

Effect of Resination Technique on Mechanical Properties of Medium Density Fiberboard

Nadir Ayırlımis^{a,*} and M. Erdal Kara^b

Effects of different resination techniques relative to the mechanical properties of commercially produced thick medium density fiberboard (MDF) were investigated. The amount of urea-formaldehyde resin (11 wt%) applied to the wood fibers was gradually decreased in the blowline (11, 10.5, 10, and 9.5 wt%), while it was gradually increased in the short-retention blender (0, 0.5, 1, and 1.5 wt%). The internal bond strength of the MDF boards considerably improved as the amount of the resin applied to the fibers in the short-retention blender was increased to 1.5 wt%. In particular, the increase in the IB strength was most pronounced as the resin content increased from 1 to 1.5%. The edge and face screw withdrawal resistances increased by 7.7 and 7.9% as the amount of the resin applied to the fibers in the blender was increased. Similar values were also observed for the flexural properties. Overall, the total resin content in the production of thick MDF can be decreased as blender resination, a means of post-dryer resin addition, is incorporated into the blowline resination technique.

Key words: Fiberboard; Blowline; Mechanical blender; Urea-formaldehyde; Mechanical properties

Contact information: a: Department of Wood Mechanics and Technology, Forestry Faculty, Istanbul University, Bahçeköy, Sarıyer, 34473, Istanbul, Turkey; b: SFC Integrated Forestry Products & Inc. Baraj Yolu, Killik Mevkii, 37000, Kastamonu, Turkey; *Corresponding author: nadiray@istanbul.edu.tr

INTRODUCTION

Medium density fiberboard (MDF) is an engineered wood product composed of fine lignocellulosic fibers and a synthetic resin, joined together under heat and pressure to form boards. The resin is one of the most important factors affecting the mechanical properties of MDF board. The MDF board has structural integrity because the cured resin binds with the fiber matrix. The resin accounts for 30% of the total cost of a MDF board. By keeping resin consumption to a minimum, *i.e.*, mixing as efficiently as possible, the total cost of the board can be significantly reduced (Sundin 2007).

In the early years of its production, the same manufacturing process commonly used for particleboard was used for producing MDF. That is, wood fibers were dried and then mixed with an adhesive in a mechanical blender (post-dryer resination system). However, the process resulted in dark resin spots in the resulting boards. Today, most MDF plants use a very different process, a so-called blowline-blending technique, which can reduce the problem of dark resin spots on the board due to bundles. In this technique, wood fibers are carried from a refiner to a flash tube dryer through the blowline, a tube about 120 to 130 mm in diameter, and an adhesive is added in the blowline before the dryer. The resin, usually urea-formaldehyde (UF), is injected via water-cooled 3 to 5 mm nozzles at high pressure (12 to 14 bars) into the blowline with other additives, *e.g.*, water,

hardener, repellents, *etc.* (Thoemen *et al.* 2010). The resin, wax, and other additives are added to wet fiber because dry fiber tends to form bundles due to hydrogen bonding, so that they would not become as uniformly covered when sprayed.

Major drawbacks of the traditional blowline technique are that more resin consumption than necessary is used to achieve the required board properties; formaldehyde is released by heating; there can be problems of resin precuring in the flash tube dryer; and more thermal energy is consumed by the dryer tube (due to a greater water content in the resin mixture) (Thoemen *et al.* 2010). Irle *et al.* (2012) reported that a key disadvantage of the blowline technique is the fact that the resonated fibers pass through a flash dryer, which tends to precure some of the resin. The mechanical properties of MDF are negatively affected by precured UF resin because adhesion between wood fibers in MDF board decreases, even if the mat is properly hot pressed. In addition, when resin is precured, the board's surface layer is weak and flaky because the precured resin bonds are broken when the hot press closes (Thoemen *et al.* 2010). To compensate for this effect, a higher resin amount is required (compared to dry resination) (Irle *et al.* 2012). In general, due to the unavoidable precuring of the adhesive, 1 to 2% more adhesive based on the oven dry weight of wood fiber is required with the blow-line process (Pichelin 2002).

A new approach to fiber blending has two stages. In the first stage, the resin is applied via the blowline. A second resination stage takes place in a separate drum blender after fiber drying. Resin is applied by air nozzles, mounted on a ring in front of the open in-feed of the drum blender. The internal paddles generate a turbulent fiber flow, ensuring effective blending. The blender and out-feed pipe are water-cooled to avoid resin and fiber deposits (Thoemen *et al.* 2010). This results in higher UF resin efficiency than the blowline or mechanical blending to achieve comparable board properties. Another benefit of this system is the reduction in dryer energy and consequent increase in dryer capacity, since less resin, and hence less water, is introduced into the dryer, making it possible to dry greater quantities of fiber.

In thick MDF production, resin consumption and the blending technique are the two most important factors of production that affect the cost and quality of the board. The blowline resination system is generally not sufficient for uniform blending in thick MDF production, namely a high flow rate of wood fibers per unit time in the blowline. The resin particles must be distributed uniformly over the surface of the wood fibers so that each resin particle contributes to the strength of the MDF without creating small resin spots on the board. Thus, two-stage resination, a combination of blowline (before drying) and short-retention blender (after drying) resination techniques, can be better for uniform resin distribution on the fibers. According to an extensive literature review, the effect of varying contents of the UF resin within blowline and blender on the mechanical properties of MDF has not been investigated. In this study, some mechanical properties of MDFs made using a combination of blowline and blender resination techniques were investigated. For this aim, the content of UF resin applied to the wood fibers in the blowline was gradually decreased, while it was increased in the short-retention blender. The amount of urea-formaldehyde resin (11 wt%) applied to the wood fibers was gradually decreased in the blowline (11, 10.5, 10, and 9.5 wt%), while it was gradually increased in the short-retention blender (0, 0.5, 1, and 1.5. wt%).

EXPERIMENTAL

Materials

Commercial size MDF boards (2800 mm × 2100 mm × 40 mm) were made from a mixture of 70 wt% birch and 30 wt% poplar furnish. The wood chips, having an average size of 25 × 20 × 5 mm, were converted into fiber furnish in a defibrator using steam pressure of 7.5 bar and a temperature of 180 °C for 2.5 minutes. The following chemicals were added to the fiber furnish: 1% paraffin, 1% NH₄Cl as hardener, and 11% UF resin, based on the weight of the oven-dry fiber. The properties of the UF resin (E2 class) were as follows: F/U ratio: 1.36, solids content: 56%, specific gravity: 1.233, viscosity: 180 cps, and pH: 7.5 to 8.5. The amounts of the UF resin applied to the wood fibers in the blowline and short-retention blender are presented in Table 1. The mats had an average moisture content of 11% and were hot pressed at a temperature of 220 °C for 4 minutes at a pressure of 3.5 N/mm². A total of 8 MDF boards, 2 for each type of board, were produced. The boards were sanded following a sequence of 40, 60, 80, and 100 grit sizes, after the cooling process. The average density values of the MDF boards varied from 680 to 708 kg/m³.

Table 1. Composition of MDF Boards

MDF type	Amount of the UF the resin applied to the wood fibers	
	Blowline resin injector (wt %)	Short-retention blender (wt %)
A	11	0
B	10.5	0.5
C	10	1
D	9.5	1.5

Determination of Mechanical Properties

Modulus of rupture (MOR) (EN 310 1993), modulus of elasticity (MOE) (EN 310 1993), internal bond (IB) strength (EN 319 1993), and screw withdrawal (SW) resistance (EN 320 1999) were determined for the produced fiberboards. Ten replicates were used for each mechanical property. Prior to the tests, the samples were conditioned in a climatized room at 20 °C and 65% relative humidity.

RESULTS AND DISCUSSION

Mechanical Properties

The MDF boards made using the blowline resination technique had lower IB strength compared with those made using a combination of blowline and blender techniques. The IB strength of the MDF boards was improved considerably by increasing the resin content in the blender. The IB strength increased by 27.2% as the amount of the resin applied to the fibers in the blender was increased to 1.5 wt%. In particular, the improvement in the IB strength was pronounced as the amount of the resin was increased from 1 to 1.5 wt% (Fig. 1). The IB values showed that the adhesion between the wood fibers noticeably improved with increasing resin content freshly added in the blender. The average IB values of the MDF boards made using a combination of blowline and

blender resination techniques complied with the minimum IB requirement (0.50 N/mm^2) of EN 622-5 (2009) for general-purpose MDF boards (40 mm) for use in dry conditions, while the boards made using the blowline resination technique did not comply with EN 622-5.

The results of the MOR and MOE tests were similar to the results of the IB test; the MDF boards made using a combination of blowline and blender resination techniques showed higher MOR and MOE values than those made using only the blowline technique. The average MOR value of the boards increased from 22.8 to 25 N/mm^2 as the amount of the resin applied to the fibers in the blender increased from 0 to 1.5%. A similar trend was observed for the MOE values (Fig. 1). A noticeable improvement in the MOR was observed as the amount of the resin in the blender was increased to 1.5%. The MOR increased more than the MOE as the amount of the resin increased in the blender. The MOR and MOE increased by 8.8 and 6.5%, respectively, as the amount of the resin in the blender was increased to 1.5%. The average MOR values of all the MDF boards met the minimum MOR requirement (17 N/mm^2) of EN 622-5 (2009) for general-purpose MDF boards (40 mm) for use in dry conditions, but the MOE values did not meet the minimum MOE requirement (1900 N/mm^2) of EN 622-5.

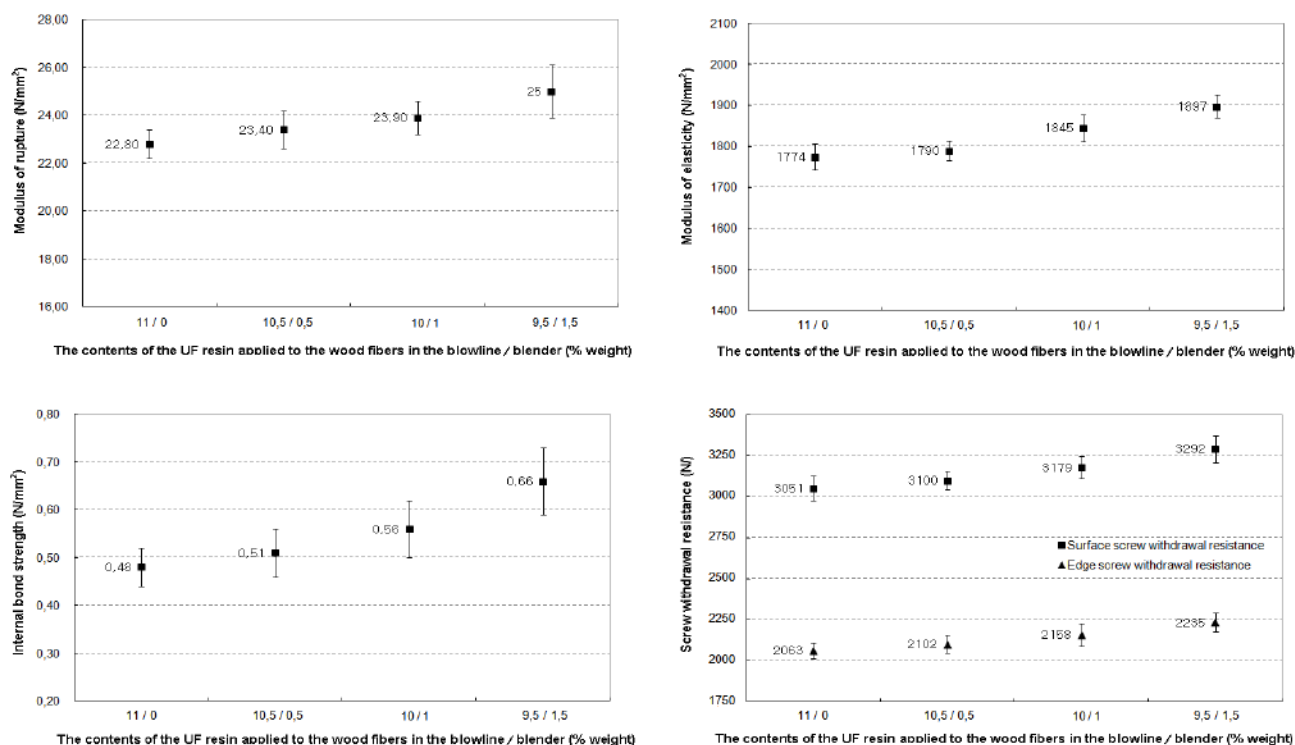


Fig. 1. Mechanical properties of MDF boards

The edge and face SW resistances of the MDF boards improved (by 7.7% and 7.9%, respectively) as the amount of the resin applied to the fibers in the blender was increased to 1.5 wt% (Fig. 1). The improved SW resistance with increasing resin content in the blender can be explained by the more compact surface of the MDF board. The MDF boards made using blowline-blender resination technique showed significantly

higher resistance to force required to turn the screw and splitting. The edge and face SW resistances of the MDF boards were considerably higher than the minimum requirements (edge: 1335 N, face: 1555 N) for grade 160 MDF specified in ANSI-A208.2 (2002). The SW resistance is particularly important for MDF boards used in furniture production.

The improvement in the adhesion between the wood fibers was primarily attributed to the use of freshly prepared UF resin in the blender after the tube dryer. The UF resin on the surface of the wood fibers can partly precure in the tube dryer due to the high inlet temperature (around 150 °C) and evaporation of water from the UF resin solution. The curing reaction of the UF resin is accelerated as the resin is exposed to high temperatures, and the reaction advances quickly over the duration of the high temperature exposure (Smith 1998). During the resination process, the fibers are carried from a refiner to a flash tube dryer through the blowline, a tube about 120 to 130 mm in diameter, and an adhesive is added in the blowline, before the dryer. These conditions likely promote condensation reactions and some degree of precuring, resulting in a loss of resin efficiency. This loss of resin efficiency has been explained in terms of the reduction in the flow characteristics of the resin during hot pressing (Bucking 1982). The more the resin is heated in the blowline due to steam pressure, and the longer it remains at high temperature, the greater the loss of bonding effectiveness in the hot press (Smith 1998). Adding some amount of the UF resin on the wood fibers following the dryer tube can prevent the precure problem of the resin because the surface of fibers will be coated with fresh UF resin drops.

Water in UF resin plays an important role as a plasticizer or diluter. The water in UF resin also decreases the concentration of reactants, which prevents the precuring problem before hot pressing (Xing *et al.* 2004). Roffael *et al.* (2003) reported that higher amounts of urea were extractable from MDF boards resinated in the blowline than in the blender. Their study showed that less cross-linking of the resin took place in the blowline than in the blender. This is one possible reason why MDF boards made using blowline-blender resination technique have higher mechanical properties than the ones made using blowline resination technique.

Some water and volatile organic compounds (VOCs), including free formaldehyde, are released from the UF resin through tube dryer (Anonymous 1999). The result is a significant reduction in resin consumption and elimination of additional emissions in the dryer exhaust gas flow typically generated by blending before drying. This results in a decrease in the efficiency of the resin. As the free formaldehyde is released from the UF resin by heating in the tube dryer, the decrease in the IB strength as well as other mechanical properties is inevitable, because the formaldehyde is one of the most important factors influencing resin performance, which improves the bonding performance of the fibers. Tice (2011) reported that a percentage of the resin is flashed off in the tube dryer into the atmosphere, and as such, its intended effect is lost. For this reason, MDF manufacturers use filters in the dryer exhaust system that catch the released formaldehyde to prevent its release into the air from the cyclone.

The IB results showed that coverage ratio of the fiber surface with UF resin increased with the incorporation of the blender into the blowline resination technique. This was also confirmed with the microphoto of the wood fibers with UF resin after the blowline-blender resination technique (Fig. 2). The UF resin coverage on the wood fibers increased as the blender was incorporated into the blowline. The increase in the coverage

ratio contributed to the crosslinking network between wood fibers and the UF resin, thereby increasing resistance to debonding and screw threads.

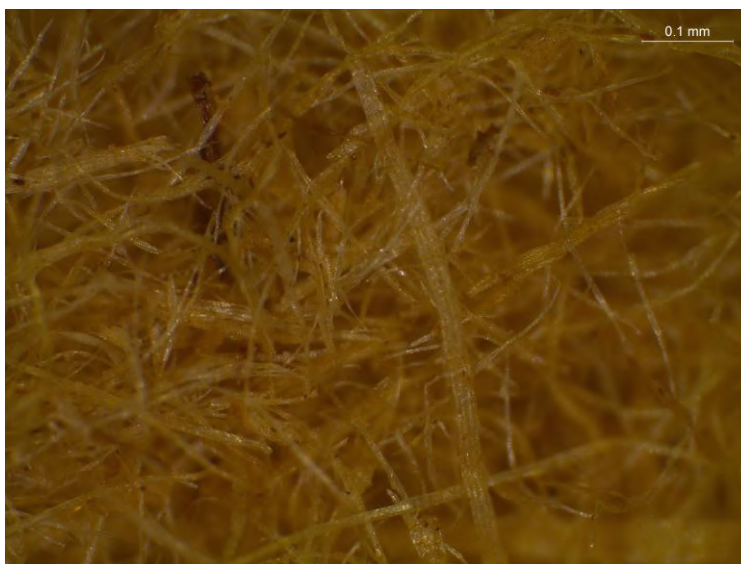


Fig. 2. Wood fibers with the UF resin after blowline-blender resination (X50 magnification)

CONCLUSIONS

1. The results of the present study showed that a combination of blowline and blender resination techniques was more effective in creating advantageous mechanical properties of MDF than the traditional blowline resination technique.
2. The mechanical properties of the boards noticeably improved as the amount of resin applied to the fibers in the blender was increased to 1.5 wt%. This can be explained by the following: (1) a decrease in the formaldehyde release and water evaporation rate, (2) an increase in the coverage ratio of the fiber surface with the resin, and (3) the prevention of precuring of the UF resin on the surface of fibers before hot pressing.
3. Three primary factors influence the resin efficiency in the blowline, which are (1) resin drop size, (2) mixing and turbulence, and (3) precure (Smith 1998). The incorporation of a short-retention blender in the blowline minimizes the problems coming from the blowline such as large resin droplets, increased resin requirement, changing steam velocity, pressure drop after resin injection, non-uniform resin distribution, and precured resin.
4. Based on the findings obtained from this study, it was concluded that the total resin used in the production of thick MDF could be decreased when a short-retention blender, allowing some of the resin to be added after drying, is incorporated into the blowline.

REFERENCES CITED

- Anonymous. (1999). "Emission estimation technique manual for timber and wood product manufacturing," National Pollutant Inventory, Canberra, Australia, p. 9.
- ANSI A208.2 (2002). "Medium density fiberboard (MDF) for interior applications," American National Standards Institute, Washington, DC.
- Bucking, G. (1982). "Resin blending of MDF fiber," *Proceedings of the 16th Particleboard/Composite Materials Symposium*, Washington State University, Pullman, WA, 269-276.
- EN 310. (1993). "Determination of modulus of elasticity in bending and bending strength," European Committee for Standardization, Brussels, Belgium.
- EN 319. (1993). "Particleboards and fiberboards-determination of tensile strength perpendicular to the plane of the board," European Committee for Standardization, Brussels, Belgium.
- EN 320. (1999). "Fiberboards determination of resistance to axial withdrawal of screws," European Committee for Standardization, Brussels, Belgium.
- EN 622-5. (2009). "Fiberboards. Specifications. Requirements for dry process boards (MDF)," European Committee for Standardization, Brussels, Belgium.
- Irle, M. A., Barbu, M. C., Reh, R., Bergland, L., and Rowell, R. M. (2012). "Wood Composites," In: *Handbook of Wood Chemistry and Wood Composites*, 2nd Ed., Rowell, R. M. (ed.), CRC Press: Boca Raton, FL, USA, Chapter 10.
- Pichelin, F. (2002). "Wood-Based Panels: MDF," In: *Wood Adhesion and Glued Products*, 2nd Ed., Johansson, C. J., Pizzi, T., and Leemput, M. V (eds.), COST Action E13.
- Roffael, E., Dix, B., Schneider, T., and Kraft, R. (2003). "Extractable urea in MDF prepared using the blowline- and blender-technique," *Holz Als Roh- und Werkstoff* 61, 73-74.
- Smith, D. C. (1998). "North American MDF Blending Technology," Evergreen Engineering Inc., 14 pp.
- Sundin, M. (2007). "Design of blowline resin injector for MDF production," Master's Thesis, Lulea University of Technology, Lulea, Sweden.
- Thoemen, H., Irle, M., and Sernek, M. (2010). *Wood-Based Panels. An Introduction for Specialists*, Brunel University Press, London, UK.
- Tice, B. (2011). "Post dryer resin addition offers cost savings and environmental benefits," *Canadian Forest Industries Magazine*, March Issue, 2 pp.
- Xing, C., Riedl, B., Cloutier, A., and He, G. (2004). "The effect of urea-formaldehyde resin pre-cure on the internal bond of medium density fiberboard," *Holz Als Roh- und Werkstoff* 62, 439-444.

Article submitted: September 30, 2012; Peer review completed: November 18, 2012;
Revised version received: November 28, 2012; Accepted: December 1, 2012; Published:
December 3, 2012.