# SAWING OF DOUGLAS FIR LOGS WITH NARROW BAND SAW BLADES IN WINTER CONDITIONS

**Zhivko Gochev, Valentin Atanasov**
**University of Forestry, Sofia, Bulgaria**
**e-mails: zhivkog@yahoo.com, vatanasov_2000@yahoo.com**

## ABSTRACT

The report presents some experimental studies carried out by sawing of logs with narrow band saw blades in winter conditions. The experiments were carried out in manufacturing conditions in February. For the purpose a horizontal band saw "Wirex CZ-1/ZM" was used.

Operating conditions were established and the quality of sawn lumber from semi frozen logs of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) was tested. The quality preparation of the band saw blade with the used horizontal band saw provides good parameters of the sawn lumber: surface roughness $\overline{R}_m$ = 190 μm; variation in the accuracy of the size and shape of 1.5 mm and 1.8 mm at a feed speed of $U$ = 11.5 m.min$^{-1}$.

**Key words:** logs, Douglas fir, sawing, narrow band saw blades, winter conditions.

## 1. INTRODUCTION

Sawing of logs with narrow band saw blades of modern horizontal band saw is becoming an increasingly important part in the woodworking industry in Bulgaria. These machines are preferred for the easy maintenance, the low energy consumption and the high quantum yield. The lumber industry has significant difficulties when sawing logs in winter conditions. Usually there are no pools to defrost the wood in the company's facilities. It was found that at a temperature of -25$^0$ C the moisture in coniferous wood is converted into ice, i.e. such wood is considered to be completely frozen (Paderin 2012).

Problems arise mostly in partially frozen wood where the density varies in different areas. This leads to a significant increase in cutting resistances, often to breakage of the cutting band saw blades. Wood temperatures below zero degrees' centigrade leads to deterioration of the processed surface, higher power consumption and wear of the cutting tool.

In such conditions particularly important for proper functioning of the processes and obtaining high quality lumber is the correct selection of band saw blade, its linear and angular parameters and the preparation of its teeth. The purpose of the study is to establish the working conditions and quality of sawing lumber of partially frozen logs of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) by carrying out some experiments.

## 2. METHODOLOGY

The experiments were carried out in manufacturing conditions in February. For the purpose a horizontal band saw "Wirex", model "CZ-1/ZM", with the following technical characteristics, was used (Fig. 1):

- saw wheel diameter – $D$ = 600 mm;
- maximum distance between the axes of the wheels – $L_0$ = 1420 mm;
- power of the motor which drives the leading wheel – $N$ = 11 kW;
- revolutions per second of the motor's shaft – $n_m$ = 24.3 s$^{-1}$;

- diameter of the electric motor pulley – $D_1$ = 190 mm;
- diameter of the wheel pulley – $D_2$ = 360 mm;
- feed speed – *U* up to 20 m.min$^{-1}$.

**Figure 1: General view of a horizontal band saw "Wirex", model "CZ-1/ZM" (Poland)**

A band saw blade made by "Carl Rųntgen" (Germany) – quality *CR-400X^treme^* (hardened teeth) with profile 10/30, and hardness HRC46 were used. Figure 2 shows schematically the general appearance of the band saw blade. Table 1 shows its linear and angular parameters. It is made of high quality tool steel with optimal balance between hardness and ductility which significantly increases its resistance to reversed cyclic loads. The microstructure of the material is tempered martensite. The chemical composition of the steel is shown in Table 2 (Atanasov 2014). Due to its flexibility, the band saw blade can maintain its integrity for a long time without breaking. Furthermore, the teeth may be sharpened repeatedly without affecting their strength.

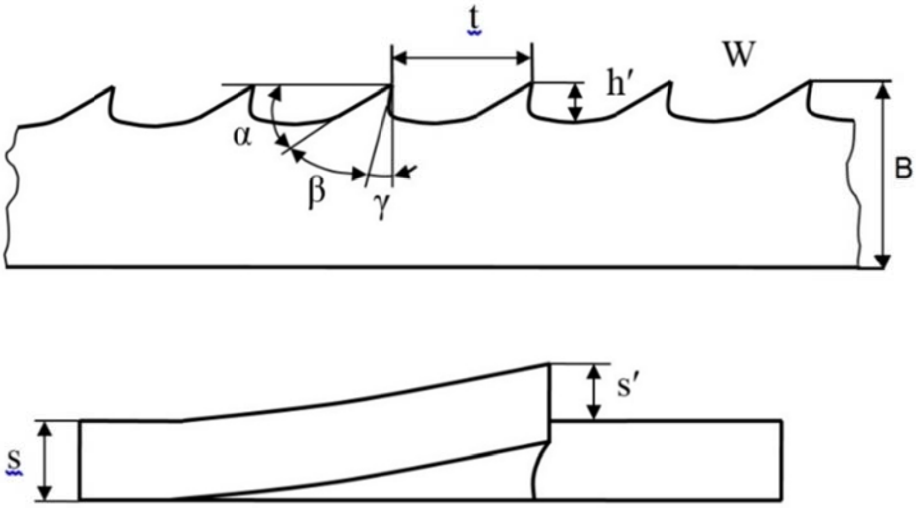



**Figure 2: Narrow band saw blade for horizontal band saw: *t* – tooth pitch; *s* – thickness of the band saw blade; *s′* - tooth part-set size; *h′* – tooth height; *α* – clearance angle; *β* – sharpness angle; *γ* – hook angle; *B* – width of the band saw blade; *W* – shape of the teeth**

**Table 1: Parameters of the band saw blade**

| Name | $\gamma/\alpha$, $^0$ | *t*, mm | *s/B*, mm | *s′*, mm | Type of teeth |
|---|---|---|---|---|---|
| $X^{treme}$ | 10/30 | 22.2 | 1/40 | 0.4 | *W* – hardened |

**Table 2: Chemical composition of the band saw blade steel, type *CR400***

| C, % | Si, % | Mn, % | $P_{max}$, % | $S_{max}$, % | Cr, % | Ni, % | V, % | $M_o$, % |
|---|---|---|---|---|---|---|---|---|
| 0.463 | 0.219 | 0.73 | 0.014 | 0.015 | 1.04 | 0.435 | 0.125 | 0.96 |

The speed of movement of the band saw blade, i. e. cutting speed, is constant during processing. It is defined by formula 1. The gear ratio is taken into account as well (Gochev 2008).

$$V = \pi.D.n = \pi.D.\frac{n_m}{i}.(1 - \varepsilon), \qquad (1)$$

where $V$ is the cutting speed, m.s$^{-1}$;

$n$ – revolutions per second of the band saw wheel, s$^{-1}$;

$D$ – diameter of the wheels, m;

$i$ –gear ratio of the belt drive, $i = \frac{D_2}{D_1}$;

$\varepsilon$ – sliding coefficient of the belt – for V-belts $\varepsilon = 0.005$.

Feed speed *(U)* is adjusted by the operator with step-less variation. This depends on the cutting height, working capacity of the band saw blade, the density of the wood and the power the cutting mechanism. In the process of cutting feed speed average value is defined by formula 2 (Gochev 2008)

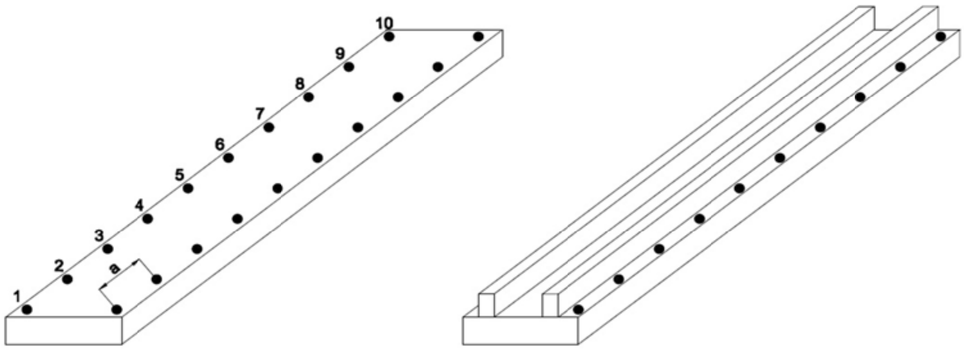
$$U_{av} = \frac{L_{\log}}{t_i}, \qquad (2)$$

where $L_{log}$ is the length of the log, m;

$t_i$ – time for a cut of the log, s.

On each of the sawing patterns (not edging boards, semi-finished prisms etc.), the average width *($h_{av.i}$)* was measured.

The qualitative evaluation of the lumber was based on the roughness of the machined surfaces (parameter $\bar{R}_m$), accuracy of the shape and dimensions. These criteria were reported in 20 points for the relevant lumber (Fig. 3) (Atanasov 2013).




*A* *B*

**Figure 3: Measurement points for the roughness, dimensional accuracy (A) and the accuracy shape (B) of machined surfaces**

To measure the surface roughness, an indicator depth gauge with measuring clock was used, in accordance with BDS 4622-86 − by standard methodology. To determine the accuracy of the dimensions a digital caliper was used. The accuracy of the shape was measured by an air gap gauge, metric gauge block set and a metal line (Fig. 4).

The results were statistically processed.

*A*

*B*

**Figure 4: Measurement of accuracy of the shape: A – metal line and gauge blocks; B – air gap gauge**

**Figure 5: Frozen logs of Douglas fir**

For conducting the experimental studies several frozen logs of Douglas fir (Pseudotsuga menziesii (Mirb.) Franco) (Fig. 5) from Rila Monastery region were used. Douglas fir is one of the most widely used introduced wood species in Europe and Bulgaria. Its valuable timber, good growth and adaptive properties, high physical and mechanical properties which are superior to those of the Spruce and between those of Scots pine and Larch, attract the attention of the lumber manufacturers.

Each of the logs was numbered and the minimum and maximum diameters were measured - in its thin and thick part respectively. The average diameter of the logs was determined by formula 3. The volume of each log was calculated by formula 4.

$$d_{av} = \frac{d_{\min 1} + d_{\min 2} + d_{\max 1} + d_{\max 2}}{4}, \quad \textbf{(3)}$$

where $d_{av}$ the average diameter of the log, m;

$d_{min1,2}$ – two crossed diameters of the log at the thin part, m;

$d_{max1,2}$ – two crossed diameters of the log at the thick part, m.

$$Q_{\log} = \frac{\pi . d_{av}^2}{4} L_{\log}, \quad \textbf{(4)}$$

where $Q_{log}$ is the volume of the log, $m^3$.

The quantity of processed timber *(Q)*, before the respective measures, was calculated in $m^2$ on the basis of cutting schemes and the length of the respective logs. The moisture of the timber was measured with a hygrometer „Lignomat Tester 1“ (Germany). The average density of the timber – by weighting method, using an electronic scale "Radwag" (Poland), with an accuracy 0.01 g.

## 3. RESULTS

The measured average temperature and humidity when carrying out the experiments are shown in Table 3. The average density of the logs is 475 kg.m$^{-3}$, their moisture is 20 %, i.e. the logs are partially frozen.

**Table 3: Results for the conditions during carrying out the experiments**

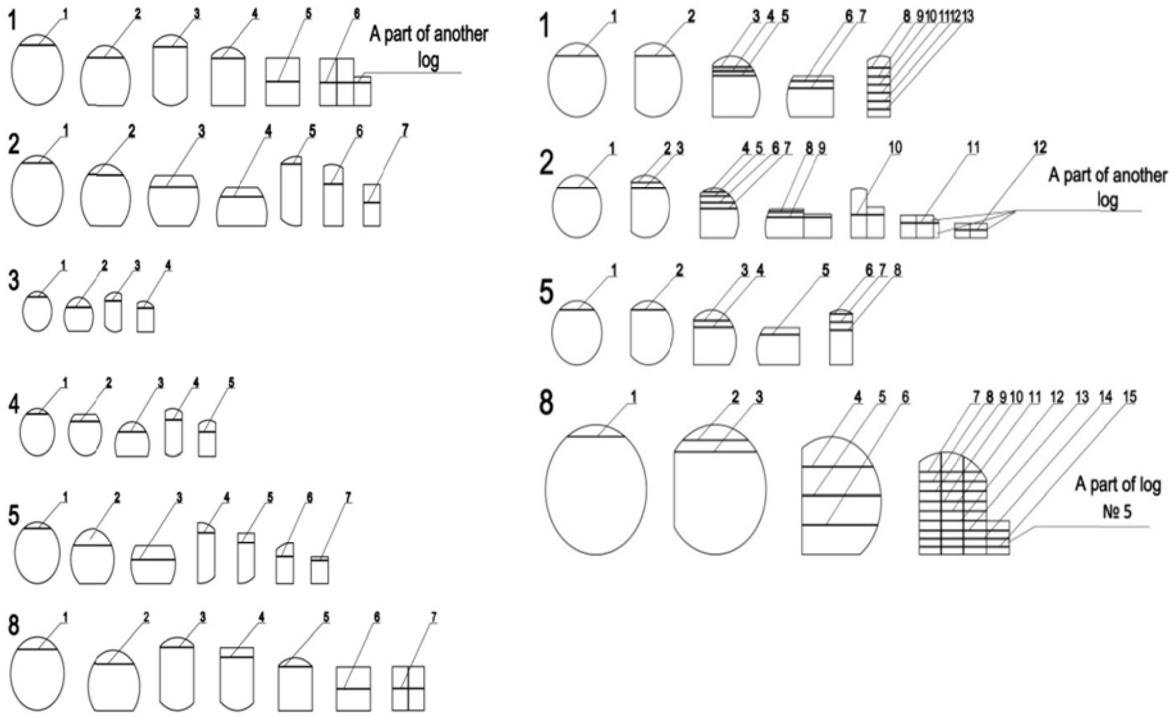
| Number of the experiment | Average air temperature in the workroom, °C | Average humidity in the working room, % |
|---|---|---|
| 1 | -5.0 | 49.0 |
| 2 | +6.0 | 65.0 |

When sawing partially frozen wood, additional difficulties arise compared to completely frozen wood. The main reason is that some of the contained moisture passes from a liquid to a solid state. Thus, the formed ice crystals into the cell gaps cannot be pushed out. Consequently, the volume of chips reduces only with the volume of the pores without the ice crystals. Furthermore, the wood of Douglas fir is composed of sapwood and heartwood with a lot of resin canals, mainly in latewood. In this case, the approach to the process of sawing is similar when cutting wood with different density.

Under these conditions two series of experiments were performed. The calculated cutting speed is $V \approx 24$ m.s$^{-1}$ and the feed speed *(U)* is in the range of 0 to 12 m.min$^{-1}$. The pattern of the sawing logs, in accordance with the production program of the company, is also shown in Fig. 6. Beams with cross sections 100/100 mm; 100/120 mm and boards 25/120 mm; 25/100 mm were obtained. The total volume of sawn logs in the experimental studies is 1,12 m$^3$ – after the first sharpening of band saw blade and 1,13 m$^3$ – after the second sharpening.

The results from the studies on the impact of feed speed *(U)*, cutting height *(h)* and quantity of sawn wood *(Q)* over the roughness of the obtained surfaces, the accuracy of dimensions and shape of the lumber are shown in Figure 7, 8 and 9. As can be seen in the figures, the feed speed is a factor which has the most significant influence on the output parameters.

At the first sharpening, feed speed in the range from $U = 1.5$ m.min$^{-1}$ to $U = 8.1$ m.min$^{-1}$, the parameter $\bar{R}_m$ varies from 130 μm to 280 μm, i.e. of fine to medium quality of machined surfaces (Fig. 7 A). Immediately before removing of the band saw blade for the second sharpening, where $U = 6.4$ m.min$^{-1}$, the surface roughness is largest, but with largest area of cutting wood $Q = 24.78$ m$^2$. This indicates that the wear of the teeth affects as well.




*A* *B*

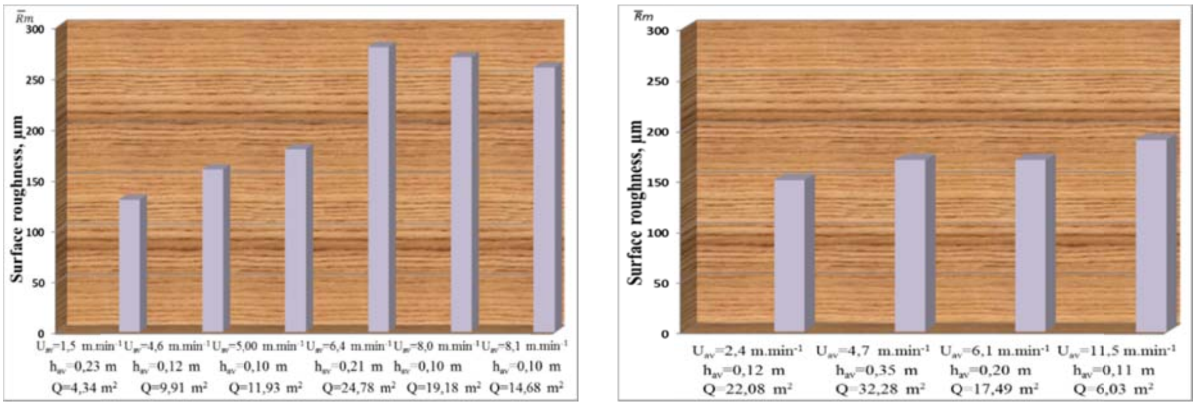
**Figure 6: Patterns of sawing Douglas fir: A – after the first sharpening of the band saw blade; B – after the second sharpening of the band saw blade. The figure shows the number of logs and cuts**

After the second sharpening of the band saw blade, the obtained results for the quality of the processed surfaces are uniformly distributed. The maximum measured value of $\overline{R}_m$ is 190 μm – after sawing 6.03 $m^2$ of wood and feed speed of 11.5 $m.min^{-1}$ (Fig. 7 B).

The largest deviation from the nominal dimensions at the first sharpening was achieved at a feed speed of 9.1 $m.min^{-1}$ (Fig. 8 A). At the second sharpening, maximum deviations in the dimensional accuracy are in the range of 1.5 mm at feed speed of 11.4 $m.min^{-1}$ (Fig. 8 B). The dependence is more pronounced and the maximum quantity of sawn timber is 32.99 $m^2$.

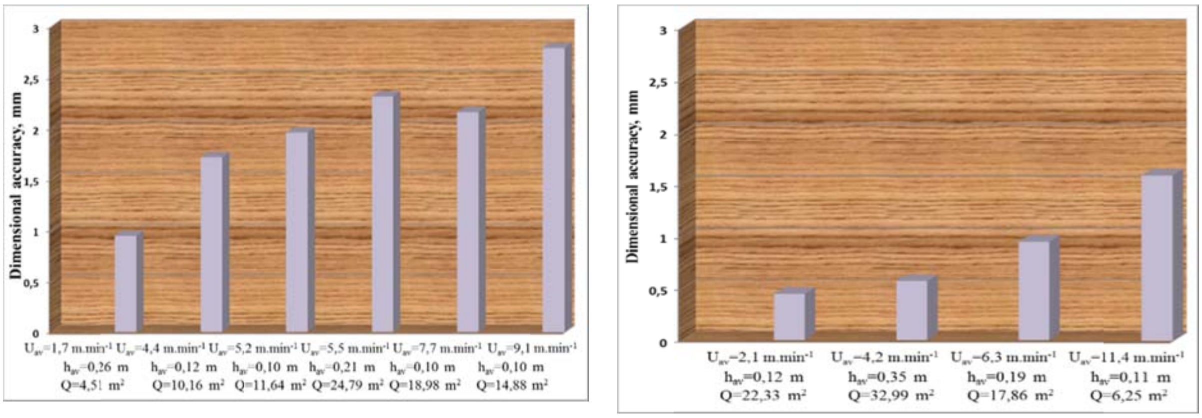
The maximum value of the deviation from the straightness (accuracy of the shape) at the first sharpening is 1.53 mm, obtained at a feed speed of 8.0 $m.min^{-1}$. The value is reported after 19.18 $m^2$ sawn timber (Fig. 9 A). The results after the second sharpening show that at the highest feed speed 11.5 $m.min^{-1}$, the variations in the accuracy of shape are 1.8 mm (Fig. 9 B).

The reasons for the better results after the second sharpening are: significantly better working conditions in this series of experimental studies – temperature t=6.0 °C and strict adherence to the technology for sharpening by using an abrasive disk of cubic boron nitride (borazine) with teeth profile 10/30.



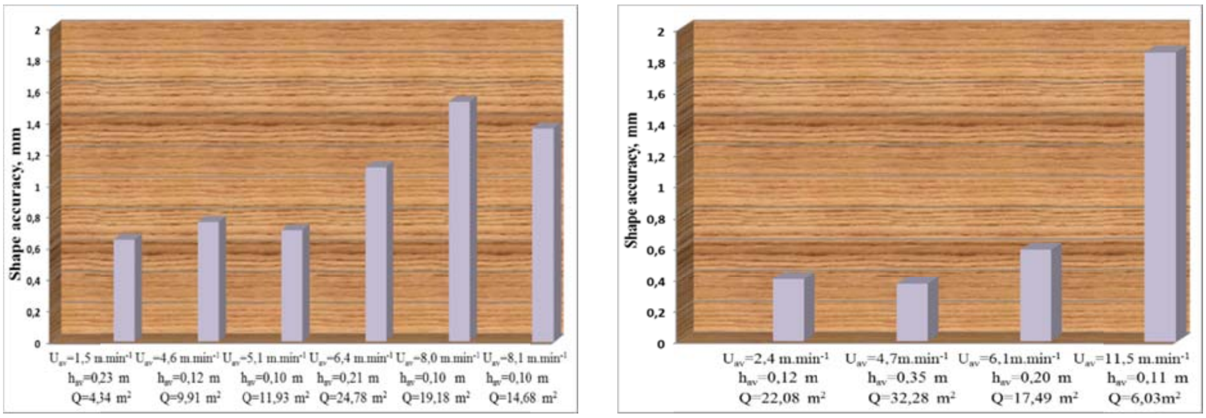

*A* *B*

**Figure 7: Influence of the feed speed, cutting height and quantity of sawing wood on the roughness of the obtained surface in: A − first sharpening of the band saw blade; B – second sharpening of the band saw blade**




*A* *B*

**Figure 8: Influence of the feed speed, cutting height and quantity of sawing wood on the dimensional accuracy in: A − first sharpening of the band saw blade; B – second sharpening of the band saw blade**




*A* *B*

**Figure 9: Influence of the feed speed, cutting height and quantity of sawing wood on the shape accuracy in: A − first sharpening of the band saw blade; B – second sharpening of the band saw blade**

## 4. CONCLUSION

Sawing of logs with narrow band saw blades is possible when the volume of the teeth gullet provides the necessary capacity to remove easily the sawed chips when the teeth are leaving the cut. When sawing partially frozen logs of Douglas fir, it can be done with a universal profile 10/30, hardened teeth – "X[treme]", which has the necessary strength and stability in interaction with different density of wood. This cutting tool has proved to be a successful option for sawing at low temperatures.

The quality preparation of the band saw blade provides better qualitative indicators of the lumber with the used model of horizontal band saw: surface roughness $\bar{R}_m$=190 μm; variation in the dimensional accuracy and shape 1.5 mm and 1.8 mm in feed speed $U$=11.5 m.min$^{-1}$.

When sawing logs at temperatures below zero degree centigrade in order to meet the requirements of the experiment it is necessary to use an antifreeze liquid (*WW – Windshield Washer*) mixed with water or to add some dishwashing substance into the reservoir to wash the band saw blade. Otherwise, when water is used as a cleaning fluid the band saw blade in many cases slips out of the wheels because it freezes and some ice deposits on the band saw blade are formed (Fig. 10).

At lower operating temperatures, below −15 $^{o}$C, an optimal variant for lubrication of the band saw blade is 50 % diesel fuel and 50 % oil for cutting mechanism of gasoline chainsaws when applied evenly on both sides.

The main task when sawing frozen (partially frozen) wood is to provide: stability of the band saw blade into the cut, required quality of the resulting surfaces, high productivity of the process and increase of the operational life of the band saw blade. This depends on the machine operator and cutting tools sharpening specialist. With proper operation of the band saw blade, the band can be used while its width decreases to 65 % of the initial.

**Figure 10: Freezing of the cleaning liquid on a saw blade**

## REFERENCES


1. Atanasov V. (2013). *Research on the quality of processed surfaces when cutting spruce logs with narrow band saw blades*, 5$^{-th}$ International Scientific and Technical Conference on Innovations in Forest Industry and Engineering Design, Sofia. 1/2013 pp. 66–70.
2. Atanasov V. (2014). *A Study on Operational Indicators of Mobile Horizontal Band Saws*, PhD thesis, University of Forestry, Sofia, p. 163. (in Bulgarian).
3. *BDS 4622:1986 − Wood products and wood materials. Surface roughness. Method for determining the parameters*. (in Bulgarian).
4. Gochev Z., et al., *Theme № 122 (2008): Comparative Investigation on Working Capacity of Wide Band Saw Blades with Setting, Swaging and Stellite teeth*, Team leader Assoc. Prof. Z. Gochev, NIS/LTU, 100 p (in Bulgarian).
5. Paderin V. (2012). *Features of cutting frozen wood*, Lesprom Inform №1 (83), pp. 102–106. (In Russian).

UNIVERSITY OF FORESTRY
------------------------------------------------------------
FACULTY OF FOREST INDUSTRY

# INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

## 1/2016

INNO vol. V Sofia

ISSN 1314-6149
e-ISSN 2367-6663

## CONTENTS