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Particle size dependent properties of three-layer particleboards with the core layer made from willow (*Salix viminalis*)

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Abstract: *Particle size dependent properties of three-layer particleboards with the core layer made from willow (Salix viminalis)*. Three-layer experimental particleboards were prepared using basket willow (*Salix viminalis*) particles for the core layer and industrial pine particles for the face layers. The effect of willow particle size (1-2.4, 2.4-4, and >4 mm) on modulus of elasticity (MOE), modulus of rupture (MOR), internal bond (IB), and thickness swelling (TS) was investigated. The medium particles (2.4-4 mm) provided better particleboard properties than the small (1-2.4 mm) and large (>4 mm) ones. For comparison, the properties of particleboards with the core layer made from pine particles of the same sizes were studied. Both MOE and MOR of particleboards with the core layer from willow and pine particles differed slightly, whereas IB of particleboards with the willow core layer was smaller and TS was greater than those with the pine core layer.

Keywords: particleboard, willow, particle size, mechanical properties, physical property

INTRODUCTION

Particleboard is one of the most important wood composites. Systematic growth of particleboard industry in many countries, including Poland, and limited wood resources make it necessary to use other alternative lignocellulosic materials in particleboard manufacturing. These alternative materials are usually weaker material than wood, therefore it is recommended to use them for production the core layer of three-layer particleboards. In recent years many investigations have been made on partial or total replacement of wood in the core layer of the particleboards with waste lignocellulosic agricultural products, such as kenaf stalks (Grigoriou et al. 2000, Kalaycioglu and Nemli 2006), castor stalks (Grigoriou et al. 2001), oat hulls (Czarnecki et al. 2001), vine prunings (Ntalos and Grigoriou 2002), kiwi prunings (Nemli et al. 2003), cotton stalks (Guler and Ozen 2004), rape straw (Frąckowiak 2004, 2007, Frąckowiak et al. 2008), cotton carpel (Alma et al. 2005), sunflower stalks (Guler et al. 2006), needle litter (Nemli and Aydin 2007), eggplant stalks (Guntenkin and Karakus 2008), peanut hulls (Guler et al. 2008), evening primrose straw (Czarnecki et al. 2009, Dukarska et al. 2010) and grass plant (Kurowska and Borysiuk 2009).

Other raw material to be used for production the core layer of particleboards can be fast growing bushes. Such a bush being cultivated in Poland for energetic purposes is basket willow. Its usefulness for production of particleboards was proved by the studies of Frąckowiak (2007) and Frąckowiak et al. (2008). Considering the needs of the Polish particleboard industry, it is recommended to continue investigations into the properties of particleboard made using basket willow particles.

The main aim of this study was to assess the effect of particle size in the core layer on some properties of three-layer experimental particleboard with the core layer made from basket willow.

MATERIALS AND METHODS

The raw material for the core layer was obtained from a basket willow plantation in Mieścisko (Poland). Three-year willow stems were stored for air-drying to a moisture content of about 12%, then chipped in a hammer-mill and screened by an analytical sieve shaker using the sieves of 5, 8 and 18 mesh to obtain three particle sizes: 1-2.4, 2.4-4 and >4 mm. The raw material for the face layers was industrial fine particles made from pine wood, supplied by Pfleiderer Prospan Wieruszów (Poland). All the particles were dried to achieve a moisture content of less than 3%. Urea formaldehyde resin was used as a binder and no hydrophobic agent was added. The resin content was 8 and 10% for the core and face layers, respectively. The ratio of the thickness of the face layers to the thickness of the board was 0.4, the target board density was 0.70 g/cm^3 and the thickness was 16 mm. The pressing conditions were: temperature of 180 ^{o}C, maximum pressure of 2.5 MPa and pressing time of 4 min. Four experimental boards were manufactured for each size of particles in the core layer.

For comparison, three-layer particleboards with the core layer made from industrial pine particles supplied by Pfleiderer Prospan Wieruszów were prepared. Particle sizes, board construction and pressing conditions were the same as for the particleboard with the willow core layer.

Prior to testing all the boards were stored in controlled conditions (50% relative humidity and 20 ^{o}C) for two weeks. The following properties of produced particleboards were determined according to EN standards: modulus of elasticity (MOE) and modulus of rupture (MOR) according to EN 310: 1994, internal bond (IB) according to EN 319: 1999, and thickness swelling (TS) after 24 h according to EN 317: 1999. Test specimens for IB and TS were prepared from the specimens that were formerly tested for MOE and MOR. Twenty replicates were run for each test.

RESULTS

Results of the tests are given in Figs 1-4. Error bars represented ±standard deviation based on twenty specimens. Mechanical properties in bending of tested particleboards (Figs 1 and 2) with the core layer made from particles of size of 2.4-4 mm are slightly better than those with the core layer made from particles of sizes of 1-2.4 and >4 mm. This relation concerns both particleboards with the willow and pine core layer. MOE of particleboards with 2.4-4 mm particles is on the average by 4.5% and 5.9% higher than MOE of particleboards with 1-2.4 and >4 mm particles, respectively. Similarly, MOR of particleboards with 2.4-4 mm particles is on the average by 3.1% and 7.6% higher than MOR of particleboards with 1-2.4 and >4 mm particles, respectively. IB of particleboards (Fig. 3) with 2.4-4 mm particles in the core layer is markedly, on the average by 22.5% and 16.4%, higher than that of particleboards with 1-2.4 and >4 mm particles, respectively. TS of particleboards (Fig. 4) with the core layer from willow particles of 1-2.4 and 2.4-4 mm is almost the same, and is on average by 15.0% higher for particleboards with willow particles of >4 mm. TS of particleboards with the core layer from pine particles increases gradually when particle size increases from 1-2.4 to >4 mm, and for particleboards with >4 mm particles it is by 17.0% higher than that for particleboards with 1-2.4 mm particles.

Mechanical properties of particleboards with the core layer from willow are worse than those of particleboards with the core layer from pine (Figs 1-3). MOE is on the average by 5.6%, MOR by 3.3% and IB by 15.0% smaller. The substitution of willow particles for pine ones in the core layer therefore results in relative small reduction in particleboard mechanical properties, especially in reduction in MOE and MOR. One should note that mechanical properties of particleboard with the core layer from willow particles of size of

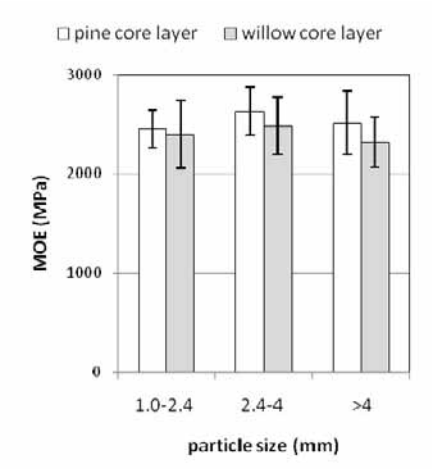

Fig. 1. Modulus of elasticity of particleboards with the core layer made from particles of different sizes

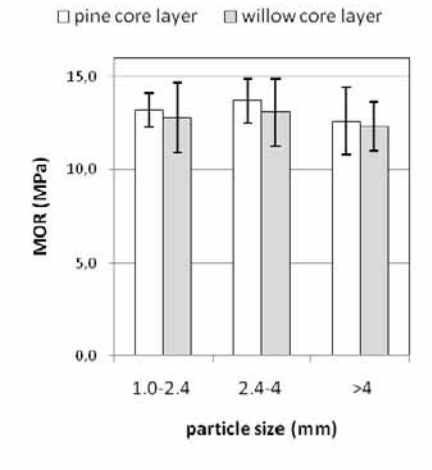

Fig. 2. Modulus of rupture of particleboards with the core layer made from particles of different sizes

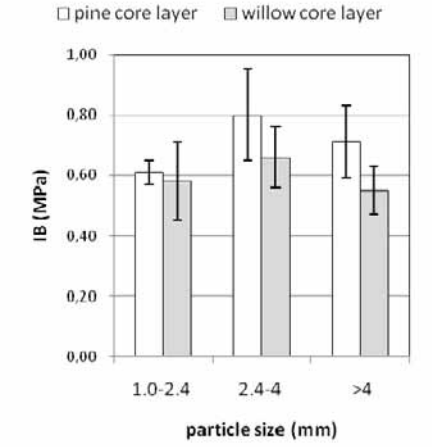

Fig. 3. Internal bond of particleboards with the core layer made from particles of different sizes

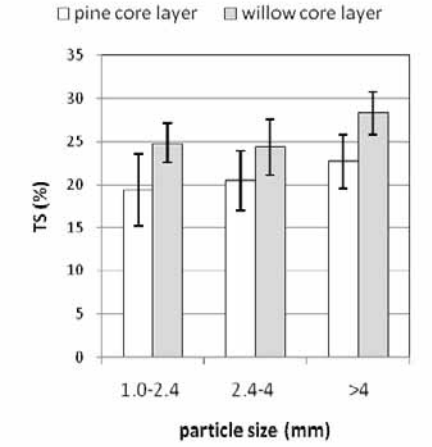

Fig.4. Thickness swelling after 24 h of particleboards with the core layer made from particles of different sizes

2.4-4 mm meet the requirements of the EN 312 standard for the particleboard of type P2 (MOE ≥ 1600 MPa, MOR ≥ 13 MPa, IB ≥ 0.35 MPa). TS of particleboards with the core layer from willow is higher, on the average by 23.8%, than that of particleboards with this layer from pine.

CONCLUSIONS

Properties of three-layer particleboards with the core layer made from basket willow particles depend on the size of particles. The particles of 2.4-4 mm provide better properties (MOE, MOR, IB and TS) than the particles of 1-2.4 and > 4 mm. Compared with three-layer particleboards with the core layer made from industrial pine particles, the properties of particleboards with this layer from willow particles are slightly smaller, but mechanical properties of particleboards with the core layer from willow particles of 2.4-4 mm meet the requirements of the EN 312 standard for the particleboard of type P2.

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Streszczenie: *Właściwości trzywarstwowych płyt wiórowych z warstwą wewnętrzną wykonaną z wiórów wierzby Salix viminalis. Wpływ wielkości wiórów.* Wykonano trzywarstwowe płyty wiórowe stosując wióry wierzby wiciowej (*Salix viminalis*) na warstwę wewnętrzną i przemysłowe wióry sosnowe na warstwy zewnętrzne. Badano wpływ wielkości wiórów wierzbowych (1-2.4, 2.4-4 i > 4 mm) na moduł sprężystości (MOE), wytrzymałość na zginanie (MOR), wytrzymałość na rozciąganie poprzeczne (IB) i spęcznienie na grubość (TS). Średnie wióry (2.4-4 mm) zapewniały lepsze właściwości płyty niż małe (1-2.4 mm) i duże (> 4 mm). Dla porównania badano właściwości płyt z warstwą wewnętrzną wykonaną z wiórów sosnowych o tych samych wielkościach. Zarówno MOE, jak i MOR płyt wiórowych z warstwą wewnętrzną z wiórów wierzbowych i sosnowych różniły się nieznacznie, natomiast IB płyt z warstwą wewnętrzną z wierzby była mniejsza a TS większe niż płyt z warstwą wewnętrzną z sosny.

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