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Dimensional Stability and Mechanical Properties of Wood/Polypropylene Composite Containing MDF Sanding Dust

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Abstract

The present study investigated the use of MDF sanding dust in the manufacture of wood polymer composites. Specimens made with 40%, 50% and 60% sanding dust and 2% coupling agent (dry wt) were compared with control specimens. All physical and mechanical properties were determined according to European norms. The results showed that sanding dust had a significant effect on all properties. The best mechanical properties and dimensional stability were found in boards composed of 40% sanding dust. The improvement in the physical and mechanical properties of composites containing sanding dust was related to the presence of urea formaldehyde resin from the MDF process in the dust. The results indicate that the use of sanding dust as a filler produced good quality composites that perform better than composites made with wood flour.

Key words: Wood Polymer composite; Sanding dust; Wood flour; Polypropylene; Urea formaldehyde resin; MDF.

ثبات ابعادی و خصوصیات مکانیکی کامپوزیت چوب/پلی‌پروپیلن حاوی داست سنباده‌زنی MDF

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چکیده

در این مطالعه امکان استفاده از نرمه سنباده‌زنی MDF (داست) در ساخت چندسازه چوب‌پلاستیک مورد بررسی قرار گرفت. نمونه‌ها با نسبت‌های ۴۰، ۵۰ و ۶۰ درصد نرمه سنباده‌زنی به همراه ۲ درصد ماده جفت کننده (MAPP) براساس وزن خشک مواد ساخته شده و سپس با نمونه‌های شاهد که از پودرچوب ساخته شده بودند، مقایسه گردیدند. تمامی خصوصیات فیزیکی و مکانیکی بر طبق استاندارد اروپا (EN) اندازه‌گیری شدند. نتایج نشان داد که نرمه سنباده‌زنی تاثیر معنی‌داری بر خصوصیات مورد بررسی داشته، به طوری که بالاترین میزان خصوصیات مکانیکی و ثبات ابعادی در تخته‌های ساخته شده با ۴۰ درصد نرمه سنباده زنی مشاهده گردید. علت بهبود خصوصیات فیزیکی و مکانیکی در چندسازه چوب‌پلاستیک ساخته شده با نرمه سنباده‌زنی به دلیل وجود چسب اوره فرم‌آلدئید در فرآیند تولید MDF بود. نتایج بیانگر این بود که با استفاده از نرمه سنباده‌زنی در ساخت چوب‌پلاستیک می‌توان از نسبت‌های بالاتر ماده پرکننده در تولید آن بهره برد.

کلمات کلیدی: چندسازه چوب پلاستیک، داست سنباده زنی، پودر چوب، پلی‌پروپیلن، اوره فرم آلدئید، MDF.

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Introduction

Wood-plastic composites (WPCs) are a relative new class of materials and one of the fastest growing sectors of the wood composites industry. The use of WPC decreases effectively plastic consumption and the products have advantages such as resistance to biological agents, moisture resistance and recyclability. They are less expensive than other wood and wood-based composites and are lower in density than plastics and fillers [1].

Thermoplastic composites have applications in flooring, railings, kitchen appliances and aerospace components [2, 3]. The construction of these composites requires polymers such as polypropylene, polyethylene, poly vinyl chloride, and polyester. Fillers and fibers from wood pulp cellulose flour, agricultural waste products and waste paper can be used [4]. Recent studies have examined the use of different fillers in the construction of WPC.

Mirmahdi et al. [5] studied the use of palm wood flour in wood/polyethylene composites manufactured by the extrusion method. They found that increasing the palm wood flour content decreased the modulus of rupture (MOR) and tensile strength and increased the modulus of elasticity (MOE) of specimens. They stated that the use of (a) palm leaf and stem flour mixture increased the MOR of the boards.

A study on the use of cotton stalk fibers in the manufacture of a wood/recycled polypropylene composite using the flat pressed method showed that increasing the percentage of cotton stalk fibers decreased tensile strength. A decrease in the percentage of fibers decreased thickness swelling (TS) and water absorption (WA) in boiling water to their lowest levels [6].

Razavi et al. [7] studied the mechanical properties and WA of rice husk/polypropylene composites. They used different percentages of rice husk in a polypropylene matrix. The results for 40% rice husk showed the highest flexural and tensile modulus, an increase in MOR and elongation at break, and a decrease in failure energy. WA increased as the percentage of rice husk increased.

Studies on the effect of coupling agents on the physical and mechanical properties of straw/polypropylene composites showed that all board properties increased significantly when a coupling agent was added [8].

Haijun and Mohini, [9] used pulp fiber, hemp, flax and wood flour mixed with polypropylene as reinforcement. The pulp fiber/polypropylene composites had higher aspect ratios and the highest tensile strength. Maleic-anhydride grafted PP (MAPP) with high maleic anhydride groups and high molecular weight was more effective in improving strength properties of PP composite as a compatiblizer.

Kazemi-Najafi and Azimi-Delarestaghi, [10] used beech bark flour to produce WPC filler for using with polypropylene. They stated that, in the absence of a coupling agent, the mechanical properties of composite materials containing bark flour increased over that of wood flour composites. Conversely, the presence of a coupling agent increased the mechanical strength of the wood flour composites. The study also used agro-residues such as wheat straw and corn stem filler with polypropylene. They found an increase in mechanical properties of composites using milled wheat straw over other lignocellulosic materials.

Panthapulakkal and Mohini, [11] produced WPC using two types of polypropylene and corn stems, wheat straw, newspaper waste and wood flour. They showed that the mechanical properties of the composites made with wood flour were higher than the other lignocellulosic materials.

Ghofrani et al. [12] investigated the physical and mechanical properties of wood-plastic composites made with rice husk flour and recycled high density polyethylene. The results showed that the optimum treatment with the best physical and mechanical properties was related to WPC with density of 0.8 g/cm3 contained 60% HDPE and 6% coupling agent.

Medium density fiberboard (MDF) is a practical and popular wood composite product. During manufacturing, the thickness gradient of the MDF board must be reduced and the surface smoothed in preparation for laminate transfer [13]. As a by-product of this step, factories accumulate a significant amount of sanding dust. There is no current optimal use for this waste product and it creates an environmental problem in industrial zones. The use of this by-product has environmental benefits and is cost effective. Since the addition of wood flour to WPCs has been shown to decrease moisture resistance, the present study investigated the dimensional stability and mechanical properties of wood/polypropylene composites made with MDF sanding dust.

Materials and Methods

Materials

Commercial hardwood flour was supplied by a furniture manufacturer and MDF sanding dust was obtained from Aryan Sina Co. The wood flour and MDF sanding dust were transferred to the laboratory and sieved using size 60 mesh (0.250 mm), then dried in a laboratory oven at 102°C to 0-1% moisture content. Polypropylene powder (MFI/230°C:6g/ 10min) produced by Arak Petrochemical Co. was used as a polymeric material. Maleic-anhydride grafted PP(MAPP) was obtained from Kimya Javid-e Sepahan Co.

Panels manufacturing

Samples containing either MDF sanding dust or wood flour were mixed with polypropylene particles in 40%, 50%, and 60% proportions (total wt). The coupling agent content was 2% of the dry weight of the solids (lignocellosic materials and Polypropylene particles). The mixture was formed into a mat on an aluminum caul plate using a forming box with an internal size of 400 × 400 mm. The mats were then hot-pressed in an electrically-heated laboratory hydraulic press at 12 MPa maximum press pressure, 190°C pressing temperature, and an 8 min total press cycle. After hot pressing, WPC panels were placed in a cold press for 15 min to prevent spring-back. The final size of the manufactured panels was 400 × 400 × 15 mm after the cooling process. There were 6 treatments and 3 panel replications for each treatment. The average density of the panels varied from 0.82 to 0.85 g/cm3. Before carrying out the tests, samples were stored at a climate chamber for at least 2 weeks kept in 20±2°C and 65±5% relative humidity.

Physical properties measurement

Water absorption and thickness swelling were measured after 7, 14, 28 and 56 days immersion in water in accordance with the standard EN 317 specifications [14]. The specimen dimensions were 50×50 mm. Weight of the specimens was measured by a digital scale with 0.01 g precision. Thicknesses of the center point were measured by a digital caliper with a 0.01 mm precision. Densities of the samples (50×50 mm) were evaluated according to the test method specified in EN 323 [15].

Mechanical Properties measurement

Three-point static flexural test were performed according to the EN 310 specifications [16]. Nominal sizes of the 15 mm thickness specimens were 350×50 mm, with loading rate of 10 mm/min. Modulus of rupture as well as modulus of elasticity were measured. The hardness was determined on samples with 50×50 mm dimensions according to EN 1534 [17]. Mechanical properties tests were carried out by INSTRON 4486 machine.

Statistical analysis

Statistical analysis was conducted using SPSS software program version 22 (2013). Two-way analysis of variance (ANOVA) was performed on the data to determine significant differences at the 95% level of confidence. Duncan Test was used to determine the significant difference among the groups. Hierarchical cluster analysis, including dendrogram and using Ward methods with squared Euclidean distance intervals, was carried out.

Results and Discussion

Physical properties

The results indicated that the type and amount of filler had no significant effect on the density of boards, as confirmed by Duncan grouping (Table 1). Boards made with sanding dust that were immersed in water for 7, 14, 28 and 56 days recorded the lowest level of TS. The highest TS and WA values were recorded for boards with 60% filler (Table 1).

Table 1. Independant comparison results for physical properties of wood/polymer composite

Facture		Physical properties								
			WA (%)				TS (%)			
		Density (g/cm3)	7 days	14 days	28 days	56 days	7 days	14 days	28 days	56 days
Filler type	Wood flour	0.83 A	16.90 A	24.22 A	29.20 A	31.68 A	4.19 A	4.45 A	29.20 A	31.61 A
	Sanding dust	0.84 A	18.11 A	20.71 B	23.95 B	25.64 B	2.8 B	3.04 B	23.95 B	25.98 B
Filler content	40%	0.85 A	11.27 C	15.68 C	19.91 C	23.26 C	2.71 B	3.02 B	19.91 C	23.26 C
	50%	0.83 A	16.47 B	21.03 B	25.69 B	29.13 B	3.11 B	3.46 B	25.69 B	29.13 B
	60%	0.82 A	24.62 A	30.70 A	34.11 A	33.93 A	4.66 A	5.01 A	32.11 A	33.93 A

The lowest WA and TS during immersion was obtained for boards made with 40% sanding dust and the highest level was obtained for boards made with 60% wood flour. (Figures 1, 2).

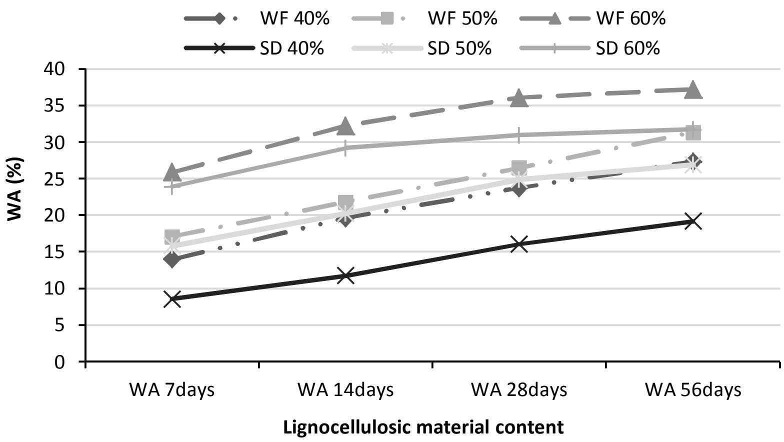

Fig. 1. Water absorption of wood/polymer composite manufactured with wood flour and sanding dust (WF=wood flour; SD=sanding dust).

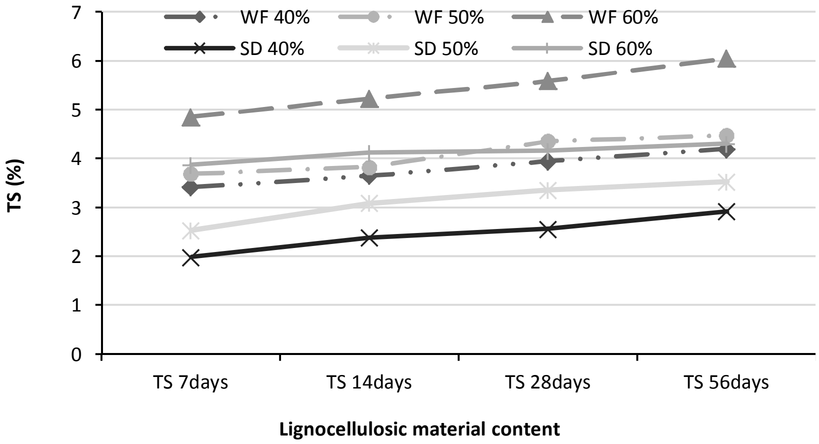

Fig. 2. Thickness swelling of wood/polymer composite manufactured with wood flour and sanding dust (WF=wood flour; SD=sanding dust).

Boards made of MDF sanding dust showed lower WA and TS after immersion in water in comparison with wood/plastic composites produced from wood flour (Figures 1, 2). MDF fibers are subjected to treatments during manufacturing such as heating, steaming, pressure and adhesives. MDF sanding dust is resistant to moisture absorption and showed lower TS. Increasing the amount of filler increased the WA and TS of the boards (Figures 1, 2). Polymeric materials used in the manufacture of WPC do not absorb water, thus the WA and TS of the boards increased significantly as the amount of filler increased. As the amount of polymeric materials increased in the manufacture of WPC, smaller pores are created due to the overlap between filler and polypropylene, which strongly decreased WA and TS [18].

Mechanical properties

Modulus of rupture and Modulus of elasticity

Results showed that boards which were made with sanding dust had the highest MOR and MOE values. The highest level obtained for MOR and MOE was for 40% filler; increasing the filler to 60% decreased MOR and MOE (Table 2).

The highest levels of MOR and MOE were found in boards with 40% sanding dust and the lowest level of MOR and MOE were observed in boards with 60% wood flour. (Figures 3, 4).

Table 2. Independant comparison results for mechanical properties of wood/polymer composite

Facture		Mechanical properties					
		Hardness (MPa)				MOR (MPa)	MOE (MPa)
		2 mm	3 mm	4 mm	5 mm		
Filler type	Wood flour	38.61 A	64.58 A	89.26 A	112.94 A	24.20 B	1818 B
	Sanding dust	46.23 B	77.52 B	108.57 B	139.33 B	26.83 A	1922 A
Filler content	40%	29.80 A	92.71 A	127.61 A	162.68 A	29.80 A	1974 A
	50%	25.12 B	63.47 A	89.23 A	113.35 A	25.12 B	1910 A
	60%	21.62 C	56.96 A	79.92 A	102.37 A	21.62 C	1726 B

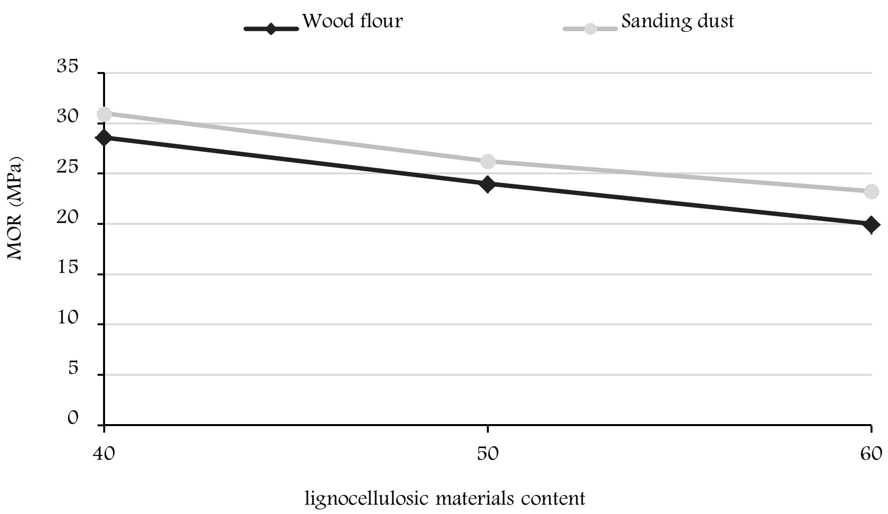

Fig. 3. Modulus of rupture of wood/polymer composite manufactured with wood flour and sanding dust.

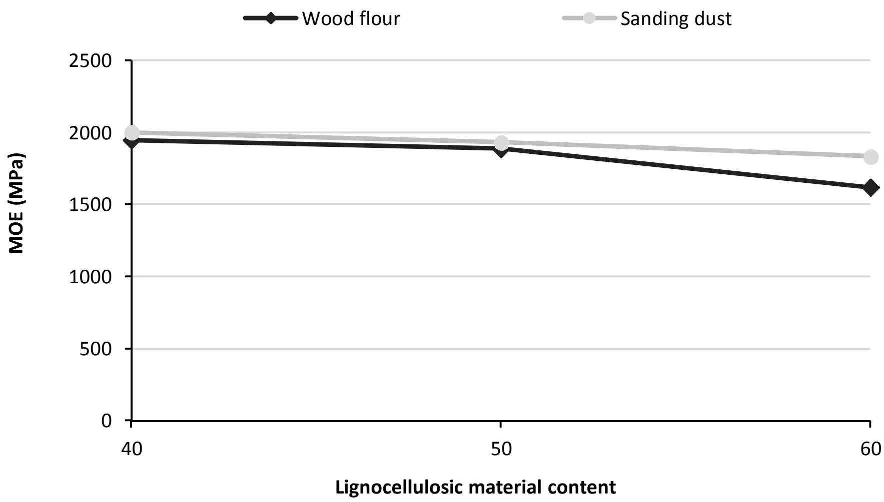

Fig. 4. Modulus of elasticity of wood/polymer composite manufactured with wood flour and sanding dust.

The addition of sanding dust as filler in the manufacture of WPC clearly increased the flexural strength and MOE over that of wood flour. The bending strength of samples made with a mixture of sanding dust the presence of urea in this matter and the nature of the adhesive polymer is that nature can make a suitable compatible with polypropylene polymer has the possible connection between these waste with polypropylene performed better than wood, which results in bending strength is improved.

Composites with higher percentages of polypropylene than filler obtained higher flexural strengths and MOE. At low percentages of filler, lignocellulosic material from sanding dust and wood flour is well-surrounded by polypropylene. The polymeric materials act as an adhesive in the pressed wood panels and form satisfactory connections between the materials. The result was an increase in the MOR and MOE of the sample boards [19]. Similar results were found by Adhikary et al. [20].

Hardness

As shown in Table 2, for the independent effect of filler, the highest level of hardness at penetration depths of 2, 3, 4 and 5 mm was found in boards made with sanding dust. The highest level of hardness was obtained for 40% lignocellulose filler and the lowest level found for 60% lignocellulose filler.

The dependent effect of amount and type of fillers showed that the highest level of hardness at all penetration depths was for samples with 40% sanding dust and the lowest hardness was obtained in boards with 60% wood flour (Fig. 5).

Hardness analysis of the sample boards indicated that composites made with sanding dust were harder than those made with wood flour. The urea formaldehyde resin in the sanding dust and the pressured applied to the MDF boards increased the hardness. WPCs made with sanding dust showed higher hardness values than boards made of wood flour.

The results indicated that hardness decreased as the wood material increased because composite hardness depends on the material used. Since polypropylene is harder than wood, increasing the percentage of wood, decreased composite hardness. Similar results were obtained by Azad et al. [8].

Cluster analysis

Cluster analysis was used to examine the effect of variables on all characteristics and the results are shown in Fig. 6. As seen, the samples made with 60% sanding dust and wood flour were grouped as similar and were weaker than the other treatments. Samples with 40% wood flour and 50% sanding dust were grouped and had similar results, which indicated that

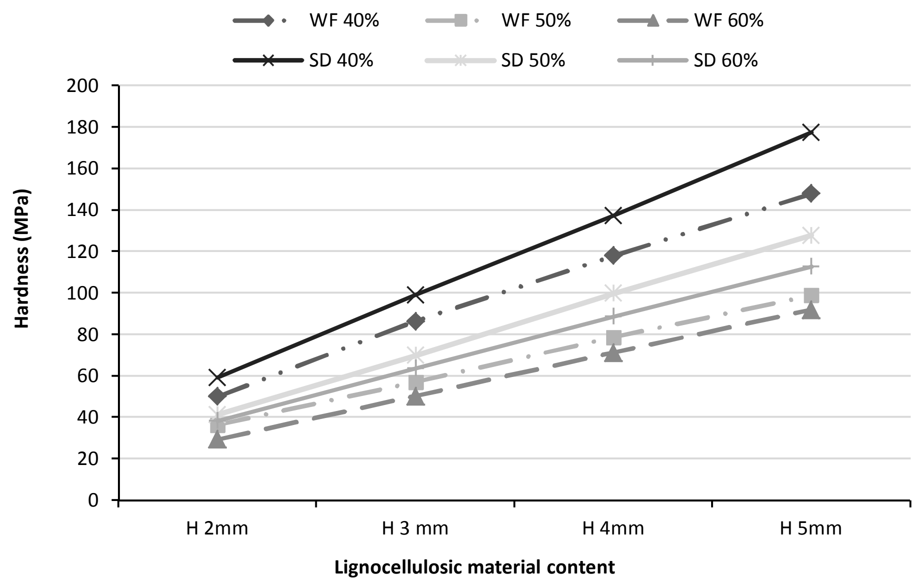

Fig. 5. Hardness of wood/polymer composite manufactured with wood flour and sanding dust (WF=wood flour; SD=sanding dust).

the high levels of dust can be same with lower percentage of wood flour. Cluster analysis showed that the samples containing 40% dust differed from samples containing 40% and 50% wood flour and 50% sanding dust.

Conclusion

The present study investigated the effect of using sanding dust from MDF as filler in the manufacture of wood/plastic composites and compared its dimensional stability and mechanical properties with composites made with wood flour. The results showed that sanding dust had significant effects on physical and mechanical properties of the WPC boards. The composites made with sanding dust showed higher MOR, MOE and hardness. Optimal dimensional stability was obtained for composite boards made with sanding dust. The presence of urea formaldehyde in the sanding dust improved the physical and mechanical properties of the WPCs because of it's polymer nature. It was concluded that increased use of sanding dust as a filler produces good quality composites that perform better than composites made with wood flour.

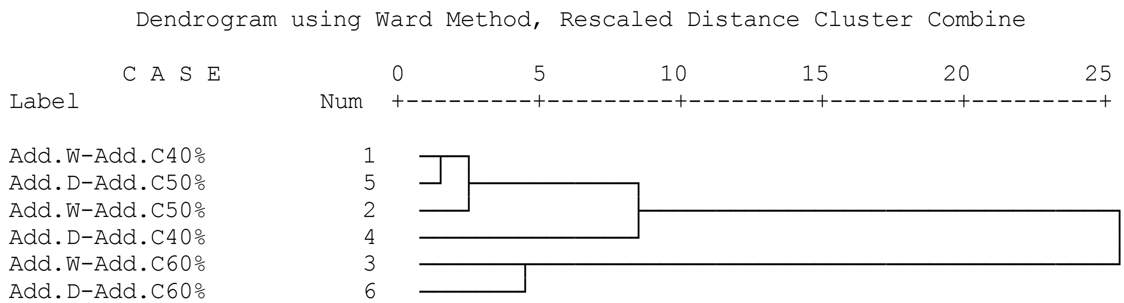

Fig. 6. Cluster analysis among the 6 different treatments based on the physical and mechanical properties (WA and TS after 7, 14, 28 and 56 days immersion in water, MOR, MOE and Hardness) (W = Wood flour; D = Sanding dust).

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