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Veneer Densification as a Tool for Shortening of Plywood Pressing Time

Stlačivanje furnira kao metoda skraćenja vremena prešanja furnirskih ploča

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ABSTRACT • *Veneer densification was performed at 105±3 ºC under pressure of 1,8 N/mm² for 30 s. The approach allowed to reduce 20-mm thick plywood pressing time by 12-25 % when compared to the non-densified controls. It was found that densification did not affect shear strength of the plywood which met the requirements of the respective standards.*

Key words: *plywood, veneer densification, pressing time, shear strengths*

SAŽETAK • *Stlačivanje furnira provedeno je pri temperaturi 105±3 ºC i tlaku 1.8 N/mm² tijekom 30 s. Na taj je način omogućeno skraćenje vremena prešanja furnirske ploče debljine 20 mm za 12-25 % u usporedbi s kontrolnim uzorcima od nestlačenih furnira. Istraživanje je pokazalo da stlačivanje furnira ne utječe na čvrstoću smicanja furnirske ploče koja zadovoljava zahtjeve odgovarajućih normi.*

Ključne riječi: *furnirska ploča, stlačivanje furnira, vrijeme prešanja, čvrstoća smicanja*

1 INTRODUCTION
1. UVOD

The pressing time is a crucial parameter of plywood processing, since it strongly affects total number of cycles during a single shift and, in consequence, the total capacity of a production line. On one hand, in order to maximize the efficacy of the process, pressing time should be as short as possible. On the other hand, it should be long enough to allow the adhesive to be cured.

Wood, as a porous body, is good insulator and therefore weak heat conductor (heat conductivity coefficient ranges from 0.12 up to 0.35 W/mK). Heat conductivity of wood is dependent mainly on the species, density, grain direction, moisture content and temperature. Dependence of heat conductivity and density of wood is practically linear (Kollmann, 1955). Increase of density causes proportional gain of wood heat transfer. Heat conductivity along the wood grain is around 2 times higher than in perpendicular direction.

Low cross the grain heat conductivity is especially visible during overheating veneer loads for thick board production. As a result, long heating (pre-pressing) times and in effect long total pressing times are needed for proper plywood production.

As it is reported in literature, the shortening of plywood pressing time can be realized by steam injection (Jokerst and Geimer, 1994) or by combining steam injection and veneer incising. Veneer incising followed by steam injection provided reduction of pressing time by 27% for 21-mm thick 7-ply plywood and by 32%

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for 40-mm thick 13-ply LVL when compared to standard technology (Troughton and Lum, 2000). Dai et al (2003) stated that veneer incisions in 13-ply LVL manufacturing did not significantly affect either pressing times or mechanical performance of the product.

Other approach to shortening of the overheating time and total pressing time is preliminary veneer densification. Bekhta and Marutzky (2007) stated that veneer densification increases the possibilities of design and control of physical and mechanical properties of the material. Densified beech veneers allow production of plywood with better shear strength properties with lowered glue consumption by 25 % and with pressure limited by 22 %. Densification process includes veneer pre-pressing by 33 % and final manufactured plywood by 0.1 %. Plywood properties are mainly dependent on the stage of the technological process and conditions in which the source material undergoes densification process (Bekhta and Marutzky, 2007; Bekhta *et al*, 2009). In contemporary plywood technologies this processing is not used at all.

The objective of the study was to investigate the possibility of shortening the overheating time and total pressing time of plywood by preliminary veneer densification.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

Pine (*Pinus sylvestris*) veneers of dimensions 350 x 350 x 1.4 mm^3 and 4 % moisture content were used in the experiments. The densification was performed at 105±3 ºC in a laboratory press under pressure of 1.2, 1.5 or 1.8 N/mm^2 for 15 or 30 s. The most effective plasticization of wood, densification and retention of the reduced thickness was obtained at 1.8 N/mm^2 pressure and 30 s pressing time. 20-mm thick, 15-ply plywood was made using densified or non-densified veneers. A urea-formaldehyde adhesive (UF - 100 p. b.w., filler - 16 p.b.w., hardener – 16 p.b.w., water – 23 p.b.w.) was used for bonding. Gelling time was measured according to the following procedure: a glass test tube with 10 g of glue was immersed in boiling water. The glue was mixed with a glass stick until gelation occurred. Measurement was made in triplicate.

Total pressing time (t_p) was calculated from the relation (1):

$$t_p = t_g + t_0 \quad (1)$$

where: t_g - gelling time at a given temperature, t_o - time of heating the most internal glueline (stack core) to a given temperature. Three temperatures were examined: 80 ºC, 90 ºC and 100 ºC.

Plywood with glue loads 160 g/m^2 and 120 g/m^2 were pressed under pressure of 1.2 N/mm^2 and at 130±2 ºC. Plywood variants and results are tabulated in Table 2.

For the plywood prepared at the shortest pressing times, the shear strength of the glue lines and wood failure percentage were determined according to EN 314-1 and EN 314-2. Twenty specimens were tested in each batch. Both the veneers prior to densification and resultant plywood were conditioned at 20±2 ºC and 65±5 % relative humidity for 7 days.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

The applied densification conditions allowed for sufficient plasticizing of the veneers and retention of their reduced thickness. Due to the process, the initial 1.45-1.55-mm thickness of the veneers (4 % moisture content) was reduced to 1.35-1.40 mm (2 % moisture content). The average densification ratio was 8 %. Gelation time (t_g) of the glue is presented in Table 1.

Veneer densification clearly reduces overheating time in comparison to unprocessed samples (Fig. 1). The shortest heating time was obtained with 120 g/m^2 glue load variant. This phenomenon is caused by lower total moisture content in the veneer stack. Furthermore, faster stack internal temperature gain is caused by more dense wood substance.

Data presented in Table 2 clearly show that 20 mm plywood made of densified veneers had 24-54 % shorter overheating time (t_o) in comparison to control sample (heating up to 100 °C). Again, taking into account glue gelation times (t_g), it was concluded that veneer densification shortened total pressing time (t_p) by 12-25 % in

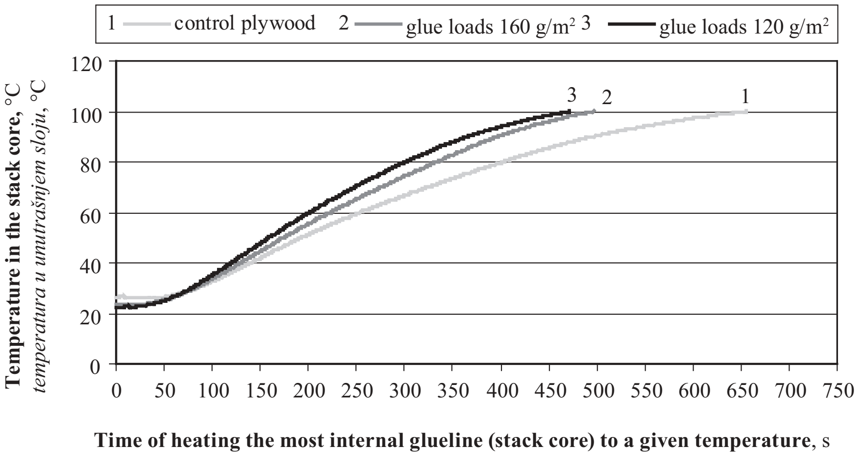

Figure 1 Overheating times determined for 20 mm plywood made of densified pine veneers
Slika 1. Vrijeme zagrijavanja furnirske ploče debljine 20 mm izrađene od stlačenih furnira

Table 1 Glue gelation time of urea-formaldehyde adhesive at different temperatures
Tablica 1. Vrijeme stvrdnjavanja urea-formaldehidnog ljepila pri različitim temperaturama

Stack core temperature, °C *Temperatura u središtu,* °C	**Gelation time** (t_g), s *Vrijeme stvrdnjavanja,* s
80	315
90	186
100	80

comparison to control samples (total pressing time is a sum of gelation and overheating times).

It was found that (Table 3) modification of veneers by densification showed no significant effect on plywood shear strength in dry and wet state. Wood shear percentage ranged from 60 up to 100 % for dry samples, and after soaking in water it dropped to 30 – 60 %. The percentage of shear in wood in dry state is significantly higher for plywood made of densified veneers than in control samples (ranging between 60 and 70 %). Strength properties characterized by lower glue bonds (in dry and wet state) of plywood made of densified veneers are caused by lower glue saturation possibilities in modified veneers. This result confirms literature results. Pocius (2002) concludes that one of the conditions of good glue bond formation is solubility of glue in the base (or intrinsic wettability) and surface development, substantially lower in densified veneers. The shear strength values as well as the percentage of wood failure met the requirements of the EN 314-2 standard. Basing on the obtained results it may be concluded that veneer densification may allow glue load reduction without negative impact on the bond strength properties. This is also confirmed by other researchers (Bekhta and Marutzky, 2007).

4 CONCLUSIONS
4. ZAKLJUČCI

This paper deals with the approach to shortening of the total possible plywood pressing time with veneer densification. The obtained results show overheating time shortening possibilities, and thus final total pressing time shortening of the 20 mm pine plywood with strength properties conforming to PN-EN 314-2:2001 standard.

The shortest total pressing time of densified veneer plywood reached 551s (variant with 120 g/m^2 glue load). Veneer densification allows shortening of overheating time by 24-54 % and pressing time by 12-25 %, at 80-100 °C while upkeeping internal stack temperature.

Densified veneers, except 25 % pressing time shortening, allow 25 % glue load reduction without affecting glue bonds strength properties.

Table 2 Pressing conditions and reduction of pressing time
Tablica 2. Uvjeti prešanja i smanjenje vremena prešanja

Variant *Varijanta*	**Glue loads** *Količina ljepila* g/m^2	**Stack core temperature** *Temperatura u središnjem sloju* °C	**Overheating time** (t_o) *Vrijeme zagrijavanja* s	**Shortening of lay up overheating time** *Skraćenje vremena zagrijavanja* %	**Pressing time** (t_g+t_o) *Vrijeme prešanja* s	**Shortening of pressing time** *Skraćenje vremena prešanja* %
control plywood *kontrolni uzorak furnirske ploče*	160	100	656	0	736	0
plywood from densified veneers *furnirska ploča od stlačenih furnira*	160	100	497	24	577	22
		90	396	40	582	21
		80	333	49	648	12
	120	100	472	28	552	25
		90	365	44	551	25
		80	301	54	616	16

Table 3 Shear strengths and wood failure percentage of plywood pressed at the shortest pressing times (values in parentheses are standard deviations)
Tablica 3. Čvrstoća smicanja i postotak loma po drvu furnirske ploče prešane pri najkraćem vremenu (vrijednosti u zagradama standarne su devijacije)

Variant *Varijanta*	**Glue loads** *Količina ljepila* g/m^2	**Glue line number** *Linija ljepila*	**Dry shear strength** *Suha smicajna čvrstoća* N/mm^2	**Percentage of wood failure** *Postotak loma po drvu* %	**Wet shear strength** *Vlažna smicajna čvrstoća* N/mm^2	**Percentage of wood failure** *Postotak loma po drvu* %
control plywood *kontrolna furnirska ploča*	160	1	3.44 (0.27)	60	2.73 (0.18)	40
		7	3.59 (0.50)	70	2.81 (0.30)	50
plywood from densified veneers *furnirska ploča od stlačenih furnira*	160	1	2.69 (0.19)	60	2.01 (0.19)	40
		7	3.11 (0.39)	70	1.92 (0.15)	30
	120	1	2.59 (0.31)	90	1.88 (0.20)	30
		7	3.63 (0.35)	100	2.52 (0.19)	60

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