NEW DEVELOPMENT IN PARTICLEBOARD TECHNOLOGY

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Particleboard was originally conceived to take advantage of the waste which was being produced by the wood-using industries. Efforts to make boards were made as far back as the turn of this century in the United States. At that time, a relatively abundant solid raw material coupled with glues which were not suitable for this purpose made the effort unsuccessful. No significant further efforts were made for some four decades in the development of particleboard technology. New discoveries made in the 1930's in resin technology, paved the way for industrial particleboard production in the 1940's.

The desire for reconstruction after the Second World War gave impetus to the development of this industry. Industrial production began in the 1940's in Europe and in the early 1950's in the United States.

The early versions of particleboard were characterized by low strength and a high degree of dimensional instability. Research and development on product refinement and performance improvement has resulted in substantial gains in strength and dimenssional properties.

Production has been steadily on the rise. In the early '60's, the production was less than 500 million ft^2 (3/4 " thick bases) increasing to nearly 5 billion square feet in 1979. During this period, the fields of furniture and fixtures, housing and other industrial applications have been the major users. In many of these applications, particleboard has replaced lumber and plywood in such products as kitchen cabinets, tables, counter tops, shelves and the like. Particleboard provided a uniform panel with acceptable surface characertistics of uniform thickness. This product substitution continues and will probably accelerate in this decade, particularly as it pertains to plywood in the field of housing.

The problems of low strength, excessive dimensional instability, rough edges, low screw holding characteristics and chipping have been the subject of much research over the last two decades.

Refinements have also included development of such concepts as particle orientation within the board, layering differential resin applications, and manipulating press and furnish parameters to produce desirable density profile within the thickness.

The Raw Material

Much of the particleboard production still relies heavily on by-products of other wood-using industries; i.e., sawmills, stud mills, and plywood plants. Planer shavings continues to constitute the largest single source of particles providing about half of the total amount used. Plywood plants provide veneer trimmings and clippings. Sawmills produce such by-products as chipped slabs, edgings and trimmings. In addition, sawdust is gradually becoming an important source of raw material.

Roundwood and some forms of residue are now being converted to pulp chips. These chips are then further reduced into strand or flakes in the production of flakeboards. The concept of whole tree chips is being pursued vigorously in the United States with the objective of converting the entire tree into usable particles. The segmentation of these particles into their most economic components has sometimes been referred to as "fiber beneficiation." These components can then be directed to the production of such products as pulp, particleboard, fiber panels and energy. The particleboard experience gained over the last three decades will be helpful as the concept of whole tree utilization becomes an industrial routine. The decade of the '80's, bringing with it substantial energy concerns and solutions is also likely to bring about not only a greater degree of total tree fiber utilization but also a degree of fiber competition - especially between the composites (particle and fiber panel products) and the pulp and paper industry.

As the decade advances, "energy fiber" will also be looked at as raw material for particle and fiber products as such material will be too valuable for products rather than fuel. Thus, the stage is being set for the most intensive raw material utilization in the history of the forest products industry.

Several concepts in relation to particle orientation are now being actively pursued by the industry. These will favor the use of small roundwood to produce the type of flakes which can then be effectively oriented.

Binders

Urea binders have traditionally been the primary adhesive for the particleboard industry. Urea adhesives are condensates of urea (NH_2-C-NH_2) and formaldehyde (HCHO) which permit dispersion in water at solid contents of about 60-65 percent. These resins are essentially monomeric or, at most, only slightly advanced in polymerization. They contain the reactive terminal groups enabling them to condense further in an acid environment under the influence of heat. Boards bonded with urea-formaldehyde adhesives are not intended for wet or damp environments and break down under heat, a characteristic which has severely limited their use in exterior particleboards.

The comparatively lower cost, versatility and the ease of application have favored the use of these binders. The properties of the board using these binders have been adequate for many interior products such as furniture. Many improvements over the last two decades have brought about reduction in press time and improved board strength. Research and development continues on these resins so that cost increases can be kept to a minimum.

Phenolic binders are the second most widely used adhesives which are gaining increasing importance with the current high level of interest in producing exterior products. These resins have some basic differences with the urea binders especially as they relate to the durability of the bond in high moisture environments. Continuous research and development in phenolic resisn has paralleled that of urea resins. The result has brought about improvements in properties and has reduced cost increases. The increasing production of exterior boards has, in turn, given phenolic resins renewed interest. This does not mean that phenolics have taken over from the ureas. They still require higher press times, higher cure temperatures and cost more.

The volume of phenolic resins used by the particleboard industry still remains far behind that of the urea resins.

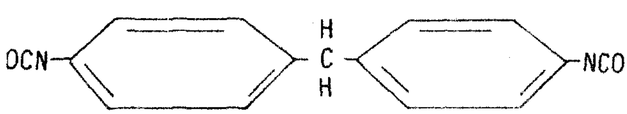
Phenolic and urea resins have provided practically all of the resins needed by the particleboard industry. The picture, however, appears to be changing due to two important factors.

First, the cost of both phenolic and urea binders is increasing rapidly. Although the availability has not been a problem so far, the questions of cost is becoming a matter of increasing concern to the industry. Secondly, the use of phenolic or urea binders has involved the release of formaldehyde both during the manufacture and subsequent use. Mobile home residents, in particular, have expressed concern over such formaldehyde release–particularly during heating and cooling seasons when ventilation within the home is minimal. Litigation in courts relative to the release of formaldehyde and possible health hazards have been common. More on this subject has been discussed later in this report.

These have brought about a new search for other sources of binders – particularly those which do not depend on petroleum or natural gas for feedstocks and do not involve the problem of formaldehyde release.

Lignin is being re-examined as a source of new binders. Research is now investigating the possibilities of producing binders which would meet current market requirements. Lignin is also being examined in connection with the use of urea or phenol-formaldehyde adhesives. In these cases, lignin is envisaged as a possible extender for such adhesives thereby reducing costs. However, problems associated with the complex chemistry of lignin is not likely to make the task an easy assignment. In addition, lignin has now become a major source of energy for pulp and paper mills which would be reluctant to trade their energy source at least for the next decade.

Isocyanates are now being used as a binder for particleboard. Much of this attempt has so far been restricted to the laboratory although several industrial plants in Europe have begun using this material regularly. The isocyanate currently considered for use in connection with wood is 4,4′-diphenylmethane diisocyanate (MD1):



Particleboard bonded with isocyanates has acceptable strength properties. It has improved dimensional properties compared with phenolic bonded boards. A reason for this dimensional improvement appears to be the chemical reaction believed to take place between the isocyanate group with hydroxyl groups in the wood cell wall in the manner shown:

$$\text{R-NCO} + \text{R}' \cdot \text{OH} \longrightarrow \text{R-}\underset{\text{H}}{\text{N}}\text{-}\underset{\text{O}}{\text{C}}\text{-O-R}'$$

The problem of formaldehyde release is not encountered with the use of MD1. However, this material tends to adhere to caul plates and other objects. The use of proper release agents is essential in their use. Such release agents are now available. MD1 costs more than both phenolic and urea resins. The cost element has, so far, kept isocyanates from widespread use by the industry. However, this cost differential can at least, in part, be made up by using particles with higher moisture, using lesser amounts of binder (compared with urea and phenolic resins) an shorter press times. In one instance, MD1-bonded particleboard has been laminated with veneer on top and bottom to produce a plywood-like product. This product is manufactured in a single-step operation. Mill trials in the United States in at least one particleboard plant have taken place. No significant problems in their use have been reported. MD1 has the potential for use in medium-density fiberboard, waferboard and flakeboards. This binder is produced in many parts of the world and is an essential component in the manufacture and rigid plastic forms.

Inorganic binders are now being considered in producing specialty products particularly for the building industry. The primary source of such binders involves portland cement. The concept of using cement and wood dates back several decades originally used to make brick-type products with sawdust as fillers. Excelsior boards also have been in use for several decades. These products involve the use of long, stringy wood particles (excelsior) and cement in the production of porous, fairly thick (over 1/2-inch) panels for certain building applications (ceilings, acoustic walls, etc.). The industrial production of such panels dates back to the mid-'60's. Such products are now manufactured in Japan, and in serveral locations in western Europe. Cement-bonded panels have escellent fire resistance, fungal and insect resistance and are exterior. The fields of low-cost housing, flooring and roofing, utility buildings and schools are some examples of application. The products also are used for general applications in industry and trades. Many wood species and other types of ligno-cellulosics can be utilized in conjunction with portland cement. However, cement is not compatible with certain wood or plant species; sugars in such species interfere with cement hydration. Current research is attempting to address these problems through the use of additives and processing techniques. Magnesites have also been tried as binders and have been reported to encounter fewer problems with difficult-to-bond species although they are more costly.

Other binders [illegible] aldehye resins and particle surface act[illegible]. The former resins are currently being eval[illegible]d in laboratories and are reported to be water-resistant. They involve similar press cycles as those of urea and phenolic resins. Particle surface activation involves the activation of wood surface molecules with such oxidizing chemical as hydrogen peroxide or nitric acid. With nitric acid, 72 percent concentration of this acid is sprayed on the particles at the rate of about 1.5 percent based on the oven-dry weight of such particles. Then, after some wait period, a cross-linking agent composed of ammonium lignosulfonate, furfural alcohol and maleic anhydride is sprayed at the rate of 7 percent with a solids content of 50 percent. Some two hours are needed after spraying for reactions to take place. Pressing of the particles is done at 177°C for seven minutes with a mat moisture content of 9 to 11 percent. Board properties compare favorably with conventionally bonded particleboards.

Formaldehyde Release

The release of formaldehyde (HCHO) from urea and phenolic-bonded particleboard has become of increasing concern in the United States as noted earlier.

Th health effects of formaldehyde exposure in housing applications, in furniture, kitchen cabinets and the like are now being studied. How toxic is formaldehyde to humans at the concentrations being encourntered?

The research on rats and mice exposed to formaldehyde fume for five days per week, six hours per day produces nasal cancer in some test rats but not in mice. At the end of 18 months, rats exposed to 15 parts per million (ppm) formaldehyde, 37 out of 200 test rats produced nasal cancer. Rats are strict nost breathers which could perhaps explain the higher rates in rats. Also, 15 ppm formaldehyde is a much higher level than humans can tolerate. Tests with monkeys exposed to inhalation for 22 hours per days, seven days per week for six months at the rates of up to 3 ppm produced no serious effects with the exception of some nasal discharge.

It is clear that the problem of formaldehyde release must be solved if continued and expanded use of particleboard in construction is to be expected.

A variety of means are now being examined to address the problem of formaldehyde release. The use of ammonium fumigation of boards has proven helpful. In such techniques, boards are exposed to ammonia gas in a fumigation room for several hours. Also, resin additives and particleboard sealants are under consideration. In one test, the use of sprayed-on sealant reduced subsequent formaldehyde release from 21.8 mg/ft^2 to 1.3 mg/ft^2. The use of newer resins such as isocyanates which produce no release of formaldehyde is also a possibility should other techniques prove impractical or too expensive.

New Products.

In this section, I would like to mention three basic categories of "New" industrial development: waferboard, oriented strand board and medium-density fiberboard. The concepts underlying these products are not new. Some have existed in the laboratories for several decades. However, due to the changing raw material picture, these products have now become of appreciable interest to the forest products industry.

A. Waferboard

The concept of making waferboard dates back to 1948. Over the last four years, it has become of increasing interest to the industry. Waferboard is a randomly layered flakeboard made up of rather large flakes. Such flakes are generally 2 inches to 3 inches in length, 2 inches in width and measure approximately 0.015 inch in thickness. The manufacture of waferboard usually involves the use of 2-foot roundwood which is first debarked and heated in hot water at 38°C to 65°C followed by cutting in drum cutters. Wafers are then dried at 115°C to a moisture content of 2 to 10 percent. Powdered phenolic resins are blended with wafers at the rate of 2-2.5 percent based on the dry weight of particles. The mat is pressed at 210°C with a pressure of about 300-500 psi. The mat is pressed for 28 seconds per each mm of thickness. After the completion of the press cycle, the panels are conditioned at 100°C to 150°C for two hours.

Waferboards offer the advantage of low resin requirements due to their low particle surface per unit weight. However, due to their "shadow effect" wafers are difficult to blend with liquid resins. Thus, only powder resins have been used so far. The use of powdered resins is inherently inefficient compared with liquid resins. Waferboards have about half of the strength of plywood and can lose as much as one-third of their strength after two years of exposure to the outdoors. Thus, it is not likely that waferboards can substitute plywood in exterior applications in the immediate years ahead.

In Canada, waferboard has gained excellent market acceptance for certain applications. In 1978, the Canadian consumption of waferboards amounted to 22 percent of the total plywood consumption. Much of the uses for waferboard has been in subordinate plywood applications. Table 1 notes the existing and new production being planned over the next two years in the United States and Canada.

It is evident that over the next two years, waferboard production in North America will shown major growth. It is anticipated that over half of the Canadian production will be marketed in the United States. The Canadians will probably export about 10 percent of their production outside the United States with the remaining portion used domestically

Table 1

waferboard Production
in the United States and Canada
Million Square Feet (3/8" basis)

	Existing	Planned
United States	255	970
Canada	460	790
TOTALS	715	1,760

B. Oriented Strand Board (OSB)

In OSB, flakes are oriented by a device before they are deposited on a caul plate. In this type of board, the particle direction simulates a sheet of veneer.

The concept of orienting particles dates back to 1946 when Armin Elmendorf of the United States conceived the idea in connection with the manufacture of cement-bonded panels. This author worked on particle orientation at Elendorf Research, Inc. in California back in 1961-62. The industry now has become intensely interested in particle orientation due to the inherent advantages it offers in simulating veneer sheets. For instance, oriented particles can be cross-layered in a manner similar to plywood. Exceptionally strong and stable panels can be produced from the type of raw material not suitable for plywood production. Particle orientation can be accmplished either mechanically or electrostatically Industrially, several mechanical methods have been developed. These include orientation across machine direction by means of a rotating drum, in-line orientation using disk rolls, and in-line or cross orientation using reciprocating fins or chains. Mechanical orientation devices now available can give good results when long, slender strands (flakes) are utilized.

Electrostatic technique of particle orientation involves passing the particle furnish through a field of high DC voltage. Wood particles act as dipoles and orient parallel to the field generated by the electrodes. In principle, all types of particles can be aligned with this technique as long as the ratio of length to width or thickness is greater than one. The degree of alignment (orientation) depends to a great extent on particle geometry of the furnish.

Table 2 shows the new OSB plants either now in existance or under construction in the United States.

Table 2

New Existing or Planned OSB Plants in the United States

		Capacity Million Sq. Ft. (3/8″-basis)
Elmendorf Board Co.	Claremont, NH	180
Potlatch Corp.	Cook, MN	150
Potlatch Corp.	Lewiston, ID	120*
Potlatch Corp.	Midge Lake, MN	150
Weyerhaeuser Co.	Grayling, MI	215
	Total	815

* Oriented signle-layer panel for comply production.

Table 3

Approximate Cost Comparisons - 1980

	Waferboard	OSB
Resin	2.5% (Powder)	5% (Liquid)
Cost/Pound	$0.62/lb	$0.39/lb
Density	40 pcf	40 pcf
Thickness	3/8 inch	3/8 inch
Resin Costs (MSF)	$21.27	$26.78
Wood (MSF)	23.70	23.25
TOTAL	$44.70	$50.03

Cost comparisons between waferboard and OSB depend on a variety of factors and can not be generalized. However, Table 3 provides an approximate cost comparison for these two types of boards in the United States.

C. Medium-Density Fiberboards

MDF refers to a family of fiber panel products characterized by a uniform, flat, smooth surface. The density range in MDF can vary considerably depending on use requirements. However, most MDF has a density in the range of 720 to 960 kg/m^3 (40 to 60 pounds per cubic foot). Thicknesses can vary from 6 mm to 20 mm (0.250 to 0.750 inches). Table 4 Shows some average properties of MDF at three different densities.

Table 4

Some Average Property Values
1/2-Inch Thick MDF*

Denity	MOR-Psi	MOE-Psi	Internal Bond-Psi	Thickness Swelling-%
48	5,319	695,000	121	6.1
55	5,710	590,000	158	5.2
60	6,175	726,000	182	2.4

*Source: Borchgrevink, K.G. 1980. Fabricating and Using MDF. 14th Particleboard Symposium, Wash. State University, Pullman, WA.

These fibrous panels are manufactured in a similar manner as that used for particleboard. The manufacture involves fiber production and drying, blending with binders, forming and hot pressing. Light sanding and cut-to-size operations complete the manufacturing process. The exceptions include the manner in which particles are produced. In MDF, wood chips are cooked in a digester where they are subjected to a moderate level of steam pressure. This cooking softens the lignin bond and facilitates defiberization in the refining step.

The blending operation in MDF can be very simple and involves the incorporation of the binder with the fibrous furnish during the refining process. Thus, the refined material is already blended with adhesive as it emerges from the refiner. Sometimes, the blending is done after the fiber furnish has been dried.

The blended furnish is subsequently formed into mats of random fiber orientation followed by pre-pressing to reduce mat thickness and improve mat consolidation. In some operations, mats are directly sent to the hot press.

MDF has a smooth, uniform surface which lends itself to good finishing, such as direct printing, or vinyl overlays. It can be machined readily with parts cut with a high degree of accuracy. MDF is used in a large variety of applications in furniture manufacture, cabinets and relieved door fronts.

Conclusions

It is clear that the industry is now moving forward to implement several innovations brought about by research: the concept of particle orientation and waferboard has been re-discovered due to new realities in the changing raw material picture and the need for cost reductions. Such products are now being looked at as substitutes for plywood for housing. Substitutions in sheathing (both roof and wall) an a variety of other applications are likely. New innovative structural applications using particleboard as load-bearing components is likely over the next few years.

Resin development has gained new momentum. New possibilities in lignin chemistry, surface activation, the use of isocyanates and furfural-aldehydes are emerging. Continued refinement in phenolic and urea resins are also likely as these resins attempt to hold on to their traditional markets. It is likely that new techniques will emerge which will address the problem of formaldehyde release in both urea and phenolic resins. Process control and refinement will continue at a brisk pace. New pressing techniques, particularly for very thin boards (less than 10mm) and very thick boards (more than 19mm) are likely to emerge which will increase efficiency and reduce cost. Swift technological research and applications in the field of process control will bring about greater efficiencies in manufacture by utilizing computer controlled data acquisition and feedback.

There is no doubt that the golden age of particleboard technology is still ahead and will be brought about by the changing nature of raw material supply and cost increases for traditional solid wood products. It is likely that the future will see substantial substitution of plywood and lumber by particle composite products.