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WASTE MELAMINE IMPREGNATED PAPER (MIP) IN THERMOSET AND THERMOPLASTIC BASED COMPOSITES

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Abstract:
In this study, thermoplastic and thermoset based composites were produced using melamine impregnated paper (MIP)-waste as a filler. Composite manufacturing was accomplished through mixing of the components and pressing in a hot press with cooling capabilities. Mechanical properties such as tensile, flexural and impact strength tests were determined in accordance with ASTM D638, ASTM D6109, and ASTM D256, respectively. Also morphologies of them were studied using scanning electron microscopy (SEM).

The effect of board type (MIP, low density polyethylene (LDPE) or MIP/LDPE) on mechanical properties were studied. Board type had statistically significant effect on all mechanical properties investigated. MIP boards provided better mechanical properties compared to the LDPE and MIP/LDPE boards. As a result, MIP might be utilized in both thermoset and thermoplastic based composite manufacturing providing economic and environmental benefit.

Key words: *thermoset; thermoplastic; composite; melamine impregnated paper waste; mechanical properties.*

INTRODUCTION

In wood based panel industry, both during manufacture of product and after the end of product service life, waste for generated. After completing their service life, panels like particleboard (PB) and medium density fiber board (MDF) were usually sent to the landfills. However, it has been banned in Central Europe since 2000. These kind of wastes contains more than 20% organic. Because of that they should be burned (Irle and Barbu 2010). There were some studies conducted on reutilizing these wastes in composite manufacturing. There is a patent for using these wastes in thermoplastic based composites (Singer 2006). In another patent, Pervan et al. (2010) manufactured a new using end-of-life coated PB, MDF, parquet, etc. In this patent, PB, MDF, parquet, etc. first grounded into smaller pieces and then mixed with thermoset adhesives (urea formaldehyde (UF), melamine formaldehyde (MF), melamine urea formaldehyde (MUF), phenol formaldehyde (PF)) to produce new panels. Makki et al. (2009) also utilized grinded household appliances produced with UF and MF as reinforcing materials in unsaturated polyesters.

Wood based panels generates wastes such as chips with resin, melamine impregnated paper (MIP), non-standard board, etc. Portion of them were reused in manufacturing panels while some other were utilized for generating energy. MIP contains chemicals (adhesives, curing agents, crosslinking agents etc.) and 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. Alpar and Winkler (2006) has used MIP powder in the manufacture of particleboard as a both filler and adhesives. As a result, no significant differences were found between particleboard manufactured with UF adhesives and the one with MIP powder. In another study, Silva et al. (2012) used various amount (% 4, 8 ve 12) of MIP wastes (6mm long) in the core section of medium density particleboard which is a lignocellulosic composite made with matrix of synthetic adhesive (urea formaldehyde resin) and reinforcement phase of particles of wood, and composed of three layers. 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. The utilization of MIP was in other panels were also studied. Ayrılmıs (2012) studied the use of waste-MIP in UF bonded MDF while Cavdar et al. (2013) investigated utilization of waste-MIP in oriented strand board (OSB).

In this study, waste-MIP powder were utilized to manufacture thermoset and thermoplastic based composites. Thermoset based composites were manufactured using waste-MIP powder without using any other adhesives. In the case of thermoplastic based composites, waste-MIP was mixed with low density polyethylene (LDPE) in a 1:1 ratio. For comparison LDPE samples were also produced. Mechanical properties such as tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus and impact strength were determined in accordance with ASTM. Sample densities were measured. Also morphologies of them were studied using scanning electron microscopy (SEM).

EXPERIMENTAL

Materials

Polymer composites were manufactured utilising waste melamine impregnated paper (MIP), low density polyethylene (LDPE) and their %50 mixtures of each (MIP/LDPE).

Composite manufacturing

MIP and LDPE groups were manufactured in a single stage process using hot press with cooling capabilities. In the case of MIP/LDPE group, composite manufacturing was accomplished in a two stage process; mixing of MIP and LDPE powders in a high intensity mixer and production of composites in a hot press with cooling capabilities. The experimental design of the study is presented in Table 1.

Table 1

Manufacturing compositions (%)

Group ID	Melamine Impregnated Paper (MIP) (%)	Low Density Polyethylene (LDPE) (%)
MIP	100	-
LDPE	-	100
MIP/LDPE	50	50

Composite testing

Testing of the samples was conducted in a climate-controlled testing laboratory. Tensile, flexural, and impact properties of all samples were determined according to ASTM D 638, ASTM D 790, and ASTM D 256, respectively. Ten samples for each group were tested. Tensile and flexural testing were performed on Zwick 10KN while a HIT5,5P by Zwick™ was used for impact property testing on notched samples. The notches were added using a Polytest notching cutter by RayRan™.

Data analysis

Design-Expert® Version 7,0,3 statistical software program was used for statistical analysis.

RESULTS AND DISCUSSION

In this study, three different groups were (MIP, LDPE and MIP/LDPE) manufactured and their mechanical properties and morphologies were determined. Mean density values of the boards are presented in Table 2 and density distribution was presented in Fig. 1. Statistical analysis was performed using general factorial design. Composite type was find to be statistically important on density values (p<0.0001). Composites produced with MIP powder provided highest density while pure LDPE giving the lowest. Density of MIP/LDPE group was in between. MIP group has the highest amount of wood fibre in it since they are produced from paper from alpha-celluloses. It is believed that the higher cell wall density of alpha-celluloses has increased the density of the MIP groups (Mengeloglu and Karakus 2008).

Table 2

Density of the manufactured composites

Group ID	Density (g/cm^3)
MIP	1.13 (0.091)*A
LDPE	0.95 (0.012)C**
MIP/LDPE	1.08 (0.014)B

*Values in parenthesis are standard deviations,
**Different capital letter shows statistically different groups.

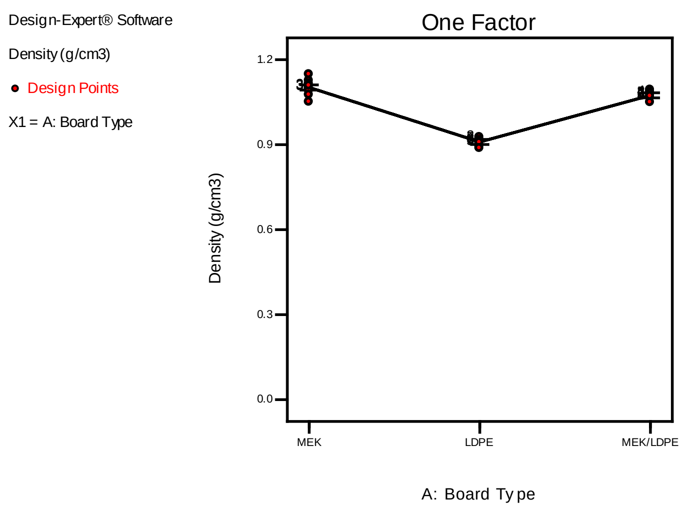

Fig. 1.
Density distribution of the manufactured test samples

Tensile, flexural and impact properties were evaluated. Tensile properties (tensile strength, tensile modulus and elongation at break) were presented in Fig. 2, Fig. 3 and Fig. 4, respectively. Board type had significant effect on tensile strength (P<0.0001). MIP board samples provided the highest tensile strength (12.86MPa). It is followed by LDPE board samples (7.62MPa). The lowest result was observed with MIP/LDPE Board samples (4.12MPa). In the case of tensile modulus (Fig. 3), once again board type had significant effect (P<0.0001). MIP provided highest tensile modulus (707MPa) while LDPE had the lowest (84MPa). LDPE is a thermoplastic material and has lower modulus values compared to thermoset plastics. However, the presence of MIP (lignocellulosic material) in LDPE improved the modulus values (179MPa).

Most of the thermoplastic polymers provide higher elongation values compared to thermoset polymers. One of the most elongating thermoplastic is LDPE and they are used for trash bad, freeze bag etc. For the manufactured samples LDPE board provided highest elongation at break values (%432). For the MIP board, mean elongation at break values was only %2.1. Mixing of MIP with HDPE improved this elongation at break values from %2.1 to %3.6 (Fig. 4).

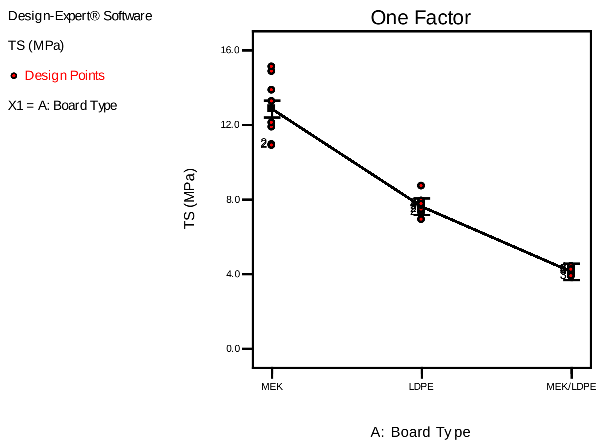

Fig. 2.
Tensile strength values of the manufactured composites

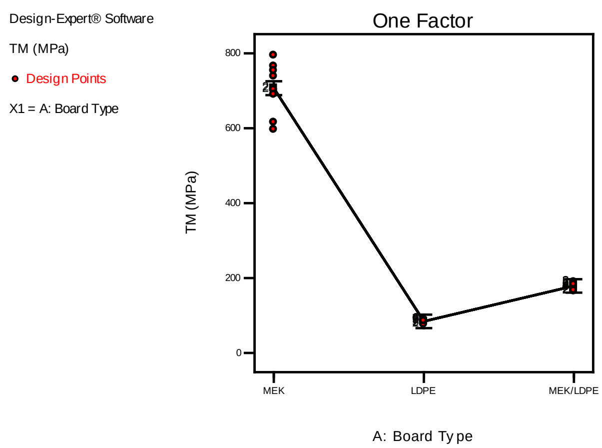

Fig. 3.
Tensile modulus values of the manufactured composites

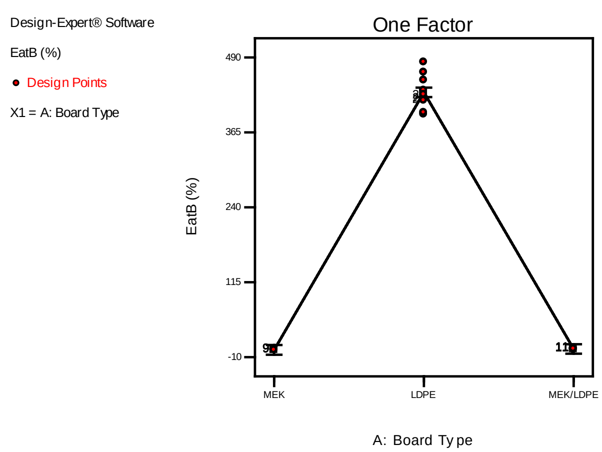

Fig. 4.
Elongation at break values of the manufactured composites

Flexural strength and flexural modulus were evaluated and their interaction graphs were presented in Fig. 5 and Fig. 6, respectively. The highest flexural strength was provided by MIP board samples (17.9MPa) while the lowest results was observed for LDPE board samples (7.2MPa). MIP/LDPE group provided flexural strength results of 9.5MPa, which is lower than LDPE group and much less than MIP group.

In the case of flexural modulus, similar trends were observed. Board type had significant effect on tensile modulus (p<0.0001). Boards having MIP powder provided higher results. The highest flexural modulus was provided by MIP board samples (1861MPa) while the lowest results was observed for LDPE board samples (153MPa). MIP/LDPE group provided flexural modulus results of 440MPa, which is lower than LDPE group and much less than MIP group.

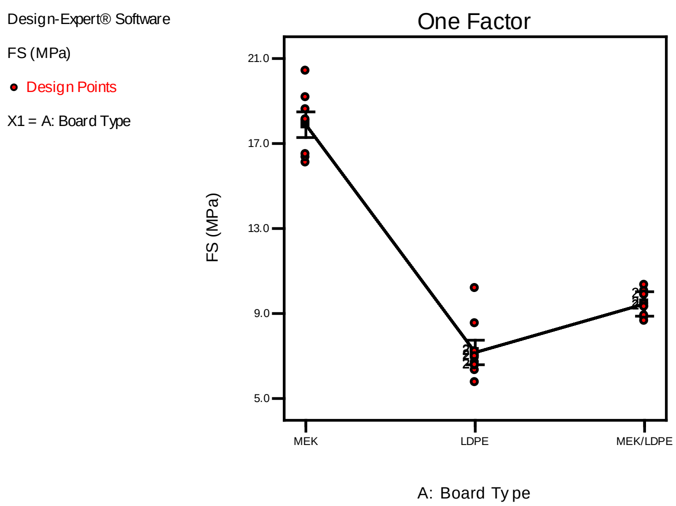

Fig. 5.
Flexural strength values of the manufactured composites

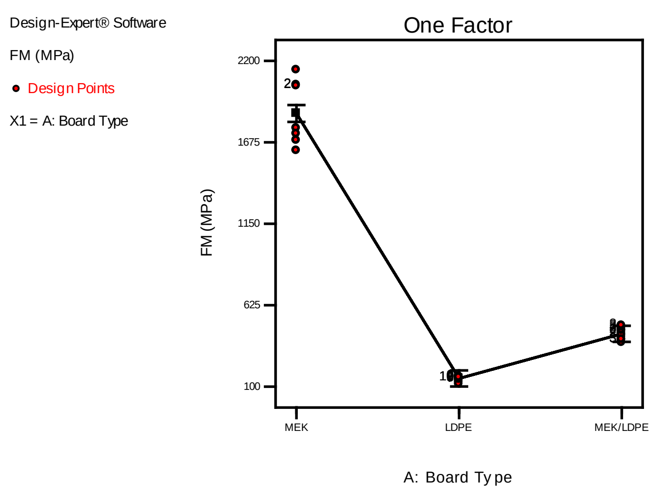

Fig. 6.
Flexural modulus values of the manufactured composites

Interaction graph for impact strength is given in Fig. 7. LDPE boards provided highest impact strength values (54.3kJ/m^2). For the MIP board, mean impact strength was only 1.6kJ/m^2. Mixing of MIP with LDPE improved impact strength 1.6kJ/m^2 to 3.6kJ/m^2 (Fig. 4).

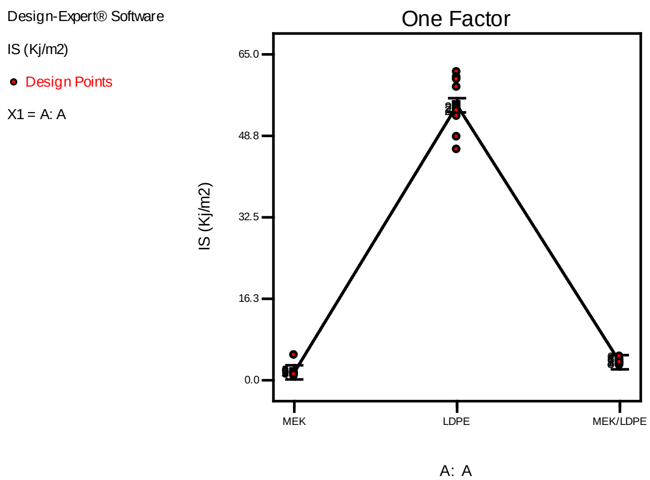

Fig. 7.
Impact strength values of the manufactured composites

Morphology of the produced samples was also studied. SEM images of MIP, LDPE and MIP/LDPE samples were presented in Fig 10.

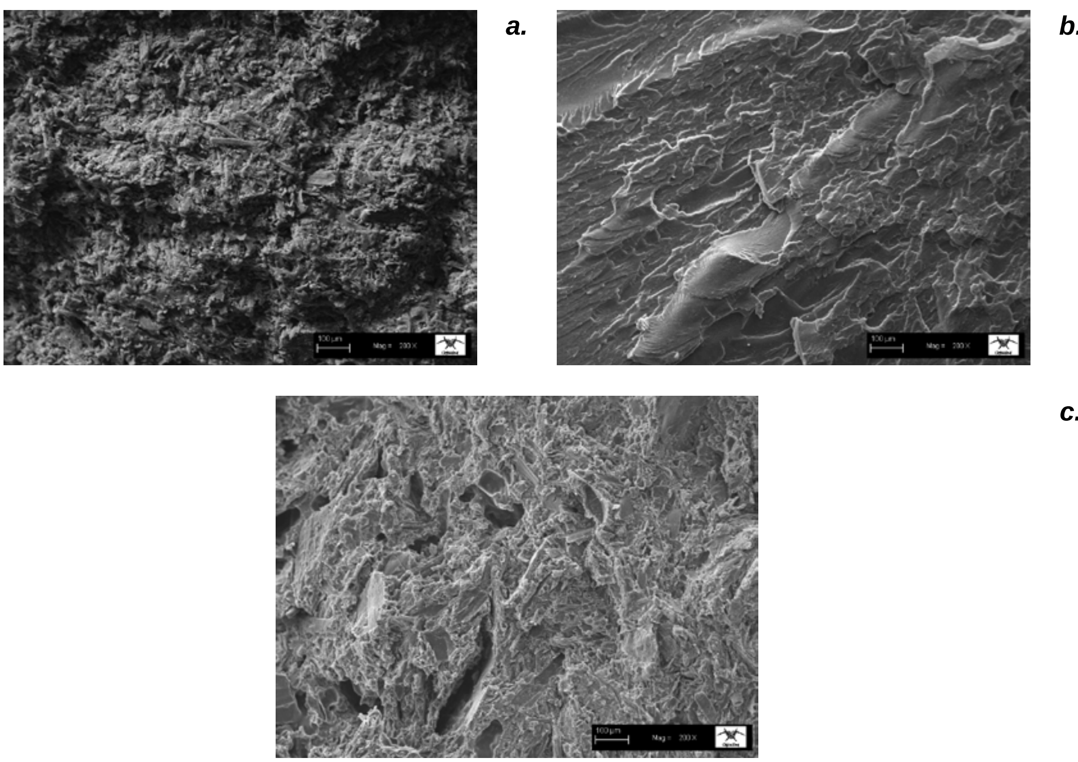

Fig. 8.
SEM Images of: a. – MIP; b. – LDPE; c. - MIP/LDPE composites

From these images, it is clear that morphology of the samples were quite different. In MIP samples (Fig. 8a), individual fibres can be seen. In Fig. 8b, morphology of the LDPE was shown while mixture of the MIP and LDPE was presented in Fig. 8c. MIP powders were homogenously distributed in LDPE matrix. However, there were some holes in the samples. It is believed that these holes occurred due to the water vapour coming from condensation reaction of melamine formaldehyde. Probably generated water vapour was encapsulated in polymeric matrix and did not have enough time to escape before solidification of the samples. These holes possible act as a defect in the samples and reduced the mechanical properties.

CONCLUSIONS

Thermoset and thermoplastic based composites were produced utilizing waste-melamine impregnated paper. Thermoset based composites were produced without using any additional adhesives. In the case of thermoplastic based composites, low density polyethylene (LDPE) was utilized. Neat LDPE samples were also produced for comparison. Following conclusions were driven;

- Melamine impregnated paper (MIP) boards provided the highest tensile strength, tensile modulus, flexural strength and flexural modulus values.
- LDPE boards provided highest elongation at break and impact strength values.
- Addition of MIP in LDPE matrix improved tensile modulus, flexural strength and flexural modulus. However, it reduced the tensile strength.
- Overall, MIP might be utilized in both thermoset and thermoplastic based composite manufacturing.

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