SURFACE QUALITY OF WOOD PLASTIC COMPOSITES COATED WITH SOLVENT AND WATER BASED PAINTS

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Abstract: This study investigated surface hardness, roughness, and abrasion resistance of hot press molded wood plastic composite (WPCs) panels coated with two types of paints, water- or solvent-based paints. The WPC panels are produced from different amounts of pine wood flour (30 to 60 wt%), virgin polypropylene (37 to 67 wt%) and 3 wt% maleic anhydride polypropylene (MAPP). The surface abrasion resistance and hardness of the WPC panels painted with water or solvent based paints increased up to 50 wt% wood flour content, but further increment in the wood flour content decreased the abrasion resistance and hardness. The surface roughness of the painted WPCs increased with increasing wood flour content. The WPCs painted with solvent-based paints showed better surface quality as compared to the WPCs painted with water-based paints.

Keywords: Hybrid composites, mechanical properties, wood plastic composite, thermoplastics, water absorption, surface hardness.

1. Introduction

Coating Technology, a new process to coat wood plastic composites in virtually any color while enabling them to resist fading, heat retention, mold, mildew, stains and abrasion. The implementation of WPC with water-based paints could open up new application possibilities and markets in the construction sector, e.g. for façade and window sections. In the last few years, the WPC market in Europe has expanded rapidly and the outlook is viewed positively. In Germany, the current annual production volume is around 50,000 t, whilst Europe has an estimated capacity of around 120,000 t [1].

Among the reinforcing agents, natural fibers have significant advantages such as low cost, highly available and renewable, with low density and high specific properties as well as biodegradable and less abrasive to processing equipments. Among commodity thermoplastics, polypropylene (PP) possesses outstanding properties such as low density, good flex life, sterilizability, good surface hardness, very good abrasion resistance, and excellent electrical properties. However, the main drawback of PP is low modulus as compared to the wood. The purpose for the addition of cellulose-based fillers to thermoplastics is to reduce the cost per unit volume and to improve stiffness.

It is currently not possible to satisfactorily coat WPC surfaces with water-based paints. The reason for this is the low surface energy and the barely-existent functionality which result in bad wettability and lack of material anchorage for aqueous binders [1]. Solvent-based paints, sometimes referred to as "oil-based" or "alkyd" paints, contain a significantly higher level of organic solvents than water-based paints. These solvents are responsible for the strong odor noticeable in buildings that have been freshly painted. They are also potentially hazardous for both human health and for the environment which is why concerted efforts are being made to reduce or remove their presence in paints without negatively impacting on paint performance. Water-based paints, often referred to as acrylic emulsions, are increasingly replacing organic solvents across a broad range of paint applications and surface areas [2].

Appropriate coatings can provide outstanding scratch resistance, as well as provide a surface that is easy to clean. Appropriate coatings can seal the WPC to prevent moisture absorption, mold growth, and physical property reduction. Using coating systems can also enable homeowners to repaint their WPC to match new decoration schemes, or repair scratches or mars over time of use [3]. There is limited information about the effect of raw material formulation on the surface properties of WPCs painted with water or solvent based paints. In this study, the surface roughness, hardness, and abrasion resistance of painted WPCs produced with different amounts of wood and PP.

2. Materials and methods

2.1. Materials

PP granulates produced by Likom PP Co., Ukraine, was used as the polymer matrix (Fig. 1). Its density and melt flow rate (230°C / 2.16 kg) were 0.90 g/cm³ and 6.5 g/10min, respectively. The compatibilizing agent, maleic anhydride modified homopolymer polypropylene (MAPP) (Optim-425, MFI/190°C; 2.16 kg = 110 g/10 min, density: 0.91 g/cm³), was supplied by Pluss Polymers Pvt. Ltd. in India.

Pine wood particles were obtained from the round woods by using a disc chipper with three knives, followed by grinding process in a laboratory type grinder. The average size of the wood flour without bark was 40 US-mesh (Fig. 2).

Fig. 1: Polypropylene and wood flour.

Fig. 2: Compound obtained from twin screw co-rotating extruder.
The water based paint which was acrylic copolymer emulsion paint and solvent based paint which was long oil alkyd paint were supplied from a commercial paint manufacturer. The density and viscosity (DIN cup 4mm) of the water-based paint were 1.52 g/ml and 115 s, respectively. These properties were found to be 1.20 g/ml and 110 s for the alkyd paint, respectively.

2.2. Preparation of hot-press molded WPCs

The wood flour was dried overnight at 90 °C in a vacuum oven prior to melt blending. The pre-mixed wood flour, polypropylene, and coupling agent were fed into the main feed throat using a volumetric feed system. The pellets were then dried in an oven at 90 °C for 24 h after the extrusion process. The mat was prepared with the dried pellets by a hot compression molding process. The mixture was weighed and formed on an aluminum caul plate, using a 290 mm × 290 mm forming frame. A steel frame was used to prevent a lateral yielding of the dry-blend mixture during the hot pressing. Wax paper was used to avoid direct contact of the polypropylene flour with the metal platens of the hot-press. Subsequently, the pellets were compression molded in a hot press. The mats were hot pressed for 8 min under 5.5 MPa at 190 °C in a one-step process (Fig. 3). At the end of the hot pressing cycle, the panel was immediately moved from the hot press into a press at room temperature for cooling. 3 mm thick WPC panels were then trimmed to a final size of 100 mm × 100 mm.

2.3. Paint application on the WPC panels

The solvent or water based paints were applied on the WPC boards by spray coating technique. The amount of the paint applied on the WPC surface was 200 g/m². The paint was uniformly applied on the surface of the WPC panels as shown in Figure 4.

2.4. Measurement of surface roughness

Two samples with a size of 50 mm by 50 mm from each type of panel conditioned at 23 °C and 50% relative humidity were used for surface roughness evaluations. A total of ten measurements with a 15-mm tracing length, 5 along the sandmarks and 5 across the sandmarks, were taken from each face of the samples. The points of roughness measurements were randomly marked on the surface of test samples. A Mitutoyo SJ-301 surface roughness tester, stylus type profilometer, was employed for the surface roughness tests. Three roughness parameters characterized by ISO 4287 (1997) standard, respectively, average roughness (Rz), mean peak-to-valley height (Rv), and maximum peak-to-valley height (Ry), and root mean square roughness (Rq) were considered to evaluate the surface characteristics of the panels. Roughness values were measured with a sensitivity of 0.5 µm. Measurements were done at room temperature and pin was calibrated before the tests. The profilometer used for the measurements consisted of main unit and a pick-up which has a skid-type diamond stylus with 5 µm tip radius and 90° tip angle. The stylus traversed the surface at a constant speed of 10 mm/min and measuring force of the scanning arm on the samples was 4 mN (0.4 gf).

2.5. Abrasion resistance of the painted WPCs

The abrasion resistance of the painted WPCs was determined according to ASTM D4060 which was standard test method for abrasion resistance of organic coatings by the Taber abraser. The test specimen is mounted to the Taber Abraser turntable and rotated at a fixed speed under a weighted CS-10 abrading wheel. Initial and final abrasion levels were determined visually based on the initial indication of pattern fading and extremely worn out pattern on the paper, respectively. Rotations of the disks were consistently counted and corresponding values at abrasion levels were used to calculate average abrasion resistance. Four measurements, two for each specimen, were used for each WPC code.

2.6. Surface hardness of the painted WPCs

The surface hardness of the WPCs was determined according to ASTM D4366 – 14. The pendulum damping test has been found to have good sensitivity in detecting differences in coating hardness, where hardness is defined as resistance to deformation. A total of 10 measurements, 5 measurement for each specimen, were used for each WPC code.

3. Result and discussion

3.1. Surface roughness of the painted WPCs

The surface roughness values of the WPCs coated with solvent and water based paints are presented in Figures 5 and 6. As compared to the control WPC samples, the average surface...
roughness ($R_a$) of the WPCs painted water-based paint slightly increased with increasing amount of wood flour while this was not observed for the WPCs painted with solvent-based paints. The average roughness of the WPCs painted with water-based paints increased from 2.36 to 2.75 μ as the wood flour content increased from 30 to 60 wt% in the WPC while this property was found to 3 to 2.5 μ for the WPCs coated with solvent-based paint. Previous studies reported that the increment in the filler content increased the surface roughness of the thermoplastic composites [4,5]. However in our study, it was observed that the surface roughness of the solvent-based paint coated WPCs decreased with increasing wood flour content.

![Surface roughness parameters](image1)

**Fig. 5:** The surface roughness parameters of WPCs coated with solvent-based paint.

![Surface roughness parameters](image2)

**Fig. 6:** The surface roughness parameters of WPCs coated with water-based paint.

3.2. Abrasion resistance

The results of abrasion resistance of the coated WPCs are presented in Table 2. In general, the abrasion resistance of the WPCs coated with water or solvent-based paints showed difference based on the wood flour content. The scratch resistance of the materials depends on the chemical composition, density and the hardness of the materials. The abrasion resistance of the materials is important when they are used as flooring material.

**Table 2: The results of abrasion resistance of the painted WPCs**

<table>
<thead>
<tr>
<th>Paint type</th>
<th>WPC code</th>
<th>Initial abrasion (cycle)</th>
<th>Final abrasion (cycle)</th>
<th>Average abrasion (cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-based paint</td>
<td>A</td>
<td>27</td>
<td>69</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>42</td>
<td>154</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>38</td>
<td>219</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>36</td>
<td>95</td>
<td>65</td>
</tr>
<tr>
<td>Solvent-based paint</td>
<td>E</td>
<td>57</td>
<td>141</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>42</td>
<td>180</td>
<td>111</td>
</tr>
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<td></td>
<td>G</td>
<td>51</td>
<td>172</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>H</td>
<td>28</td>
<td>78</td>
<td>53</td>
</tr>
</tbody>
</table>

3.3. Persoz pendulum

The results of persoz pendulum test are presented in Table 3. The number of oscillation of the WPCs coated with water-based paint increased up to 50 wt% wood flour content but further increment in the wood flour content decreased the number of oscillation. A similar results was found in the WPCs coated with solvent-based paint. However, the number of oscillation of the WPCs produced with 60 wt% was found to be higher than that of WPCs produced with 30 wt% wood flour. This was not observed for the WPCs coated with water-based paint.

**Table 3: The results of persoz pendulum of the painted WPCs**

<table>
<thead>
<tr>
<th>Paint type</th>
<th>WPC code</th>
<th>Number of Oscillation</th>
<th>Duration (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-based paint</td>
<td>A</td>
<td>67</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>73</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>55</td>
<td>55</td>
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<tr>
<td>Solvent-based paint</td>
<td>E</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>G</td>
<td>73</td>
<td>74</td>
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<tr>
<td></td>
<td>H</td>
<td>70</td>
<td>71</td>
</tr>
</tbody>
</table>

4. Conclusions

The results of the research revealed that the surface properties of the WPCs coated with water or solvent based paints showed the differences based on the wood flour content. There was no significant difference in the average surface roughness values among the painted WPCs produced with the 30 wt% and 60 wt% wood flour. The highest abrasion strength and hardness were found in the coated WPC specimens produced with 50 wt% wood flour. Based on the findings obtained from the present study, it can be said that the WPCs prepared from the PP/wood flour/MAPP (47/50/3 wt%) had the optimum surface quality properties among the evaluated WPC codes.

5. Acknowledgement

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6. References


