

Granulometric analysis and separation options of dry sawdust exhausted from narrow-kerf frame sawing machines

Granulometrijska analiza suhe piljevine odsisane s uskolisnih pila jarmača i izbor odvajajača čestica

Original scientific paper • Izvorni znanstveni rad

Prispjelo - received: 16. 5. 2005. • Prihvaćeno - accepted: 5. 12. 2005.

UDK 630*822.04; 674.823

ABSTRACT • This paper presents granulometric analyses of dry pine sawdust produced by narrow-kerf frame sawing machine, type PRW-15, in the process of longitudinal sawing of wood, and dry spruce sawdust produced by narrow-kerf frame sawing machine, type CLASIC 150/200, in the process of longitudinal re-sawing of spruce wood. The dry sawdust is a polydisperse bulk material with grain dimensions ranging between 84.7 μm and 28.2 mm. In view of the shape of grains, coarse and medium coarse fractions of dry sawdust mostly consist of fibrous grains. The fine fraction consists of isometric grains - cube shape. The analyses of conditions of separation of dry spruce and pine sawdust in separators and filters shows that battery separators with elements T4/630 and filters are suitable for the separation of sawdust produced in re-sawing operations of wood carried out with narrow-kerf frame sawing machines, type CLASIC 150/200 and PRW 15.

Key words: narrow-kerf frame sawing machine, dry sawdust, granulometric analysis, separation, environment

SAŽETAK • U radu se prikazuju rezultati granulometrijske analize suhe borove piljevine nastale u procesu uzdužnog piljenja drva na uskolisnoj pili jarmači, tip PRW-15, te suhe smrekove piljevine nastale na uskolisnoj pili jarmači, tip CLASIC 150/200, također u procesu uzdužnog piljenja drva. Suha je piljevina polidisperzni sipki materijal veličine čestica između 84,7 μm i 28,2 mm. S obzirom na oblik, frakcije krupnijih i srednje krupnih čestica uglavnom su sastavljene od vlaknastih čestica, a frakcije sitnijih čestica uglavnom sadržavaju izometrične čestice - čestice kockastoga oblika. Analiza uvjeta odvajanja čestica suhe smrekove i borove piljevine od zračne struje u centrifugalnim i filtarskim odvajajima pokazala je da su odvajajači s elementima T4/630 i filtarski odvajajači pogodni za odvajanje odsisane piljevine nastale u procesu uzdužnog piljenja drva na uskolisnim jarmačama tipa CLASIC 150/200 i PRW 15.

Ključne riječi: uskolisne pile jarmače, suha piljevina, granulometrijska analiza, odvajanje, okoliš

¹ Author is professor at Faculty of Wood Science and Technology, Technical University in Zvolen, Slovak Republic, ² Authors are associate professors at Mechanical Engineering Faculty, Gdańsk University of Technology, Gdańsk, Poland.

¹ Autor je profesor na Fakultetu za znanost o drvu i drvne tehnologije Tehničkog sveučilišta u Zvolenu, Slovačka, ² Autori su profesori na Strojarskom fakultetu Tehničkog sveučilišta u Gdanjsku, Poljska.

1 INTRODUCTION

1 UVOD

In the late 20th century, narrow-kerf frame sawing machines were designed for efficient and economical re-sawing operations for the production of thin lamellas from dried timber, intended for the production of multi-layered construction boards, floorings, boxes (cases) for fruits and vegetables, but also for manufacturing products of cabinet making - construction production and sport equipment. In the process of sawing with narrow-kerf frame sawing machines not only the main product - lamella is produced, but also the waste - sawdust. The shape, dimensions and amount of sawdust in the process of chip-splitting of wood depends on physical and mechanical characteristic of the sawn material, but also on the shape, dimensions and sharpness of the saw teeth of the used sawing machine and technical and technological conditions of the sawing process, as well as on the machine kinematics (Prokeš 1978, Hejma 1981, Goglia 1994, Lisičan 1996, Wasielewski 1999, Dzurenda 2002, Orłowski 2003, Orłowski Et al. 2003).

In reference literature, sawdust is characterised as a polydisperse bulk material consisting of coarse or medium coarse fractions (Hejma Et al. 1981) - bulk material with the size of granules exceeding 0.5 mm, not excluding the share of fine fractions with the size even smaller than chips. According to the classifying indicators of bulk materials introduced in STN 260070, dry sawdust is classified as B-45UX - bulk material of fine granularity (0.5 - 3.5 mm), hygroscopic and abrasive material with tendency to agglutinate. Microscopic analysis of dimensions and shapes of spruce sawdust, with the use of the method of microscopic analysis carried out in the research (Dzurenda

and Mazal 1999), showed that spruce sawdust also includes dust particles with the size smaller than 70 μm .

One of the alternatives for the removal of chips from the place where they are produced to the place of their further processing or storage is an air-technical transport - exhaustion. Separation of sawdust from transport air may be achieved in unicameral separators, battery separators or filters. Optimal technical solution of air-technical systems and conditions for the separation of sawdust from transport air can be determined upon getting precise information about physical characteristics, granularity and geometrical shapes of chips of exhausted bulk material.


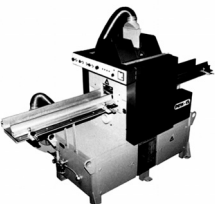
The objective of this paper is the analysis of dimensions, shapes and granulometric composition (distribution) of sawdust produced in the process of longitudinal sawing of dry timber with the use of narrow-kerf frame sawing-machines CLASIC 150/200 and PRW 15. The efficiency of separation of dry sawdust is analysed by means of characteristics of fractional separation of mechanical separators and material filters.

2 MATERIAL AND METHODOLOGY

2 MATERIJA I METODE

Samples for granulometric analyses of dry spruce and dry pine sawdust were taken iso-kinetically from the exhaust pipe of the frame sawing machine CLASIC 120/200 and from the exhaust pipe of the sash gang saw PRW-15 in accordance with STN ISO 9096 during the sawing process of timber with thickness $h = 100$ mm at feed speed $v_f = 0.5$ m/min. Stellite tipped saws with pitch $P = 13$ mm were used on both sash gang saws. Humidity of spruce sawdust $w = 8.0$ %

Table 1 Technical and technological conditions of sawing during sampling (www.neva.cz, www.rema-sa.pl).
Tablica 1. Tehnički i tehnološki uvjeti piljenja tijekom uzimanja uzorka

Narrow-kerf frame sawing machine CLASIC 150/200 <i>Uskolisna pila jarmača CLASIC 150/200</i>			
	Stroke of the saw sash <i>Duljina stapaja</i>	mm	210
	Number of saw blades <i>Broj listova pila</i>	-	8
	Cutting kerf – <i>Širina propiljka</i>	mm	1.4
	Max. height of sawn material <i>Najveća visina piljenog materijala</i>	mm	200
	Max width of sawn materia l <i>Najveća širina piljenog materijala</i>	mm	155
Narrow-kerf frame sawing machine PRW 15 <i>Uskolisna pila jarmača PRW 15</i>			
	Stroke of the saw sash <i>Duljina stapaja</i>	mm	160
	Number of saw blades <i>Broj listova pila</i>	-	10
	Cutting kerf – <i>Širina propiljka</i>	mm	1.3
	Max. height of sawn material <i>Najveća visina piljenog materijala</i>	mm	150
	Max width of sawn materia l <i>Najveća širina piljenog materijala</i>	mm	170

and pine sawdust $w = 8.5\%$ were set by the weight method. Technical and technological conditions of sawing timber with narrow-kerf frame sawing machines used in the tests are shown in Table 1.

The basic granulometric analyses were carried out by sieving, which means by screening of dry sawdust on a set of sieve screens sized as follows: 2 mm; 1 mm; 0.5 mm; 0.25 mm; 0.125 mm; 0.090 mm during the time $\tau = 15$ min on a RETSCH automatic vibration sieving machine AS 200. The weights of fractions were determined on sieves by use of a BOSCH laboratory balance EP 200 with the weighting precision 0.001 g.

For the purpose of specifying the information about the size of the smallest particles of fine fraction of dry sawdust, a microscopic analysis of granules of dry sawdust fraction with the size lower than 125 μm was performed. The proposed analysis of dry spruce and pine sawdust was carried out by an optical method - analysis of the image obtained from the microscope Nikon Optiphot-2 with the objective Nikon 4 \times in the Biometric Laboratory FLD MZLU Brno. Granules of sawdust were scanned by three chip television CCD cameras HITACHI HV-C20 (RGB 752 \times 582 pixel), with horizontal resolution 700 TV lines and evaluated by a software LUCIA-G 4.0 (Laboratory Universal Computer Image Analysis), installed on a PC with the processor Pentium 90 (RAM 32 MB) with the graphic card VGA Matrox Magic under the operation system Windows NT 4.0 Workstation. The program of image analysis LUCIA-G enables the identification of individual particles of disintegrated wood material, quantitative determination of individual particles situated in the analysed image and establishment of basic information such as: width and length of particles, circularity expressing the measure of deviation of projection of a given chip shape from the projection of the shape of a circle according to the formula:

$$\psi = \frac{4 \cdot \pi \cdot S}{O^2} \quad (1)$$

Where: S - particle surface (*površina čestice*), m^2 ,
 O - particle perimeter (*opseg čestice*), m .

3 RESULTS AND DISCUSSION

3 REZULTATI I RASPRAVA

The results of sieve analysis - granulometric consistence of dry spruce and pine sawdust produced in the processes of sawing with narrow-kerf sawing machines - CLASIC 150/200 and PRW - 15 at feed speed $v_f = 0.5$ m/min are presented in Table 2.

The results of sieving analysis show that the sawdust produced by sawing dry pine timber with thin-cutting frame saw PRW 15 at feed speed $v_f = 0.5$ m/min is more homogeneous than spruce sawdust produced by use of a frame saw CLASIC 150/200.

The basic dimensions of the granules of dry spruce and pine sawdust were evaluated under the terms set for the identification of particle sizes, including their sizes larger than 1 mm and also the granules of the fine fraction lower than 0.125 mm. The dimensions of the largest granules of coarse fraction and the smallest particles of the fine fraction of dry spruce and pine sawdust are shown in Table 3.

Image analyses of shapes and dimensions of spruce and pine sawdust particles of coarse and medium coarse fractions have shown that the preponderance of sawdust granules of these fractions created in the process of longitudinal sawing of spruce and pine wood belong to the group of polydisperse fibrous materials, which have stick shapes with considerable elongation in one of their dimensions. Microscopic analyses of sizes and shapes of fine fraction particles of dry sawdust have revealed that particles of this fraction with their shape belong to the group of isometric particles, which means particles with the same values in all 3 dimensions. This finding is quantitatively supported by the share of granules in individual fractions with values of circularity ranging between $\psi = 0.7 - 1.0$ in a bar chart as shown in Figure 1.

Figure 2 presents the investigation of separation of dry spruce and pine sawdust of granularity ranging between 84.7 μm and 28.2 mm in mechanical separators and material filters by means of integral curves of residues Z_a of spruce and pine sawdust produced in the process of sawing on narrow-kerf sawing machines. Furthermore, characteristics of fractional separation of unicameral mechanical separators, battery mechanical

Table 2 Granulometric consistence of dry spruce and pine sawdust produced by frame sawing machines CLASIC 150/200 and PRW 15

Tablica 2. Granulometrijski sastav suhe smrekove i borove piljevine nastale na jarmačama CLASIC 150/200 i PRW 15

Dimensions of sieve screen , mm <i>Veličine otvora sita, mm</i>	Mark of fraction <i>Oznaka frakcije</i>	Fractions in dry sawdust, % <i>Udjeli frakcija u suhoj piljevini, %</i>	
		spruce - <i>smreka</i>	pine - <i>bor</i>
2.000	Coarse - <i>krupna</i>	4.37	0.92
1.000		4.38	1.51
0.500	Medium coarse <i>srednje krupna</i>	41.38	36.74
0.250		30.63	41.30
0.125	Fine - <i>sitna</i>	15.63	16.37
0.090		2.75	2.71
>0.090		0.37	0.45

Table 3 The measures of the largest particles of dry spruce and pine sawdust and the smallest particles in analysed fine fractions of dry spruce and pine sawdust**Tablica 3.** Dimenzije najvećih i najmanjih čestica suhe smrekove i borove piljevine u analiziranoj frakciji sitnih čestica

Material Materijal	Maximum measures of sawdust granules dimenzije najvećih čestica mm	Planar measures of minimal sawdust particles dimenzije najmanjih čestica μm
Dry spruce sawdust suha smrekova piljevina	1.1 × 1.8 × 28.2	87.88 × 87.37
	1.0 × 1.3 × 25.4	87.64 × 84.49
	0.9 × 3.2 × 10.4	85.38 × 78.31
Dry pine sawdust suha borova piljevina	2.5 × 3.8 × 14.0	88.52 × 87.37
	1.5 × 3.2 × 12.6	86.67 × 82.35
	1.8 × 2.9 × 6.4	84.71 × 78.89

separators with elements T4/630 and filters (Stallherm 1973, Hajzok 1986, Dolný 1999) are also given.

Based on the comparison of integral curves of residues Z_a of dry spruce and pine sawdust with curves of fractional separation of unicameral mechanical separators, battery separators with elements T4/630 and filters, it results that the finest fraction of granularity of dry spruce and pine sawdust is on the limit value of separation set for unicameral mechanical separators ($SL_A = 80 \mu\text{m}$). Battery separators with elements T4/630 and filters are suitable for the separation of sawdust exhausted from sash gang saws CLASIC 150/200 and PRW 15. Isometric granules of the smallest size of dry spruce and dry pine sawdust are considerably lower than the separation limit value not only of the battery mechanical separators with elements T4/630 ($SL_B = 18 \mu\text{m}$) but also of filters whose separation limit is $SL_C = 3.5 \mu\text{m}$.

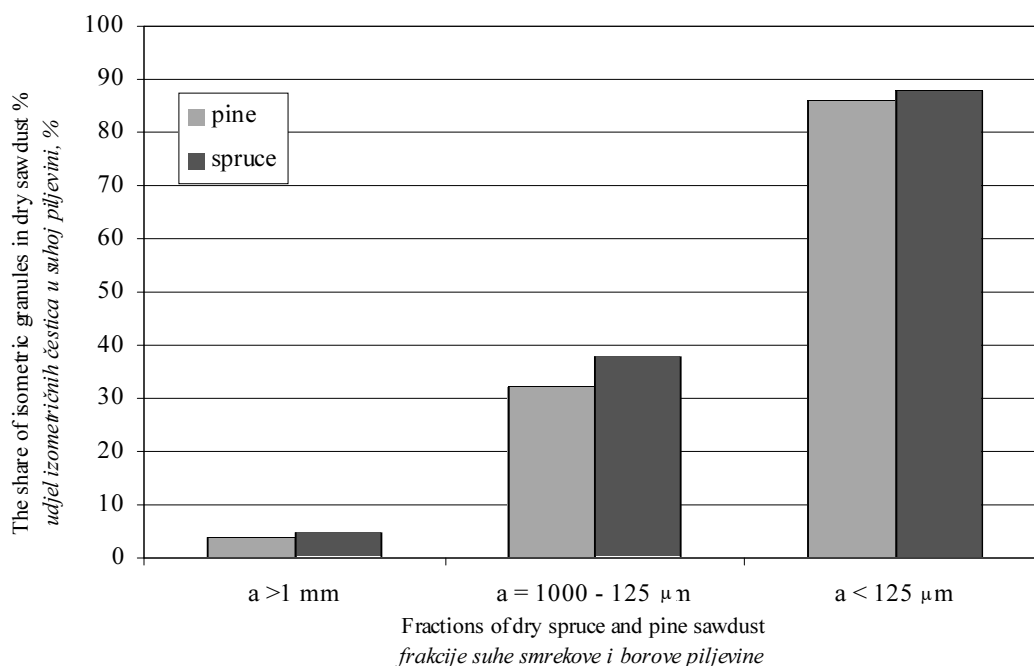
4 CONCLUSIONS

4 ZAKLJUČCI

The results of the granulometric distribution of sawdust produced by longitudinal sawing of dry spruce and pine wood with narrow-kerf frame sawing machines: CLASIC 150/200 and PRW 15 characterise dry sawdust as a polydisperse bulk material with the size of granules ranging between $84.7 \mu\text{m}$ and $28.2 \mu\text{m}$.

The largest share of dry pine sawdust have fractions with granule dimensions ranging as follows $a = 125 - 1000 \mu\text{m}$, which is equal to 87 - 94 % of pine sawdust exhausted from narrow-kerf frame sawing machines.

From the point of view of granules shape, coarse and medium coarse fractions of dry pine sawdust mainly consist of fibrous granules - of stick shape. Fine fraction consists of 86 - 88 % of isometric gran-

**Figure 1** The share of particles of isometric granules in dry spruce and pine sawdust with circularity value ranging between $\psi = 0.7 - 1.0$ **Slika 1.** Udjel čestica izometričnog oblika u suhoj smrekovoj i borovoj piljevini ($\psi = 0,7 - 1,0$)

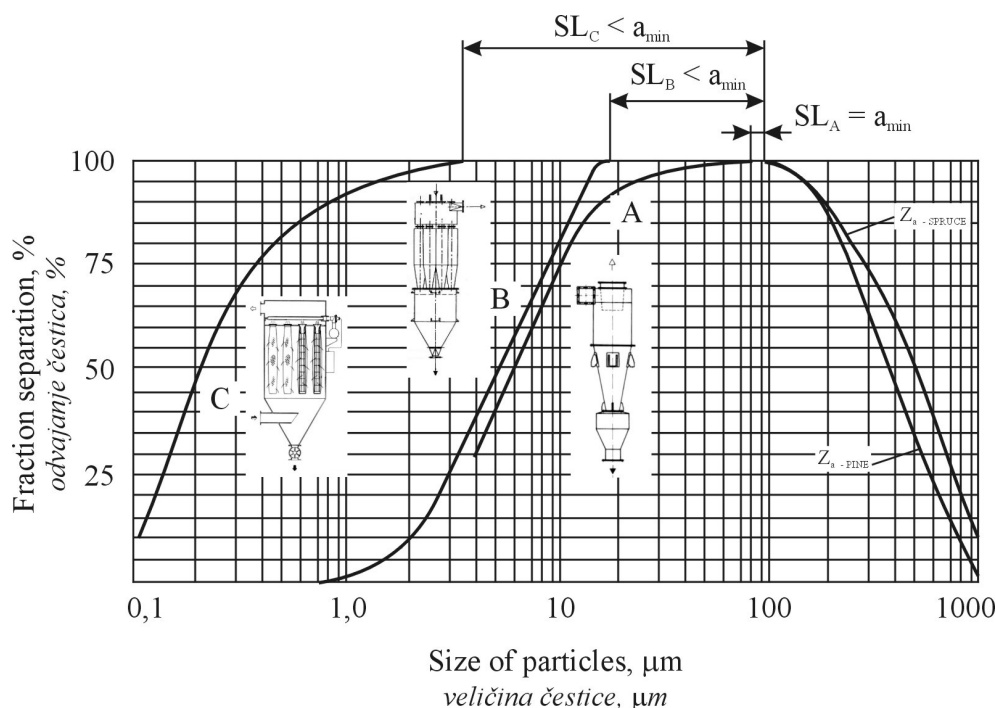


Figure 2 Separation analysis of dry spruce and dry pine sawdust in the process of sawing with sash gang saws: CLASIC 150/200 and PRW 15 in individual types of separation technology: A - unicameral mechanical separators, B - battery separators with elements T4/630 and C - filters, SL_A - separation limit unicameral mechanical separators, SL_B - separation limit battery separators with elements T4/630, SL_C - filters, Z_a -SPRUCE - integral curves of dry spruce sawdust residues, Z_a -PINE - integral curves of dry pine sawdust residues

Slika 2. Analiza odvajanja čestica suhe smrekove i borove piljevine nastale u procesu uzdužnog piljenja na pilama jarmačama CLASIC 150/200 i PRW 15 u različitim tipovima odvajanja: A - mehanički centrifugalni odvajajući, B - odvajajući s elementima T4/630 i C - filtarski odvajajući, SL_A - granica odvajanja mehaničkim centrifugalnim odvajajućem, SL_B - granica odvajanja odvajajućem s elementima T4/630, SL_C - granica odvajanja filtrima, Z_a -SPRUCE - integralna krivulja odvajanja čestica suhe smrekove piljevine, Z_a -PINE - integralna krivulja odvajanja čestica suhe borove piljevine

ules - of cube shape.

Based on the comparison of integral curves of residues Z_a of dry spruce and pine sawdust with curves of fractional separation of unicameral mechanical separators, battery separators with elements T4/630 and filters, it results that battery separators with elements T4/630 and filters are suitable for separation of sawdust exhausted from the re-sawing process conducted with narrow-kerf frame sawing machines CLASIC 150/200 and PRW 15, because the smallest isometric granules are considerably lower than the separation limit value of these separation devices ($a_{min} > SL$). The finest fraction of dry spruce and pine sawdust is on the limit value of separation of unicameral mechanical separators $SL_A = 80 \mu m$.

5 LITERATURA 5 REFERENCES

1. Dolny, S. 1999: Transport pneumatyczny i odpływanie w przemyśle drzewnym. Poznan, Wydawnictwo Akademii Rolniczej w Poznaniu. 245 pp.
2. Dzurenda, L.; Mazal, P. 1999: Mikroskopická analýza rozmerov a tvaru smrekovej piliny. In: Stroj-nástroj-obrobok "99". Nitra, Vydavateľstvo Technickej univerzity vo Zvolene. pp. 43-47.
3. Goglia, V. 1994: Strojevi i alati za obradu drva I. Zagreb, GRAFA, 235 pp.
4. Hajzok, L. 1986: Vzduchotechnické zariadenia drevo-priemyslu. Bratislava, Alfa, 180 pp.
5. Hejma et al. (1981): Vzduchotechnika v drevospracovávajícím průmyslu. Praha, SNTL, 398 pp.
6. Lisičan, J. et al. 1996: Teória a technika spracovania dreva. Zvolen, Matcentrum, 626 pp.
7. Orłowski K. (2003): Materiałoszczędne i dokładne przecinanie drewna pilami. (In Polish - Narrow-kerf and accurate sawing of wood). Politechnika Gdańska, Monografie 40. Wydawnictwo Politechniki Gdańskiej, 146 pp.
8. Orłowski, K.; Przybylski, W.; Wasielewski, R. 2003: Frame sawing machines for accurate wood re-sawing. In: Proceedings of 16th Inter. Wood Machining Seminar 16 IWMS. August 24 - 30, 2003, Matsue, Japan. Matsue, Faculty of Science and Engineering, Shimane University, Japan. Part 1: Oral Presentations, pp. 248 -256.
9. Prokeš, S. 1978: Obrábění dřeva a nových hmot ze dřeva. Praha, SNTL, 583 pp.
10. Stallherm, H. 1973: Sicherheitstechnik für Absaugung, Enstaubung und Bunkerung. Die Holzbearbeitung 3, pp. 41 - 44.
11. Wasielewski, R. (1999): Pilarki ramowe z eliptyczną trajektorią prowadzenia pił i hybrydowym wyrównanym układem napędu głównego. (In Polish - Frame sawing machines with an elliptical trajectory of saw blades guiding and the hybrid dynamically balanced main driving system). Politechnika Gdańska, Monografie 10. Wydawnictwo Politechniki Gdańskiej, 106 pp.
12. *** [http // www.rema-sa.pl](http://www.rema-sa.pl)
13. *** [http // www.neva.cz](http://www.neva.cz)

Acknowledgement: This paper has been produced under conditions set for the project VEGA-SR č. 1/2402/05, and it is the result of work of the authors with considerable help of the grant agency VEGA-SR.

Corresponding address:

Professor Eng. LADISLAV DZURENDA, Ph.D

Faculty of Wood Sciences and Technology
Technical University in Zvolen
T. G. Masaryka 24
960 53 Zvolen
SLOVAKIA
dzurenda@vsld.tuzvo.sk

Vodeći informativni časopis u sektoru prerade drva i proizvodnje namještaja

Distribucija na 2000 stručnih adresa u Hrvatskoj i zemljama Regije

Šest brojeva godišnje, 26 rubrika s aktualnostima, besplatnim malim oglasima i tržišnim barometrom

Tjedne elektronske vijesti s pregledom najnovijih informacija

TJEDNO BESPLATNO DOSTAVLJAMO SEKTORSKE VIJESTI NA VAŠ E-MAIL
REGISTRIRAJTE SE: newsletter@drvo-namjestaj.hr

Izdavač: Centar za razvoj i marketing d.o.o.
J. P. Kamova 19, 51 000 Rijeka

Tel.: + 385 (0)51 / 458-622, 218 430, int. 213
Faks.: + 385 (0)51 / 218 270
E-mail: mail@drvo-namjestaj.hr

www.drvo-namjestaj.hr

DRVO & NAMJEŠTAJ

TEMATSKI PRILOZI

STRUČNI ČASOPIS