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Effectiveness of Melamine Impregnated Paper (MIP) Waste as an Adhesive in Particleboard Manufacturing

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Abstract

Aim of study: The objectives of this research were to determine the effectiveness of melamine impregnated paper (MIP) waste as an adhesive in the particleboard manufacturing and effects of the MIP waste using as an adhesive on the some technological properties of particleboard.

Area of study: To determine the mechanical, physical and formaldehyde content of particleboards manufactured with different resins (MIP waste, neat MIP resin).

Material and Methods: In this study, particleboards were produced with utilizing MIP waste and neat MIP resin. No additional adhesive was used for MIP waste. Two different types of mixture of Turkish red pine (90%) and poplar wood (10%) particles (fine and coarse) were used. Eight different particleboard groups and three particleboards with three layers (two surface layers and one core layer) were manufactured for each group in hot press.

Main results: As results of this study, amount of adhesives had significant effect on panel properties. With the increasing of both adhesive rates (MIPW and neat MIP resin), mechanical and physical properties of particleboard were improved. However, formaldehyde content values were worsen with the increasing of both adhesive rates. The best result for MIPW and neat MIP resin were obtained when highest rates of them (25% and 13%, respectively) were used.

Research highlights: Particleboards were successfully manufactured with using of the MIP waste as adhesive. Although the MIPW (25%) boards were provided lower mechanical and physical values than neat MIP resin (13%) boards, they were satisfied the most of standard requirements.

Keywords: Melamine impregnated paper waste, neat MIP resin, urea formaldehyde and melamine formaldehyde, mechanical, physical and formaldehyde content of particleboards.

Yongalevha Üretiminde Melamin Emprenye Kağıt Atıklarının Tutkal Olarak Etkinliği

Öz

Çalışmanın amacı: Yongalevha üretiminde melamin emdirilmiş kağıt (MEK) atıklarının tutkal olarak etkinliğinin ve MEK atıklarının tutkal olarak kullanılmasının yongalevhaların bazı teknolojik özellikleri üzerinde ki etkilerinin belirlenmesi amaçlanmıştır.

Çalışma alanı: MEK atıkları ve saf MEK tutkalı kullanılarak üretilen yongalevhaların mekanik, fiziksel ve formaldehit emisyonu özelliklerinin belirlenmesidir.

Materyal ve Yöntem: Bu çalışmada MEK atıkları ve saf MEK reçinesi yongalevha üretiminde tutkal olarak kullanılmıştır. MEK atıklarına ilave olarak tutkal kullanılmamıştır. İki farklı tipte (kaba ve ince) kızılçam (%90) ve kavak (%10) yonga karışımları kullanılmıştır. 8 farklı yongalevha grubu oluşturulmuştur. Her bir grup için 3 tabakalı (iki yüzey ve bir orta tabaka) 3 adet yongalevha tam otomatik sıcak pres kullanılarak üretilmiştir.

Sonuçlar: Çalışmanın sonucu olarak, tutkal miktarının yongalevha özellikleri üzerinde önemli derecede etkili olduğu belirlenmiştir. Her iki tutkal miktarının (MEK atıkları ve saf MEK reçinesi) artması ile mekanik ve fiziksel özelliklerinin iyileştiği, bunun yanı sıra formaldehit emisyon değerlerinin ise kötüleştiği belirlenmiştir. En iyi sonuçlar MEK atıklarının (%25) ve saf MEK reçinesinin (%13) maksimum oranda kullanıldığı levha gruplarında gözlemlenmiştir.

Araştırma vurguları: MEK atıklarının tutkal ikamesi olarak kullanılması ile yongalevha üretimleri başarılı bir şekilde gerçekleştirilmiştir. MEK atıklarının %25 oranında kullanıldığı levha grupları, saf MEK reçinesinin %13 oranında kullanıldığı levha gruplarına nazaran daha düşük mekanik ve fiziksel özellikler göstermesine rağmen, standart gereksinimlerin çoğunu sağlamıştır.

Anahtar kelimeler: Melamin emdirilmiş kağıt atıkları, saf MEK reçinesi, üre formaldehit ve melamin formaldehit, yongalevhaların mekanik, fiziksel ve formaldehit emisyon özellikleri.

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Introduction

Particleboards are extensively used in indoor applications and have large surface area which combining particles and thermoset resin (urea formaldehyde, melamine formaldehyde, phenol formaldehyde, etc.) under high temperature and pressure conditions. During particleboard manufacturing, wastes such as particles with resin, melamine impregnated paper (MIP), non-standard board, etc. were generated. Portion of them were reused in manufacturing panels while some other were utilized for generating energy (Mengeloglu, Bozkurt, Başboğa, & Yüce, 2015).

Melamine impregnated paper (MIP) is decorative paper for wood based boards coating. The coating are provided a better visual for wood based board products and helps to keep humidity at the best levels for products. In addition, the coating improves the mechanical properties and keeps the nocuous gases such as formaldehyde, pesticides, etc. inside of boards (Nemli, Yıldız, & Gezer, 2005).

In literature, there are some studies for improving the MIP properties for getting better coated board. Nemli and Usta (2004) investigated to effects of some producing factors on the resistances to the scratch (SR), abrasion (AR), cigarette burns (CB) and staining (S) properties of melamine-impregnated papers in their study. Liu and Zhu (2014) and Liu, Shen & Zhu (2015) determined the effects of the coating of wood-based panels with MIPs produced by the addition of nano-material on formaldehyde and VOCs emissions from panels and mechanical properties of panels.

MIPs are frequently used in wood based panels sector for coating. Kandelbauer and Teischinger (2010) reported that in wood-based panel sector, approximately 70% of the boards were coated with MIPs while the remaining 30% with thermoplastic film and wood veneer or painted-printed the surface of the boards. Besides, four hundred tonnes of MIP wastes (MIPW) occur for a year in just a medium sized paper impregnation factory while MIPs are producing (Le Fur, Galhac, Zanetti, & Pizzi, 2004). During MIP preparation, almost 15.210.000 m^2 MIPW was generated in the middle-size medium density fiberboard plant in Turkey which uses 450 million m^2/year MIP, approximately. MIP contains 60% chemicals (adhesives, curing agents, crosslinking agents, etc.) and 40% alpha cellulose décor paper (Alpar and Winkler, 2006). Due to the fact that chemical content, it is not suitable for generating energy through burning them. It is required special running boilers at higher temperatures (Barbu and Steinwender, 2009). Researches have looked for alternatives to utilize these wastes. Le Fur et al. (2004) examined the potential of utilization of MIP waste in the single-layer particleboard manufacturing as adhesive or melamine source for adhesive. As a result of the study, MIPW can be directly applied as adhesive in the particleboard production or can be used instead of melamine in melamine-urea-formaldehyde resin production. Alpar & Winkler (2006) have searched about MIP powder using in the manufacture of particleboard as filler and adhesives. They reported that there were not significant differences between particleboard manufactured with MIP powder and the one with UF adhesives. Silva, Varanda, Christoforo & Lahr (2012) used various amount (4, 8 and 12%) of MIP wastes (6 mm long) in the core section of medium density particleboard. In this study, adhesives amount was constant for each group. Particleboard having %4 and 8 MIP waste provided enough results to meet with standards; however, %12 ones did not. In another study, Ayrılmış (2012) grinded MIP with hammer-mill and screened them. The size of 2-3mm MIPs were utilized with glued fibers in fiberboard manufacturing. Adding of MIP in to the glued fibers improved mechanical properties. Çavdar, Yel, Kalaycıoğlu & Hızıroğlu (2013) investigated utilization of waste-MIP in oriented strand board (OSB). Waste-MIP was used with urea formaldehyde resin. It has been found that waste-MIP using positively affects some of mechanical and physical properties of panels. In literature, generally MIP waste was used as filler in the board manufacturing with virgin resins and the studies about MIP waste using in the board production as an adhesive are very scarce.

In this study, effectiveness of melamine impregnated paper waste as an adhesive in three-layer particleboard manufacturing was investigated. On this purpose, three-layer particleboards were manufactured with melamine impregnated waste (MIPW) and neat-melamine impregnated resin (neat-MIPR) with different rates of MIPW (10, 15, 20, %25) and (5.2, 7.8, 10.4, 13%) in particleboard manufacturing for this study. Mechanical and physical properties of the samples were determined according to TS EN 310, TS EN 319, TS EN 311 and TS EN 317 standards.

Materials and Method

Materials

Particleboards were produced utilizing waste melamine impregnated paper waste (MIPW) and neat-melamine impregnated paper resin (neat-MIPR) as adhesives and 2 different types of particle (fine and coarse). Sulfamic acid was utilized as a hardener. MIP waste was got from the impregnation line of Kastamonu Integrated Adana MDF Facility. Neat-MIPR was also prepared in the same plant. Particles were obtained from Kastamonu Integrated Tarsus Particleboards Facility.

Synthesis of Neat-Melamine Impregnated Paper Resin

Melamine-formaldehyde (MF), urea-formaldehyde (UF) resin and added chemicals were mixed in mixer according to manufacturing schedule for general producing. Total resin (52% solid content) consisted of 50% MF and 50% UF. Used chemicals were hardener, wetting, antidusting, antiblock and form release agents.

Particleboard Manufacturing

Melamine impregnated paper waste (MIPW) granulated in Pulverizator with cooling capabilities into the flour form. These flours, screened and passed from 0,2mm sieve, were used as an adhesive in this study. Neat-melamine impregnated paper resin (neat-MIPR) was also used as an adhesive. Sulfamic acid was used just in core layer as a hardener (%2.8 of solid content of core layer resin) for neat-MIPR groups. Any hardener was not used for MIPW groups. Fine particles were utilized in surface layers (SL) while coarse ones in core layer (CL). Eight different particleboard groups and three different particleboards with three layers (two surface layers and one core layer) were manufactured for each group. Three samples were tested for each board to determine each property. In total, nine samples were examined for all properties testing. The experimental design of the study was presented in Table 1. The core layer was accounted for 67% of the total board weight. Surface layers were contained 33% of the total board weight.

Table 1. Experimental design

ID	MIPW (%)*	Neat MIPR (%)*
W10	10	---
W15	15	---
W20	20	---
W25	25	---
N10	---	5.2**
N15	---	7.8**
N20	---	10.4**
N25	---	13**

*Same rate of adhesive (MIPW or neat MIP resin) was used to all the layers.

**MIP waste used in this study contained %52 solid adhesive content (approximately 50% MF and 50% UF). The Same amount of adhesive was applied as 52% of the ratio used for MIP-waste.

Depending on the given formulation (Table 1) particles, MIPW and neat-MIPR were dry-mixed in a high-intensity mixer to produce a homogeneous blend. The blends were laid into frame of 500mm x 500mm. A hot press was used for forming of particleboards (0.4-6.2 MPa). The target thickness was 19mm. Pressing time and temperature were 240s and 200 °C, respectively. After pressing, particleboards were conditioned at a temperature of 20 °C and 65% relative humidity. The conditioned boards were cut from four edges and grinded thickness range of 0.40 – 0.80 mm. Then test samples were cut according to TS EN standards.

Particleboard testing

Testing of the samples was conducted in a climate-controlled testing laboratory.

Densities were measured by air-dried density method according to the TS EN 323 standard. Bending strength, modulus of elasticity, internal bond strength, surface soundness, screw withdrawal strength, thickness swelling and water absorption of the samples were determined according to TS EN 310, TS EN 319, TS EN 311 and TS EN 317 standards, respectively. Nine samples for each group and three samples for each manufactured board were examined for all properties testing. Mechanical properties testing were performed on Zwick Z010 (10KN).

Data Analysis

Design-Expert® Version 7.0.3 statistical software program was used for statistical analysis. The effectiveness of MIPW as an adhesive in particleboard manufacturing was evaluated.

Results and discussion

Density of the manufactured panels were in the range of 730-778 kg/m^3. In this study, mechanical (bending strength, modulus of elasticity, internal bond strength and surface soundness and screw withdrawal strength), physical (density, thickness swelling and water absorption) and formaldehyde content properties of all samples were determined. All data were summarized in Table 2. The average values and standard deviation values were given for each group.

Table 2. Summarize of mechanical, physical and formaldehyde content properties

ID	BS (MPa)	MOE (MPa)	IBS (MPa)	SS (MPa)	S.W.S (N)	TS (%)	WA (%)	FC (mg/100gr)	Density (kg/m^3)
W10	17.03 (1.82)*	3317.84 (174.76)	0.29 (0.05)	0.85 (0.21)	733.00 (108.20)	34.98 (2.71)	92.48 (6.91)	30.68 (1.55)	739.01 (19.15)
W15	24.04 (1.53)	3693.65 (262.88)	0.36 (0.07)	0.90 (0.25)	952.78 (134.24)	26.74 (2.08)	82.08 (9.57)	30.07 (3.65)	752.60 (38.50)
W20	20.25 (4.48)	3373.81 (530.41)	0.40 (0.14)	1.00 (0.27)	949.89 (241.00)	21.52 (2.83)	77.13 (6.41)	34.31 (4.19)	760.51 (16.63)
W25	25.55 (2.94)	3843.51 (225.47)	0.58 (0.10)	1.19 (0.28)	1070.78 (99.84)	17.82 (1.85)	71.30 (10.66)	39.88 (1.10)	778.39 (49.07)
N10	14.36 (1.84)	2633.42 (313.59)	0.48 (0.16)	0.84 (0.27)	841.89 (155.54)	31.40 (2.11)	84.26 (4.63)	16.33 (1.25)	729.64 (24.78)
N15	17.92 (2.03)	3025.10 (371.99)	0.66 (0.17)	1.08 (0.20)	1170.22 (167.92)	19.26 (1.30)	74.36 (5.09)	20.73 (1.68)	736.31 (36.38)
N20	20.61 (2.93)	3194.84 (403.99)	0.75 (0.08)	1.42 (0.35)	1131.22 (91.90)	14.46 (0.78)	66.78 (8.24)	28.11 (1.33)	758.90 (32.29)
N25	22.37 (4.38)	3311.45 (414.33)	0.90 (0.13)	1.58 (0.26)	1185.89 (248.26)	11.57 (0.38)	56.78 (3.51)	28.75 (1.47)	759.68 (19.77)
Standard	≥ 11	Min. 1600	≥ 0.35	≥ 0.80	≥ 450	Max. 15	Max. 80	E1 ≤ 8.00**	630-650

*Values in parenthesis are standard deviations.
**According to the EN 120 perforator method which stay in EN 13986 standard for European Countries, E1 limit for wood based boards such as particleboard and MDF.

BS: Bending Strength
MOE: Modulus of Elasticity
IBS: Internal Bonding Strength
SS: Surface Soundness
SWS: Screw Withdrawal Strength
TS: Thickness Swelling
WA: Water Absorption
FE: Formaldehyde Content

Interaction graph of density of the manufactured boards was presented in Figure 1. Statistical analysis showed that while resin amount had signicifant effect on density (p=0.0107), resin type did not (p=0.1548). When the interaction graph of boards density was examined, boards densities were at the same range. In both resin type, density was slightly increased with rising of resin amount. It was thought that, there was getting better adhesion in core layer with increasing of resin amount. Better adhesion helped to preserve dimensional stability for boards after pressing.

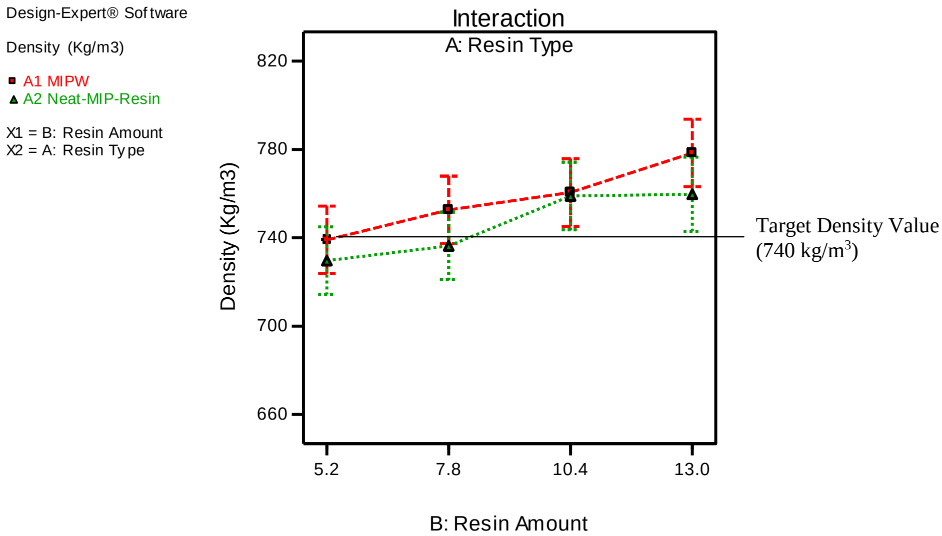

Figure 1. Interaction graph of density with resin amount

The Interrelation of resin amount between internal bond (IB) strength was given in Figure 2. In the case of internal bond strength values, both resin type and amount had significant effect ($p<0.0001$).

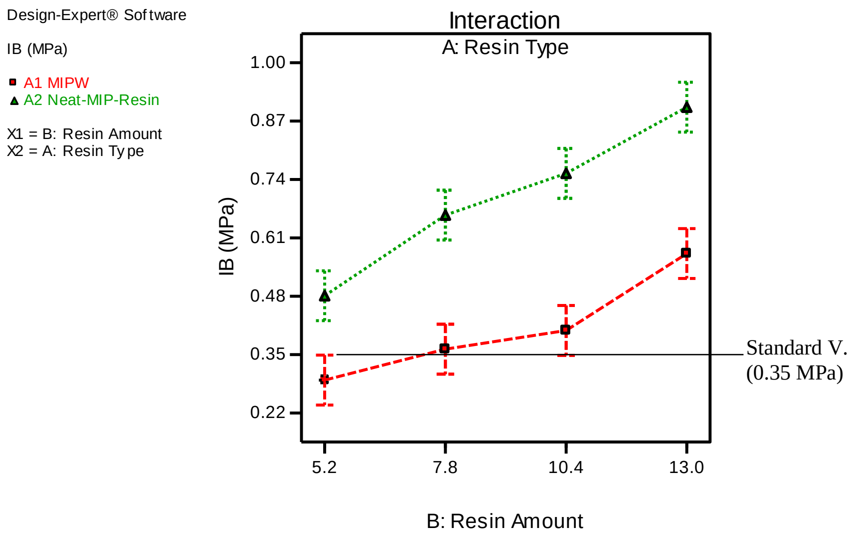

Figure 2. The effect of resin amount on the internal bond strength

Based on results, internal bond strength increased with rising of both MIPW and neat-MIPR rate in the boards. When the studies which have been used different types of resin and waste-MIP were examined in literature, it was expected that mechanical and physical properties were increased with rising of adhesive amount. (Maloney, 1970; Lehmann, 1970; Akbulut, 1991; Ayrılmış, 2012; Cavdar et al., 2013; Özçifçi, Kara, Karakaya & Biçer, 2017). The best result was obtained from N25 group which included 13% of neat-MIPR. All groups manufactured with neat-MIPR were satisfied standard values (0.35 MPa). In addition, the boards which produced with MIPW were also shown higher IB strength than standard requirements except W10 group produced with the lowest MIPW ratio. If groups contained the same ratio of resin were compared between each other, neat-MIPR were shown better result than MIPW. It was reported that melamine formaldehyde glue was cured at 90-140 °C (Bozkurt and Göker, 1990) and urea formaldehyde was cured at 100 °C (Huş, 1977). During the impregnation, the paper was exposed hot weather between 140-170 °C for drying. That temperature was enough for curing reaction to both UF and MF resin. It is mean the resin has curing reaction for a short time in oven. The reduction of reactive groups in resins might cause to poor adhesion and decreasing on the mechanical properties. It might help to explain why neat-MIPR was provided better IB strength values than MIPW. Moreover, all the boards produced with both MIPW and neat-MIPR were satisfied standard requirements for IB strength except W10 boards.

The interaction graph of screw withdrawal strength (SWS) (average maximum load) with resin amount was shown in Fig. 3. Parallel with internal bonding strength properties were observed for SWS properties. Both resin type and amount were significantly effective on SWS properties (p=0.0003 and p<0.0001, respectively). With the rising of MIPW and neat-MIPR, SWS properties were also increased. The neat-MIPR boards had higher SWS values than MIPW boards. It wqas thought that better adhession in the core layer lead to better SWS values. All the manufactured groups were satisfied standard requirements (450 N).

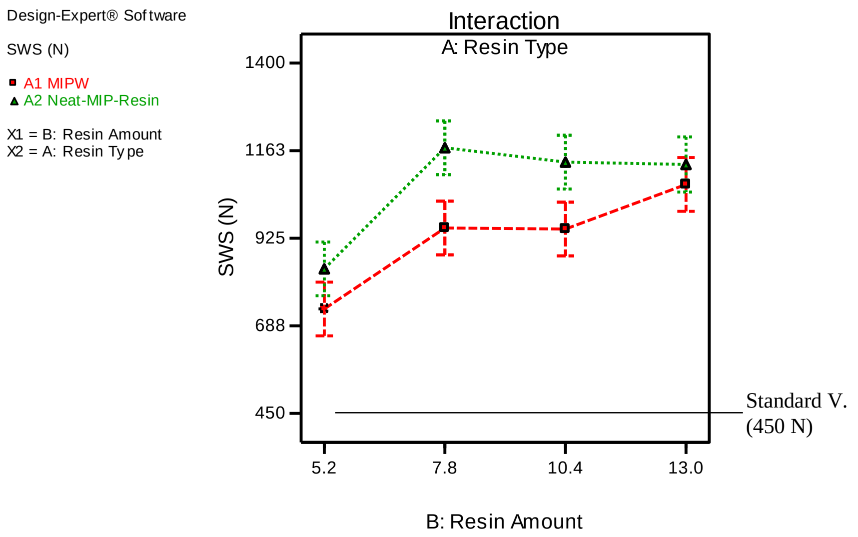

Figure 3. Interaction graph of screw withdrawal strength with resin amount

Effect of resin amount on bending strength was shown in Figure 4. Depending on the results, with the increasing of MIPW and neat-MIPR, bending strength was also raised. To mention on bending strength values, both resin type and amount had significant effect (p<0.0001). The best result was observed from W25 boards produced with maximum rate of MIPW. Boards manufactured with MIPW were provided better bending strength than neat-MIPR when compared the same usage rate. It was believed that alpha-cellulose paper which contained fibers (40%) helped to obtain better bending strength values. All manufactured particleboards reached standards requirements for bending strength (11 MPa).

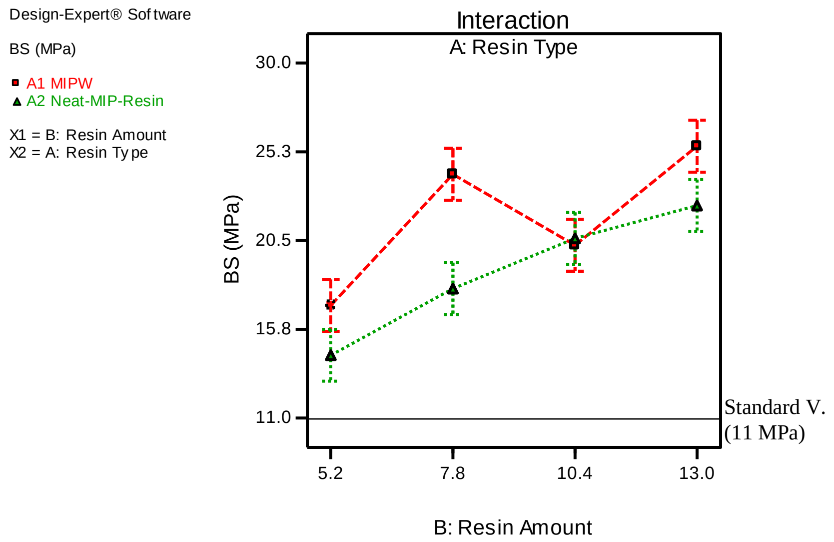

Figure 4. Interaction graph of bending strength with resin amount

To mention on modulus of elasticity (MOE), all observed data was summarized on the interaction graph which was given in Figure 5. Parallel with bending strength properties were observed for MOE properties. Both resin type and amount were significantly effective on MOE values (p<0.0001). With the rising of both resin types, modulus of elasticity was tightly increased. Parallel with bending strength, the best result was obtained from W25 boards. The other groups also had close values. Modulus of elasticity (MOE) values for all produced boards were over the standards requirements (1600 MPa).

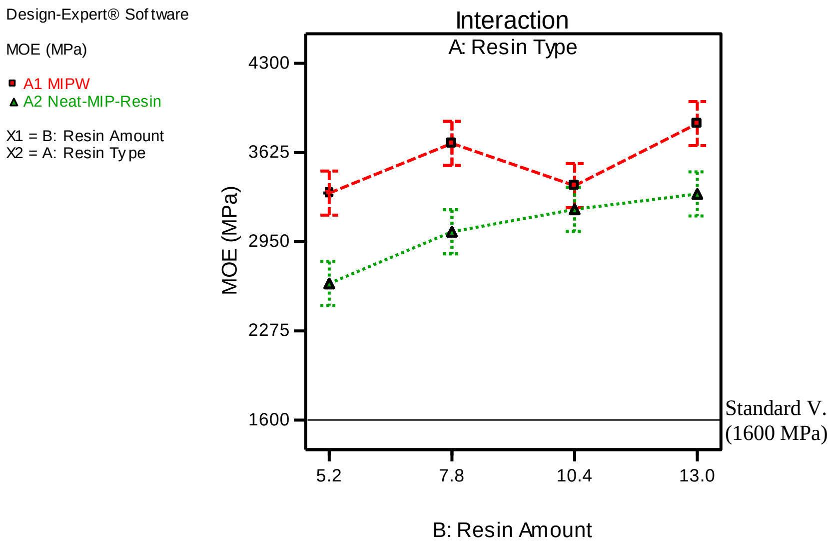

Figure 5. Interaction graph of modulus of elasticity with resin amount

In figure 6., interaction graph of surface soundness (SS) properties was shown. Depending on the results, surface soundness properties was slightly increased with the rising of MIPW and neat-MIPR in the boards. Resin type and amount had significant effect on SS properties (p=0.0002 and p<0.0001, respectively). The best result was obtained from N25 board. The boards manufactured with neat-MIPR were provided better SS properties than MIPW. All produced boards provided standards requirements for SS properties (0.80 MPa).

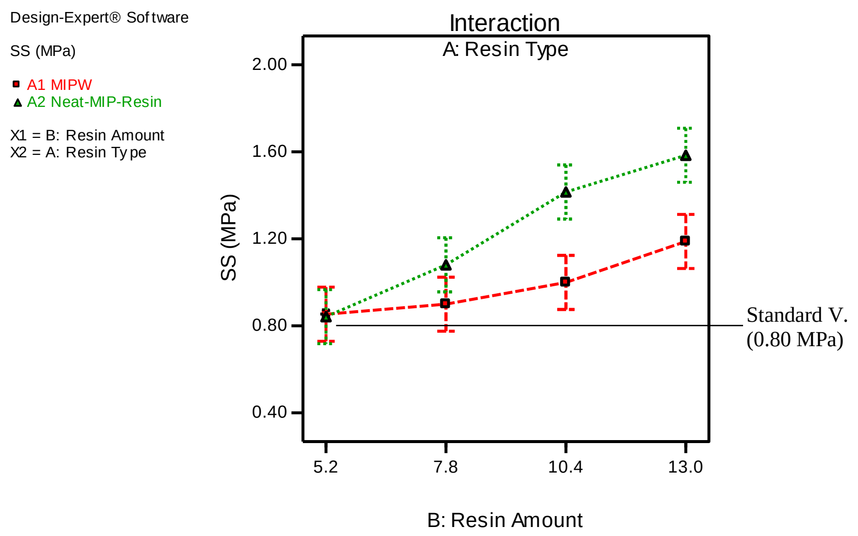

Figure 6. Interaction graph of surface soundness with resin amount

The interaction graph of thickness swelling and water absorption are shown in Fig. 7, Fig. 8, respectively. To mention on the thickness swelling properties, all the boards manufactured with MIPW were not satisfied standards requirements (Max.15%). However, boards contained maximum and 20% rate of neat-MIPR were reached the standard values for thickness swelling properties. While boards manufactured with maximum MIPW rate and with 7.8, 10.4, 13.0% rate of neat-MIPR were provided standard values, the others were not. Amount of resin and type were significantly effective on both thickness swelling and water absorption ($p<0.0001$). To parallel with internal bond strength, Neat-MIPR was shown better properties than MIPW for thickness swelling and water absorption. It was thought that neat-MIPR might provide better adhesion in core layer than MIPW. That could be explained why neat-MIPR provide better properties than MIPW for thickness swelling and water absorption. In addition, during commercial particleboard manufacturing paraffin (0.5-1%) is used as water repellent material for help to obtain better thickness swelling and water absorption properties. In this study, nothing was used as a water repellent. It was believed that usage of paraffin or other water repellent chemicals might help to satisfy standard requirements or provide over the standard values for all groups. In literature, it has been reported that some rate of paraffin usage in certain proportions in manufacturing of particleboard improved thickness swelling and water absorption properties (Heebink, 1967; Amthor and Böttcher, 1984; Nemli, Demirel, & Zekoviç, 2006). In the case of water absorption properties, the boards manufactured with MIPW rate of 5.2%, 7.8% and with neat MIPR rate of 5.2% were not satisfied standards requirements (Max.80%). All the other particleboard groups provided standard values.

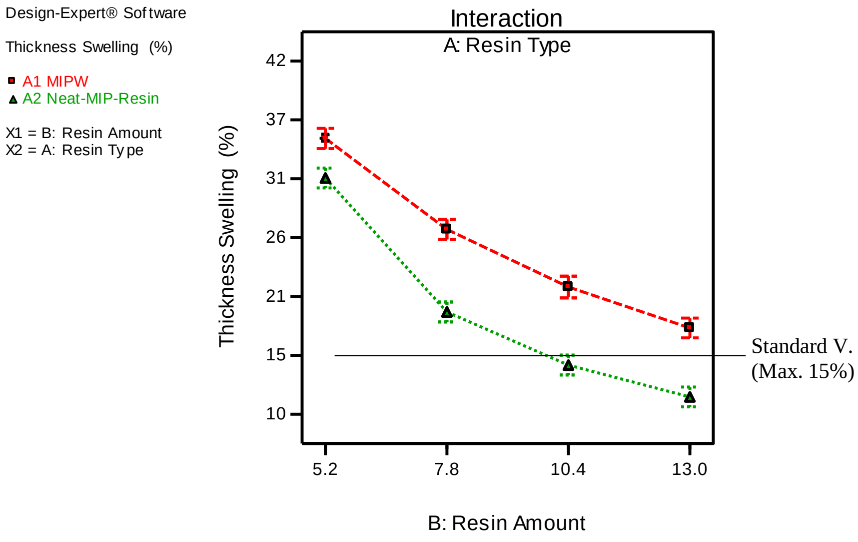

Figure 7. Interaction graph of thickness swelling with resin amount

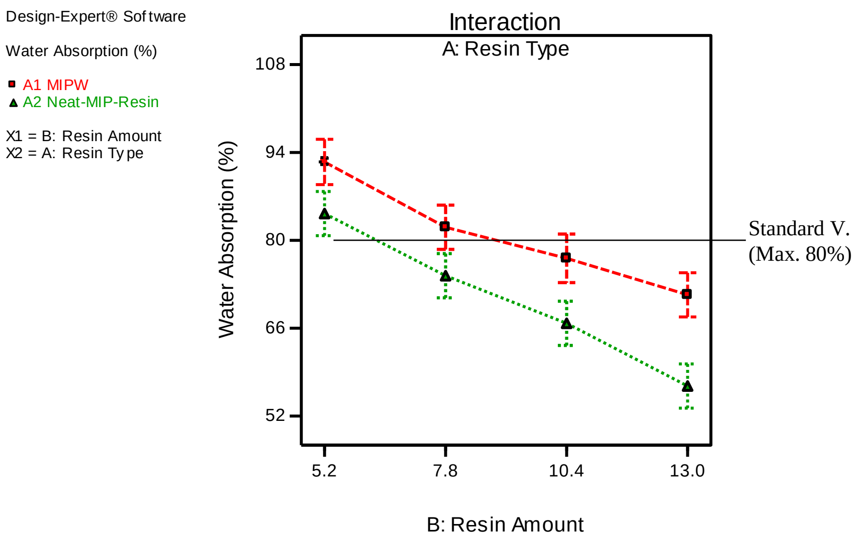

Figure 8. Interaction graph of water absorption with resin amount

The interaction graph of formaldehyde content was given in Figure 9. Depending on the results, with the rising of MIPW and neat-MIPR, formaldehyde content was also increased. To mention on formaldehyde content properties, both resin type and amount were statistical significantly effective on the formaldehyde content values ($p<0.0001$). Boards manufactured with neat-MIPR were provided better formaldehyde content values than MIPW when compared the same usage rate. Kohlmayr, Stultschnik, Teischinger & Kandelbauer (2013) noted that, during the drying process in MIP manufacturing, the most important thing was the ratio of cross-linking of the neat-MIP resin should be the melamine-impregnated paper did not lose its self-adhesive property. That is reason a very low amount of hardener is used for MIP. However, in this study, Sulfamic acid was used approximately the amount of hardener used in commercial particleboard production for core layer of neat-MIPR groups. It was thought that using of the high amount of hardener in the core layer helped to have lower non-cross-linked groups for neat-MIPR groups than MIPW groups. It was believed that this is one of the reasons for the Neat-MIPR groups showed a better formaldehyde content result than the

MIPW group. E1 limit for wood based boards such as particleboard and MDF is set to 8mg/100g oven dry board as specified in EN 13986 for European countries, based on Perforator test. All the produced groups were over the standard values for formaldehyde content.

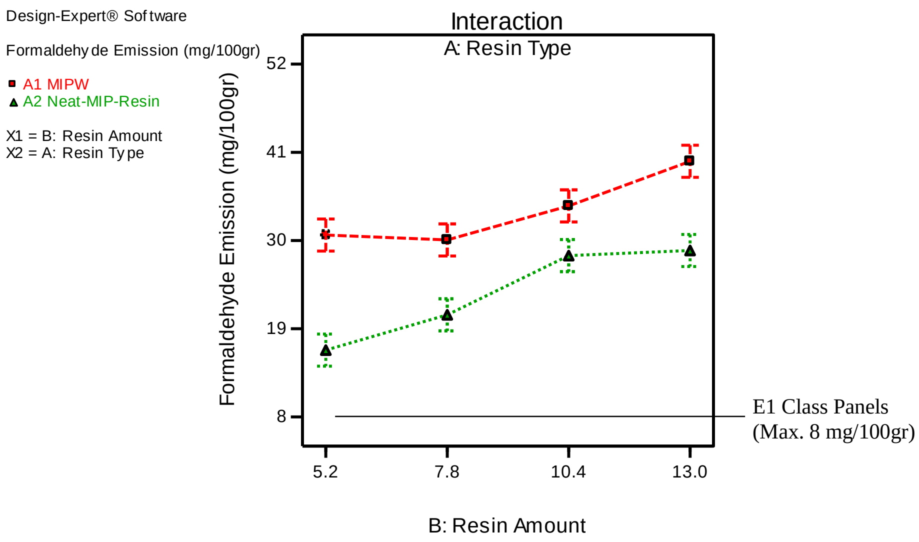

Figure 9. The influence of resin amount on the formaldehyde content

Moreover, all the data and standard requirement were summarized in Table 3. Values do not match standards were painted in gray.

Table 3. Comparison of all data with standard

ID	BS (MPa)	MOE (MPa)	IBS (MPa)	SS (MPa)	S.W.S (N)	TS (%)	WA (%)	FC (mg/100gr)
W10	17.03 (1.82)*	3317.84 (174.76)	0.29 (0.05)	0.85 (0.21)	733.00 (108.20)	34.98 (2.71)	92.48 (6.91)	30.68 (1.55)
W15	24.04 (1.53)	3693.65 (262.88)	0.36 (0.07)	0.90 (0.25)	952.78 (134.24)	26.74 (2.08)	82.08 (9.57)	30.07 (3.65)
W20	20.25 (4.48)	3373.81 (530.41)	0.40 (0.14)	1.00 (0.27)	949.89 (241.00)	21.52 (2.83)	77.13 (6.41)	34.31 (4.19)
W25	25.55 (2.94)	3843.51 (225.47)	0.58 (0.10)	1.19 (0.28)	1070.78 (99.84)	17.82 (1.85)	71.30 (10.66)	39.88 (1.10)
N10	14.36 (1.84)	2633.42 (313.59)	0.48 (0.16)	0.84 (0.27)	841.89 (155.54)	31.40 (2.11)	84.26 (4.63)	16.33 (1.25)
N15	17.92 (2.03)	3025.10 (371.99)	0.66 (0.17)	1.08 (0.20)	1170.22 (167.92)	19.26 (1.30)	74.36 (5.09)	20.73 (1.68)
N20	20.61 (2.93)	3194.84 (403.99)	0.75 (0.08)	1.42 (0.35)	1131.22 (91.90)	14.46 (0.78)	66.78 (8.24)	28.11 (1.33)
N25	22.37 (4.38)	3311.45 (414.33)	0.90 (0.13)	1.58 (0.26)	1185.89 (248.26)	11.57 (0.38)	56.78 (3.51)	28.75 (1.47)
Standard	≥ 11	Min. 1600	≥ 0.35	≥ 0.80	≥ 450	Max. 15	Max. 80	E1 ≤ 8.00**

*Values in parenthesis are standard deviations.

BS: Bending Strength
MOE: Modulus of Elasticity
IBS: Internal Bonding Strength
SS: Surface Soundness
SWS: Screw Withdrawal Strength
TS: Thickness Swelling
WA: Water Absorption
FC: Formaldehyde Content

When Table 3 was examined; all produced boards were satisfied standard requirements for mechanical properties, except W10 group which produced with lowest ratio of WMIP. To mention on physical properties, while two groups produced with 10.4% and 13.0% rate of neat-MIPR were meet standard requirements for thickness swelling properties, the other groups were not. Moreover, groups manufactured with lowest rate of neat-MIPR, 5.2% and 7.8% rate of MIPW were not provided standard values for water absorption, while the others were provided. In this study, water repellent chemicals were not used in the manufacturing of panels. It was believed that, it was the reason why the some groups were not meets the standard values for physical properties. All the produced groups were over the standard values for formaldehyde content.

Conclusion

As results of the study, MIPWs had reactive groups and they might utilize in the manufacturing of particleboards. Even if neat-MIPR provided better results than MIPW for many of mechanical and physical properties, MIPW also satisfied standard requirements, parallel with neat-MIPR. Particleboards were successfully produced with using MIPW and neat-MIPR as an adhesive and the following conclusions were reached;

1. N20 and N25 groups were satisfied all standard requirements for all properties, except formaldehyde content,
2. N15, W20 and W25 groups were also reached standard values for all properties except thickness swelling and formaldehyde content,
3. The boards produced with 7.8% rate of MIPW and with lowest rate of neat-MIPR were provided standard requirements for all mechanical properties,
4. For Internal bond strength, just W10 group was not satisfied standard values,
5. The boards manufactured with neat-MIPR were provided better mechanical and physical properties when groups with same ratio of resin content they were compared between each other, except bending strength and MOE properties,
6. Amount of both adhesives had significant effect of panel properties,
7. Some of the produced groups were not satisfied the standard requirements for physical properties. Using of some water repellent chemicals might help to overcome that problem.
8. All the produced groups were not satisfied the standard requirements for formaldehyde content. Using of formaldehyde scavenger chemicals might help to decrease the formaldehyde content. In addition, applying longer press time might also help to reduce formaldehyde content.

As a result, Melamine impregnated paper waste was effective on mechanical, physical and formaldehyde content properties as an adhesive and it might utilize as an adhesive in particleboard manufacturing.

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