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The Effects of Press Method and Coating Material Differences on the Properties of Medium Density Fiberboard

Utjecaj metode prešanja i materijala za oblaganje na svojstva MDF ploča

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ABSTRACT • *This article deals with the effects of press method and coating material differences on some properties of medium density fiberboard (MDF) covered with PVC, which has an important place in furniture production materials. For this purpose, test samples were prepared from MDF with 18 mm thickness covered with high gloss (HG) and matt PVC using wrapping and membrane press methods. Apart from affecting the values of water absorption of HG covered samples and the values of thickness swelling of samples processed by membrane press, the test results showed a statistically significant effect of the pressing method and coating material on water absorption, thickness swelling, modulus of elasticity, bending strength and adhesion strength values in all other tests. At the same time, it was determined that samples covered with HG material received less water, while MDF samples covered with matt material had a low thickness swelling. Also, modulus of elasticity of the samples covered with matt material was much higher and adhesion strength of the HG covered samples was much better.*

Key words: *MDF, wrapping method, membrane method, high gloss PVC, mat PVC*

SAŽETAK • *U radu je prikazano istraživanje utjecaja različitih metoda prešanja i materijala za oblaganje na neka svojstva ploča vlaknatica srednje gustoće (MDF ploča) obloženih PVC folijom, koje imaju važno mjesto među materijalima za proizvodnju namještaja. Za tu su svrhu uz pomoć preše za oblaganje profila i membranske preše pripremljeni uzorci za ispitivanje izrađeni od MDF ploča debljine 18 mm i obloženi mat PVC folijom i PVC folijom visokog sjaja (HG). Osim za vrijednosti upijanja vode uzoraka obloženih PVC folijom visokog sjaja i vrijednosti debljinskog bubrenja uzoraka obloženih uz pomoć membranske preše, rezultati ispitivanja pokazali su statistički značajan utjecaj metoda prešanja i materijala za oblaganje na upijanje vode, debljinsko bubrenje, modul elastičnosti, čvrstoću savijanja i čvrstoću prianjanja u svim ostalim testovima. Ujedno je utvrđeno da su MDF uzorci obloženi HG folijom upili manju količinu vode, dok su MDF uzorci obloženi mat PVC folijom imali manje debljinsko bubrenje. Također, uzorci obloženi mat PVC folijom imali su mnogo veći modul elastičnosti, ali je čvrstoća prianjanja uzoraka obloženih HG folijom bila mnogo bolja.*

Ključne riječi: *MDF, metoda oblaganja profila, membranska metoda, PVC folija visokog sjaja, mat PVC folija*

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1 INTRODUCTION
1. UVOD

In recent years, forests have been increasingly disappearing and the quality lumbers obtained from trees and used in plywood and veneer industry are decreasing. Quality trees are decreasing while prices are increasing. Poor quality wood can be used in MDF production (Akgül and Çamlıbel, 2006).

Medium density fiberboard (MDF) panels are extensively used in furniture industry. MDF and other panel boards are produced as flat and homogenous surface. The panels have pointed surfaces with coating materials. These coated panels are used in laboratories paneling, kitchen furniture, and other industrial product applications. The performance of the coated panels is based on the type of the coating material and the quality of wood-based panel (Sparkes, 1993; Hoag, 1992).

Wood-based panels may be exposed to many destructive factors such as fungi, humidity, low and high environmental temperatures. To reduce the damage caused by these factors, wood based panels are coated with different materials and different coating methods according to conditions of use (Bozkurt and Göker, 1986; İstek *et al*., 2012).

Surface coating of composite boards (chipboard, MDF, plywood, etc.) is especially important to increase the aesthetic value and strength properties. In fact, the panels are coated to widen the range of application and improve their strength characteristics (Thoemen *et al*. 2010; İstek *et al*. 2010). Coating process can improve the surface quality of panels as well as color properties (Nemli, 2000). Performance of panel surface during the coating process is assessed by characteristics of wood species and manufacturing method (Cassens and Feist, 1991; Richter *et al*., 1995).

The aim of this study is to reveal the changes in MDF properties coated with different PVC folios by using membrane and wrapping press by different press methods.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

2.1 Material used in tests
2.1. Materijal uzoraka

Medium density fiberboards (MDF), with 18 mm thickness covered with 0.50 mm high gloss (HG) and 0.40 mm matt PVC (MT) using wrapping and membrane press methods in accordance with related standards, were used as a test material. HG and matt PVC grammage was 0.697 gr/cm^2 and 0.512 gr/cm^2, respectively.

2.2 Press methods used in experiments
2.2. Metode prešanja

Two methods used for coating the test specimens are briefly described below.

Wrapping press method (WP): With this method, straight and milled surfaces could be covered up to 0.15µm-0.50µm high gloss and matt PVC materials. Generally, hot-melt glues with double component polyurethane based are used as adhesive. Covering process within the wrapping method is carried out in this way. Firstly, glue melted in pressure tanks at 120-140ºC is spread on the back of the PVC, after being filtered. Later, with the help of the pressure, glued PVCs are adhered on the panel surface that comes from the coating machine feed track.

Membrane press method (MP): Generally, this method is used for covering MDFs. Firstly, single component polyurethane based glue is spread twice on MDF surface, and then dried. Later, the press process is carried out at the temperature of 55-80ºC and at the pressure of 6-14 atm for 5-10 minutes.

2.3 Experimental tests
2.3. Provedba eksperimenta

The standards for the procedures followed in the tests are summarized in Table 1. Additionally, tests were carried out on 30 samples prepared in accordance with the standards given in Table 1.

2.4 Statistical analyzes
2.4. Statistička analiza

The Independent Samples *T*-test was performed to determine the effect of press method and coating material differences on the properties of MDF samples.

3 RESULTS AND DISCUSSIONS
3. REZULTATI I RASPRAVA

The findings obtained in the tests were analyzed by grouping the results according to coating materials and press methods. They are evaluated below.

3.1 Water absorption (WA)
3.1. Upijanje vode (WA)

The analysis results of Independent Samples *T*-test after 24 h water absorption are given in Table 2.

The analysis of *T*-test results given in Table 2 showed that, as $p>0.05$, there is no significant difference in HG covered samples depending on different press methods, whereas, since $p<0.05$, there is a significant difference in matt folio covered samples. Water absorption value after 24h was higher in MDFs covered with matt material using WP than using MP.

Table 1 Standards used in tests
Tablica 1. Standardi prema kojima je provedeno istraživanje

Experimental tests / *Provedeni eksperiment*	**Standards** / *Standardi*
Water absorption and thickness swelling / *upijanje vode i debljinsko bubrenje*	TS EN 317
Static bending strength and Elastic modulus of bending *statička* čvrstoća *savijanja i modul elastičnosti pri savijanju*	TS EN 326-1, TS EN 310
Bonding strength / č*vrstoća prianjanja*	TS EN 311

Table 2 Results of *T*-test analysis of water absorption values
Tablica 2. Rezultati analize vrijednosti upijanja vode *T*-testom

Water absorption *Upijanje vode*			**Mean** *Prosječna vrijednost* %	**Stand. deviation** *Stand. devijacija*	**Stand. Error** *Stand. pogreška*	**Coefficient of variation** *Koeficijent varijacije*	t_{value}	**Sig. (2-tailed)**
Coating material *Materijal za oblaganje*	High gloss / *visoki sjaj* (HG)	WP	11.02	0.694	0.219	6.30	0.811	0.428
		MP	10.51	1.869	0.591	17.78		
	Matt / *mat* (MT)	WP	13.23	0.766	0.242	5.79	2.682	0.015
		MP	12.36	0.861	0.272	6.97		
Press method *Metoda prešanja*	Wrapping *oblaganje profila* (WP)	HG	11.02	0.694	0.219	6.30	6.752	0.000
		MT	13.23	0.766	0.242	5.79		
	Membrane *membransko prešanje* (MP)	HG	10.51	1.869	0.591	17.78	2.879	0.013
		MT	12.36	0.861	0.272	6.97		

The same table shows that water absorption values are lower in HG covered samples (11.02 % and 10.51 %) than in matt PVC covered ones (13.23 % and 12.36 %). The reason for this difference could be the result of different adhesive and PVC folios. Coating material thickness improved water absorption values as seen in Table 2. In a study conducted on particleboards, Nemli (2000) emphasized that the thickness of the coating material did not affect the water absorption values. However, these values were affected by the type of coating materials.

Considering Table 2 in terms of covering material, significant differences could be seen within the water absorption percentages at 999.9 % (p<0.001) confidence level of HG and matt PVC folios using WP and in MP covered samples at 95 % (p<0.05) confidence level. Özdemir *et al*. (1999) determined that the particle board surfaces coated with varnished veneer, lacquer coating, continuous pressure laminate, high pressure laminate and polyvinylchloride coating materials resulted in a significant decrease in water absorption ratios.

3.2 Thickness swelling (*TS*)
3.2. Debljinsko bubrenje (*TS*)

Results of the statistical analysis of thickness swelling values obtained in the experiments aimed at finding the differences of press methods and covering materials within the MDF samples, 18 mm thick and covered with PVC folios, are given in Table 3.

According to Independent Samples T-test given in Table 3, different press methods significantly affect the material's thickness swelling percentages of high gloss covered fiberboards at a confidence level of p<0.001. Likewise also, different press methods resulted in a significant difference in thickness swelling values of the MDF samples covered with matt material at a confidence interval of p<0.01. In both covering processes, it was observed that samples covered with MP had a low thickness swelling.

By using WP, the difference in thickness swelling between the samples covered with HG and matt materials were found to be statically significant at a (p<0.001) level. On the other hand, as (p>0.05), the relation between thickness swelling percentages of the samples covered with membrane press were considered non-significant, as seen in Table 3. In his article, Akkılıç (1998) also determined that there was no difference between the oak veneer and laminate veneer samples after 24-hour soaking. In the same study, it is stated that the thickness swelling values of the samples covered with the finished folio are very high and even close to the results of raw samples.

Besides, it was also determined that samples covered with matt PVC (0.99 % and 0.88 %) had a lower thickness swelling than the HG covered samples (1.86 % and 0.90 %) after 24h according to Table 3. Moreover, Nemli (2000) noted that particleboard surfaces coated with lacquer paint, melamine-impregnated pa-

Table 3 Results of thickness swelling measurements after 24 h
Tablica 3. Rezultati mjerenja debljinskog bubrenja nakon 24 sata

Thickness swelling *Debljinsko bubrenje*			**Mean** *Prosječna vrijednost* %	**Stand. deviation** *Stand. devijacija*	**Stand. Error** *Stand. pogreška*	**Coefficient of variation** *Koeficijent varijacije*	t_{value}	**Sig. (2-tailed)**
Coating material *Materijal za oblaganje*	High gloss / *visoki sjaj* (HG)	WP	1.86	0.045	0.014	2.40	24.713	0.000
		MP	0.90	0.114	0.036	12.58		
	Matt / *mat* (MT)	WP	0.99	0.080	0.025	8.10	2.969	0.008
		MP	0.88	0.087	0.028	9.94		
Press method *Metoda prešanja*	Wrapping / *oblaganje profila* (WP)	HG	1.86	0.045	0.014	2.40	29.758	0.000
		MT	0.99	0.080	0.025	8.10		
	Membrane *membransko prešanje* (MP)	HG	0.90	0.114	0.036	12.58	0.496	0.626
		MT	0.88	0.087	0.028	9.94		

pers, veneer sheets and roller laminates resulted in a significant decrease in the thickness swelling values after 24 hour soaking.

3.3 Modulus of elasticity (*MOE*) and static bending strength (*STS*)
3.3. Modul elastičnosti (*MOE*) i statička čvrstoća savijanja (*STS*)

Data obtained by tests for modulus of elasticity and static bending strength of samples covered with high gloss and matt materials using two different press methods are given in Table 4.

As seen in Table 4, different press methods significantly (p<0.001) affect the elastic modulus of MDF samples covered with HG material. The same result is applicable to the samples covered with matt PVC material. Table 4 shows that the elastic modulus values of the MDFs are higher when pressed with MP than with other methods. This difference in elastic modulus values are probably the result of the PVC thickness. Nemli (2000) noted that coating the particleboards with different materials increased the bending strength and modulus of elasticity, and that the coating material thickness did not affect the results. Likewise, Table 4 shows that there is a significant difference between HG and matt covering materials at a confidence level of (p<0.001) between the elastic modulus values for both press methods applied. At the same time, the table shows that samples covered with MP have a high elastic modulus. Yet, it has been calculated that samples covered with PVC folios have a higher elastic modulus than the samples covered with HG. This difference in values could be derived from the press method, because matt PVC is coated on one side, while HG PVC is double-side coated.

On the other hand, Table 4 also shows that different press methods have a significant effect on the static bending strength of the fiberboard covered with both HG and matt materials at a confidence level of 999.9 % (p<0.001). In elastic modulus tests, while covered samples using MP reach a high bending strength, samples covered with matt covering materials using WP were calculated to have a higher (41.5 N/mm^2) bending strength. Statistical data presented in Table 4, obtained from the Independent Sample T-test applied on the bending strength values calculated in both WP and MP, showed a significant effect on the strength values of different covering materials at a confidence interval of p<0.001. Similarly, Akkılıç (1998) stated that there are statistical differences between the bending strength values of particleboard coated with finished folio, oak veneer and laminate materials.

Contrary to the elastic modulus, bending strength of the samples covered with matt folios using WP was higher than when using MP. Likewise, the average bending strength (43.7 N/mm^2) measured in samples covered with HG material using MP were calculated to be higher than when using the other method. Özdemir (1996) determined that particleboard coated with PVC had higher bending strength than the uncoated particleboard.

3.4 Bonding strength (*BS*)
3.4. Čvrstoća prianjanja (*BS*)

The analysis of bonding strength values obtained from the tests and calculations is presented in Table 5.

The results of *T*-test analysis given in Table 5 reveal that there are significant differences (p<0.001) in the bonding strength depending on the press method (WP and MP) used for covering samples with HG and matt PVCs. At the same time, bonding strength values of MDFs covered with both materials were higher when WP was used. This result may be caused by the application technique and the type of adhesive used.

As it is known, in most uses of this type of material, distinction can be made between the bonding strength and other properties. For this reason, accord-

Table 4 Results analysis of modulus of elasticity and static bending strength values
Tablica 4. Analiza rezultata mjerenja modula elastičnosti i statičke čvrstoće savijanja

Tests *Veličina*	**Parameters** *Svojstva*			**Mean** *Prosječna vrijednost* N/mm^2	**Stand. deviation** *Stand. devijacija*	**Stand. Error** *Stand. pogreška*	**Coefficient of variation** *Koeficijent varijacije*	t_{value}	**Sig. (2-tailed)**
Modulus of elasticity *Modul elastičnosti*	Coating material	HG	WP	3573.2	77.27	13.548	2.16	18.156	0.000
			MP	4023.6	13.55	4.284	0.34		
		MT	WP	3938.1	28.45	8.961	0.72	32.705	0.000
			MP	4302.5	20.94	6.623	0.49		
	Press method	WP	HG	3573.2	77.27	13.548	2.16	14.016	0.000
			MT	3938.1	28.45	8.961	0.72		
		MP	HG	4023.6	13.55	4.284	0.34	35.353	0.000
			MT	4302.5	20.94	6.623	0.49		
Bending strength *Čvrstoća savijanja*	Coating material	HG	WP	37.6	1.022	0.323	2.72	18.320	0.000
			MP	43.7	0.275	0.087	0.63		
		MT	WP	41.5	1.314	0.415	3.17	11.745	0.000
			MP	35.9	0.713	0.226	1.99		
	Press method	WP	HG	37.6	1.022	0.323	2.72	7.447	0.000
			MT	41.5	1.314	0.415	3.17		
		MP	HG	43.7	0.275	0.087	0.63	32.122	0.000
			MT	35.9	0.713	0.226	1.99		

Table 5 Independent Samples *T*-test analysis of bonding strength values
Tablica 5. Rezultati analize vrijednosti čvrstoće prianjanja *T*-testom

Bonding strength Čvrstoća *prianjanja*			**Mean** *Prosječna vrijednost* N/mm²	**Stand. deviation** *Stand. devijacija*	**Stand. Error** *Stand. pogreška*	**Coefficient of variation** *Koeficijent varijacije*	t_{value}	**Sig. (2-tailed)**
Coating material *Materijal za oblaganje*	High gloss / *visoki sjaj* (HG)	WP	2.09	0.145	0.046	6.95	4.972	0.000
		MP	1.80	0.113	0.036	6.27		
	Matt / *mat* (MT)	WP	1.16	0.066	0.021	5.64	5.698	0.000
		MP	0.96	0.095	0.030	9.91		
Press method *Metoda prešanja*	Wrapping *oblaganje profila* (WP)	HG	2.09	0.145	0.046	6.95	18.368	0.000
		MT	1.16	0.066	0.021	5.64		
	Membrane *membransko prešanje* (MP)	HG	1.80	0.113	0.036	6.27	18.145	0.000
		MT	0.96	0.095	0.030	9.91		

ing to Table 5, the choice of WP could contribute to obtaining better results.

On the other hand, when Table 5 is evaluated taking into consideration the covering material difference, it can be seen that the covering material difference has a significant effect on MDF test sample bonding strength at a confidence interval of 999.9 %. At the same time, it could be said that bonding strength values (2.09 %, 1.80 %) of the samples covered with HG using WP are better than matt covered samples using MP (1.16 %, 0.96 %). This improvement can be explained by the difference in coating material thicknesses. In a study, Kılıç (2006) researched the quality of bonding strength of beech, pine and oak veneers adhered to surfaces of flat pressed particleboard, medium density fiberboard and oriented strand board with polyvinyl acetate, urea-formaldehyde and contact adhesive. As a result of the tests, the highest bonding strength was obtained from the combination of radial cross-section beech veneer, oriented strand particleboard and urea-formaldehyde adhesive, whereas the lowest strength was obtained from the combination of tangential beech veneer, fiberboard and contact adhesive.

4 CONCLUSION
4. ZAKLJUČAK

The aim of this study was to research the difference of some properties of MDF samples, which are the key input of forest products sector, using two different press methods with high gloss and matt PVC folios. The conclusions of this study could be summed up as below.

Except for the HG covered samples, water absorption percentages were determined to be statistically affected by the press method and covering material difference in other samples. At the same time, samples covered with HG material absorbed less water.

In determining the difference of the covering material based on thickness swelling values, an insignificant effect was observed in membrane press covered samples, while there were significant differences in other samples. MDF samples covered with matt material showed a lower thickness swelling than the others.

Tests showed that both the press method difference and the covering material difference had a significant effect on elastic modulus, bonding strength and static bending strength at (p<0.001) level.

Besides, the values of elastic modulus of the samples covered with matt material were higher than the values of HG covered samples, while bonding strength of the HG covered samples was better than that of the matt covered samples. Considering the static bending strength, it was determined that the difference of the covering material did not have a similar effect on both strengths.

For this reason, when selecting the coating material to be adhered to board surfaces, due to different adhesion properties of HG and mat coatings, it is necessary to consider the characteristics, quality, surface condition of the board and properties of the environment.

A survey of the literature also reveals that so far few studies have been focusing on press methods. For this reason discussion has not been adequately included. This topic definitely requires further research.

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5 REFERENCES
5. LITERATURA

1. Akgül, M.; Çamlıbel, O.; 2008: Manufacture of medium density fiberboard (MDF) panels from rhododendron (*R. ponticum* L.) biomass. Building and Environment, 43: 438-443. https://doi.org/10.1016/j.buildenv.2007.01.003.
2. Akkılıç, H., 1998: Comparison of the technological properties of particleboard's covered with different surface materials. İstanbul University, Institute of Science and Technology, İstanbul, Turkey.
3. Bozkurt, A. Y.; Göker, Y., 1986: Stratified Wooden Material Technology. Istanbul University Press, İstanbul, 287 pp.
4. Cassens, D. L.; Feist, W. C., 1991: Exterior wood in the South: Selection, application and finishes. GTR-69.

USDA Forest Serv., Forest Prod. Lab., Madison, Wis. USA. 56 pp.
5. Hoag, M., 1992: Surface testing of particleboard and medium density fiberboard for laminating applications. Tappi Journal, 75: 116-121.
6. İstek, A.; Aydemir, D.; Aksu, S., 2010: The effect of decor paper and resin type on the physical, mechanical, and surface quality properties of particleboards coated with impregnated decor papers. Bioresources, 5: 1074-1083.
7. İstek, A.; Aydemir, D.; Eroğlu, H., 2012: Surface properties of MDF coated with calcite/clay and effects of fire retardants on these properties. Maderas, Ciencia y technologia, 14 (2): 135-144. https://doi.org/10.4067/S0718-221X2012000200001.
8. Kılıç, İ., 2006: Determination of the resistance of the veneer adhesion on some wooden boards comman uses. Gazi University, Institute of Science and Technology, Ankara, Turkey.
9. Nemli, G., 2000: Effects of surface coating materials and process parameters on technical properties of particleboard. Karadeniz Technical University, Institute of Science and Technology, Trabzon, Turkey.
10. Richter, K.; Feist, W. C.; Knaebe, M. T., 1995: The effect of surface roughness on the performance of finish. Part 1. Roughness characterization and stain performance. Forest Products Journal, 45 (7-8): 91-96.
11. Özdemir, T., 1996: The effect of surface coating materials used for kitchen cabinets on the quality of particleboard, Master Thesis. Karadeniz Technicial University, Institute of Science and Technology,Trabzon, Turkey.
12. Özdemir, T.; Kalaycioğlu, H.; Malkoçoğlu, A.; Nemli, G., 1999: Effects of surface coating materials on the physical and mechanical properties of particleboard used for kitchen cabinets and surface quality properties: Part 1. Effects of physical properties. Turkish Journal of Agriculture and Forestry, 23: 969-976.
13. Sparkes, T., 1993: Substrate selection for end user applications. European Plastic Laminates Forum, Koln, Germany, 27-31 pp.
14. Thoemen, H.; Irle, M.; Šernek, M., 2010: Wood-based panels: An introduction for specialists. Brunel University Press, Uxbridge, UK.
15. ***TS EN 310:1999, Wood-based panels – determination of modulus of elasticity in bending and of bending strength, TSE Ankara.
16. ***TS EN 310:2005, Wood-based panels – surface soundness – test method, TSE Ankara.
17. ***TS EN 317:1999, Particleboards and fibreboards – Determination of swelling in thickness after immersion in water, TSE Ankara.
18. ***TS EN 326-1:1999, Wood-Based Panels – Sampling, cutting and inspection – Part 1: Sampling test pieces and expression of test results, TSE Ankara.

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