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**BUCKING OF CONIFERS USING THE WOODY H60 PROCESSOR ON THE SYNCROFALKE 3 T CABLE YARDER IN THE ALPINE FOOTHILLS**Jurij MARENČE<sup>1</sup>, Jernej VADNJAL<sup>2</sup> and Boštjan KOŠIR<sup>3</sup>

## Abstract

The paper investigates mechanized bucking of conifers with a processor mounted on a cable crane system in the mountain conditions of the Alpine foothills. It analyses the measurement accuracy of various log types and explains its effect on the market price of these products. In the studied area, trees were felled by chain saw and the full-tree method was used to skid the felled trees to the cable yarder site using the Syncrofalke cable crane with a mounted Woody H 60 processor head. Further wood processing operations were carried out at the yarder site. Length measurement accuracy was illustrated through the frequency distribution and the modulus of various lengths. The share of logs within a  $\pm 5$  cm interval - modulus - (the best five) was 54.3%. The difference between the nominal log length and the minimum required length resulted in a loss of 4.38% of the total log value. Furthermore, it was established that the first quarter of the stem actually contained 64% of the total stem value. This means that the first cross-cut was responsible for nearly 50% of the total loss and the second cross-cut pushed the figure to 80%. The present research only considered the losses incurred either by positive or negative cross-cut allowance or by insufficiently accurate length measurement of a certain log type.

Key words: bucking, processor, conifers, cable crane, Slovenia

**KROJENJE IGLAVCEV Z GLAVO ZA IZDELAVO WOODY 60 NA ŽIČNEM ŽERJAVU SYNCROFALKE 3 T V PREDALPSKIH RAZMERAH**

## Izvleček

V članku obravnavamo strojno krojenje iglavcev s procesorjem na žičnici na objektu v predalpskem hribovju. Predstavljamo natančnost izmere posameznih sortimentov in njen vpliv na njihovo tržno vrednost. Posamezna drevesa so podrlji z motorno žago in jih nato z žičnim žerjavom s stolpom Syncrofalke, na katerem je bil montiran procesor Woody H 60, z drevesno metodo spravili do stojišča žičnega žerjava. Na stojišču žičnice so opravili dodelavo. Natančnost merjenja dolžin smo ponazorili s pomočjo njihove frekvenčne porazdelitve in modusa. Izračun deleža sortimentov znotraj  $\pm 5$  cm širokega intervala, v sredini katerega je bil modulus porazdelitve (the best five), je znašal 54,3 %. Zaradi razlike med dejansko dolžino hloda in minimalno zahtevano dolžino smo ugotovili izgubo v višini 4,38 % od vrednosti sortimentov. Ugotovili smo, da je v prvi četrtini debla 64 % njegove celotne vrednosti. Tako smo že ob prvem prerezu dosegli skoraj 50 % skupne izgube, pri drugem prerezu pa že več kot 80 %. To so zgolj izgube, ki so nastale zaradi prevelike ali premajhne nadmere pri določenem sortimentu, torej zaradi premalo natančne izmere dolžin posameznih sortimentov

Ključne besede: krojenje, glava za izdelavo, iglavci, žični žerjav, Slovenija

**INTRODUCTION****UVOD**

Wood production from stump to the consumer's hand includes several operations, which may lead to a potential loss of income. These operations can be divided into those involving a change of location (all transport operations) and the procedures, which involve a change in the shape of material (felling and processing). It is essential, however, to identify the operations involving the highest possibility of an error and its economic impact on timber value and costs.

The most important phase of tree felling and processing is bucking, which also determines the technology to be used.

During bucking, final wood measurements are done and the quality of the product is determined. Felled trees can be bucked into logs at the stump, at a landing or at a central mechanized storage place. Today, most trees are felled, delimited and bucked by chain saw. This situation will – at least in private forests and some other working units – last long in coming years.

Introduction of mechanized harvesting is linked to an increase in the share of machine-bucked wood, in particular in state-owned forests where new technologies are more commonly used (KOŠIR 2002, 2004). As a result of this state-of-the-art technology, many processes have become automated and computer-controlled (SONDELL 1987, UUSITALO,

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KIVINEN 2001, MOLLER *et al.* 2003, UUSITALO *et al.* 2003), their efficiency rising significantly. On the other hand, mechanized harvesting has raised a number of questions, some associated with the quality of work and the related costs and the implications of mechanized harvesting on the value of wood products. In private forests and in large-diameter trees, a combination of manual and mechanized bucking will continue to prevail. Still, regardless of the bucking technique and tools used, the main problem remains unchanged: what assortments (length, diameter, quality) should the tree be cut into to maximize its value?

To maximize log value it is important how precisely the stems, which had been skidded to the truck road using the full-tree method, are measured and then bucked. The issue has been addressed by many authors (ANDERSSON, DYSON 2002, MAKKONEN 2001, GEERTS, TWADDLE 1984, MOLLER, ARLINGER 2007) as it has important implications for the economic efficiency of the entire process of wood harvesting and yarding. The procedures of bucking conifers and non-conifers are essentially different (LIPOGLAVŠEK 1988, FURLAN, KOŠIR 2006): conifers are normally cut to standard lengths, but in non-conifer bucking more attention is paid to wood defects that determine log value. The present paper focuses on the bucking of conifers, which is more common in mechanized harvesting (VADNJAL 2008).

## RESEARCH OBJECTIVES

### CILJI RAZISKOVANJA

The research was focused on determining the accuracy of cross-cutting carried out during mechanized bucking by the processor head of the cable yarder and the impact of measurement accuracy onto the market value of cross-cut products. Length measurement accuracy was presented through a frequency distribution and modus of log lengths.

Moreover, the study examined the following:

1. the relations and dependence between tree value and diameter at breast height (dbh) and tree height, and
2. the relations and dependence between the value of errors caused by inaccurate cross-cutting and tree height.

In recent time, there has been increasing demand for greater mechanization of forest operations, including bucking. The change is mainly driven by advanced wood harvesting technology, higher economic efficiency and safety at work as

well as shortage of forest production workers. Evidently, these changes in forest operations have also affected length and diameter measurement methods of different log types. In fact, measurements have a decisive impact on the optimization of tree-bucking as the process can yield significant differences in the quality and value of bucked logs (ENG *et al.* 1986, MARSHALL, MURPHY 2004, BOSTON, MURPHY 2003, OLSEN 1988).

On account of various factors affecting the measuring process, random or systematic measurement errors may occur. Problems associated with the accuracy of mechanized bucking have been recognized internationally. Many authors find that poor measurement accuracy often leads to net income losses (MURPHY 2003, HAMISH *et al.* 2006, MARSHALL 2005).

Therefore, the aim of the research was to determine the level of length measurement inaccuracy and determine its effect on the value of different log types for the case of the studied work site where cable yarding was applied, whereas further processing of wood was carried out by processor at the landing. The research was performed to inform the users of such technology about the importance of correct processor head setting and maintenance and the role of calibration, which would reduce or eliminate errors. Apart from the settings of the processor, errors may be caused by a number of other factors, including the shape and state of trees (e.g. sapping, barkless drywood) and the skill of the harvester operator. These causes were not analysed in this study.

## METHODS

### METODE

## OBJECT OF RESEARCH

### OBJEKT RAZISKAVE

Harvesting was carried out in an old pole stand and mature forest of spruce planted about 50 years ago (Table 1). The stand has a northern exposure and a 60% terrain sloping. Spruce as the predominating species (70%) is followed by beech (20%) and ash (5%), whereas the remaining part of the stand is composed of maple, linden and sessile oak. The estimated growing stock of the stand is 450 m<sup>3</sup>/ha. In such steeply-sloping terrains with poor skid trail network, cable yarding is the most appropriate skidding option. Three cable lines were planned on the site.

Table 1: Diameter distribution of the trial

*Preglednica 1: Razpored premerov v poskusu*

| DBH (cm)<br><i>Prsni premer (cm)</i> | No. of trees<br><i>Št. dreves</i> | No. of pieces<br><i>Št. kosov</i> | Piece / tree<br><i>Kos / drevo</i> |
|--------------------------------------|-----------------------------------|-----------------------------------|------------------------------------|
| 10 - 14 cm                           | 4                                 | 10                                | 2,5                                |
| 15 - 19 cm                           | 21                                | 59                                | 2,8                                |
| 20 - 24 cm                           | 25                                | 98                                | 3,9                                |
| 25 - 29 cm                           | 15                                | 75                                | 5,0                                |
| 30 - 34 cm                           | 12                                | 62                                | 5,2                                |
| 35 - 39 cm                           | 4                                 | 20                                | 5,0                                |
| 40 - 44 cm                           | 6                                 | 29                                | 4,8                                |
| 45 - 49 cm                           | 4                                 | 21                                | 5,3                                |
| 50 - 54 cm                           | 3                                 | 15                                | 5,0                                |

**DESCRIPTION OF MACHINE****OPIS STROJA**

The trees marked for felling were felled by chain saw and yarded to the landing using the Syncrofalke mobile tower cable crane (Figure 1) type 3 t. Further processing of felled trees was carried out on the site with the Woody H 60 processor (Figure 2), mounted on the crane LIV 24.94. Woody H 60 is a harvester head which can – when mounted on an all-terrain vehicle – fell trees (measuring up to 65 cm in diameter) and process them. The harvester head is designed for delimiting (stems up to 60 cm thick), measure and buck (cross-cut) the tree. When Woody H60 is mounted on a cableway it operates as a processor which makes logs out of whole trees, sorts and moves wood products (Tables 2 and 3). Processor has twin chain blades where frontal is smaller and designed for cutting thicker branches when processing hardwoods or topping when processing softwood. The processor is a self-propelled machine with a hydraulic drive system fed by the hydraulic pump, and is computer-controlled. The harvester head can measure lengths and diameters and determine the point of cross-cutting with computer parameters that can be changed rapidly. In bucking conifer products, the cross-cutting points are pre-determined with regard to the target log type, although the point of cross-cutting can subsequently be changed by the operator if so required by the properties of the tree. In bucking non-conifers, which often cause problems in delimiting and bucking brought about by the thickness of branches, the machine operator normally performs bucking in accordance with the estimated quality of the tree, i.e. cuts the wood to lengths suitable for further transport. In order to ensure uninterrupted bucking of conifers, computer settings need to be checked regularly, normally prior to the actual beginning of works at the site.



Fig. 1: Syncrofalke cable crane 3 t

*Slika 1: Žični žerjav Syncrofalke 3 t*

Fig. 2: Woody H 60 processor head

*Slika 2: Glava za izdelavo Woody H 60***MEASUREMENT METHOD****METODA MERITVE**

For the purpose of this research, data on diameter at breast height, tree height, length, diameter and quality of cut-to-length logs were collected for trees with a total volume of 66,70 m<sup>3</sup>. A total of 94 conifer trees were measured (VADNJAL 2008).

Data on the trees and log types were entered into the record sheet. The length and diameter of tree segments were

Table 2: Technical data on the cable crane

Preglednica 2: Tehnični podatki o žičnem žerjavu

|  |                       |
|--|-----------------------|
| Cable crane Syncrofalke 3 t<br><i>Žični žerjav Syncrofalke 3 t</i>       | Meyr Melnhof, Austria |
| Truck<br><i>Kamion</i>   | MAN 33.430, 6x4       |
| Skyline: length, diameter<br><i>Nosilna vrv: dolžina, premer</i>         | 800m, 20mm            |
| Haulback line: length, diameter<br><i>Povratna vrv.: dolžina, premer</i> | 1600m, 11mm           |
| Main line: length, diameter<br><i>Vlečna vrv: dolžina, premer</i>        | 1600m, 8,5mm          |
| Auxilliary rope<br><i>Montažna vrv</i>                                   | 1600m, 6mm            |
| Anchor ropes: length, diameter<br><i>Sidrne vrvi: dolžina, premer</i>    | 4x70m, 18mm           |
| Carriage<br><i>Voziček</i>   | SHERPA U III, 3 t     |
| Crane<br><i>Dvigalo</i>  | LIV 24.94             |

measured with 1 cm accuracy; the length of the top tree section was also measured to determine the tree height. Slovenian standards (SIST 1998) were used to determine the quality of logs. The settings for automated mechanized bucking were also recorded. These data were essential as they allowed us to control the accuracy of length measurements by the machine and compare them against nominal measurements. Aware of the fact that there are always some differences between length measurements obtained in mechanized bucking and manual bucking, we wished to determine the extent of these differences for the presented case.

Wood products obtained after bucking were financially evaluated on the basis of prices provided by the Agricultural and Forestry Cooperative Pivka (KGZ 2007). The value of logs by quality class is given in Table 4.

## RESULTS

### REZULTATI

Several scientific papers published to date (HAMISH *et al.* 2006) contain findings that can be compared with the

Table 4: Value of 1m<sup>3</sup> of conifer wood u.b.Preglednica 4: Vrednost 1m<sup>3</sup> lesa iglavcev brez lubja

| Quality class*<br><i>Kakovostni razred</i> | Value (€/m <sup>3</sup> )<br><i>Vrednost (€/m<sup>3</sup>)</i> |
|--|--|
| B  | 70   |
| C  | 58   |
| D  | 48   |
| Pulp wood / <i>Celulozni les</i>           | 22   |

\*SIST 1998

Table 3: Technical data on the processor

Preglednica 3: Tehnični podatki o glavi za izdelavo

|  |                    |
|--|--------------------|
| Processor Woody H 60<br><i>Glava za izdelavo Woody H 60</i>      | Konrad, Austria    |
| Maximum delimiting diameter<br><i>Največji premer klešččenja</i> | 8 - 60 cm          |
| Forward feed power<br><i>Podajalna moč</i>                       | 36 - 45 kW         |
| Forward feed speed<br><i>Podajalna hitrost</i>                   | 0 - 4 m/s          |
| Recommended driving power<br><i>Priporočena moč motorja</i>      | 140 kW             |
| High pressure system<br><i>Največji pritisk v sistemu</i>        | 300 - 350 bar      |
| Cutting speed<br><i>Hitrost prežaganja</i>                       | 40 m/s             |
| Rotator<br><i>Rotator</i>  | Int. Endlosrotator |
| Measuring system<br><i>Merilni sistem</i>                        | Konrad KSS 3.2     |

values obtained in this study. The results from these papers indicate that the highest losses in bucking arise as a result of diameter and length measurement errors. Losses from stem diameter measurement are greatest when the measured diameters are lower than the diameter measured in standard way. Similarly, losses incurred by length measurement errors are greatest when the measured lengths are lower than the nominal lengths. In both cases, the main reason for the error lies in the fact that various log types measured by a machine fail to meet the dimensions required by the relevant standards and are therefore classified into a lower quality class when sold. As has already been said, positive length and diameter measurement errors (nominal dimensions exceed the measured values) cause lower losses than the negative errors. This is due to a simple fact that logs which are too long need not be classified into a lower quality class on account of the error, which is, on the other hand, obligatory for logs which are too short to achieve the required dimensions.

In order to establish the accuracy of cross-cutting carried out by the processor head in the course of bucking operations, several indicators were used that had already been applied in other similar studies (CONRADIE *et al.* 2004, SONDELL *et al.* 2002). The indicators used in this study were frequency distribution of log lengths and the share of logs in the five-centimetre interval, with the modus of frequency distribution located in its centre (the best five). Frequency distribution of conifer log lengths is given in Figure 3.

Figure 3 shows a distinctively asymmetrical distribution of log lengths. Logs which are longer than required by the provisions of the standard dominate the sample. The value of

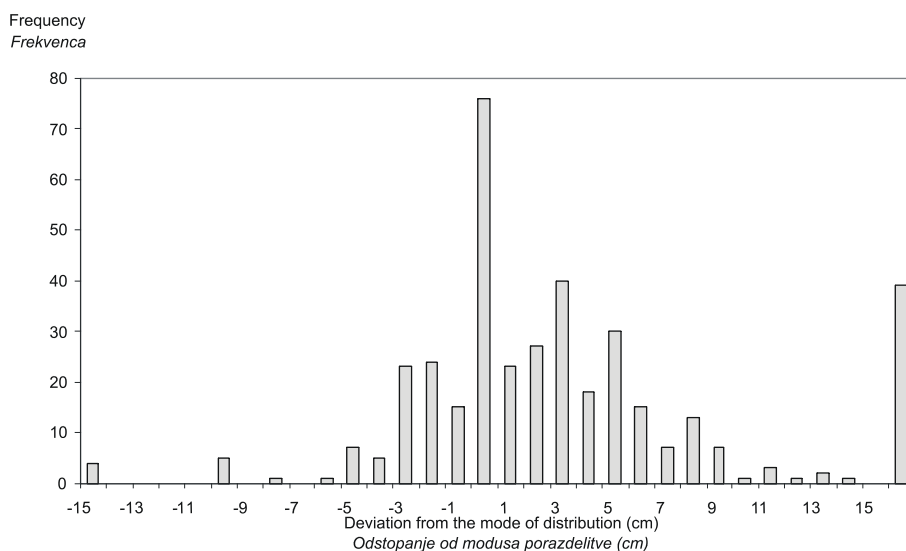


Fig. 3: Frequency distribution of conifer log lengths

*Slika 3: Frekvenčna porazdelitev dolžin sortimentov iglavcev*

the modus is higher than the value of the required length set on the machine. Evidently, this is a systematic error which is consciously tolerated during harvester operation, which is largely due to the already mentioned fact that the economic loss is lower for excessively long logs than in short logs, as has also been reported by other authors (HAMISH *et al.* 2006).

The calculated share of logs within the interval of  $\pm 5$  cm, at whose center lies the modus of distribution (the best five), is 54.3%. Other similar studies indicate similar results for length measurement accuracy in mechanized bucking (TOPLITSCH 1991). It was established that the Woody H60 processor produces a systematic error on account of which cross-cut tree sections are 6 cm longer than the pre-determined length value. The error, which is in fact unnecessary as

it results from machine settings, was first identified during this study. The error can be reduced with frequent calibration of the machine's measuring system. The obtained finding clearly shows that log length measurement systems should be checked more regularly. Regular checks are crucial in advanced technology, that is wherever mechanized harvesting is carried out and when log dimensions are measured with harvester or processor heads.

Another finding of this research was how in conifers a rise in diameter at breast height increases the value of wood and, consequently, the value of bucking errors. These findings are consistent with certain recent studies (REBULA 1996, 1998). In his study, the author finds that in fir logs the values first increase with growing diameter at breast height and reach the

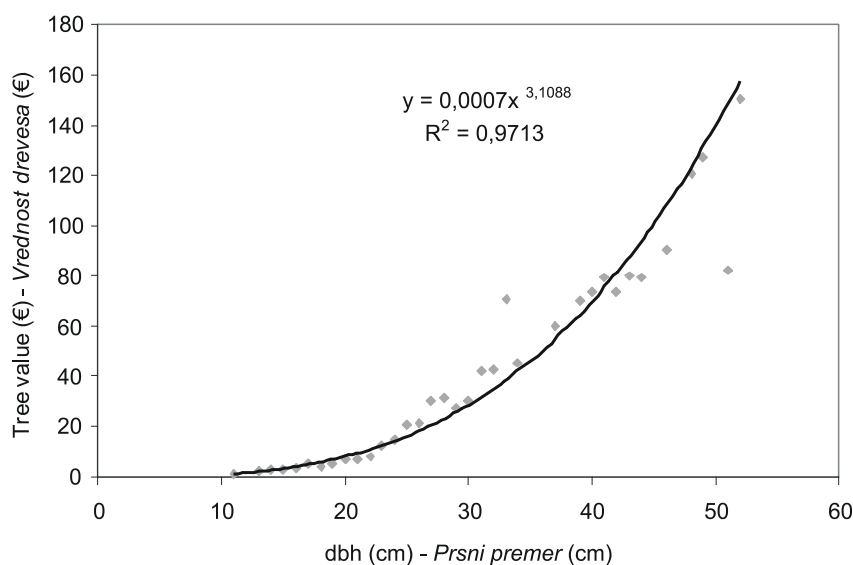


Figure 4: Value of the tree in relation to diameter at breast height

*Slika 4: Vrednost drevesa glede na prsni premer*

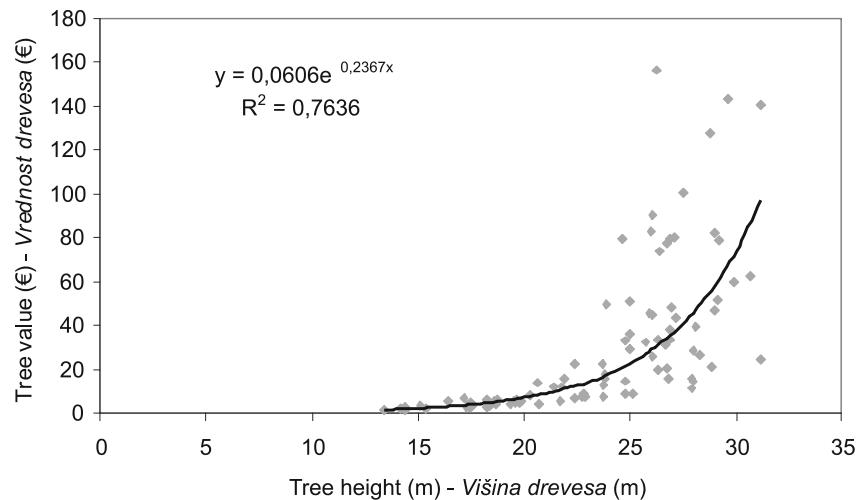


Fig. 5: Tree value in relation to tree height

*Slika 5: Vrednost drevesa glede na njegovo višino*

peak at a thickness of 40 to 50 cm. The present research focused on thinner stems, and the ratio between the value of wood and diameter at breast height is presented in Figure 4.

Tree value also increases with tree height. REBULA (1996) states that with increasing length the value of the stem rises progressively at the same diameter of the tree. The relation between tree height and tree value (from present research) is given in Figure 5.

In order to determine the effects of cross-cutting inaccuracy on loss value we first needed to explain the accuracy calculation method. For the purpose of this study, accuracy was expressed as cross-cut allowance, which is added to each log length and given to the customer free-of-charge. In this study, 2.71 m<sup>3</sup> of excess size was generated, amounting to 4.06% of the total quantity, which in terms of value amounts to 129 Euros or 4.38% of the total log value. Loss of value is caused by the difference between the nominal length of the stem (on average exceeding the required value) and the minimum required length of 404 cm.

Considering the poor accuracy of cross-cutting in mechanized bucking and simultaneous assessment of value loss, we needed to determine the section of the tree which contains the majority of the stem value. The process requires special attention to be paid to relative value relations that exist within the stem segments. The data was gathered by comparing the values of a specific tree section against the value of the whole tree. The figure presents the changes in the total tree value. The research found that 64% of the tree value is contained within the first quarter of conifer stems. The finding is relevant for the studied work site and cannot be generalized, although it is typical for the described conditions.

The described distribution of values relative to the length of the tree is closely linked to the loss incurred as a result of inaccurate cross-cutting in mechanized bucking. Our objective was to find out in which section of the stem the measurement errors were greatest. In order to determine this, the value of tree logs was replaced with the relative value of errors. An analysis into the share of loss in relation to tree height showed that the first cross-cut was responsible for nearly 50% of the total loss and the second cross-cut pushed to figure to over 80%. The percentage would be even higher for large-diameter trees occasionally harvested at Syncrofalke sites.

The research found that value loss from inaccuracy of cross-cutting in conifers amounted to 4.38% of the total log value. We have to stress that the present research only focused on the losses incurred either as a result of positive or negative cross-cut allowance or due to insufficiently accurate length measurements of certain log types.

## CONCLUSIONS AND DISCUSSION ZAKLJUČKI IN RAZPRAVA

Mechanized wood harvesting or wood processing carried out at a landing by a wood processor brings higher efficiency, economic value and better safety into forest production. Various forest operations are no longer carried out at the forest work site; on the contrary, as a result of the use full tree method and cable yarding, these operations are being moved to the landing site and truck road.

In the presented case, both delimiting and bucking were performed at the landing. New technologies have considerably changed the process of bucking and measuring log leng-

ths. Classical bucking at the stump and measuring logs using a measuring tape have been taken over by a cableway processor. Length measurement performed by a processor is more time-efficient but also prone to inaccuracy. When mechanized bucking was introduced at the site, our aim was to determine the level of errors occurring at the selected work site and to estimate the economic impact of such measurements.

Bucking accuracy was presented with a frequency distribution and the share of logs within the  $\pm 5$  cm interval surrounding the distribution mode. The figure amounted to 54%, which is very poor. We found that distribution of lengths was asymmetrical; on average, logs are longer than required with regard to standard lengths, which is, however, still better than logs which fail to meet the required lengths because they are too short.

The value of the tree and the value per  $1 \text{ m}^3$  of wood rises in line with increasing diameter at breast height and tree height. The study showed that the first quarter of the tree contains 64% of the total tree value. When discussing the losses incurred during bucking due to inaccurate length measurements, we have to stress that the first measurement and cross-cut in the thicker and normally more valuable section of the stem is responsible for the most significant portion of the total quantity and value loss. In fact, the first cross-cut was responsible for 50% of the loss and the second cut pushed the figure up to 80% of the total value loss incurred in mechanized bucking of wood.

We have to mention the possibility of reducing the losses through deliberate cutting to longer lengths; however, a certain amount of loss is pending as the customer cannot be charged for cross-cut allowance. Furthermore, such bucking involves the threat of losing the last log, as this one is either too short due to positive cross-cut allowances of previous logs or fails to meet the required quality for any other reasons (diameter decrease, various defects). The price drop is most dramatic between the prices of logs and pulpwood.

## SUMMARY

The aim of the research was to establish the errors that occur in length measurements performed in the course of mechanized conifer bucking and to assess the economic impact of these errors. Three lines of the Syncrofalke tower cable crane were studied for the following: accuracy of cross-cutting and its impact on the product's market value, the relation between diameter at breast height and tree value and the relation between tree height and tree value. On the basis of gathe-

red data, log values were determined relative to the value of the total stem, and the results obtained were used to estimate the level of the error caused by inaccurate cross-cutting with the Woody H60 processor.

Fifty-four percent of all logs fell within the interval of  $\pm 5$  cm from the mode of distribution of log lengths. Inaccurate length measurements result in log value loss, which was expressed as the value of cross-cut allowance given to the customer free-of-charge. In this study crosscut allowance amounted to  $2.71 \text{ m}^3$  or 4.38%. It needs to be noted that the present research only focused on the losses incurred either by positive or negative cross-cut allowance or by insufficiently accurate length measurement of a certain log type.

In our case, 64% of the tree value was contained within the first quarter of the tree. Although the result is only applicable to the studied work site and cannot be generalized, it is typical of the described conditions. As a result, errors caused by inaccurate measurement are highest in the lower section of the tree. The analysis showed that the first cross-cut on the stem was responsible for nearly 50% of the value total loss and the second cross-cut pushed the figure up to 80%.

## POVZETEK

Raziskava je nastala z namenom, da ob uvajanju strojnega krojenja iglavcev ugotovimo napake pri izmeri sortimentov in ocenimo njihov vpliv na gospodarnost takšnih izmer. Tako smo na treh linijah žičnega žerjava s stolpom Syncrofalke ugotavljali: natančnost prežagovanja in njegov vpliv na tržno vrednost sortimenta, odvisnost med velikostjo prsnega premera in vrednostjo drevesa ter odvisnost med drevesno višino in vrednostjo drevesa. Na podlagi teh podatkov smo ugotavljali vrednosti posameznega sortimenta v vrednosti celega debla, iz tega pa velikost napake zaradi nenatančnega prežagovanja z glavo za izdelavo Woody H 60.

Znotraj  $\pm 5$  cm intervala okoli modusa porazdelitve dolžin sortimentov je bilo 54 % vseh sortimentov. Zaradi nenatančnosti izmer dolžin prihaja do izgube vrednosti sortimentov, ki smo jo izrazili z vrednostjo nadmere, ki jo kupcu podarimo. Pri tej raziskavi je nastalo  $2,71 \text{ m}^3$  nadmere oz. 4,38-odstotni vrednostni delež. Treba je poudariti, da se je naša raziskava osredotočila zgolj na izgube, ki nastanejo zaradi prevelike ali premajhne nadmere pri določenem sortimentu, oziroma zaradi premalo natančne izmere dolžin posameznih sortimentov.

V našem primeru je bilo v prvi četrtini debel iglavcev 64 % vrednosti drevesa. To velja seveda za preučevano delovišče in rezultata ne gre posploševati, čeprav je za opisane razmere

tipičen. Zato so v spodnjem delu drevesa tudi napake zaradi nenatančnih izmer največje. V analizi smo ugotovili, da smo že ob prvem prerezu na deblu dosegli skoraj 50-odstotne skupne izgube vrednosti, pri drugem prerezu pa že več kot 80-odstotne.

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