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Influence of resin content on the surface covered with adhesive

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ABSTRACT

It is well known that the resin content within a particleboard influences the extent of the surface covered with adhesive and thus the properties of particleboards produced. The purpose of this research was to determine how the resin content and particle size class influence the surface of particle covered with the adhesive. For that purpose, wood particles used for particleboard production were used. Particles were blended with a UF adhesive with 0.05% of fluorescent dye added prior to blending and subsequently exposed to a resin curing temperature of 180°C. The resin content was varied between 7.5 and 12.5%. The adhesive surface coverage was determined using a microscope with a fluorescent light source and a CCD camera. The results showed that the surface coverage increased with increasing resin content and increasing wood particle size.

Key words: resin content, surface covered with adhesive, particle surface

1 INTRODUCTION

In order to attain good bonding quality between the constituents of a particleboard and, with that, panels with good properties, a few conditions must be fulfilled. First, the surface of the wood particles should be smooth and clean to enable wetting and spreading of adhesive to allow sufficient coverage of the particle surface. When considering particleboards and with that bond(s) between particles, this is easier said than done. Due to mechanical processing, the particle surface can become damaged and crushed, resulting in a potentially rough and inactive surface.

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Another important factor influencing bond quality is resin efficiency, which Burrows (1960) defined as the least amount of resin that enables the production of panels with optimum properties.

Lehman (1970), as well as Christensen and Robitschek (1974), presented correlations between the internal bond strength of particleboards towards the resin droplet size employed during the manufacturing process. They determined that by decreasing the droplet size, internal bond strength increases. Lehman (1970) also mentioned that there are two limits in relation to resin droplet size that needs to be considered, specifically if the droplet is too small or too big to become efficient.

Duncan (1974) determined that the adhesive is uniformly spread across particle surface, irrespective of the particle size. He determined that bigger particles with lower specific surface areas could receive more adhesive than smaller particles. Hill and Wilson (1978) determined differently, specifically that smaller particles could receive, due to their higher specific surface area, more adhesive than particles with smaller specific surface areas. Dunky (1988) researched the influence of particle size on the degree of blending. He determined that the adhesive is not uniformly spread between different fractions of particles, but that more adhesive remains on bigger particles. Such an influence could be the outcome of the adhesive drop size that is, according to the author, bigger than the surface of finer particles. Scott (2001) researched the blending of fibres where the UF adhesive employed was dyed with a fluorescent dye. He determined that board properties depend on the amount of adhesive added. Furthermore, he stated that the dyeing method can be used in production processes as well.

Resin distribution on strands was evaluated by Dai et al. (2007). The authors determined that an increase in resin content leads to an increase in resin coverage area.

Blending is, according to Lampert (2014), a process, where the landing of individual or multiple resin droplets on particles is random. Also, the location of droplet(s) landing on particle surfaces is random.

The aim of the paper is to present the differences in surfaces covered with adhesive in relation towards wood particle size class and resin content (amount of resin applied on particles).

2 MATERIALS AND METHODS

Wood particles used in this research were collected after undergoing a drying process (before screening), from local industry. Regarding the wood species present in the particles, 75% was softwood and 25% hardwood. Prior to blending, wood particles were dried at 70°C for 16 hours which was sufficient to generate moisture contents below 2%. For blending, a urea-formaldehyde adhesive was used, the properties of which are presented in Table 1.

Table 1: Properties of the UF adhesive used

Density	1.280 g/cm^3
Solid content	65%
pH value	8.15
Gel time	60 sec.
Viscosity	486 mPa·s

Since cured UF adhesives are colourless, it is hard to determine whether a surface has been covered with it. For this purpose wood, resin, or both must be dyed. In our research, 0.05% of a fluorescent dye – Rhodamine B, was added to the adhesive for better determination of surface covered with adhesive. The blending of particles (3.5 kg) was carried out in a laboratory blender. Resin content was varied between 7.5 and 12.5% (Table 2).

Table 2: Resin content

	Resin content in %
A	7.50
B	8.75
C	10.00
D	11.25
E	12.50

Blended particles were then placed into an oven for four minutes at a temperature of 180°C, which simulated the conditions frequently employed during pressing procedures.

Subsequently, blended particles were cooled to room temperature and separated into 8 different size classes (Table 3).

Table 3: Size classes of particles regarding sieve opening

Size class	**Sieve opening in mm**
SC1	0.237
SC2	0.600
SC3	1.000
SC4	1.270
SC5	1.500
SC6	2.000
SC7	4.000
SC8	6.140

The surface and share of adhesive on particle surfaces were determined (for individual size classes) by image analysis. The image was obtained using a microscope with a fluorescent light source on which the CCD camera was attached (Figure 1).

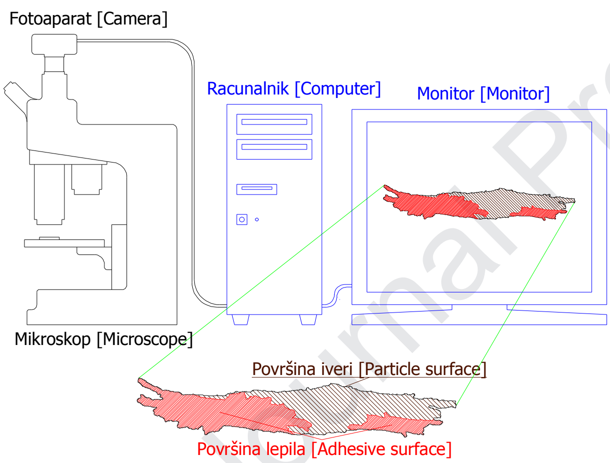


Figure 1: Microscope and CCD camera for image scoping and schematic layout of particle (black outline) and adhesive (red outline) surface determination

The surface covered with adhesive (SCA%) was determined by the ratio between the surface of adhesive and the particle surface as shown in the following equation 1:

$$SCA\% = \frac{A_L}{A_P} \times 100 \tag{1}$$

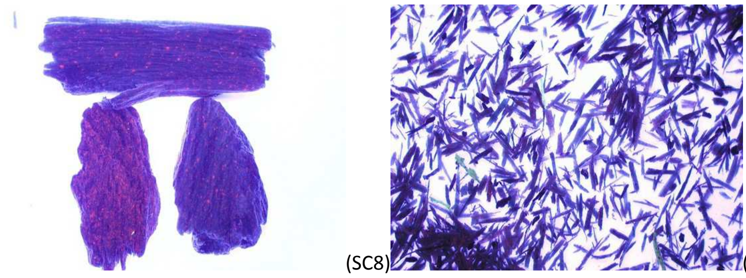
where:

A_L surface of adhesive in mm^2

A_P surface of particle in mm^2

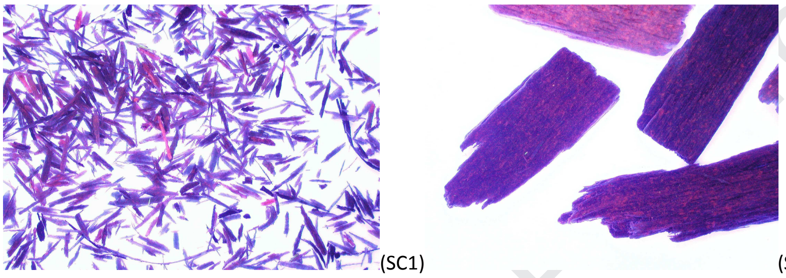
3 RESULTS AND DISCUSION

The fluorescent microscopy and dyeing of resin with Rhodamine (also proposed by Loxton et al., 2003) prior to blending is an efficient way for analysing the surface covered with resin (Figure 2 and 3).



(SC8) (SC1)

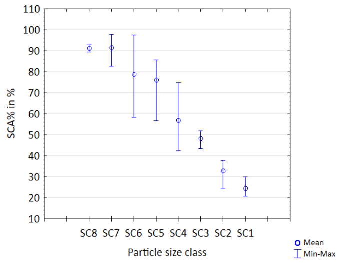
Figure 2: Particles SC1 and SC8 at 7.5% resin content (photo: Grudnik)



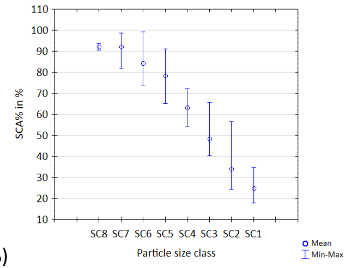
(SC1) (SC8)

Figure 3: Particles SC1 and SC8 at 12.5% resin content (photo: Grudnik)

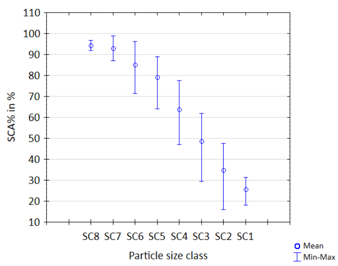
The surfaces of particles covered with adhesive depend on the size of the particles (Figure 4) as well as on resin content (Figure 7).



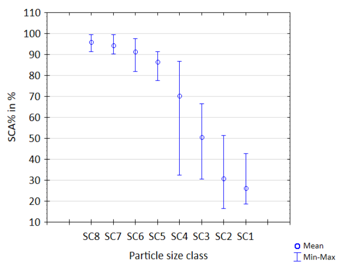
(7.5%)



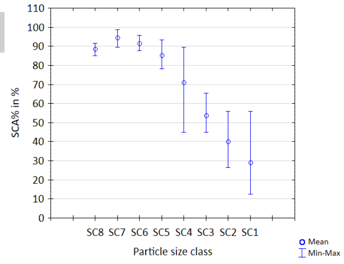
(8.75%)



(10%)



(11.25%)



(12.5%)

Figure 4: Surface covered with adhesive regarding the particle size class (with marking in brackets representing the resin content)

Looking at the values, it can be seen that an increase in particle size also leads to a higher SCA%, but it also needs to be underlined that the differences in SCA% between SC7 and SC8 are mostly low, and can even be said that the differences are not statistically significant (T-test, at α=0.05). Such low differences occurred at 7.5% resin content (p-value=0.9528), 8.75% (p-value=0.7471) 10% (p-value=0.4555) and 11.25% (p-value=0.3256). Additionally, statistically insignificant differences were determined also at SC5:SC6 (7.5% resin content), SC6:SC8 (at 8.75% resin content), between SC6:SC8, SC6:SC7 and SC1:SC2 (at 11.25% resin content) and between SC6:SC8 and SC5:SC8 (at 12.5% resin content). The relation between particle size and coverage of particles with resin have been discussed by Meinecke in Klauditz (1962), Duncan (1974), Dunky (1988) Scott (2001). They all determined that more adhesive remains on bigger particles, with smaller specific surface area. The difference in specific surface area or total area of particles that can be covered with adhesive is relatively high when comparing particles surface area. According to Medved (2004) specific surface area of particles SC1 (fraction 0.237) could be between 4 and 6 m^2/100 g of particles, while SC5 (fraction 1.5) would have a specific surface area between 1 and 1.5 m^2/100 g of particles and SC8 (fraction 6.4) only 0.3 to 0.6 m^2/100 g of particles. What also needs to be considered is the share of individual fraction in composition of constituents. In the presented research, most wood particles were SC5 and SC6 (Figure 4).

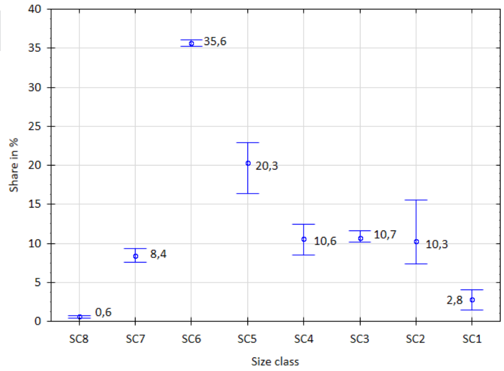


Figure 5: Sieve analysis of blended particles

Since the share of bigger particles (SC5 and higher) is more than 60%, it is understandable that SCA%, too, is higher compared to smaller particles, but when comparing the share of particle SC8 (fraction 6.14) in comparison to SC7 or SC6 we can see that the size of particles is, regarding SCA%, more important than its share in particle mixture. Although the share of SC8 is only 0.6%, the SCA% is high, i.e. between 88% and 98%.

There are several possible reasons for a higher SCA% with bigger particles (SCA5% and higher):

- As already mentioned, a higher share of bigger particles;
- More resin droplets are hitting bigger particles: one of the reasons for such a conclusion is related to the larger surface area of the bigger particles, as was also determined my Dunky (1988). Resin is sprayed through a nozzle creating a resin mist, and when fine particles pass through this mist less resin droplets hit the fine particles, compared to the number of resin droplets that hit bigger particles (figure 6);
- During blending, two operations are conducted side by side, specifically spraying of resin and mixing. Although the speed of rotation is low, it can still be assumed that due to mass, bigger particles are more inclined to exist on the outer layer of the mixer, while smaller particles are more in the middle (close to axis). And if coarser particles are on the outer layer of the machine it also means that they are closer to the source of the resin droplet (spraying nozzle), hence supporting the idea that more resin droplets are on the coarser particles.
- In addition to the aforementioned, the spreading of resin across the surface, also needs to be considered. When small amounts of resin droplets hit particle surfaces, the distance between individual droplets could be relatively large

preventing merging of droplets, hence enlarging the surface covered with adhesive, which is a possible scenario with bigger particles where a large number of droplets merge together, forming a larger, almost continuous resin film, on the surface.

- During the mixing operation, particles get in contact with one another, hence creating the possibility that part of the resin transfers from one to another, which enables the creation of a larger surface covered with resin. Although such a transfer is possible between all particles, coarser particles again have an advantage, hence higher SCA%.

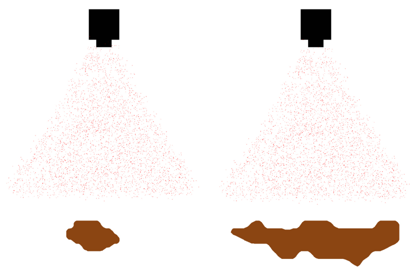
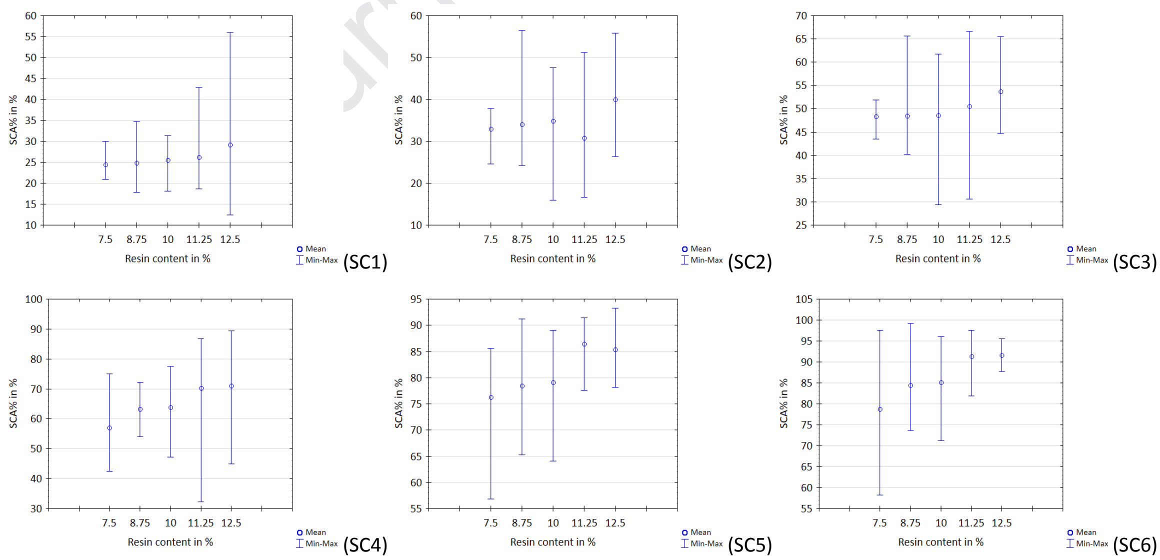


Figure 6: Schematic layout of small and big particles during blending

The SCA% value, within one size class, depends also on the resin content (Figure 7).



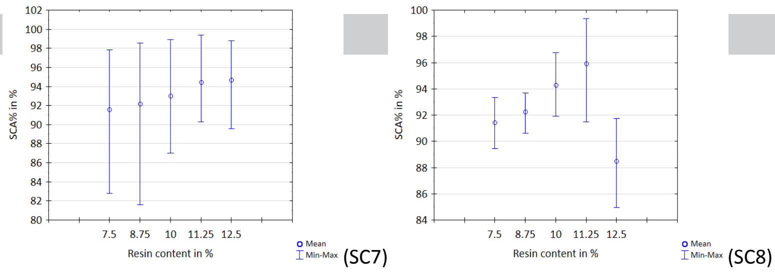


Figure 7: Surface covered with adhesive regarding resin content (the marking in bracket represents the wood particle size class)

The increase in resin content results in the SCA% increase, although the differences in SCA% in relation to resin content are relatively small. The differences between minimum and maximum average values is 4.19% at SC7 to 13.86% at SC4.

When considering the SCA% of particles used for the core layer (SCA5 to SCA8), there is a decrease in SCA% at the highest resin content (12.5%) compared to SCA% at 11.25% resin content, which was most evident with the biggest particles (SC8). This behaviour could be the result of higher penetration of resin into particles. Due to the already wetted surface (with the bigger particles), the penetration of adhesive is easier, hence reduced spreading of resin and a lower SCA%.

4 CONCLUSIONS

The presented results show that it is possible to determine the surface covered with adhesive by using a dying technique (addition of dye into resin).

Surface coverage with resin depends on:

- Wood particle size class: an increase in wood particle size class results in an increase of the surface covered with adhesive (SCA%);
- Resin content: the highest surface covered with resin (SCA%) was determined at the highest resin content.

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