60s, these bio-based adhesives were replaced by adhesives synthesised from petrochemicals due to cost, durability and availability factors. More recently, the environmental problems caused by the use of petrochemicals and the increases in oil prices have renewed the interest in bio-based products.

The most common representatives of bio-based adhesives are protein-, tannin- and lignin-adhesives. Several other lignocellulosic residues and materials extracted from biomass can be used as natural adhesives as well. They possess good dry strength, but have insufficient wet strength and durability when compared to synthetic resins.

Protein adhesives are adhesives based on blood proteins, soybean proteins and casein. Soybean protein adhesives have attracted considerable attention over the years due to their low cost feedstock, and their renewable nature.

However, 100 percent soybean adhesives do not have sufficient dry and wet strength for application in wood panel manufacture. Their performance can be improved by combining their use with other adhesives like PF resins or by using special cross-linking agents and additives, which can also be of natural origins.

Soy-based adhesives are applied to a limited extent these days in the production of plywood in North America. Their use in particleboard and MDF production has been proposed as well. Feedstock availability and competition with food applications are important considerations in regard to the application of soy-based adhesives in bulk wood panel manufacture.

Blood adhesives made from dried animal blood albumen are inexpensive but their use in board manufacture is hindered by the limited feedstock availability and the objectionable workplace conditions that they create. They are used in combination with PF resins at some plywood factories.

Casein adhesives, derived from milk, possess high dry strength and better moisture resistance than either blood or straight soy adhesives. However, the cure time of casein adhesives is too long for cost effective industrial production of particleboard or MDF, and they are subject to microbial attack. Their cost is competitive with UF resins but their availability is limited as most of the feedstock (milk) is used by the food products industry.

Tannins are polyhydroxypolyphenolics that occur in many plant species, but it is worthwhile to isolate them from only a few. They are more reactive than phenol and create water-resistant bonds when co-polymerised with formaldehyde.

Tannin-formaldehyde resins have been used in the production of particleboard and MDF in countries like Argentina, Brazil, South Africa, Australia and New Zealand due to the availability of tannin in these countries.

The limitations for such adhesives are their high viscosity, limited availability and like many natural products, an inconsistent source and therefore leading to inconsistent reactivity. A promising way to tackle the problems of tannins is to combine them with PF resins.

Lignins are phenolic derivatives but different from tannins. They constitute 16-33 percent of wood depending on the species and they are available in large quantities at low cost, as the by-product of the pulping processes for papermaking.

Lignins are much slower in their reaction with formaldehyde and many researches have been devoted to finding ways to convert lignin into useful thermosetting adhesives. Modified lignin from paper manufacture has been used as an extender for PF and UF resins. It has also been used in combination with PF in plywood bonding. However, such systems are still some distance away from wide commercial adoption.

Jon Rawlinson

Isocynate adhesives have shown increasing use in wood bonding applications due to its bonding efficiency even with the presence of moisture.

Choice Of Adhesive

The degree of industrial application and market acceptance of bio-based adhesives is still low due to availability and technical performance reasons. Combinations with synthetic binders are a preferable option for the moment.

The choice of the wood panel adhesive highly depends on its cost and performance. Based on the form of the wood substrate, a wide variety of wood panel products can be made.

Wood-based panels, being commodity materials, are highly sensitive to material input cost. A substantial increase in the cost of adhesive raw material or in board processing cost, due to the use of an alternative adhesive, can increase the board cost up to a point where it is susceptible to replacement by alternative panel products.

Health safety issues are a further concern in regard to the adhesives used in wood products and therefore, a continuous evolution of synthetic binders has been occurring to meet the corresponding health standards. Modern formaldehyde-based resins can provide panels with formaldehyde emission values at the level of natural wood.

Given the finite nature of the oil deposits, the long-term availability of petroleum-derived products is not guaranteed. The efforts to develop and apply effective bio-based binders for wood-based panels are intensified as a means to promote the sustainability of the resin and panel industries. FDM