MEDIUM DENSITY FIBREBOARD
- A REVIEW

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- A REVIEW

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Dedicated to

My beloved Parents.

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ABSTRACT

Medium-density fibreboard (MDF) is an engineered wood product formed by breaking down softwood into wood fibres, often in a defibrator, combining it with wax and resin, and forming panels by applying high temperature and pressure. It is a building material similar in application to plywood but made up of separated fibres, not wood veneers. It is denser than normal particleboard. MDF typically has a density of 600-800 kg/m³, it is also known as Customwood or Craftwood. It was first developed in the United States during the 1960s. It is easier to machine than natural wood and can be laminated and painted to produce almost any board finish. It can be sawed and shaped very evenly and smoothly - a process which cannot be achieved to the same degree with particle boards. It can be nailed, stapled, routed, sanded and screwed just like any natural wood product. It has the mechanical and physical characteristics approaching the levels associated with solid wood and in many applications can be used as an ideal substitute for solid wood. Typical applications in furniture include drawer bottoms, backs of cabinets and centre panels in framed doors. In building interiors, thin MDF can be used for wall and ceiling paneling, as skins for flush doors, portioning, office screens, lightweight doors and exhibition paneling. Given developments in High Moisture Resistant panel boards, MDF is finding growing markets for exterior applications as well. Thin MDF has found its way into novel applications such as shoe making, motor vehicle interior parts, toys, printed circuit board production and blades for electric fans. For versatile use and great importance bring these materials as one of the substitute of solid wood. Further research should be taken to initiate MDF in the market to conserve the forest resources and ensure maximum utilization of the Forest products.

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CHAPTER ONE
INTRODUCTION

1.1. Background of the study

Medium-density fibreboard (MDF or MDFB) is an engineered wood product formed by breaking down softwood into wood fibres, often in a defibrator, combining it with wax and resin, and forming panels by applying high temperature and pressure. It is a building material similar in application to plywood but made up of separated fibres, not wood veneers. It is denser than normal particleboard. Large-scale production of MDF began in the 1980s. Its name derives from the distinction in densities of fibreboard. MDF typically has a density of 600-800 kg/m^3, it is also known as Customwood or Craftwood (Clarke, 1991). It was first developed in the United States during the 1960s, with production starting in Deposti, New York. A similar product, hardboard (compressed fiberboard), was accidentally invented by William Mason in 1925, while he was trying to find a use for the huge quantities of wood chips that were being discarded by lumber mills. He was attempting to press wood fiber into insulation board but produced a durable thin sheet after forgetting to shut down his equipment. This equipment consisted of a blow torch, an eighteenth-century letter press, and an old automobile boiler (Haygreen, 1930). William H. Mason was experimenting with the process of converting wood chips and edgings into fiber without loss of lignin. His patents produced the Masonite-type fiberboards that are still manufactured today. His process subjected wood particles to high steam pressure in a digester; the pressure was suddenly released to atmospheric level, thus exploding the fiber. The steam softened the lignin and fiberized the wood particles. When compressed under heat, the pulp was converted to a hard, rigid board in which the lignin served as a bonding agent. (Suchsland and Woodson, 1986).

MDF is one of four main categories of wood based panels - laminated boards, particle boards, fibre boards and oriental strand boards. These different types of boards are distinguished by the level of conversion of the wood raw material into veneers, particles or fibres. MDF is a type of fibreboard made from wood or other lignocellulosic materials, refined into fibres and reconstituted with a resin binder (glue) carried out at elevated temperatures. The raw wood material can be in almost any form or specie and in almost any mixture such as low grade wood specie, branches, small diameter trees, hardwood, softwood, mill waste and forestry waste chips. As such, the recovery rate of the raw material is almost 100% (Greubel and Drewes, 1987). In MDF individual raw wood elements cannot be identified in the finished board. This is due to the fibre-izing process. It has a homogeneous structure with uniform texture and properties throughout. There are no identifiable grains or knots seen at the edge, end or face nor any internal voids or pits or variation in surface hardness. MDF is easier to machine than natural wood and can be laminated and painted to produce almost any board finish. It can be sawed and shaped very evenly and smoothly - a process which cannot be achieved to the same degree with particle boards. MDF can be nailed, stapled, routed, sanded and screwed just like any natural wood product. It has the mechanical and physical characteristics approaching the levels associated with solid wood and in many applications can be used as an ideal substitute for solid wood. Rubber wood MDF is particularly light in color which makes it especially easy to paint and permits the application of very thin laminates without the underlying board color darkening the laminate. Thin MDF boards are an ideal alternative to plywood. Typical applications in furniture include drawer bottoms, backs of cabinets and centre panels in framed doors. In building interiors, thin MDF can be used for wall and ceiling paneling, as skins for flush doors, portioning, office screens, lightweight doors and exhibition paneling. Given developments in High Moisture Resistant panel boards, MDF is finding growing markets for exterior applications as well. Thin MDF has found its way into novel applications such as shoe making, motor vehicle interior parts, toys, printed circuit board production and blades for electric fans. Due to its excellent acoustic properties, MDF is also being successfully used in Hi-Fi equipment (Evans, 1998).

Builders use MDF in many capacities, such as in furniture, shelving, laminate flooring, decorative moulding, and doors. They value MDF for its insular qualities in sound and heat. Also, it can be nailed, glued, screwed, stapled, or attached with dowels, making it as versatile as plank wood. Usually, people working with MDF use a carbide saw fitted with a vacuum to reduce the amount of airborne dust. Since MDF is strengthened with resin containing formaldehyde, those at exposure try to reduce their risk of inhalation, or use special MDF with lower formaldehyde levels. Reconstituted, engineered wood products like MDF are often covered in a veneer or laminate. These thin layers of vinyl or real wood disguise the MDF, especially along visible edges. Some people prefer using MDF over regular lumber because it has a lower impact on the environment. MDF is solely made from waste products, the leftover scraps that would otherwise be dumped in a landfill. This attraction has helped it gain popularity among homeowners. It's now available not just to contractors. Many home improvement centers and lumberyards stock it in sheets for the general public (McKay, 1997).

Thick MDF boards can be used in building as architectural features such as columns and archways where the warp resistance, torsional stability, screws holding strength and edge finishing characteristics of MDF make it a good substitute for solid wood. Thick MDF is used as a core substrate material for paneling with veneers, printed surfaces, vinyl and low pressure laminates due to its dimensional stability and smoothness. Thick MDF can also be used for a wide range of furniture such as tables cabinets, windows, doors, frames, handicraft items, display or exhibition stands and signs, ceiling, toys, carving, partitions, maritime applications and educational equipment. Thick MDF is also widely used as a base material for laminated and veneered wood products for flooring and wall paneling, and for foil wrapped mouldings. MDF is easily shaped into almost any form and is commonly available in lengths up to 18 feet and therefore an excellent material for finished interior mouldings. MDF has a good bonding strength and resistance to compression, and so can be finished by a variety of secondary processes such as flooring, partitions and table tops. The complete versatility of MDF is yet to be utilized (English, *et al.*, 1997).

1.2. Objectives of the study

The objectives of the study are:

- To accumulate the available knowledge on Medium Density Fibreboard for future use by the educationists, researchers, foresters and planners.
- To highlight the importance of Medium Density Fibreboard in respect of Bangladesh.

CHAPTER TWO

METHODOLOGY AND DESCRIPTION

2.1. Description

This project thesis paper is based on literature review. To prepare this project thesis paper all relevant information has been collected from secondary sources. Information has been mainly collected from different types of journals, textbooks, thesis paper and internet.

2.1.1. Definition

MDF or medium density fibreboard is a composite board material now being used worldwide. It is made by refining hardwood and softwood chips plus sawdust and then bonding them together with a formulated resin. It offers several advantages including a consistent uniform surface... and ease of painting for a top quality look that is easy on your budget. It belongs to the hardboard family of products which are made from wood fibers glued under heat and pressure. Medium Density Fiberboard typically has densities between 33 and 50 pounds per cubic feet while High Density Fiberboard (HDF) ranges between 50 and 80 pounds per cubic feet. Hardboard was first produced in 1924 by W. H. Mason, founder of Masonite Corp. The term Masonite is therefore often used to denote hardboard products, especially HDF (Boehme, 1992).

2.1.2. Scope

Although there is a broad range of wood composites and many applications for such products, wood composites are grouped into three general categories: plywood, particle and fiber composites, and wood–nonwood composites. Books have been written about each of these categories, and the constraints of this chapter necessitate that the discussion be general and brief. References are provided for more detailed information. Information on adhesive-bonded-laminated (glulam, timbers, and structural composite lumber, including laminated veneer lumber) and adhesive-bonded members for lumber and panel products is presented in this handbook. Many composite materials, like fiberboard, MDF, and particleboard, can be made from wood alone or in combination with agricultural fibers (Youngquist and others, 1993a, 1994; Rowell and others, 1997). The first category, plywood, is covered in some detail because the process for manufacturing this kind of material is quite different from that used for other composite materials and because there are many different classes and grades of plywood in the marketplace. The second category, composite materials, includes oriented strandboard (OSB), particleboard, and fiberboard. These types of composites undergo similar processing steps, which are discussed in general terms for all the products in the Particle and Fiber Composites section. The first and second categories of composite materials are further generally classified as conventional composite materials. The third category, wood–nonwood composites, includes products made from combining wood fibers with agricultural fibers, with thermoplastics, and with inorganic materials (Minato, *et al.,* 1993).

2.1.3. Sources of MDF

MDF is a type of hardboard, which is made from wood fibres glued under heat and pressure. Hobbyists have found MDF from a wide variety of sources including, but not limited to:

- large warehouse style supply dealers (Home Depot, Lowes, etc)
- small local lumber yards
- cabinet shops who buy in large quantities and are willing to part with some
- surplus building supply dealers

2.1.4. Advantages

There are a number of reasons why MDF may be used instead of plywood or chipboard. It is dense, flat, and stiff, has no knots and is easily machined. Because it is made up of fine particles it does not have an easily recognizable surface grain. It can be painted to produce a smooth quality surface. Because it has no grain it can be cut, drilled, machined and filed without damaging the surface. It may be dowelled together and traditional woodwork joints may even be cut. It may be glued together with PVA wood glue. Oil, water-based paints and varnishes may be used on MDF. Veneers and laminates may also be used to finish MDF. It can be made from 100% recovered fiber, thus reducing the amount of wood waste being sent to landfills, slowing deforestation and preserving natural habitats. It can be made without urea formaldehyde resin, eliminating toxic air emissions, to create healthier work places and living environments.

- Less expensive than natural wood
- High moisture resistance
- Providing greater dimensional stability and product longevity
- Fire resistant
- Isotropic (no grain), so no tendency to split
- Consistent in strength and size

It is the core material or "substrate" to which stylish and attractive finishes and laminates are applied. The strong, smooth, knot-free characteristics of MDF make it an ideal core material for components which require intricate shaping, or surfacing operations (Minato, *et al.*, 1993).

2.1.5. Disadvantages

MDF can be dangerous to use if the correct safety precautions are not taken. MDF contains a substance called urea formaldehyde, which may be released from the material through cutting and sanding. Urea formaldehyde may cause irritation to the eyes and lungs. Proper ventilation is required when using it and facemasks are needed when sanding or cutting MDF with machinery. The dust produced when machining MDF is very dangerous. Masks and goggles should always be worn at all times. Due to the fact that MDF contains a great deal of glue the cutting edges of your tools will blunt very quickly. It can be fixed together with screws and nails but the material may split if care is not taken. If you are screwing, the screws should not be any further than 25mm in from the edge. When using screws always use pilot holes. Urea formaldehyde is always being slowly released from the surface of MDF. When painting it is good idea to coat the whole of the product in order to seal in the urea formaldehyde. Wax and oil finishes may be used as finishes but they are less effective at sealing in the urea formaldehyde (Minato, *et* al., 1993). It also has the following drawbacks

- Heavier (the resins are heavy)
- Requires painting
- Swells and breaks when waterlogged

- Warps or expands if not sealed
- Dulls blades more quickly than many woods

2.2. Activation of waste MDF sawdust charcoal and its reactive dye adsorption Characteristics.

This paper reports an experimental investigation of converting waste medium density fibreboard (MDF) sawdust into chars and activated carbon using chemical activation and thermal carbonisation processes. The MDF sawdust generated during the production of architectural mouldings was characterized and found to have unique properties in terms of fine particle size and high particle density. It also has a high content of urea formaldehyde resin used as a binder in the manufacturing of MDF board. Direct thermal carbonization and chemical activation of the sawdust by metal impregnation and acid (phosphoric acid) treatment prior to pyrolysis treatment were carried out. The surface morphology of the raw dust, its chars and activated carbon were examined using scanning electron microscopy (SEM). Adsorptive properties and total pore volume of the materials were also analyzed using the BET nitrogen adsorption method. Liquid adsorption of a reactive dye (Levafix Brilliant red E-4BA) by the derived sawdust carbon was investigated in batch isothermal adsorption process and the results compared to adsorption on to a commercial activated carbon (Filtrasorb F400). The MDF sawdust carbon exhibited in general a very low adsorption capacity towards the reactive dye, and physical characterization of the carbon revealed that the conventional chemical activation and thermal carbonization process were ineffective in developing a microporous structure in the dust particles. The small size of the powdery dust, the high particle density, and the presence of the urea formaldehyde resin all contributed to the difficulty of developing a proper porous structure during the thermal and chemical activation process. Finally, activation of the dust material in a consolidated form (cylindrical pellet) only achieved very limited improvement in the dye adsorption capacity. This original study, reporting some unexpected outcomes, may serve as a stepping-stone for future investigations of recycle and reuse of the waste MDF sawdust which is becoming an increasing environmental and cost liability (Dube and Kehr, 1995).

2.3. Joints used in MDF

Because MDF can be milled to just about any profile, there are many possible joints.

- Butt - this simplest of joints may not be ideal for furniture but works very well for building speakers, especially when combined with biscuits (for alignment) and screws (for holding strength while the glue dries).
- Miter - works well when using pre-finished MDF (veneered or laminated) thus leaving no exposed unfinished surfaces.
- Lock-Miter, dovetail and other routered joints - works just like lumber. These joints have limited use in most speaker enclosures.
- Rabbets, dadoes, grooves and other saw cut joints - same as with hardwood. Note that these can also be cut with a router. These joints may be useful, depending on the design of the speaker.
- Spline, biscuit, dowel - as with lumber, the glue joint is stronger than the MDF. Dowel holes should be 0.002 to 0.003 inch larger than the average dowel diameter, and 1/32 to 1/16 inch deeper than the actual depth used. Plain or spiral grooved dowels are preferred over fluted or multigrooved dowels. Biscuits are very handy for alignment of parts in addition to the additional gluing surface provided.

MDF can also be edge glued to make larger surfaces, although this is not likely to happen except with exceptionally large speakers. Panels can be scarfed, doweled, tongue & grooved and finger jointed (Hashim, *et al.*, 1994).

2.4. Fasteners used with MDF

Some typical fasteners and their uses follow:

- Staples - Do not staple within 3/4 inch of any corner. Coated staples hold better than smooth staples. Use a finer wire staple if splitting is a problem.
- Drive at right angle to the surface to avoid bending.
- Nails - The same rules apply to nails as they apply to staples. Use ring-shank nails to avoid fiber rising around the nail head; do not use smooth nails.
- Screws - Drill pilot holes between 85 % and 90 % of the root diameter of the screw used and at least as deep as the screw. Untapered sheet metal screws with constant size shank are good, as are some untapered wood screws. Pilot hole sizes and minimum edge distances for common screw sizes are :
    - #6 screw - 3/32 inch pilot - 1/2 inch edge distance

- #8 screw - 7/64 inch pilot - 5/8 inch edge distance
- #10 screw - 1/8 inch pilot - 1 inch edge distance

Do not rely solely on the above fasteners for building speaker enclosures. This is especially true for butt joints. Combine glue with screws for a simple and strong joint (Hashim, *et al*., 1994).

2.5. Glues used with MDF

Good glues to use are gap-filling glues such as polyvinyl acetate (PVA) typically known as yellow glue, modified PVA glues like Titebond II or white glues. Epoxy, urea and hot melt glues may also be used (Rijsdijk and Laming, 1994).

2.6. Safety issues to consider when working with MDF

MDF is typically made with urea-formaldehyde resin totaling 9% by weight. While most people will not be affected by this, people sensitive to formaldehyde emissions should consider low formaldehyde or formaldehyde-free MDF, or consider methods of controlling these emissions through proper finishing. Finishes that work best at controlling formaldehyde emissions are solid add-on surfaces such as high pressure laminates, vinyl covering, and finished wood veneers. Less effective at controlling emissions are simple seal coats, oil and latex paints, danish oil, and wax. Plum Creek makes low-formaldehyde MDF, while Medite II and Medex from Medite Corp. are formaldehyde-free MDF. Dust is another MDF hazard. The large amount of dust released when working MDF makes proper respiratory and eye protection mandatory. At a minimum use a dust mask. A respirator is preferable. Shop dust collection (or even a ShopVac) would greatly help the removal of dust from not only the air but also the working surfaces, making them easier to see. Goggles should always be worn while using tools (Pizzi, 1994).

2.7. Eco-efficiency of recycled MDF

Presently, it is not possible to use more than 3-5% old wood-based panels in medium-density fiberboard (MDF) manufacturing without loss of mechanical properties and production capacity. A Greek company has developed a process that allows using much higher percentages of waste boards, raw, laminated or veneered. The final value will depend on each line conditions and needs. The company is looking for industrial partners interested in the purchase of the patented process. A Greek company has developed a process that allows using much higher percentages of waste boards, raw, laminated or veneered. The final value will depend on each line conditions and needs. The process does not require major investments in the manufacturing unit, using a hammer mill to break down the waste boards. The resulting chips (depending on the feedstock, they may have to be sieved) have to be washed and thoroughly mixed with fresh chips, at a controlled weight ratio. From here they follow the normal production process. A mix of chemicals is added in the digester through a hole (Park and Seo, 1993).

2.8. Uses of MDF

Medium Density Fibreboard, or MDF, has a range of uses within business trades, but most extensively in building and DIY, due to its high strength and stable. MDF is an ideal alternative to solid woods and it is used for a number of purposes including making office furniture, kitchen cabinets, panel mouldings, dining sets, fire surrounds and many more. Due to its smooth and stable surfaces, MDF is also used for decorative wood or laminate veneers and it can easily be drilled and cut to specific sizes. MDF is inexpensive and easy to work with and MDFs mild reaction to moisture makes it ideal for bathroom cabinets and other high humidity applications. MDF is renowned for its high strength properties and it is becoming increasingly popular for kitchen applications. The smooth and stable surfaces of MDF provide an excellent substrate of decorative laminated or wood veneers. The inherent stability, good machinability and high strength of MDF create opportunities for it to be used as alternative solid wood. The MDF can also be used to make office furniture systems, kitchen cabinets, bedroom sets, dining sets, TV racks, speaker boxes, decorative doors, panel mouldings and much more. Medium Density Fiberboard (MDF), considered as the best value in the lumber products, is being developed for various uses with its good workability and economical efficiency. It is widely used as the principle material for wood products such as household furniture, architecture interiors, floor materials, packaging materials, small-sized materials; we shall expect high growth or the MDF with cultural growth of wood industry. MDF was originally developed exclusively for furniture. But its weight strength and aesthetics have seen its proliferation to many uses. It is used extensively in kitchens and for mouldings, and in bathroom environments. Its use as an exterior cladding for housing has successfully been trialed, and structural applications are increasing (Salehuddin, 1992).

2.8.1. Interior use

MDF is used in shelves, TV cabinets, drawer fronts, pool tables, office furniture, door frames window frames, kitchen cabinets and for interior door skins.

2.8.2. Exterior Use MDF

Exterior Use MDF can also be manufactured with special adhesives suitable for exterior applications. Uses include brick moulding, mouldings around doors and windows, exterior window sills, column facings, gable vents and louvers, soffit trim and other exterior trim.

2.8.3. Typical MDF applications include

- Laminate flooring
- Building & construction (wall paneling, flooring, doors etc.)
- Furniture (fitted kitchens, bathroom fitments, bedroom furniture etc.)
- Interior fitments (in offices, hotels, museums etc.)
- House ware (storage boxes, picture frames, toys etc.)

2.8.4. Making Cupboard Doors in MDF

Medium Density Fibreboard (MDF) is a manufactured board that is often used in the furniture making industry. It has some advantages over solid timber in that it is made in large flat sheets of an even thickness, it is stable and it can be machined in any direction, leaving a smooth surface ready for finishing. MDF cupboard doors can be made by removing material from the original piece with a router, by adding material to the original piece, or by a combination of both methods. MDF doors are made of medium density fiberboard, which can be routed into a raised panel design. They can be thermal-foiled, stained or painted in a solid color. The advantage of choosing a MDF door as opposed to a constructed wood door when selecting a solid color is that there are no joints, as opposed to a wood door in a solid color where you will notice visible separation lines that show when the wood expands and contracts (ASTM, 1992).

2.9. Radiation curing

Radiation curing ads speed and lower curing temperatures to the known advantages of powder coating systems. In particular, UV-radiation offers quick curing of powder coatings on thermally sensitive substrates, and the rapidly developing near infrared (NIR) curing allows extremely high curing rates with selective heating of the coating.

The article describes curing mechanisms, state-of-the-art and first commercial applications of both technologies (Seborg, *et al.,* 1953).

2.9.1. UV-Powder Coating on MDF

UV-powders have had their first commercial success in applications where the substrate cannot be heated to higher temperatures. The first commercial application in Europe is the coating of TV and music furniture that is constructed from medium density fibre board (MDF). This material is becoming increasingly popular in the furniture industry due to its good balance of properties and economies. UV-powder coatings offer the possibility to coat three dimensional details, e.g. millings or rounded edges, on furniture prepared from MDF boards with a single coat that combines a good appearance with scratch resistance and excellent chemical resistance (Seborg, *et al.,* 1953).

For the first application on TV furniture, a slight texture of the coating was required by the customer. A single coat of a specially developed UV-powder coating is applied to the MDF surface. Heat-up of the coating is accomplished with a specially designed oven that is using a combination of different infrared radiators and convection heat. A proper layout of the oven for this heat-up phase is critical for the coating quality. The subsequent curing step with high intensity UV-radiation only takes some seconds. After some cooling, the pieces are ready for shipment. The temperature of the MDF never exceeds 120 °C, in the centre of the board the temperature stays well below 100 °C. This is in sharp contrast to coating MDF with low temperature conventional powder coatings that require heating of the coating for 20 minutes to 140 °C. Under these conditions, the MDF board will heat up to these temperatures. This exposure to high temperatures for prolonged periods of time may have a negative impact on the long term performance of the MDF board and the coating. In the worst case, the board can split or the coating may crack if the piece is exposed to changing humidity conditions during use. In contrast, the low temperatures in the UV-curing process eliminate this potential quality problem completely (Spalt, 1977).

CHAPTER THREE

MANUFACTURING PROCESS OF MEDIUM DENSITY FIBREBOARD

3.1. General Manufacturing Issues

Successful manufacture of any composite wood product requires control over raw materials. Ideally, raw materials are uniform, consistent, and predictable. Wood does not offer these qualities but instead varies widely between species. For the purpose of producing a composite product, uniformity, consistency, and predictability are accomplished by reducing separated portions of the wood into small, relatively uniform and consistent particles, flakes, or fibers where effects of differences will average out. Size reduction is sometimes augmented by chemical treatments designed to weaken the bonds between the components. The degree of size reduction and the shape of individual lignocellulosic components will depend on the application. Different composites tolerate or demand different sizes and shapes. Generally speaking, all the conventional composite products discussed in this chapter are made to conform to product or performance standards (English, *et al.*, 1997).

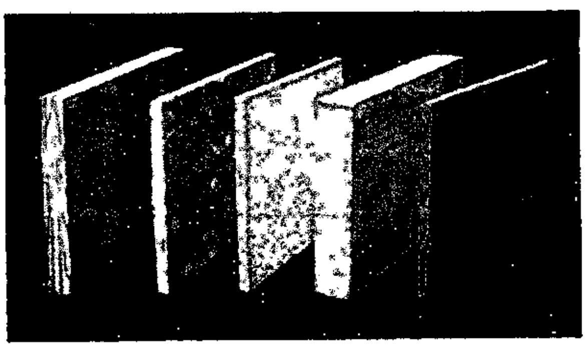

Figure-1: Examples of various composite products. From left to right: plywood. OSB, particleboard, MDF and hardboard (From Youngquist, 1988).

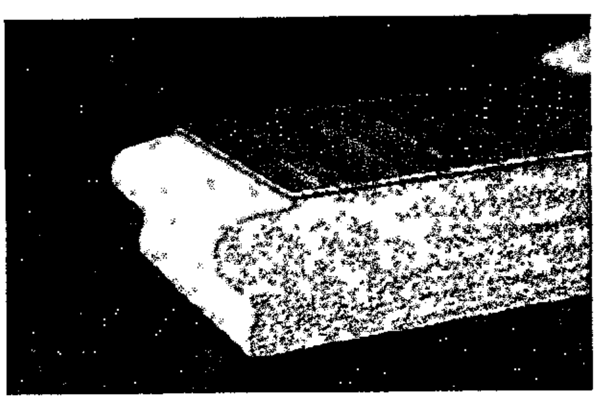

Figure-2: MDF with veneer overlay (From Youngquist, 1988).

3.2. Manufacturing Process

MDF is a wood based composite. The primary constituent is a softwood that has been broken down into wood fibres; that is the very cells (tracheids, vessels, fibres and fibre-tracheids), which are far smaller entities than than those used in particleboard. In Australia the main species used in the production of MDF is plantation grown radiata pine, but a wide variety of softwood species will constitute a suitable base for MDF production, though if too many species are used too great a variation in the properties of the finished MDF will result. Other materials successfully used have been waste paper, randomly collected waste wood and bamboo. Mixing wood and other non-wood materials such as fibres of glass, steel, carbon and aramide have all resulted in successful MDF type products being produced. The two major MDF manufacturers in Australia are Laminex , a subsidiary of BTR Nylex, with MDF plants at Gympie, Queensland and Wagga Wagga, NSW and the CSR Company, with a plant at Oberon, NSW (Boehme, 1992)

3.2.1. Debarking

Once the MDF plant has obtained suitable logs, the first process is debarking. The logs could be used with the bark, as could any fibrous material, but for optimization of the final product the bark is removed to; decrease equipment damaging grit, allow faster drainage of water during mat formation, decrease organic waste load by 10-15 %, stabilize pH levels (reduces corrosion of tools) and increase surface finish. The most popular debarker used in MDF manufacture is a ring debarker (shown below), though rosser head and drum debarkers can be used.

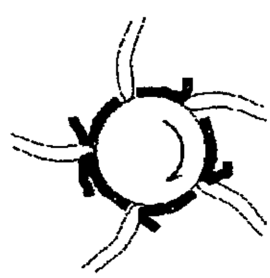

Figure-3: Ring Debarker (From Maloney, 1977).

In some manufacturing plants the debarking process is not important as the plant obtains chips rather than logs. The chips can come from the waste of another operation or from logs chipped in the forest. A Cambio ring debarker can operate at feeds of up to one tone per minute, the logs being typically 2 to 2.5 m in length. The tool heads, held in place pneumatically or by springs, rotate about the logs and rip off nearly all the bark, and do little damage to the log. The waste bark can be sold, for landscaping or to power on-site furnaces (Environmental Considerations).

3.2.2. Chipping

Though some plants accept chips directly from other operations, chipping is typically done at the MDF plant. A disc chipper, containing anything from four to sixteen blades, is used. The blades are arranged radially on a plate and the spinning plate is faced perpendicularly to the log feed. The feed speed of the logs, the radial speed of the knife plate, the protrusion distance of the knives and the angle of the knifes, control the chip size. The chips are then screened and those that are oversized may be rechipped, and those that are undersized used as fuel. Stockpiles of several hundred tonnes of chips are maintained. There may be a blending of chips from different sources or timber species to enhance certain properties. For example the highly moisture resistant high density boards that many manufacturers make typically use a eucalypt content of 10%. The chips are washed, and a magnet or other scanner may be passed over to detect impurities (Boehme, 1992).

3.2.3. Pulping

MDF takes much of its characteristics from the fact that it uses wood cells, (tracheids, vessels, fibres and fibre-tracheids), rather than particles. This can be done by a Masonite gun Process, Atmospheric or Pressurized Disk refiner. The Asplund defibrator pressurized disk refinement being that primarily used in MDF manufacture. The chips are compacted using a screw feeder into small plugs which are heated for 30 to 120 seconds (this softens the wood), then fed into the defibrator. The defibrator consists of two counter wise rotating plates each with radial grooves that get smaller as they get closer to the circumference. The plug is fed into the centre and gets broken down as the centrifugal forces push it toward the outside of the plates where the groves are finer. The feeding devices at the entrance and exit to the defibrulator maintain suitably high pressure and temperature (about 150 C).

Figure-4: The Micrograph of an MDF sample shows the fibre walls are still intact.

Source: http://online.anu.edu.au/Forestry/wood/mdf/manufacture.html.

The high temperatures lower the energy required to defibrate wood as there is a softening of lignin that facilitates fibre separation along the middle lamella. The steam is then separated from the pulp, the total time in the defibrator is about one minute. They pulp may pass through a secondary refiner to ensure the fibres meet pre-determined levels of `freeness'. The resulting pulp is light, fine, fluffy and light in color. As the accompanying micrograph of an MDF sample shows the fibre walls are still intact (Boehme, 1992).

3.2.4. The Blowline

After defibration fibres enter the blowline. The blowline is initially only 40mm in diameter with the fibres passing through at high velocity. Wax, used to improve the moisture resistance of the finished board, and resin are added in the blowline while the fibres are still wet, as dry fibres would form bundles, due to hydro bonding, and material consistency would be lost. The blowline now expands to 1500mm in diameter and fibres are dried by heating coils warming the blowline to about 550 F. The air-fibre ratio is about 500 cubic ft/lb with air speed of 500 ft/min though the air is still humid and the resin does not yet cure. The agitation of fibres in the blowline helps disperse resin consistently. Exit temperature is about 180 F. The fibres may be stored in bins for an unspecified length of time but the board making process is usually continuous from here on. The Moisture Content of the fibres is 12%, and thus this is considered a dry process. The blowline mixing process and the use of dry fibres are distinguishing characteristics of MDF (Boehme, 1992).

3.2.5. Mat Formation

In order to form a continuous and consistent mat the following problems must be over come: the fact that considerable air velocities must be maintained to suspend fibres, fibre/air suspension does not flow laterally on a horizontal support and fibre form lumps. One way of overcoming this is a Pendistor. Impulses of air act on the fibre as it falls down the shaft to a vacuum box at the start of the conveyor belt that carries the mat. The oscillatory action on the fibres spreads them uniformly into a mat and they begin their run on the conveyor belt at between 230-610 mm thick.

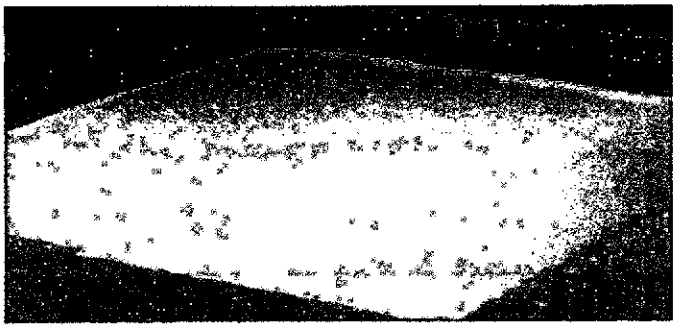

Figure-5: Laboratory-Produced air laid Mat before Pressing (From Maloney, 1977).

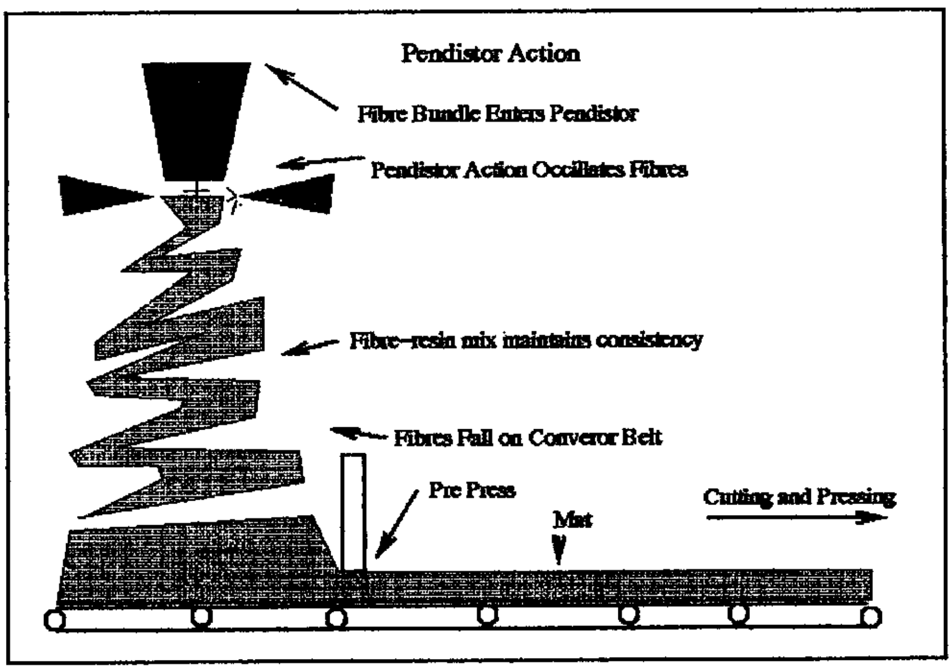

Figure-6: Schematic of the Mat Formation Process

Source: http://online.anu.edu.au/Forestry/wood/mdf/manufacture.html.

3.2.6. Pressing

The mat can either be laterally cut to size as it leaves the pendistor or it can be cut half way through its run by a synchronized flying cut off saw. The density profile of the panel is critical to achieving satisfactory strength properties. Concentrating mass and hence load bearing ability, at the top and bottom of the board means that inertial properties are maximized and the greatest strength can be obtained for minimal weight. This is achieved by the press acting at impacted pressure initially and then slower pressure application. As an example for a 16mm board:

- Press closed. 20 seconds to bring mat to 28 mm.
- 28 seconds at 26mm.
- 23 seconds at 25mm.
- 125 seconds at 18.3
- Total time of 330 seconds to bring board to 16mm, then decompression time.

The pressure may reach 3500 MPa and be heated to over 200 C. Thicker boards may require up to 750 MPa and additional steam or radio frequency heating. The MDF plant at Wagga uses a hot press with seven daylight openings to accommodate reasonable production rates. Press sizes can be from 1.5-2 m wide by 5-20m long. (Boehme, 1992).

3.2.7. Finishing

After pressing boards are cooled in a star dryer and final trimmed and sanded. They are given a few days storage to allow complete curing of resins. The boards are commonly given a colored melamine laminate, though natural wood veneers and raw MDF are common.

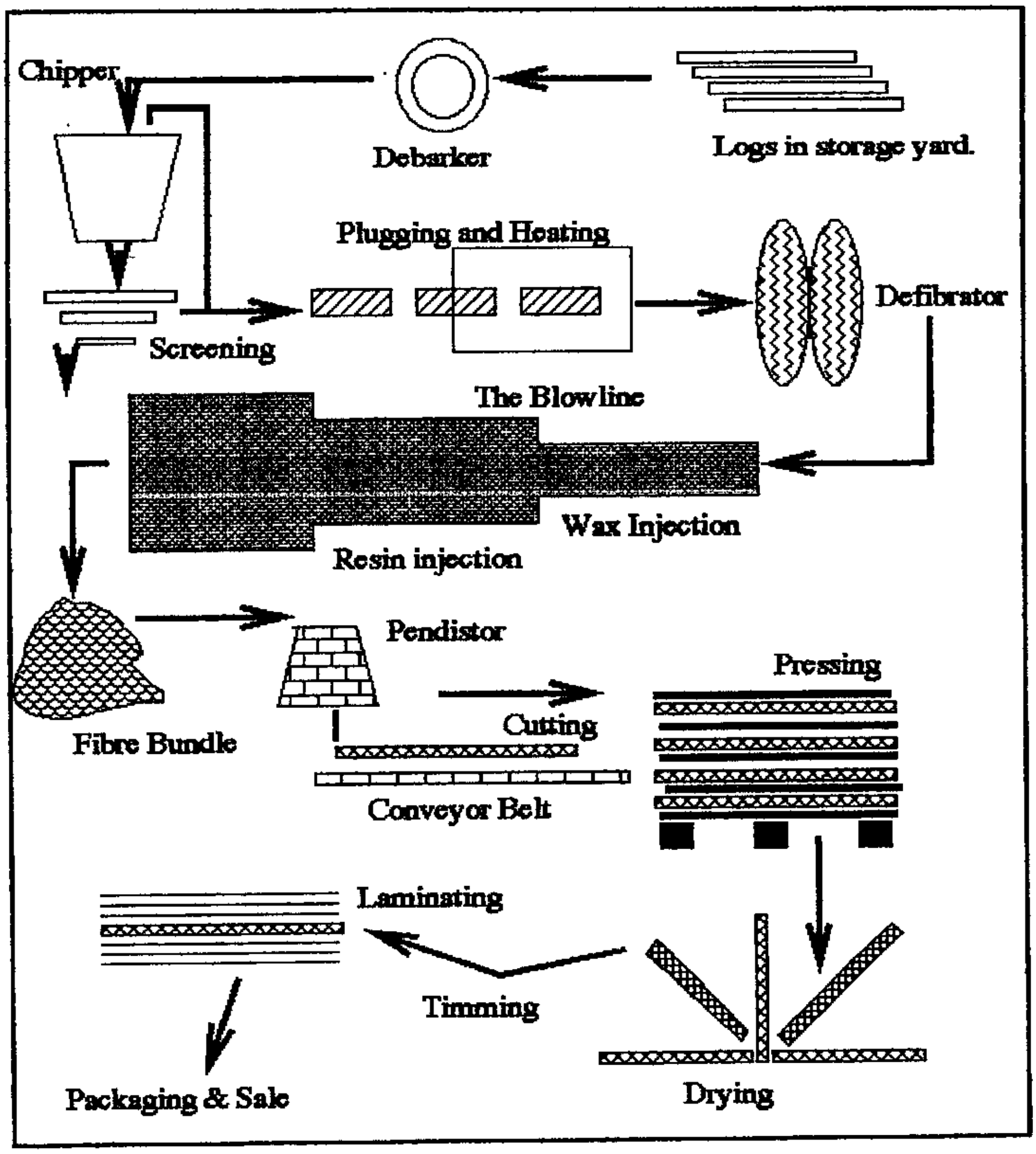

Figure-7: Schematic of the MDF production Process

Source: http://online.anu.edu.au/Forestry/wood/mdf/manufacture.html.

3.3. Resin Used In MDF

3.3.1. Melamine in MDF

Melamine is used as Melamine-Urea-Formaldehyde (MUF) resin in the moisture-resistant grades of MDF that are predominantly used as the substrate for flooring panels. The swelling values of these panels have to be very good, and melamine is used to achieve this (Youngquist, 1988).

3.3.2. Urea-formaldehyde (UF)

Urea-formaldehyde (UF) manufacture of products where dimensional uniformity and surface smoothness are of primary concern, for example, particleboard and MDF. Products manufactured with UF resins are designed for interior applications. They can be formulated to cure anywhere from room temperature to 150□ (300□F); press times and temperatures can be moderated accordingly. Urea-formaldehyde resins (often referred to as urea resins) are more economical than PF resins and are the most widely used adhesive for composite wood products. The inherently light color of UF resins make them quite suitable for the manufacture of decorative products (Youngquist, 1988).

3.3.3. Phenol-formaldehyde (PF)

Phenol-formaldehyde resins are typically used in the manufacture of products requiring some degree of exterior exposure durability, for example, OSB, softwood plywood, and siding. These resins require longer press times and higher press temperatures than do urea-formaldehyde resins, which results in higher energy consumption and lower line speeds (productivity). Products using PF resins (often referred to as phenolics) may have lowered dimensional stability because of lower moisture contents in the finished products. The inherently dark color of PF resins may render them unsuitable for decorative product applications such as paneling and furniture (Youngquist, 1988).

These adhesives have been chosen based upon their suitability for the particular product under consideration. Factors taken into account include the materials to be bonded together, moisture content at time of bonding, mechanical property and durability requirements of the resultant composite products, and of course, resin system costs. Some natural options may someday replace or supplement these synthetic resins. Tannins, which are natural phenols, can be modified and reacted with formaldehyde to produce a satisfactory resin. Resins have also been developed by acidifying spent sulfite liquor, which is generated when wood is pulped for paper. In the manufacture of wet-process fiberboard, lignin, which is inherent in lignocellulosic material, is frequently used as the resin (Suchsland and Woodson, 1986).

3.4. Additives

A number of additives are used in the production of conventional composite products. One of the most notable additives is wax, which is used to provide finished products with resistance to aqueous penetration. In particle- and fiberboard products, wax emulsion provides excellent water resistance and dimensional stability when the board is wetted. Even small amounts (0.5% to 1%) act to retard the rate of liquid water pickup. These improved water penetration properties are important for ensuring the success of subsequent secondary gluing operations and for providing protection upon accidental wetting to the product during and after construction. The water repellency provided by the wax has practically no effect upon dimensional changes or water adsorption of composites exposed to equilibrium conditions. Other additives used for specialty products include preservatives, fire retardants, and impregnating resins (Youngquist, 1988).

CHAPTER FOUR
CLASSIFICATION OF MDF

4.1. Basic Element of Composite Wood

The basic element for composite wood products may be the fiber, as it is in paper, but it can also be larger wood particles composed of many fibers and varying in size and geometry. These characteristics, along with control of their variations, provide the chief means by which materials can be fabricated with predetermined properties. In any discussion of the strength properties of wood-based panels and other adhesive-bonded wood composites, the first consideration is the constituents from which these products are made (O'Halloran and Youngquist 1984; Youngquist 1987). The basic wood elements that can be used in the production of wood-based panels are shown in the figure. The elements can be made in a great variety of sizes and shapes and can be used alone or in combination. The choice is almost unlimited (Marra, 1979).

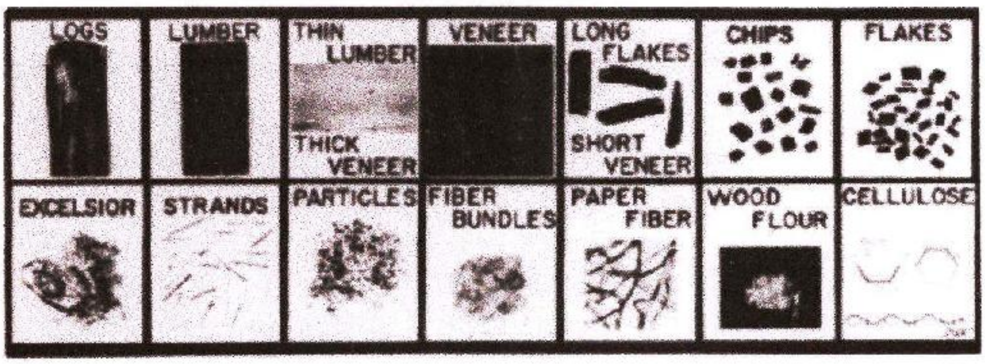

Figure-8: Basic wood elements, from largest to smallest (Marra, 1979).

Currently, the term composite is being used to describe any wood material adhesive-bonded together. This product mix ranges from fiberboard to laminated beams and components. Table shows a logical basis for classifying wood composites proposed by Maloney (1986). These classifications were slightly modified from those in the original version to reflect the latest product developments. Composites are used for a number of structural and nonstructural applications in product lines ranging from panels for interior covering purposes to panels for exterior uses and in furniture and support structures in many different types of buildings.

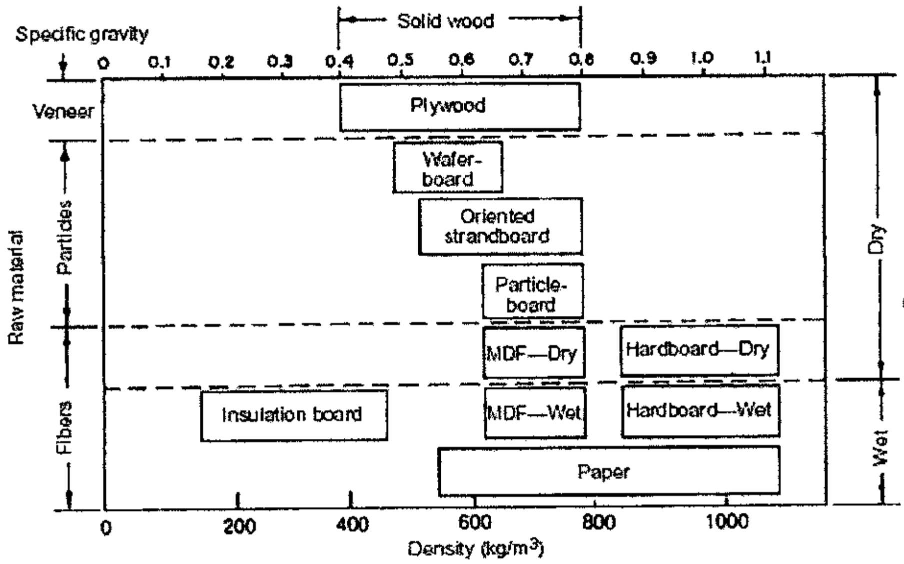

Figure-9: Classification of wood composite boards by particle size, density and process type (Suchsland and Woodson, 1886).

Above figure provides a useful way to further classify wood-based composite materials. This figure presents an overview of the most common types of products discussed as well as a quick reference to how these composite materials compare to solid wood from the standpoint of density and general processing considerations (Voevodin, 1986). Classification of Medium Density Fibreboards are discussed below-

4.2. White MDF

White MDF is a high quality medium density fibreboard with a white melamine surface bonded to both sides. The melamine surface is non-porous and hardwearing making it ideal for cabinetry. And it makes building cabinetry fast and easy. As the board is pre-decorated, all you do is cut, drill and edge it. White MDF is also very versatile, as the MDF core allows the panel to be used as a pre-finished product, or face routed and finished with a paint system where required. White MDF is a versatile panel that can be used for making cabinets, wardrobes, or shelving. The reconstituted wood fibres used to make White MDF are obtained from Australian pine plantations – a sustainable renewable resource. In fact only renewable plantation timber is used in the manufacture of White MDF. White MDF allows you to achieve fast, cost effective cabinetry results without destroying our precious wilderness or the rainforests of other countries (Flinn and Trojan, 1990).

Figure-10: White MDF (Flinn and Trojan, 1990).

4.2.1. Applications

White MDF is available in Moisture Resistant and Standard grades and a select range of thicknesses, sheet sizes and finishes to suit a wide range of applications. MDF is a wood based panel and reacts to changes in moisture like natural timber, i.e. High or low humidity will cause some expansion or contraction without any effect on the strength of the board. Specific applications are detailed separately on the following pages (Flinn and Trojan, 1990).

4.3. White MDF MR

White MDF MR is highly moisture resistant medium density fibreboard with a hardwearing white melamine surface bonded to both sides. It is suitable for use in areas of high humidity, or where accidental exposure to moisture may occur. The highly moisture resistant properties of White MDF MR are due to the bonding of the wood fibres with a specially formulated moisture resistant resin (Flinn and Trojan, 1990).

4.3.1. Applications

White MDF MR is designed for interior use in the following applications: Kitchen cupboards, bathroom vanities, laundry cupboards, shelving, built in cupboards, wardrobes and furniture, wall linings and all detailed joinery where a moisture resistant decorative board is required.

- Moisture resistance
- Surface finishes-Décor Texture, Velvet and Satin finishes.
- Decorative surface properties
- Resistance to wear
- Resistance to steam

4.4. White MDF Standard

White MDF STD is a high quality MDF substrate with a hardwearing white melamine surface bonded to both sides. The MDF substrate is made up of wood fibres bonded together with a specially formulated durable resin. It has a light compact core that allows clean machining (Flinn and Trojan, 1990).

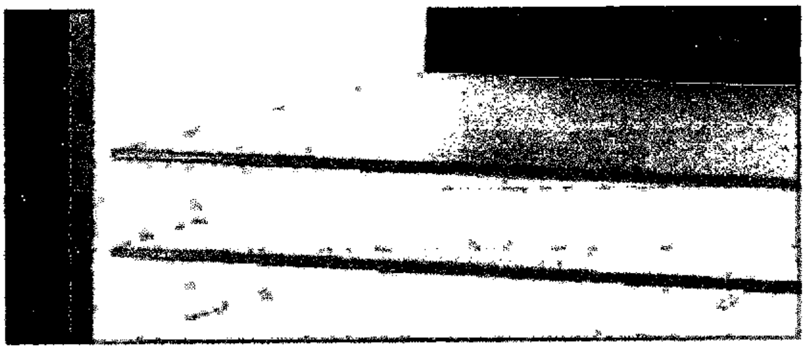

Figure-11: white MDF standard (Flinn and Trojan, 1990).

4.4.1. Applications

White MDF STD is designed for interior use for the following applications: Built in cupboards, wardrobes and furniture, shelving, wall linings and all detailed joinery where the product will not be exposed to damp conditions or high humidity.

Surface finishes

Décor Texture, Velvet and Satin finishes.

Decorative surface properties

When tested in approved manner complies with the relevant sections of AS/NZS 1859.3: 1996 for surface properties as follows:

- Resistance to wear.
- Resistance to steam
-

4.5. Peacock MDF

Peacock MDF is manufactured for internal applications and should not be exposed to water or high humidity environments such as bathrooms It should be kept clear of heat sources such as stoves and heaters. PEACOCK MDF physical properties provide natural resistance attack by the common household wood borer and provided the panel does not reach 20% moisture content for extended periods it is also resistant to fungal decay. PEACOCK MDF is a premium quality MDF with unique physical properties making it suitable for a wide range of manufacturing, trade and building applications. PEACOCK MDF is the product of the future bringing comfort, convenience and contemporary style to the environments of today. PEACOCK MDF is easier to machine than natural wood and can be laminated and painted to produce almost any board finish. It can be sawed and shaped very evenly and smoothly. PEACOCK MDF can be nailed, stapled, routed, sanded and screwed just like any natural wood product. It has the mechanical and physical characteristics approaching the levels associated with solid wood, and in many applications can be used as an ideal substitute for solid wood (Hsu, *et al.,* 1989).

4.5.1. Features OF Peacock MDF Boards

- COATING, LAMINATING, VENEER -The very smooth surface of PEACOCK MDF allows you to utilize this product as ideal carrier for any laminate.
- CUTTING -PEACOCK MDF boards provide ideal condition to achieve top processing quality with every sawing equipment.
- DRILLING -PEACOCK MDF Boards can be drilled very easily. Any common drilling tool can be used.
- GLUING -All common and standard wood-glues are possible.
- MOULDING -PEACOCK MDF products are very suitable and high moulding quality is obtained. The material will guarantee best milling abilities, usually only possible with high quality hardwood.
- PAINTING -PEACOCK MDF boards are ideal for efficient paint jobs and surface treatment of any kind.
- PLUGGING -Standard rough plugs are recommended.
- SANDING -PEACOCK MDF boards are ready to be used without additional sanding.
- SCREWING -Easy and fast. It is recommended to pre-drill for best results.

4.5.2. Applications

PEACOCK MDF boards are the best alternative to plywood. Typical applications in furniture include drawer bottoms, backs of cabinets and centre panels in framed doors. In building interiors, thin PEACOK MDF can be used for wall and ceiling paneling, Kitchen compartments, as skins for flush doors, partioning, office screens, lightweight doors, exhibition paneling, used to make office furniture systems, kitchen cabinets, bedroom sets, dining sets, TV racks, speaker boxes, decorative doors, panel mouldings and much more . PEACOCK MDF boards can also be used for a wide range of furniture such as tables cabinets, interior – windows & doors, frames, handicraft items, display or exhibition stands and signs, ceiling, toys, carving, partitions, maritime applications and educational equipment. Thick PEACOCK MDF board is also widely used as a base material for laminated and veneered wood products for flooring and wall paneling and for foil wrapped mouldings. PEACOCK MDF board has a good bonding strength and resistance to compression and so can be finished by a variety of secondary processes such as flooring, partitions and tabletops. The complete versatility of PEACOCK MDF board is yet to be utilized (Hsu, *et al.,* 1989).

4.6. NUWUD MDF

India's are the largest agro and plantation based Medium Density Fibreboard manufacturers in collaboration with M/s Sunds Defibrator AB, Sweden. The plant is situated at Tohana, Haryana state having an installed capacity of 60,000 m2 per year. NUWUD MDF is the most versatile of wood panel products specially developed for furniture and construction industry. The main advantages of NUWUD MDF is its homogeneous nature which gives it consistency from surface to core and high density edges. These characteristics allow intricate and precise machining and finishing techniques when producing high quality furniture, cabinetry and construction components. The flat smooth surface of NUWUD MDF is uniform, dense and free of knots & grain patterns, making finishing operations simpler and more economical (Flinn and Trojan, 1990).

4.6.1. Application Areas

NUWUD MDF's superior machining and finishing characteristics, strength and stability makes it an ideal panel product to be used in may applications like-

- Building and Construction Partition; Ceiling; Flooring; Paneling; Door; Moulding; Cornice; Pelmet; Skirting etc.
- Furniture for Home; Office; Hotel; School; Hospital etc.
- Industrial Laminate substrate; Scientific Instruments, Musical Instruments; Stationery items; Office equipments; Speaker boxes; T.V Cabinets; Fridge &

Sewing machine tops; Package; Shop heels; Toys; Sports goods; pool tables; Cutouts, photo lamination; Moulds & dies; clocks, trophies. Interiors of buses, & railway coaches etc.

- Handicraft Artifacts; sculptures; decorative items.

TABLE-1: A comparison between MDF and other panel products brings out the advantages in use of MDF:

Property	Plywood	Block Board	Particle Board	Natural Wood	NUWUD
Acoustics	No	No	No	No	Yes
Design Creativity	Yes	No	No	Wastage	Yes
Economy	No	No	Yes	No	Yes
End Product Quality	Yes	Yes	No	Yes	Yes
Homogeneity	No	No	No	Yes	Yes
Machining	No	No	No	Wastage	Yes
Physical Properties	Limited	Limited	Limited	Seasoned	High level
Smooth Surface	No	No	No	No	Yes
Stability	Peels	Peels/Warps	Warps	Contracts / Expands	Yes
Uniform strength in all directions	No	No	No	No	Yes

Source: NUWUD Marketing Division E46/12 Okhla Industrial Area Phase II, New Delhi 110-020.

Some MDF manufacturers have increased their product range by the introduction of boards and panels with decorative surfaces achieved by painting or lacquering. Thin MDF manufacturers in particular can supply painted or wood grain printed boards for door skins and wall panelling.

4.7. High Moisture Resistance MDF

High Moisture Resistance MDF are designed for interior applications involving exposure to high humidity situations such as joinery, flooring, windows, skirting and architectural mouldings. HMR boards are also an ideal substrate for laminating with natural wood veneer, vinyls, printed papers, foils and melamine papers (McNatt, 1974).

4.8. Colored MDF

Since its conception, colored MDF has been improved in co-operation with technicians, architects and designers, in order to assess and enhance the benefits for a variety of uses. This ongoing dialogue has helped to develop color/performance that meets the needs of these designers. Articles produced using colored MDF will only require a clear finish to seal the surface once the panels have been given finishing sand. This will bring out the full color, which is integrated into the very fibres of the panel (ANON, 1989a).

4.8.1. Main advantages of colored MDF

- Uniformity of color throughout
- Environmentally friendly
- Non toxic
- Can be fitted without further finishing - maintains its technical and decorative features.
- Can be waxed or varnished
- Mechanical resistance 30% higher than standard MDF *(Colour Extra)*
- Moisture resistant *(Colour Extra)*
- Excellent for deep and heavily patterned CNC machining *(Colour Extra)*
- Stock size of 2500x1250mm yields size 2440x1220mm, even in the case of edge damage in transit when delivered to site in less than pallet quantities.

4.9. Powder Coating MDF

MDF Powder Coat Systems, LLC (MDFPCS) is a worldwide leader in development of curing powder coating on MDF. Powder coating has now evolved to offer many advantages over liquid paint application. Advances in technology continue to increase the efficiency and cost effectiveness of the process. As part of ongoing research, MDFPCS has found significant opportunities in powder coating, but the most exciting of these existed in the wood industry, and in particular, M.D.F. M.D.F (Medium Density Fiberboard) is well known for its versatility, particularly in the furniture and construction industries, with new applications being developed continually. Although the material itself is relatively inexpensive, much of the production cost of mass produced products is associated with the finishing of the product's surface, either by conventional wet paint spraying, vacuum coating or membrane pressing. The method adopted is dependant on the type of board, production requirements, and the finish and of course the cost (ANON, 1989b).

4.9.1. Benefits

Benefits of powder coating are cited below-

- ecological, even after tightened EU regulations effective from 2007
- 99% material utilization thanks to powder recovery
- only 1 working step to achieve the requested film thickness
- quick and simple color changes
- excellent chemical and physical surface properties
- easy to use for flat and cubic shapes
- high cost-effectiveness

4.9.2. Prospect of applying powder coating

The prospect of applying powder coating material to M.D.F. and curing using Ultra Violet Light (U.V.) created an interest in potential advantages of this application. U.V. curing powders, however, cost significantly more than conventional coating powders and at present the range of colors and finishes is still somewhat limited. It was then found that ultra low bake conventional powders could be flowed and cured quickly using just Infra Red (I.R.) before the M.D.F. became hot enough to be damaged, thus, no need for UV. With the application of powder coating, liquid paint problems can easily be overcome. As powder is a dry film when applied' solvents are not required, thus alleviating the major hurdles imposed by legislation on V.O.C emissions. Also, because powder is a dry film and subsequently heated to melt and cure the film, the over sprayed powder can be potentially collected and re-used, thus minimizing waste. The design and shape of the M.D.F. board can utilize unusual shapes, which would be impossible for membrane pressing. Finally, powder coating is easily automated, not only the application but also the recovery and introduction of fresh virgin powders into the system. A simple on line pre-conditioning of the board, again using I.R., has overcome the problem of coating consistency from one batch of M.D.F. to another or due to the shaping of the surface. Pre-conditioning is in fact an essential part of the process whether using I.R. and U.V., or simply I.R, in the final cure. This draws moisture and resins to the surface of the M.D.F. facilitating uniform attraction of the charged powder particles to the substrate. Pre conditioning may be achieved using I.R. or hot air circulating ovens or a combination of the two. The ultra low bake system is a proven and highly utilized system which has now been put to use in an application which previously would have been inconceivable! Capital investment is lower, therefore pay back times for the investment are shorter.

The requirements for the final cure of ultra low bake powders will vary depending upon a number of factors. the M.D.F. board and of course the conveyor speed, whether I.R. or hot air recirculating ovens are to be used, or a combination of the two. These factors may be determined during trials at Eurotec's headquarters. A great deal of excitement and interest is now being generated by the fact that this is now a proven production process using standard powder coating application equipment and virtually standard format coating powders. This means of course that manufacturers can now mass-produce a variety of products finished with all the advantages of powder coating (ANON, 1989b).

4.10. Design MDF

Design MDF provides many creative possibilities for furniture, cabinetry, displays, and exhibit and store fixtures,"says Wolfgang Adams, Business Manager for BASF's Performance Chemicals business in North America. The many features and advantages that Design MDF brings to the marketplace is causing the excitement. Typically composite wood panels, or fiberboard, are the characteristic straw color, and are usually unimpressive. Design MDF is a highly colored composite panel that creates an innovative look for composite wood products. The most evident property of Design MDF is that the color is intense, and is consistent from one side through to the other. No longer does composite wood need to be covered up by decorative overlays and laminates. Nicks and scratches are not as noticeable with Design MDF and can easily be removed, which is not possible with conventional MDF (NPA, 1994).

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1. Grades of Medium Density Fibreboard

A. Thin MDF
B. Thick MDF
C. Low formaldehyde MDF (Class E1)
D. Moisture resistant MDF (MDF.H and MDF.HLS)
E. Exterior MDF (MDF.E)
F. Flame Retardant MDF
G. High Density MDF (also referred to as HDF)
H. Decorative surfaced MDF

The characteristics of standard grade MDF in the middle thickness ranges have been sufficient for most furniture and interior design applications up to now. Any relatively new material is however subject to continuing development. As a consequence of developments in the last 2 to 3 years, MDF manufacturers are now able to offer a wider range of standard boards covering thicknesses down to 1.8mm and up to 60mm, and specialty boards with improved moisture resistance, low formaldehyde emission, flame retardancy, and higher density. These enhancements of standard grade MDF have been achieved by changes in manufacturing procedures, different resin binders or the use of additives. An increasing volume of these specialty boards are now being used in the furniture, interior design and building industries and for outdoor applications (Youngquist, 1987).

5.1.1. Thin MDF

Several MDF manufacturers are now offering thin boards starting at 1.8 mm thickness. These can be considered as alternatives to hardboard and thin plywood with the added advantage of being smooth on both surfaces and free the grain features which can show through paint finishes and thin foils applied to plywood substrates. Now that the properties of very thin MDF boards are well defined in the 1.8 to 2.5mm, greater than 2.5 to 4mm and greater than 4 to 6mm thickness bands of the European Standard EN 622-5, designers and specifiers have all the information necessary to make good use of these materials in furniture, interior fitments.

Typical applications in furniture include drawer bottoms, backs of cabinets and centre panels in framed doors. All the finishing and surfacing treatments applied successfully to thicker MDF can equally be applied to thin MDF. In building interiors, thin MDF can be used for wall and ceiling paneling, as skins for flush doors, partitioning, office screens, lightweight doors and exhibition paneling. Experience has shown that thin MDF can easily be cut using steel rule dies or blanking presses. Whole patterns punched through the board provide an opportunity for a wide range of decorative panels some with acoustic properties. Another possibility, worthy of further exploration is the manufacture of curved panels, reception desks, bar fronts and shop counters for instance, constructed by laminating several layers of thin MDF in a former to build up the required shape and thickness (Youngquist, 1987).

5.1.2. Thick MDF

Several manufacturers are now able to supply MDF up to 60 mm thickness compared with an upper limit of approximately 30 mm several years ago. Previously, users requiring thick MDF had to laminate several thinner boards to achieve the required thickness. The properties of these thicker boards are specified in the greater than 30 to 45mm and the greater than 45mm thickness bands. The greatest potential for these thicker boards is in buildings as architectural features, columns, pilasters and archways, for instance, where the good surface and edge finishing characteristics of MDF can be used to good advantage. Other possibilities include heavy duty flooring and shelving, worktops, stair treads, bench seating and internal doors with deep moulded faces. Taking advantage of the good machining characteristics of MDF, slabs cut from thick boards can be turned to form a wide range of table legs, underframes and display or exhibition features. Thick MDF is also widely used as a base material for wood veneer and foil wrapped moldings (Youngquist, 1987).

5.1.3. Low formaldehyde MDF (ClassE1)

The formaldehyde content of standard grade MDF can vary according to the nature of the urea formaldehyde or other resin used as a binding agent. MDF will normally be supplied with free formaldehyde content, measured by the EN 120 (perforator) method, not exceeding 30mg/100g. MDF which satisfies this requirement is considered to be suitable for most applications in furniture, interior design or buildings where sufficient ventilation is available to remove small quantities of formaldehyde as they are emitted. Low formaldehyde MDF is recommended for all applications where the ventilation is likely to be restricted, where damp conditions or high ambient temperatures prevail or where the occupants of a building have special needs, in sheltered accommodation, schools and hospitals, for instance. Low formaldehyde MDF should be used for showcases and other fitments for museums to minimize possible corrosion of metal artifacts by formaldehyde products.

Note should be taken of any national regulations which may refer to the use of low formaldehyde boards for building components and furniture. Users should also take note of the effect of any surface coatings on formaldehyde emission. Some, such as acid catalyzed lacquer and paper foil, may increase formaldehyde emission while others such as plastics laminate, PVC foil, polyurethane lacquer and cured melamine paper can reduce the emission from the surfaces of MDF panels (O'Halloran and Youngquist, 1984).

5.1.4. Moisture resistant MDF (MDF.H and MDF.HLS)

MDF with improved resistance to moisture for interior applications involving exposure to relative humidities up to 80%, with only short term exposure to higher relative humidities, is manufactured by upgrading the normally used urea formaldehyde resin binder or by using an alternative moisture resistant resin. All the desirable properties of standard grade MDF are retained in these boards with the added advantage of a higher level of strength retention and less swelling when used in extreme interior conditions or sheltered outside conditions.

Possible applications for moisture resistant MDF include the following:

- Bathroom furniture
- Kitchen furniture
- Flooring
- Window boards
- Double glazing infils
- Skirting boards
- Stair components
- Architectural mouldings
- Informative signs in semi exposed situations

Where intermittent contact with water is likely in kitchens and bathrooms, for instance, and some building applications, special care should be taken with the sealing/finishing treatments, particularly in respect of exposed edges (Minato, 1993).

5.1.5. Exterior MDF (MDF.E)

As part of the further development of MDF, an exterior grade is now available with all the good machining and finishing characteristics and substantially higher strength than standard MDF, with the added advantage of resistance to outside exposure conditions, subject to adequate sealing of all surfaces and edges with a proven exterior durability coating. As an indication of durability, road signs manufactured from exterior grade MDF and subjected to the extremes of weather have been used for eight years without signs of deterioration. It has also been used successfully for shop fronts exposed to the elements for several years (Liiri, 1960).

Possible applications for exterior grade MDF in non structural situations include:

- Road signs
- Advertising hoardings and business signs
- Shop fronts and facial panels
- Garden furniture Playground fittings
- Boat cabin linings
- Exterior mouldings
- Sports score boards
- Shelving in open storage areas
- Exterior door panels

5.1.6. Flame Retardant MDF

Standard grade MDF would normally be expected to achieve the same surface spread of flame ratings as other wood based sheet materials and wood itself when assessed by the appropriate national standard of each country. An improved surface spread of flame rating can sometimes be achieved by coating the surfaces of standard grade MDF with an in tumescent paint or other specially formulated finish, subject to achieving the specified coating weight. Alternatively, the surface spread of flame characteristics of standard grade MDF can be uprated by impregnating manufactured boards or panels with fire retarding salts using a vacuum pressure impregnation process. As water based solutions are normally used for this impregnation treatment, some raising of the surface fibres and loss of strength is inevitable.

The most satisfactory method of achieving a high resistance to surface spread of flame for MDF requires the addition of the appropriate flame retarding salts to the fibres as an integral part of the board manufacturing process. Boards of this type are now more generally available and should be used in preference to boards which have been treated after manufacture. A wider range of finishing materials can be used on these impregnated boards without significant loss of flame retardancy (NPA, 1994).

Possible applications of flame retardant MDF include:

-wall and ceiling linings
- Office partition systems
- Institutional furniture
- Builtin fitments
- Shopfittings
- Exhibition displays
- Bulkhead and cabin linings in ships

5.1.7. High Density MDF (also referred to as HDF)

Standard grade MDF in the thickness range 12 to 19 mm normally has a density in the range 700 to 800 kg/m3. Higher density grades of MDF are now available with densities in excess of 800 kg/m3. This increase in density is achieved by increasing the amount of resin binder added to the fibres, increasing the bulk density of the fibres used to form the mat, and increasing the pressure applied to form the board, all factors together resulting in a substantial increase in strength. The even closer compaction of the fibres in high density MDF enhances the machining characteristics of the board allowing more complicated profiles to be cut. The well compacted surfaces and edges result in excellent paint finishes with only minimum surface preparation. Several bedroom and kitchen door manufacturers are using high density MDF to take advantage of these good machining and finishing characteristics. High density MDF can be processed in the same way as standard grade MDF. The finishing treatments applied to standard grade MDF can equally be applied to high density MDF with better results (NPA, 1994).

Possible applications for high density MDF include:

-Industrial shelving

- Work benches

- Heavy duty flooring

- Staircases

- Furniture underframes

- Doors for kitchen and bedroom units

5.1.8. Decorative surfaced MDF

5.1.8.1 Wood veneered.

Standard grade MDF is widely used as a base for wood veneering for many applications in the furniture and interior design industries. Large furniture companies are likely to have their own wood veneering facilities. Interior design companies and small furniture companies without these facilities can obtain wide ranges of wood veneered MDF boards and panels from some MDF manufacturers or from specialist fabricators who provide a wood veneering service using veneers from a standard range or specially selected veneers to suit customer's requirements (Youngquist, *et al.,* 1994).

5.1.8.2. Melamine surfaced.

A high durability finish can be obtained by direct surfacing MDF with melamine resin impregnated papers essentially following the high temperature, high pressure, laminating procedure used for the manufacture of melamine surfaced chipboard. A wide range of decorative effects are available, including plain colours, woodgrains, prints, all with smooth finishes or textures built into the surfaces at the time of laminating. Having regard for the sophistication of the short cycle or continuous laminating press procedures, melamine surfaced MDF cannot easily be produced by non-specialists companies. However, a wide range of melamine surfaced MDF with an even wider range of finishes is available from those board manufacturers who provide this important value added service or from specialist laminators (Youngquist, *et al.,* 1994).

5.1.8.3. Paper and PVC foils.

Some MDF manufacturers and many specialist laminating companies can supply MDF sheets surfaced with any one of a large number of decorative paper and PVC foils. The thickness, decorative effect and durability of the surfacing material can be selected to suit the requirements of particular applications. Subject to the selection of foils with suitable finishes, these boards can be used without the need for further finishing treatments.

MDF overlaid with plain or textured papers are available from some manufacturers for painting applications where the requirements for appearance are particularly demanding, high gloss finishes, for instance (Youngquist, *et al.*, 1994).

5.1.8.4. Textured surfaces.

Some MDF manufacturers are now offering standard grade boards with a texture embossed into the surface as a secondary manufacturing operation. These also can be finished effectively by direct painting.

5.1.8.5. Paint and Lacquer finishing

Some MDF manufacturers have increased their product range by the introduction of boards and panels with decorative surfaces achieved by painting or lacquering. Thin MDF manufacturers in particular can supply painted or wood grain printed boards for door skins and wall paneling (NPA, 1994).

5.2. Physical and Mechanical Properties

As wood properties vary among species, between trees of the same species, and between pieces from the same tree, solid wood cannot match reconstituted wood in the range of properties that can be controlled in processing. When processing variables are properly selected, the end result can sometimes surpass nature's best effort. With solid wood, changes in properties are studied at the cellular level. With reconstituted wood materials, changes in properties are studied at the fiber, particle, flake, or veneer level. Properties of such materials can be changed by combining, reorganizing, or stratifying these elements.

MDF has many qualities that make it an ideal replacement for plywood or particle board. It is dense, flat, stiff, has no knots and is easily machined. Its fine particles provide dimensional stability without a predominant "grain" (as is the case with lumber). Unlike most plywoods, MDF contains no voids, and will deliver sharp edges with no tearout. MDF is very well damped acoustically thus making it an ideal material for speaker enclosures. Below are some typical values for the modulus of elasticity (in million pounds per square inch) and density (in pounds per cubic feet) for MDF, Oak, Pine and Fir Plywood

- MDF - 0.53, 48
- Oak - 1.55, 38
- Pine - 1.3, 29
- Fir plywood - 1.2. 33

The modulus of elasticity (MOE), also called Young's modulus, is the ratio of stress to strain, where stress is the force per unit area placed on the item and strain is the deformation caused by the stress. The MOE is therefore a measure of stiffness. Medium-Density Fiberboard—Minimum property requirements, as specified by the American National Standard for MDF, A208.2 (NPA 1994) are given in the Table. This standard is typically updated every 5 years or less. The furniture industry is by far the dominant MDF market. Medium-density fiberboard is frequently used in place of solid wood, plywood, and particleboard in many furniture applications. It is also used for interior door skins, mouldings, and interior trim components (Youngquist, *et al.*, 1997).

Table-2: Medium Density Fibreboard (MDF) Property Requirments

Product class[b]	Nominal thickness (mm)	MOR (MPa)	MOE (MPa)	Internal bond (MPa)	Screw-holding (N) Face	Screw-holding (N) Edge	Formaldehyde emission[c] (ppm)
Interior MDF							
HD		34.5	3,450	0.75	1,555	1,335	0.30
MD	≤21	24.0	2,400	0.60	1,445	1,110	0.30
	>21	24.0	2,400	0.55	1,335	1,000	0.30
LD		14.0	1,400	0.30	780	670	0.30
Exterior MDF							
MD–Exterior	≤21	34.5	3,450	0.90	1,445	1,110	0.30
adhesive	>21	31.0	3,100	0.70	1,335	1,000	0.30

Source: Wood-based composites and panel product (Suchsland and Woodson, 1886).

MDF is resistant to warp, moisture and compression. It is dimensionally stable with close tolerances". Thin MDF boards are an ideal alternative to plywood. Typical applications in furniture include drawer bottoms, backs of cabinets and centre panels in framed doors. In building interiors, thin MDF can be used for wall and ceiling paneling, as skins for flush doors, partitioning, office screens, lightweight doors and exhibition paneling.

MDF can be machined into intricate patterns as easily as natural wood with the advantage of no grain telegraph. Thick MDF boards can be used in building as architectural features such as columns and archways where the warp resistance, tensional stability, screws holding strength and edge finishing characteristics of MDF make it a good substitute for solid wood. Thick MDF is used as a core substrate material for paneling with veneers, printed surfaces, vinyl and low pressure laminates due to its dimensional stability and smoothness (Watkinson and Van, 1990).

TABLE-3: MAIN PHYSICAL AND MECHANICAL PROPERTIES OF NON-WOOD FIBRE BASED MDF

	Cotton straw		Bamboo	Reed	Bagasse
Board thickness (mm)	18	9	9	9	9
MOR (Mpa)	30-40	32-36	25	26-30	30-35
IB (Mpa)	0.5-0.6	0.60-0.65	0.50	0.45-0.55	0.60-0.65
Absorptivity	14-17	22-26	20	16-20	12
TS	6-8	6-10	9	7-8	4-6
Length Swelling	0.30-0.40	0.35-0.50	0.30	0.30-0.38	0.30
Density (g/cm^3)	0.65-0.69	0.70-0.75	0.70-0.75	0.72-0.76	0.70

Source: MDF improvement by non-wood materials (Park and Seo, 1993).

5.3. MDF Mouldings and Millwork

MDF is an exceptional product for mouldings and millwork. The surface is flat, smooth, uniform and free of knots and grain. MDF is easily shaped into almost any form. High quality, clean, sharp contours and edges can be achieved in a wide range of profiles. The homogeneous composition of MDF is compatible for high quality finishing techniques. MDF's uniform composition and smooth, tight surface, allows finishes to be applied directly to the surface. There are no finger joints so it is easy to create an even finish (Minato, *et* al., 1993).

5.4. Moisture Resistant MDF

Mouldings with properties that enhance moisture resistance should be considered for use in bathrooms and for baseboards where the construction is slab-on-grade. While the most common binder for MDF is urea-formaldehyde, other adhesives or additives may be used as well to provide special properties such as reduced thickness swell or enhanced bond durability (McNatt, 1974).

5.5. Environmentally Friendly

The MDF are made of old rubber trees, which in the pass were cut down and burnt causing both air pollution and wastage of valuable wood resources. Now we have brought it to productive use. Its timber is suitable for making furniture; and its wood chips are ideal for processing into fibreboard. This new application is ecologically friendly to our environment.

5.6. Impact of bark content on the properties of MDF

Medium density fiberboard (MDF) is generally produced from bark-free raw materials. The maximum bark content of MDF products is about 1 percent by weight. The potential of using large amounts of bark as raw material for MDF and the effects of bark content on panel properties are still unclear. The characteristics of wood fibers and bark fibers of four species grown in eastern Canada (hybrid poplar, jack pine, red pine, and white spruce), as well as the influence of bark-derived fiber content on the performance of MDF were investigated. There was no obvious change in pH between bark and bark-derived fiber, but the pH of wood-derived fiber was obviously lower than that of wood. The bulk density of refined bark fibers was higher than that of wood fibers for the same species at the same refining conditions. The effect of including bark on all mechanical properties including modulus of rupture (MOR), modulus of elasticity, internal bond, and linear expansion is more detrimental than that of thickness swelling and water absorption. However, all the properties of bark-included MDF panels, made from up to 40 percent bark fibers met the ANSI standard (except for TS and for one case of MOR).

Although paper producers consider bark in any form to be a very undesirable component in pulps, bark could be used for wood-based composite manufacturing. Various researchers have investigated the use of bark as raw material in the production of particleboard and hardboard. Dost (1971) studied the effect of redwood bark content on the performance of redwood particleboard and the results indicated that board properties became poorer as bark content increased. Maloney (1977) investigated the properties of bark particleboards made from four west coast softwood species (western larch, Douglas-fir, ponderosa pine, and western redcedar) and found board properties differed (FAO, 2001).

5.7. MDF in Bangladesh

In Bangladesh, production of Medium Density Fibreboard is zero. Still now no plant has been developed to produce MDF.

5.8. MDF in New Zealand

New Zealand leads the world in the manufacture and use of medium density fibreboard or MDF. This wood panel product delivers good working properties and stylish looks to furniture-makers, joinery companies and builders. MDF is a wood residue-based composite material, pioneered in New Zealand. Fine wood fibres are bonded under heat and pressure with an adhesive. The resulting product is available in a wide range of thicknesses, including ultra-thin sheets. New Zealand's abundant radiata pine is the acknowledged leading raw material for MDF. Innovation and state-of-the-art technology delivers product which is noted for:

- consistent density
- pale color
- smooth finish
- material uniformity
- ease of machining

These qualities ensure strong consumer demand within New Zealand, and a premium in markets such as China, Japan and the United States of America. New Zealand has been a major force in the large growth of Pacific Rim MDF capacity. New Zealand MDF manufacturing plants access a stable supply of radiata pine. Supply is expected to substantially increase over the next decade, enabling New Zealand to meet growing global demand for MDF products. World demand for MDF is growing at 2.6 times the rate for all wood products (Watkinson and Van, 1990).

Excellent environmental credentials give New Zealand MDF strong consumer appeal. These credentials include:

- all radiata is grown in environmentally-sustainable plantations
- New Zealand MDF utilizes special formulations to enable the smallest possible amount of adhesive use.

5.9. MDF in Australia

In Australia the main species wood used for MDF is plantation-grown radiata pine. However a variety of other products have also been used including other woods, waste paper and fibres. The trees are debarked after being cut. The bark can be sold for use in landscaping, or burned in on-site furnaces. The debarked logs are sent to the MDF plant where they go though the chipping process. A typical disk chipper contains 4-16 blades. Any resulting chips that are too large may be re-chipped; undersized chips may be used as fuel. All chips are then washed and checked for defects. The chips are then compacted using a screwfeeder, and will be heated for 30-120 seconds to soften the wood; they are then fed into a defibrator which maintains high pressure and temperature. The pulp that exits from the defibrator is fine, fluffy, and light in weight and in colour. From the defibrator the pulp enters a blow line where it is joined with wax (to improve moisture resistance) and resin (to stop the pulp from forming bundles). The material expands in size and is then heated by heating coils. When it comes out it may be stored in bins for an indefinite length of time. After this drying period the board goes through a "Pendistor" process which creates 230-610 mm thick boards. Then it is cut and continues to the press. Here it is pressed for a few minutes, to make a stronger and denser board. After pressing MDF is cooled in a star dryer, trimmed and sanded. In certain applications boards are also laminated for extra strength. The Environmental Impact of MDF has greatly improved over the years. Today many MDF boards are made from a variety of materials. These include other woods, scrap, recycled paper, bamboo, carbon fibres and polymers, steel, glass, forest thinning and sawmill off-cuts (Rowell and Young, 1997).

5.10. MDF in The Other Parts of The World

Medium Density Fibreboard is the new dimension in the world particularly in the north America. It is being produced in the other parts of the world, as it has medium density which enables furniture light in weight and easily portable from one place to another. It has other qualities like, high moisture resistance, fire retardant, less expensive than natural wood, consistant in strengh and size etc.

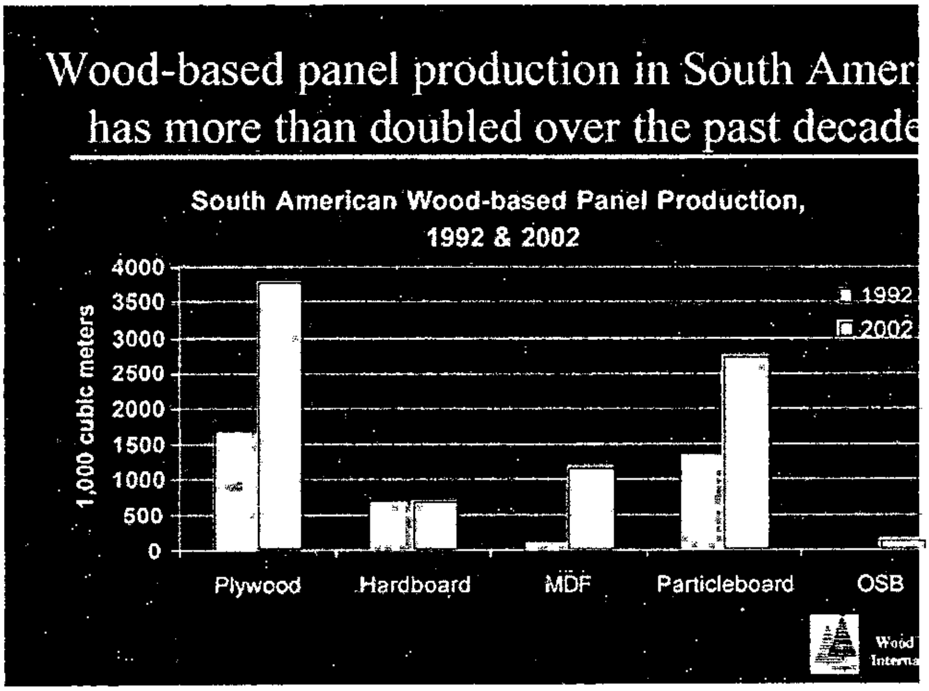

Figure-12: Wood-based panel production in South America (Flynn, 2004).

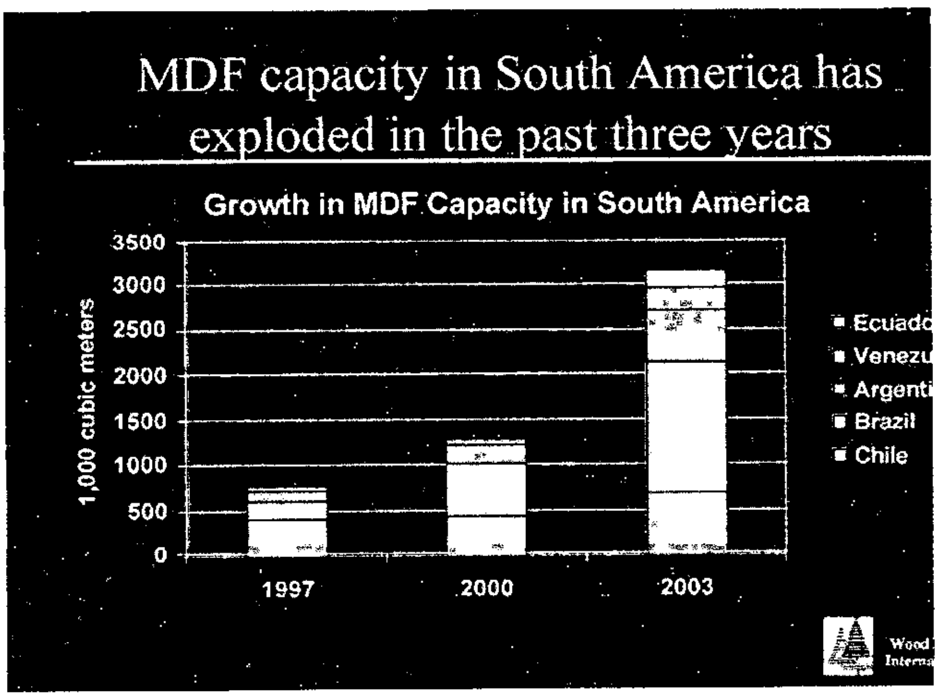

Figure-13: Growth in MDF Capacity in South America (Flynn, 2004).

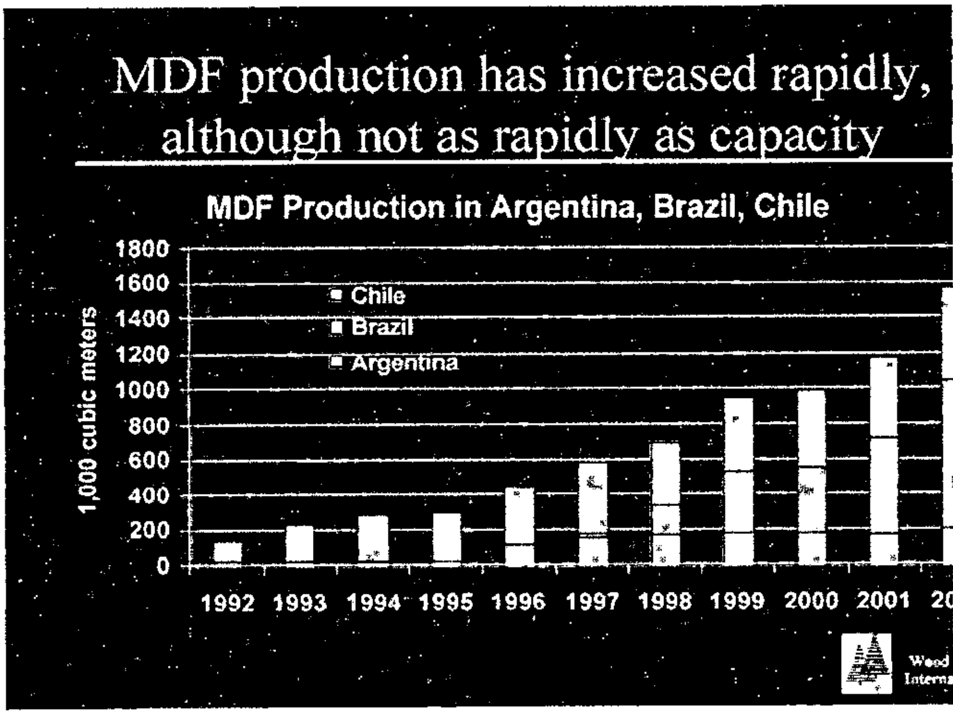

Figure-14: MDF Production in Argentina, Brazil and Chile (Flynn, 2004).

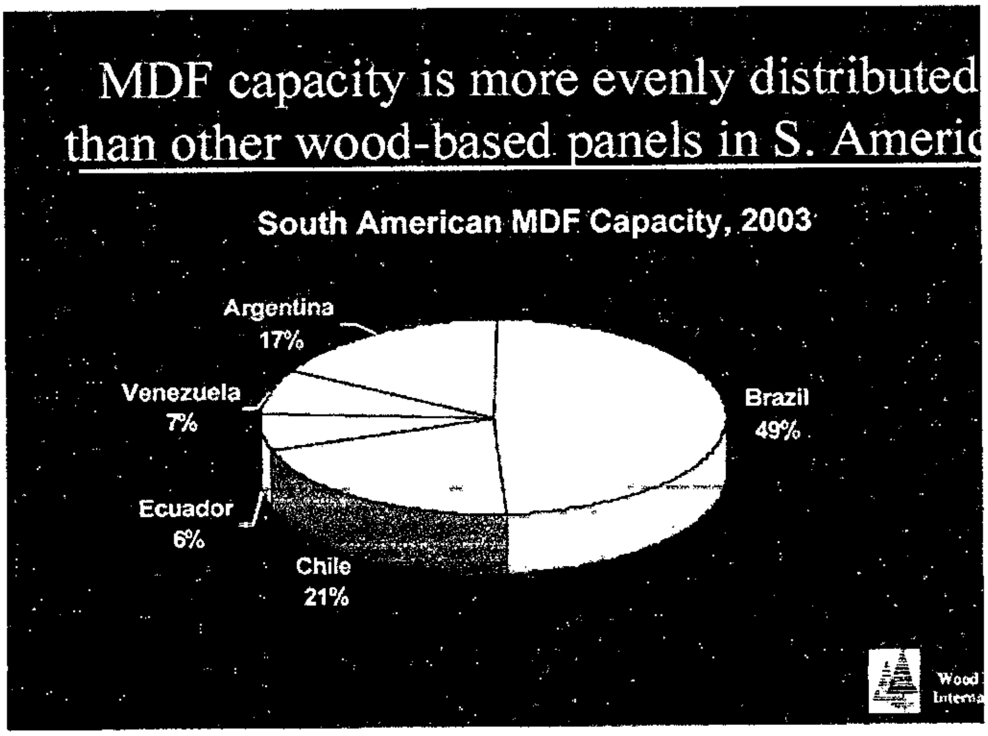

Figure-15: South Americam MDF Capacity (Flynn, 2004).

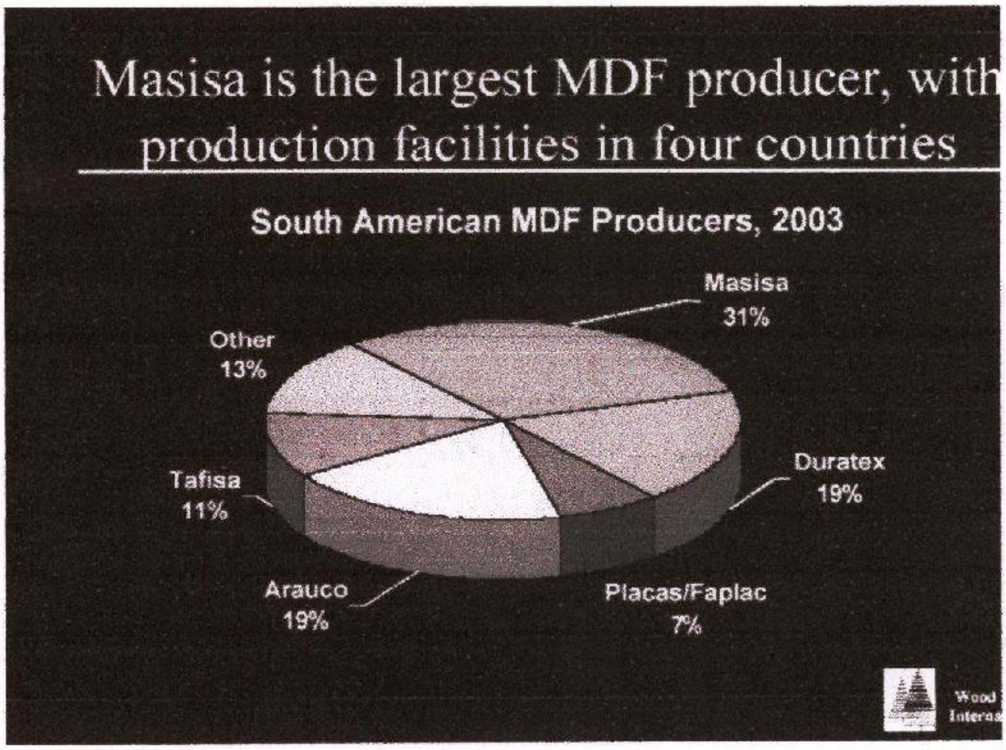

Figure-16: South American MDF Producers (Flynn, 2004).

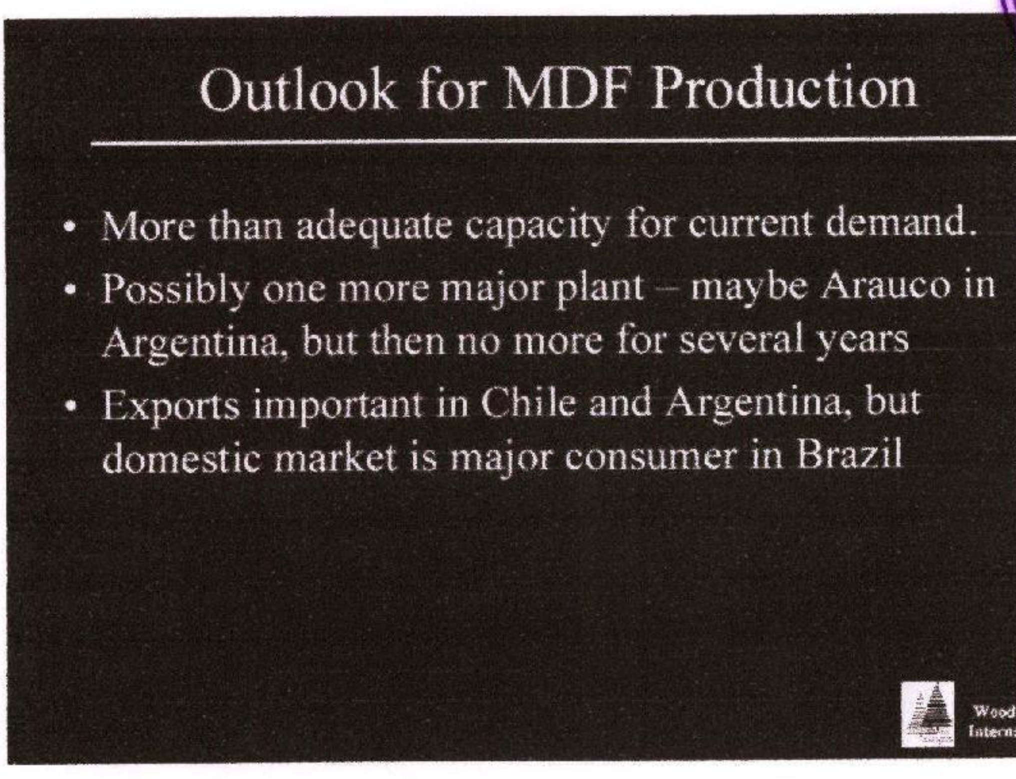

Figure-17: Outlook for MDF Production (Flynn, 2004).

Figure-18: Role of Foreign Investment in Development of the wood panel Industry (Flynn, 2004).

Medium density fiberboard (MDF) production has experienced a period of fast growth in the past decades. The worldwide MDF capacity has increased from 8.5 million [m.sup.3] per year in 1990 to 40 million [m.sup.3] per year in 2003 (Flynn, 2004). Utilization of nontraditional sources of raw materials has become more and more necessary. Because fiberboard is manufactured by reconstituting fibers through a flexible and wide range of manufacturing conditions, any wood fiber including various residues could become potential raw material for the manufacture of MDF. Wood bark constitutes a considerable volume of a log, normally ranging from 9 to 24 percent varying from species and log diameters (Suzuki and Saito, 1988). It is a major source of forest industrial residues. About 17 million [m.sup.3] of bark is produced annually by Canadian wood processing industries, of which more than half is incinerated or landfilled. Only a small portion of bark is used for thermal energy production. At the same time, environmental agencies are invoking stricter regulations with regard to landfill disposal and burning of large quantities of bark. The environmental and disposal problems created by the accumulation of considerable volumes of bark in the forest industry and the increasingly scarce supply of wood and fiber resources are forcing the industry to seriously consider all possible utilization of bark as a raw material, particularly in the form of higher value products.

CHAPTER SIX

PROBLEMS RELATED WITH MDF

6.1. Problems with MDF

MDF is a type of hardboard which is made from wood fibres glued under heat and pressure. MDF has many qualities that make it an ideal alternative to plywood or chipboard. It is dense, flat, and stiff, has no knots and is easily machined. Its fine particles provide a material without a recognizable "grain". Unlike plywood and block board, MDF contains no internal voids, and will produce better edges providing that it is correctly machined. But use MDF with care - it is manufactured using urea-formaldehyde resin which may be released in low concentrations over a long period of time. Formaldehyde can cause temporary eye and respiratory irritation; it can also aggravate respiratory conditions or allergies in some people. Proper ventilation and precautions during working and use will reduce the risk of such problems. Some people have been reported as being affected by just a piece of MDF in a room (Minato, 1993).

6.2. Working with MDF

Dust is a major hazard when working with MDF. The large amounts of dust generated by cutting and machining require the use of proper breathing and eye protection. As a minimum, always use a dust mask while there is dust in the air, not just while actually cutting. A professional style respirator is preferable. Goggles should always be worn while using tools on MDF. MDF can be cut in the same manner as a fine-grained hardwood although as it does not have a grain, it can be successfully sawn in any direction. MDF can also be machined, drilled and tapped. Due to its high glue content, steel cutting tools will dull very quickly; the use of carbide tools is preferred. Being without a grain, cutting or machining MDF will result in a very smooth edge providing that the tools are sharp and used correctly (Minato and Seto, 1995).

6.3. Fixing problems & solution

Screws and nails can be used to fix MDF, however with these fixings; there is a risk of the MDF splitting if care is not taken. The risk of splitting depends upon the thickness of material; generally fixings should not be less than 25mm from the edge.

When using nails, drive them in at right angle to the surface, this will avoid bending and reduce the chances of splitting. Use ring-shank nails to ensure a good grip. With screws, always use pilot holes - about 85 % to 90 % of the root diameter of the screw being used and at least as deep as the screw. Straight sheet metal screws with constant size shank give best results, avoid using tapered wood screws.

Because MDF can be milled to just about any profile, many of the traditional woodworking joints can be used as can dowels. MDF can be glued using gap-filling or PVA glues. Epoxy and hot melt glues are also suitable. The edges of pieces of MDF can be glued to make larger sheets (Minato, 1993).

6.4. Finishes problem & Solution

As MDF is typically made using urea-formaldehyde resin which will be gradually released into the atmosphere wherever MDF is used. While this will not affect most people, some people are sensitive to formaldehyde emissions so precautions must be taken. Where possible, use low formaldehyde or formaldehyde-free MDF, or consider methods of controlling these emissions through proper finishing.

Where a finish is applied, it should be applied to all exposed surfaces, even those not immediately visible. Finishes that work best at controlling formaldehyde emissions are solid surfaces such as laminates, vinyl covering, and finished wood veneers. Oil based paints and varnishes can be used. Less effective at controlling emissions are simple wax and oil coatings (Minato, *et al.,* 1993).

6.5. Health Risks

MDF is generally a safe product. However, its use of the carcinogen formaldehyde presents a clear health risk to those that work with MDF. Exposure to dust from milling and cutting MDF presents a risk to workers, though steps can be taken to minimize risk.The Health and Safety Co-ordinator has received a number of enquiries about the safety of MDF in schools. Enquirers have raised concerns about the effects on health from the dust produced from sawing or sanding MDF. There seem to be two concerns:

- The dust produced when machining MDF is much finer than the dust produced when machining other commonly used woods.
- Formaldehyde used in the manufacturing process can be given off. Both of these substances have Maximum Exposure Limits (MEL's) set by the Heath

and Safety Executive (HSE), these limits should never be exceeded at any time.

- Wood dusts 5 mg/m^3 over an 8 hour reference period.
- Formaldehyde 2ppm over an 8 hour reference period.

When MDF is machined it can generate greater quantities of dust which is much finer than the dust produced when machining other commonly used woods. In some instances a higher standard of extraction is required when machining MDF. The Directorate of Education and Leisure Services' Code of Practice 'Woodworking' outlines the standards of extraction that is required in Bexley Schools. The HSE indicate that formaldehyde is unlikely to be a risk when machining MDF. The Code of Practice recommends that where MDF is obtained as off-cuts from the manufacturer, it should be stored in a well-ventilated area prior to use. The Health and Safety Executive has published a Hazard Assessment Document for medium density fibreboard (MDF). The publication of this document follows on from an announcement in October 1997 that the HSE would be reviewing the health effects of exposure arising from machining MDF. HSE's Working Group on the Assessment of Toxic Chemicals (WATCH) endorsed the conclusion of the hazard assessment that there is no evidence that the ill-health effects associated with exposure arising from the machining of MDF are different from those associated with similar exposure arising from machining other forms of wood. There is some evidence for more frequent reporting of respiratory symptoms in workers receiving exposures arising from machining MDF compared to other forms of wood or wood products (Minato and Seto, 1995).

6.6. Risk Management

Working Group on the Assessment of Toxic Chemicals (WATCH) expressed the view that the most appropriate risk management strategy for MDF is the one currently recommended by HSE. This specifies that

- The level of dust arising from the machining of MDF should be kept as low as reasonably practicable below the maximum exposure limits (MELs) for softwood dust and hardwood dust; and
- Levels of free formaldehyde should be kept as low as reasonably practicable below the MELs for formaldehyde.

Source: http://www.childrensfurniture.co.uk/mdf.html.

6.7. MDF Material Safety Data Sheets

The Canadian Dangerous Goods Shipping Regulations do not class MDF as dangerous goods and do not require that MDF be specially labeled. MDF is an unregulated product. Manufacturer's safety data sheets for the use of industry describe MDF as being normally stable, flammable in the presence of naked flames, sparks or heat and that MDF may polymerize at increasing high temperatures. Decomposition products may include: CO, CO_2, aldehydes (including formaldehyde), hydrogen cyanide. MDF does not entail any fire or explosion hazard but cutting, sanding and milling may produce wood dusts which may constitute an explosion hazard if the dust concentration comes into contact with an ignition source. The data sheets state that the measures for fighting a wood-composite fire are well known, that water, CO_2 and sand should be applied and that a Class A extinguisher should be used (McKay, 1997).

6.8. Storage of the MDF

To protect the MDF from the elements, the main-deck hatches were closed every night and on rainy days. Reportedly, the crew did not operate the 'twin-deck hatch covers during the call at port. However, it could not be confirmed whether the electrical system of the 'twin-deck hatches remained under power. There are no regulations governing inspection of a ship before loading general cargo. However, around 0720 on October 22, the superintendent of the stevedores visited the vessel holds and noted that they were in satisfactory state to receive a cargo of MDF. Stevedores operated the vessel cranes. In each hold there was a crew chief, a forklift operator, slingers and dunnaging carpenters. The officer of the watch oversaw the loading from the main deck. An able seaman on the 'twin-deck signaled to the stevedores any damaged bundles requiring makeshift repairs, and noted the work done. MDF panels were packaged in bundles by the manufacturer. Each bundle had an approximate volume of 2.5 m^3 and was wrapped in polyethylene film under cardboard on five surfaces. The panels rested on MDF braces. The panels, packaging, and braces were held in place by metal straps. In each hold, the bundles were stowed on the tank top along the forward bulkhead, then along the sides, and finally along the aft bulkhead. The superintendent oversaw the stevedores on the wharf and on board the ship. The ship ventilation system was not used (Minato, *et al.*, 1993).

CHAPTER SEVEN

7.1. RECOMMENDATIONS

- MDF or medium density fibreboard is a composite board material now being used worldwide. But in our country there is no MDF producing industry. So wood industries authorities should take initiative to initiate MDF production in different industries.
- We should develop technical knowledge and incorporate improved technology so that we can produce quality MDF in our country.
- Seminars, symposiums and conference should be arranged to disseminate knowledge and make people aware of MDF producing furniture.
- As MDF producing furniture is durable and comparatively cheap in compared to solid wood, so government should take initiative to produce MDF in a large scale.
- Heat treatment of MDF was unsuccessful in decreasing the moisture sorption characteristics or reducing the effect of moisture on the mechanical properties of boards. There are many other heat treatments and variations of the heat treatment conducted here that may prove to be more successful.
- Moisture content and thickness swelling of MDF increased with increasing relative humidity as the boards adsorbed moisture macro-molecularly (within fibres) and poly-molecularly (in the resin matrix, between fibres). Such increases may be due an increase in the number of moisture accessible sites and a breakdown of the resin matrix and can be managed through effective treatment.
- Fibre pull out or inter fibre shear causes the primary failure mechanism of specimens when tested at high humidity's. The thermosetting resin-cellulose bond is known to be quite strong and it is suggested that weakening of the resin itself, rather than the resin-fibre bond. At low humidity's the fibre resin matrix remains intact and fibre failure is the primary failure mechanism.
- Powder coating should be used on MDF that balances the furniture properties and dimensional stability and furniture prepared from MDF boards with a single coat that combines a good appearance with scratch resistance and excellent chemical resistance.

7.2. CONCLUSION

MDF or medium density fibreboard is a composite board material now being used worldwide. It offers several advantages including a consistent uniform surface and ease of painting for a top quality look that is easy. It belongs to the hardboard family of products which are made from wood fibers glued under heat and pressure. The future looks bright for the MDF industry and as a follow on effect this should boost the forestry industry in the world. Major MDF plants in the world have been expanding and upgrading to keep up with demand and a new plant from a new competitor is to be built. The mechanical and physical properties of MDF will continue to improve with further research. The technology may soon be around to produce an MDF or similar wood composite that can mimic the structural properties of solid timber beams. There may soon come a time when economics will dictate that it is cheaper to produce MDF from recycled materials and with current environmental concerns, particularly over forest reserves, this may see the proliferation of MDF even further. In the context of Bangladesh, research on MDF is imperative to expedite the process and extend the knowledge to the users.

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