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The Haphazard Wooden Material Converted to Healthy MDF Product

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Abstract: During machining of wood and wood composites materials, fine particles and dusts are created. These minute wooden materials can easily be carried out to human lungs by air and can cause serious health problem. Even though this material is too fine and created in huge amount, it can be stored and used as raw material in wood composite industry. The addition of wood dust into MDF contents can improve the physical and mechanical properties of the products. Small particles can fill the spaces between fiber and act as matrix material to improve adhesion properties. However, the addition of dust into MDF receipt decreased bending strength, internal bond values and MOE. In contrast, these mechanical strengths meet the standard values and fulfill the requirements.

Key words: Thickness swelling, bending strength, internal bond strength, MOE, MDF, wood dust

INTRODUCTION

The demands for forest products are increasing with increase in population. This need is rising the pressure on the natural resources. The lack of raw material and environmental concern leads to search for new sources. As a result of that different wood composites are produced to imitate solid wood. In order to produce these composites materials, small diameter wood, juvenile wood, twigs and agricultural products are utilized. During production, each process generates some fine dust and small particles. In addition to that, other wood using industries propagate huge amount of dust during sanding and converting wood to product. These minute wooden materials can easily be carried to human lungs by air and can cause serious health problem. Wood dust can cause sinonasal cancer, asthma, rhinitis, conjunctivitis, chronic bronchitis and dermitis (Palmqvist and Gustafsson, 1999; Holmstrom *et al*., 1991; Herbert *et al*., 1994; Hossini *et al*., 2001; Carton *et al*., 2002). It is also waste material to be discarded for the wood products industry and usually these materials utilized in burner to generate energy or utilized in gardening as plant bed. However, these dust/small particles can be utilized in production to obtain smooth surface of the board and/or improve the bonding ability of the material produced from it.

Adhesion and material combination is an important phenomena in composite production. Adhesion is related to surface phenomena that attaches different material together (Pocious, 1997). Particle or dust can have a dimension from a few nanometers to millimeters (Renliang, 2002). Concerning the size of tiny particles and dust, these material will have large specific surface area. Particles with high specific surface area lead to many significant interfacial phenomena, such as surface interaction with the surrounding medium and neighboring particles. As a consequence, adhesion bond can be strong as much interaction occurs between the surfaces. Therefore, particle size and distribution can affect the adhesion properties of material. Small particle can easily fill the space, have high surface area to bond and provide better adhesion and effect the mechanical properties of the assembled products. According to Nemli, wood dust addition to particleboard cake about 10% improved thickness swelling, internal bond and decreased the static bending and modulus of elasticity of particleboard produced from *Alnus glutinosa* subsp. Barbata (Nemli, 2003). In other research, addition of different size of polymeric fluff to medium density fiberboard improved significantly the thickness swelling, internal bond strength (Shi *et al*., 1999). Even though this change may be due to polymeric material properties, small particle size

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may improve interfacial phenomena and mechanical properties. According to Groom *et al*. (1999) the addition of fines to MDF receipt decreased the mechanical properties.

As the demand for MDF is rapidly growing, the fine sawdust presents an ever increasing cost and environmental liability to the manufacturers. The dust is too fine and voluminous to be easily handled, stored and transported. It also reduces formaldehyde emission and renders hazardous effect to human. Therefore, the objective of this study was to determine the small particle effect on the mechanical and physical properties of MDF.

MATERIALS AND METHODS

Materials: The raw materials for the study consisted of industrial wood (*Pinus sylvestris* L., *Fagus orientalis* and *Quercus robur* L.-*Quercus petraea* L.) which were collected from the West Black Sea Region (Düzce), and different part of Turkey.

In order to assemble MDF board, the following ingredient were added to the fiber furnish. These ingredient were 1% wax (Polisan, Gebze, Turkey), 0.8% NH_4Cl (Polisan, Gebze, Turkey) as hardener and 11% urea-formaldehyde (Polisan, Gebze, Turkey) resin. The urea formaldehyde resin specifications were given in Table 1.

Methods: Medium Density Fiberboard furnish were manufactured at Divapan Integrated Wood Company located in Duzce, Turkey.

The chips having an average dimension of 20 by 25 by 5 mm were produced from low-quality roundwood. Raw material was converted into fiber furnish in an Asplund defibrator using a steam pressure of 7.8 bar at a temperature of 175°C for 3.5 min.

MDF panels were made from dust and industrial wood furnishes (*Pinus sylvestris* L., *Fagus orientalis* and *Quercus Robur* L.- *Quercus petraea* Lieble) in various wood fiber/dust contents (100:0, 95:5, 90:10, 80:20 and 70:30) based on the ovendry weight at a set specific gravity. The panel manufacturing experimental design is outlined in Table 2. Firstly, the fibers produced from industrial wood and dust (from sanding and MDF cut) was mixed and fiber mat was prepared. Secondly, fiber mat was pressed with pressure of 25 kg cm^{-2} at 150°C for 6 min. Panel MDF produced in laboratory having dimension of 50×50×2 cm. were conditioned at 20±2°C and 65±5% of relative humidity to the moisture content of 12%. Finally, edges of the boards were trimmed to the final dimension of 48×48×2 cm.

In order to determine the physical and mechanical properties of each panel, density, thickness swelling at 2 and 24 h soaking period, bending strength, modulus of elasticity and internal bond strength were tested and compared according to standard TS 64-5, EN622-5 (1999). The density determination was performed with TS EN-323, (1999) (Turkish standard-extended), thickness swelling test at 2 and 24 h were performed according to EN 319, (1993a). The bending strength and modulus of elasticity (MOE) were evaluated according to TS-EN 310 (1999) (Turkish standard-extended). The experiments were carried out with Universal test machine (Imal mobiltemp shc22 model ib400). Tension strength parallel to the plane, Janka hardness perpendicular to the plane were determined according to EN 317 (1993b) and ASTM D 1037-78 (1994) standards. The average of 20 measurements was recorded. All data were evaluated by using the analysis of variance (ANOVA) and Duncan mean separation tests.

Table 1: The properties of urea-formaldehyde resin (UF)

Properties	Unit	Value
Solid content	%	55±1
Density (20°C)	g cm^{-3}	1.227
Viscosity (20°C)	Cps	185
Flowing time (20°C)	S	25-40
Free formaldehyde (max)	%	0.7
Gel time (100°C) (10% luk NH_3SO_4)	S	40-60
Shelf time (20°C)	day	45
pH	-	7.5-8.5

Table 2: MDF produced from the furnish from industry and fine particles

	Percentages of raw materials (%)	
Board type	Industrial furnish	Dust
$I_{100}D_0$	100	0
$I_{95}D_5$	95	5
$I_{90}D_{10}$	90	10
$I_{80}D_{20}$	80	20
$I_{70}D_{30}$	70	30

RESULTS AND DISCUSSION

The density of manufactured MDF panel has shown in Table 3. Each panel mean density difference was not significant due to production of set specific gravity. These panels were utilized to determine physical and mechanical properties of MDF.

Fiberboard is utilized in different environment as part of furniture such as in kitchen, bathroom, living room etc. These environments may carry different moisture contents and each material due to structural properties can absorb water. As a result of that, water causes to change dimensions of the board. Therefore, the thickness swelling becomes important character to determine in end products. The thickness swelling properties of the panels were given in Table 4. The panel made from industrial fiber has showed the least thickness swelling for 2 and 24 h tests. Extending soaking time in water significantly increased the swelling which is parallel to the increased amount of dust content (Table 4). Small particle size improves the specific surface area and leads to more

Table 3: The density of manufactured MDF panel

Board type	n	Density (g cm^{-3})
$I_{100} D_0$	20	0.749 (0.052)[a]
$I_{95} D_5$	20	0.751 (0.010)[a]
$I_{90} D_{10}$	20	0.752 (0.045)[a]
$I_{80} D_{20}$	20	0.753 (0.065)[a]
$I_{70} D_{30}$	20	0.755 (0.065)[a]

[a] Standard deviation n: sample size

Table 4: Thickness swelling properties of MDF

	%			
Board type	Thickness swelling (2 h)	Thickness swelling (24 h)	Duncan Grouping (2 h)	Duncan Grouping (24 h)
$I_{100}D_0$	1.614 (0.318)	8.579 (0.391)	A	A
$I_{95}D_5$	7.814 (1.093)	13.499 (1.419)	B	B
$I_{90}D_{10}$	8.991 (1.695)	15.228 (1.114)	CC	C
$I_{80}D_{20}$	9.925 (1.604)	17.877 (0.996)	CD	D
$I_{70}D_{30}$	10.577 (1.580)	20.370 (0.510)	D	E

* Number in parentheses represents the standard deviation

Table 5: Mechanical properties of MDF

Board type	Internal bond strength (N mm^{-2})	Bending strength (N mm^{-2})	Janka hardness (kPa)
$I_{100}D_0$	7.87 (1.31)*	39.61 (2.26)	78.40 (1.85)
$I_{95}D_5$	7.32 (0.53)	25.75 (3.03)	72.70 (3.15)
$I_{90}D_{10}$	6.82 (0.68)	25.28 (5.39)	69.00 (1.59)
$I_{80}D_{20}$	6.57 (0.79)	20.71 (2.84)	68.85 (3.48)
$I_{70}D_{30}$	5.93 (1.06)	14.78 (1.64)	68.50 (2.48)

* Number in parentheses represents the standard deviation

contact with moisture and increases the absorbed water content. Duncan test shows the relationship among the means. Means with the same letter are least significantly different at alpha 99% confidence level (Table 4).

The addition of dust, fine particles may also affect the mechanical properties of the MDF and these properties are usually defined as the strength and resistance to deformation (Haygreen *et al*., 1989). According to Eroglu and Usta, mechanical properties of MDF are affected by the raw material properties and production methods (Eroğlu and Usta, 2000). Fresh material can give better mechanical properties whereas the raw material that was stored in for a long time shows lower mechanical properties. In addition to that, MDF made from softwood fiber has higher mechanical properties than MDF made from hardwood fiber. In production, extending steaming period in termomechanical refining reduces the bending strength.

In order to determine the effect of dust content on mechanical properties of MDF, internal bond strength, bending strength and Janka Hardness were tested (Table 5).

The highest internal bond strength was obtained from industrial fiber. However, there were no significant difference detected for the mean values of internal bond strength with different fine particle contents. In contrast to that, bending strength and Modulus of elasticity

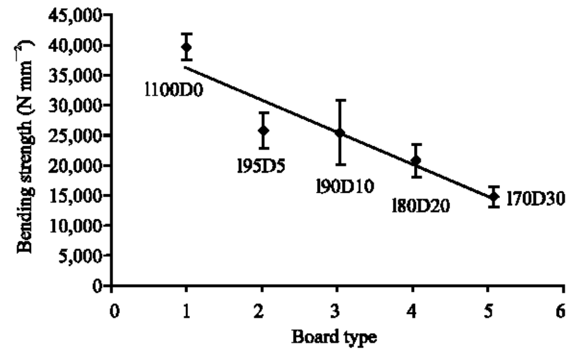

Fig. 1: The effect of fine dust addition on bending strength

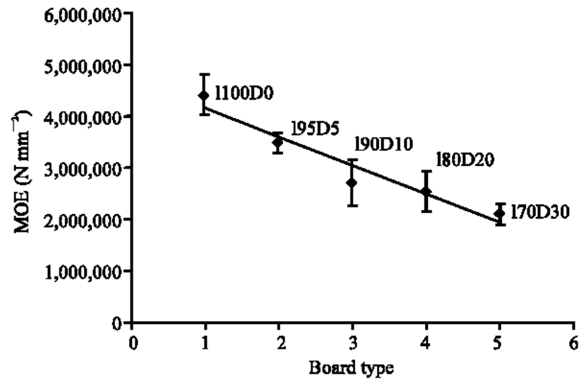

Fig. 2: Effect of dust content on MOE

showed significant change (Fig. 1-2). Increasing the amount of short material in the receipt significantly decreased the bending strength (Fig. 1). According to standard (EN 622-5 1997), bending strength should be at least 20 N mm^{-2}. The highest bending strength was 39.61 N mm^{-2} and this value was obtained from board made from industrial fiber. Dust content 5 and 10% in board is not statically different. However, further addition of dust in mixture was negatively affecting the bending strength. This could be due to the fiber properties. Virgin long fiber had better bending strength than short fiber. Virgin fiber was also beaten to have better bonding ability. Fibrillation causes to improve fiber-to-fiber contact. Therefore, the weakness of the board was due to the lack of fiber length, resulting in low fiber aspect ratios and ultimately poor physical interlocking and fiber-to-fiber contact. In contrast, all panels were met the requirement in standards.

Medium density fiber boards contains fine materials were generally well consolidated. However, its modulus of elasticity was significantly affected by the addition of dust (p = 0.01). Statistically, least significant difference among the board with different dust contents were given in Table 6.

Table 6: Modulus of elasticity (N mm^{-2})

Board type	X (mean)	s (Standard deviation)	Variance S^2	Coefficient of variation V%	Duncan grouping
$I_{100}D_0$	4391.390	401.624	161301.796	9.146	A
$I_{95}D_5$	3455.970	195.237	38117.674	5.649	B
$I_{90}D_{10}$	2684.880	464.174	215457.357	17.288	C
$I_{80}D_{20}$	2524.710	386.694	149532.091	15.316	C
$I_{70}D_{30}$	2081.530	207.319	42981.313	9.960	D

The modulus of elasticity and mechanical properties inversely correlated to dust loading (Fig. 2).

Measuring hardness is the way of showing how surface of the board will resist abrasion and scratching. Wood particles are converted to fiber with refining and these fiber blended with resin and hot pressed to form MDF board. After formation of the board, individual wood elements cannot be identified. During heat treatment, strength properties were developed, however, at the same time, deterioration of fiber take places. Addition of dust increase the interfacial phenomena between fiber and the particle, fill the spaces between fibers and improve the surface and adhesion properties. However, the addition of dust into the prescription significantly reduced the surface hardness and this change was not altered too much when adding more dust. The highest surface hardness was obtained with industrial fiber. This could be due to the aspect ratio of fiber. Nonfibrous fine dust may reduce the bonding ability of the fiber and surface hardness of the material.

CONCLUSIONS

The demand for forest products increasing with increase in population. The lack of raw material and environmental concern leads to search for new resources. The potential of waste material has received considerable attention in recent years. Utilization of fine wood dust in MDF production is possible. Addition of wood dust into MDF contents can change the physical and mechanical properties of the products. Thickness swelling was increased. This could be due to improved surface area. However, bending strength, internal bond strength, MOE and Janka hardness within the range of standards required. This shows that wood dust can be used in panel products.

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