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TIME EXPENDITURE ANALYSIS OF CUT-TO-LENGTH HARVESTERS IN INCIDENTAL FELLINGS COMPARED WITH PRODUCTION EFFICIENCY

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Abstract: *A series of time-studying pictures were taken between November and December 2008, emphasizing the time consumption on individual working sections of wood felling realized by cut-to-length harvesters. Measurements were done in a same-aged stand of spruce (Picea abies), completely destroyed by wind disaster, the age of 129 years with an average diameter of 30 cm / DBH and average volume of 0,91 m3. Machines participating in the experiment were Rottne H20 with an EGS-700 cutting head and Rottne 5005 with a n EGS-604 cutting head. A total of 25 000 m3 of wood was harvested and a total of 3390 time-studying data was obtained. Data obtained from field measurements were analyzed using statistical functions and then compared with the results of data in regular felling. The aim of the experiment was to assess the efficiency of harvesters in incidental felling and compare it with the efficiency of regular felling. Results of the experiment: It has been proved that the difference between harvester time consumption in incidental felling and regular felling under comparable conditions of forest stand is not statistically significant. It follows that wind damage to crops in the incidental felling does not lowers the harvester working efficiency. Deploying harvesters to liquidate wind damaged stands can be recommended not only for its high level of safety, but also because of high production efficiency.*

1. Introduction

Cut-to-length method (CTL) is probably the most advanced logging and transportation system nowadays. In this technique, sometimes called the Nordic harvesting, mostly referred to as the CTL, tree stems are divided (processed) into smaller logs at the logging place. CTL is very fast, powerful, versatile and also environmentally friendly method. High level of a personal safety is a very important advantage to. Harvesters combined with forwarders can be deployed into a versatile stand conditions with a slope up to 40 % (Janeček, 2002). It can be used also in waterlogged stands, if the machines are equipped with a tank tracks.

According to a many advantages of the CTL, there is a large increase in the number of harvesters and forwarders all around the Europe including the Czech Republic.

While, at the end of year 2006, there were 222 registered harvesters in Czech Republic, of which 201 were wheeled harvesters (MZE 2006), at the end of year 2008, there were 332 machines in operation, 307 of them were wheeled harvesters. In 2008, the CTL is was participating on total wood logging of 30%, what, compared to year 2002, represents an increase of 23.2% (MZE 2008). Multiple increase in the use of CTL in the Czech Republic over the past few years shows the enormous potential of this mining method. Moreover, compared with most developed countries of forestry, such as Finland or

Norway, where harvesters share up to 80% of total amount of wood logging (Nabuurs et al. 2007), promises to the CTL i the Czech Republic a very competitive future.

In connection with the upsurge in the number of harvesters, there is a large increasing of pressure on operators of harvesters and forwarders. The operator effect may be regarded as the most important factor, witch influences the cutting productivity. It is therefore necessary to pay attention to an improvement of teaching, or training new operators in order to respond to the increasing demands placed on them.

2. Material and Methods

2.1 Aim

The aim of the experiment is, using data collected by measurements in situ, record, evaluate and describe the time consumption of processing of wind damaged trees. The comparison of the results of the measured values with values derived from the planned logging shows the influence of wind damaged stand conditions ion harvester efficiency in incidental felling.

2.2 Time Frames Method

A method of time frames is the main basis to describe the working day and processing of each tree. It was shown that the average time required for processing a single tree do not significantly changes with growing tree volume, assuming that an appropriate performance class harvester was selected and that the tree volume is in the normal dimensions (Kellogg - Bettinger 1994, Bulley 1999 Jiroušek et al . 2007, Puttock et al. 2009). This paradox can be explained by the fact, that more powerful harvester, which is used for the higher tree volume, has also stronger hydraulic crane, faster shift of cutting head and more powerful cutting device than harvester with less power, which usually processes lower tree size. Basically, smaller harvester needs approximately the same time for processing smaller trees as the stronger one for bigger trees. A prerequisite for this is that the right performance class of harvester is used for processing of concrete tree size.
The partition of performance classes according Janecek (2002):

- Low Performance: engine output power up to 70 kW
- Medium Performance: engine output power between 70-140 kW
- High Performance: engine output power over 140 kW

A snapshot of the time consumption for each work operation is a very effective tool for assessing the impact of random stand conditions on logging productivity, but it eliminates the impact of the daily performance, which may be misleading. It is therefore necessary to combine data of the time consumption for processing each tree with an indication of the overall daily performance.

2.3 Work Phase Classification

Cutting and processing each tree were considered as a working cycle which can be divided into smaller frames called work phases. These elements of time helped for better overview of share of every different part of work on working cycle. In this study the following work phases were determined:

- Moving: Begins when the harvester starts its move and ends when the wheels of the machine stops. It is not conclusive if the harvester is moving forward or backward, or if it is a combination of more directions. If the harvester stops and than starts to move again without processing a tree, it is deemed as one work phase.

- Positioning of Cutting Head: Begins when the crane starts to move towards a tree and ends when the cutting head snaps on the tree. Clamping of jaws is not deemed in this phase.

- Clamping the Tree and Cutting: Begins when the jaws of cutting head clamps on the tree and ends when the chainsaw finishes main incision and the tree falls down.

- Handling the Tree: Begins when the tree falls down and the operator starts to handle it and ends when the harvester starts the processing. This work phase was used especially for the conditions in incidental felling, because it was assumed that the biggest difference in time consumption in incidental felling and regular felling will be registered in handling of the tree which is more difficult in conditions of a wind damaged stand.

- Processing: Begins when the feeding rolls start to run and ends when whole tree is processed and the harvester starts to move to another position. This phase includes delimbing, sorting and cutting logs.

2.4 Measurement

The measurement was carried out using simple equipment as a stopwatch and simultaneously recorded into the table. An effort was to made all measures in precision in seconds. However, there were variations caused by blurred transition between work phases. These unpredictable errors were normalized using a big number of measured cycles. There was also a video record for better self-control and minimizing errors. Sample of a used table below:

Table 1. Table used for recording the data of time consumption of harvester (s)

sheet no:	group no:		
Measurement no.	1	2	3
Moving			
Positioning			
Clamping			
Handling			
Processing			
Miscellaneous			
Total			

2.5 Data Analysis

Given the fact that there were 3390 time study data obtained, it was necessary to analyze it using statistical functions.
For its simplicity and comfort while in orientation were selected following statistical tools:

- Arithmetic Mean
- Standard Deviation
- Modus
- Median

2.6 Machines

Two different harvesters were studied, both in the Hight Performance class, Rottne H20 with EGS 700 cutting head and Rottne 5005 with EGS 604 cutting head, see technical specifications in tables below. Each operator was used to work with this type of machine for more than four years. All operators worked the same technique. They produced the same types of logs and put them on both sides of a strip road. Majority of logs were 2 and 4 meters long sawlogs (60 %), the rest was pulpwood and firewood.

Table 2. Technical specification (reparoservis catalog)

	Rottne H20	Rottne 5005
Engine		
Cylinder displacement	9 000 cm3	6800 cm3
Torque at 1400 rpm	1095 Nm	809 Nm
Output at 2200 rpm	187 kW (250 hp)	149 kW (200 Hp)
Cutting head		
Cutting diameter	750 mm	550 mm
Delimbing diameter	50 - 700 mm	50–450 mm
Feed force	27 kN	22 kN
Feed speed	3,7 m/s	3,4 m/s
Weight	1 400 kg	900 kg
Crane		
Reach	10 m	10,3 m
Lift torque	200 kNm	150 kNm
Total weight		
	21 000 kg	15 000 kg

2.7. Stands

The time study was done in the November and December 2008. There were two stands observed - 713 D 13 (SA) and 721 B9 (SB) in the Nasavrky forest district. SA was a monoculture of spruce (Picea Abies), completely destroyed by wind disaster, the age of 129 years with an average diameter of 30 cm / DBH and average volume of 0,91 m^3. SB was a monoculture of spruce (Picea Abies), also completely destroyed by wind disaster, the age of 110 years with an average diameter of 26 cm / DBH and average volume of 0,67 m^3. The terrain conditions of stands were measured using table method (Dvořák, 2004). SA was, according to a very difficult conditions (slope up to 25%), put into a class Hard to gauge. SB was put into a class Easy to gauge. In both cases, the barriers do not exceed the allowable limit for moving (barriers over 0,5 m hight spacing 4 m).

3. Results

Harvesters Rottne 5005 needed an average of 11,8 seconds more to perform one operation than Rottne H20. This could be explained by the demanding conditions of the terrain on which Rottne 5005 realized the logging. This assumption is confirmed by the higher variability in the data set of measurements the harvester Rottne 5005. Higher feeding speed of cutting head of Rottne H20 harvester is reflected in the results of separate work phases, the machine needed average of 8 seconds less for the processing than Rottne 5005 harvester. It is evident that the difference in the time consumption between these two harvesters was caused by different technical equipment and specifications in the first place, and by the stand conditions on the second place.

678 cycles were monitored, witch represent 678 of trees processed and 3390 time-data. Data were than analyzed using statistical tools. Extreme time fluctuations were eliminated. The results of statistical analyses see below.

Table 3. Results of the statistical analyze for the Rottne 5005 harvester

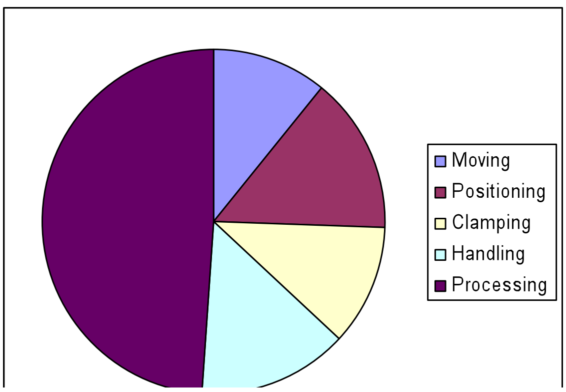
	Arithmetic Mean	Modus	Median	Standard Deviation	number of measurements
	(s)				(-)
Moving	6,7	0	4	10,57	438
Positioning of C. Head	9,1	5	8	4,65	438
Clamping the Tree	7	2	7	3,77	438
Handling the Tree	8,8	2	7	9,07	438
Processing	30,2	31	29	16,53	438
Total	61,8	44	59	22,72	438

Table 4. Results of the statistical analyze for the Rottne H20 harvester

	Arithmetic Mean	Modus	Median	Standard Deviation	Number of Measurements
	(s)				(-)
Moving	5,1	0	2	0,65	240
Positioning of C. Head	6,2	3	5	6,06	240
Clamping the Tree	3,5	2	2	3,67	240
Handling the Tree	13	0	8	18,18	240
Processing	22,2	0	19	18,26	240
Total	50	36	44	27,46	240

Table 5: Percentage of individual work phases of the whole working cycle (%)

	Rottne 5005	Rottne H20
Moving	10,8	10,2
Positioning of C. Head	14,7	12,4
Clamping the Tree	11,3	7
Handling the Tre	14,3	26
Processing	48,9	44,4



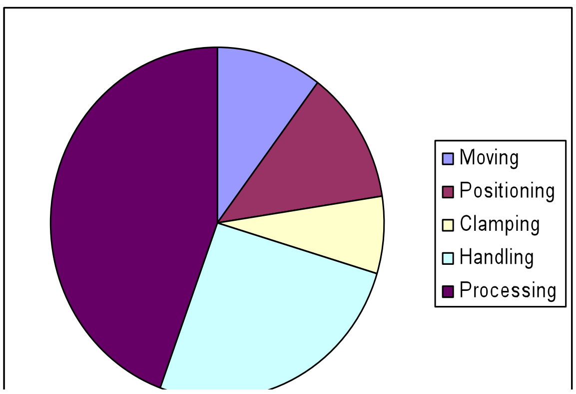


Figure 1. Layout of the work phases Rottne 5005

Figure 2. Layout of the work phases Rottne H20

4. Discussion

Comparison of experiment results with the work of Ulrich et al. (2002) and Nurminen et al. (2006) shows that the time consumption of logging in incidental felling and regular felling under similar conditions (tree volume, density, performance of harvester), do not shows statistically significant difference. That can be explained by the fact, that the work phases affected by the specific conditions in incidental felling (moving, positioning, handling) represent relatively small share in the total time. On the other side processing, which is the most time-consuming work phase is not affected by the specific conditions in incidental felling.

The results do not confirm that the difference in the efficiency of wood production is not statistical significant. It is clear, that the trees damaged by wind will not provide hight quality logs in such quantities as the intact trees, so the overall review of wood production and its realization has to be lower in incidental felling, but it has been proved, that the time consumption of harvesters in incidental felling and regular felling is approximately the same. In any case, the standard deviation, which is relatively hight, shows that the dataset of this experiment is very variable and will need further research for a final conclusion.

Due to the limited number of study stands, operators and processed trees, the result of this experiment represent just a small part of nationwide time consumption of CTL. The conclusions from this experiment can not be applied to various production conditions. An further research is much needed for refine of results.

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