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Effects of density and resin content on mechanical properties of particleboards with the core layer made from willow *Salix viminalis*

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Abstract: *Effects of density and resin content on mechanical properties of particleboards with the core layer made from willow Salix viminalis.* Three-layer experimental particleboards were prepared using willow *Salix viminalis* particles for the core layer and industrial pine particles for the face layers. The board density at three levels (0.60, 0.63 and 0.66 gcm^{-3}) and resin content in the core layer (6.5, 8.0 and 9.5 %) were variable parameters. The modulus of elasticity (MOE), modulus of rupture (MOR) and internal bond (IB) of particleboards were investigated. These properties increased with increasing board density and resin content according to quadratic functions.

Keywords: particleboard, willow, mechanical properties, density, resin content

INTRODUCTION

Fast growing shrubs of willow *Salix viminalis*, cultivated in Poland for energy purposes, can be one of the possible alternative raw materials in particleboard manufacturing (Frąckowiak et al. 2008, Wilczyński et al. 2011, Warmbier et al. 2013). Previous studies on the properties of particleboards made using willow *Salix viminalis* were related mainly to the impact of willow content in particleboard (Sean et al. 2005, Frąckowiak et al. 2008, Wilczyński et al. 2011, Warmbier et al. 2013). The objective of this study was to evaluate the effects of particleboard density and resin content in the core layer on the mechanical properties of particleboards with the core layer made from willow *Salix viminalis*.

MATERIALS AND METHODS

The raw material for the core layer was obtained from a 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. To obtain particles for the core layer of experimental particleboards, particles from the hammer-mill were screened and those which passed through the sieve of 5 mesh (4 mm) and remained on the sieve of 18 mesh (1 mm) were used. 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. The resin content of 10 % for the face layers was assumed. The ratio of the thickness of the face layers to the thickness of the board was 0.35 and the thickness was 16 mm. The pressing conditions were as follows: temperature of 180 ^{o}C, maximum pressure of 2.5 MPa, and pressing time of 4 min. Two factors were taken into account: particleboard density (0.60, 0.63 and 0.66 gcm^{-3}) and resin content in the core layer (6.5, 8.0 and 9.5 %). Four experimental boards were manufactured for each type of boards.

Prior to testing all 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, and internal bond (IB) according to EN 319: 1999. Twenty replicates were run for each test.

RESULTS

The analysis of variance showed that all the mechanical properties of tested particleboards vary significantly with the board density and resin content in the core layer. Based on the experimental data, the nonlinear regression equations for MOE, MOR and IB were obtained as follows:

$$\text{MOE} = -26.33 - 0.692x + 91.22y + 0.0081x^2 + 1.056xy - 74.07y^2, \quad R^2 = 0.949 \quad (1)$$
$$\text{MOR} = -207.83 + 0.694x + 627.78y + 0.0444x^2 - 1.667xy - 444.44y^2, \quad R^2 = 0.979 \quad (2)$$
$$\text{IB} = -4.334 - 0.198x + 16.83y + 0.0126x^2 + 0.0556xy - 12.96y^2, \quad R^2 = 0.922 \quad (3)$$

where x is the resin content in the core layer (%), y is the board density (gcm^{-3}) and R is the regression coefficient.

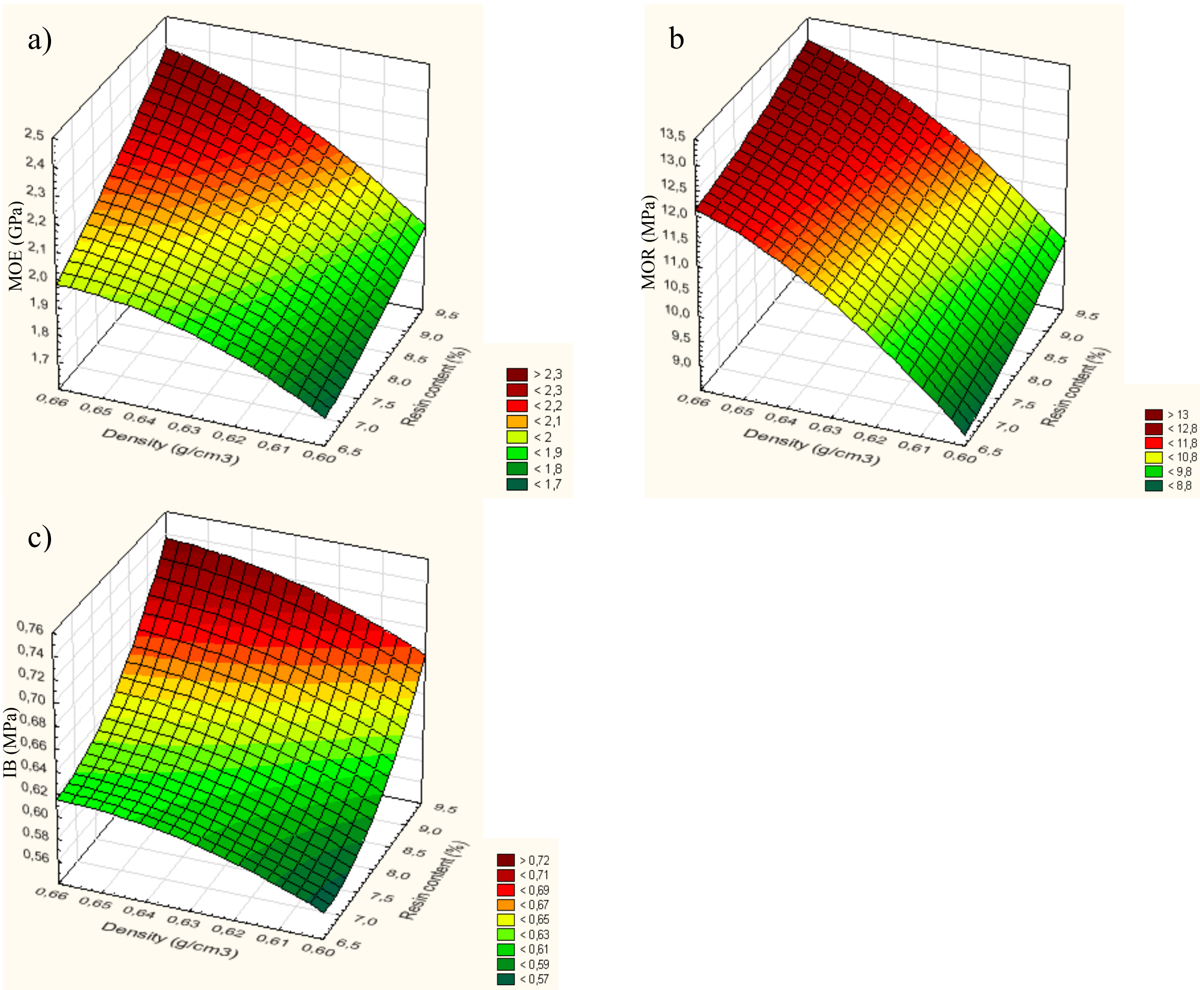

Fig. 1 Mechanical properties of particleboards as functions of board density and resin content in the core layer: a) modulus of elasticity, b) modulus of rupture, c) internal bond

Figure 1 shows the effects of board density and resin content in the core layer on the mechanical properties of particleboards as described by Equations (1) – (3). MOE, MOR and IB increased with increasing board density and resin content in the core layer. The increases in MOE, MOR and IB with increasing board density from 0.60 to 0.66 gcm^{-3} were on average 21, 35 and 9 %, respectively. The increases in MOE, MOR and IB with increasing resin content from 6.5 to 9.5 % were on average 16, 10 and 20 %, respectively. Thus, increasing board density most affected MOR whereas increasing resin content most affected IB. These results were due to the fact that an increase in resin content caused a more uniform coating of particle surface by adhesive, and also that an increase in board density resulted in an increase in the surface of particles due to increasing a wood compression (Rackwitz 1963). Similar effects of resin content and/or board density on the mechanical properties of particleboards were reported in other studies (Dziurka et al. 2005, Kalaycioglu et al. 2005, Ashori and Nourbakhsh 2008, Lin et al. 2008, Kowaluk 2009, Czechowska et al. 2010, Arabi et al. 2011, Kowaluk et al. 2011, Wilczyński et al. 2011, Eslah et al. 2012, Warmbier et al. 2013).

Using Equations (1) – (3), MOE, MOR and IB of three-layer particleboards with the core layer from willow can be predicted on the basis of the target board density and resin content in the core layer.

CONCLUSION

Mechanical properties of three-layer particleboards with the core layer made from willow *Salix viminalis* depend significantly on particleboard density and resin content in the core layer. MOE, MOR and IB increase with increasing density and resin content in a quadratic fashion. Increasing board density from 0.60 to 0.66 gcm^{-3} most affects MOR and increasing resin content from 6.5 to 9.5 % most affects IB.

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Streszczenie: *Wpływ gęstości i stopnia zaklejenia na właściwości płyt wiórowych z warstwą wewnętrzną z wierzby Salix viminalis.* Wykonano trzywarstwowe płyty wiórowe stosując wióry wierzby *Salix viminalis* na warstwę wewnętrzną i przemysłowe wióry sosnowe na warstwy zewnętrzne. Parametrami zmiennymi były: gęstość płyty (0.60, 0.63 i 0.66 gcm^{-3}) i stopień zaklejenia warstwy wewnętrznej (6.5, 8.0 i 9.5 %). Badano moduł sprężystości (MOE), wytrzymałość na zginanie (MOR) i wytrzymałość na rozciąganie poprzeczne. (IB) Właściwości te wzrastały ze wzrostem gęstości płyt i stopnia zaklejenia zgodnie z funkcjami kwadratowymi.

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