УДК 630

TIME STUDY ANALYSES OF SKIDDING WITH CABLE-GRAPPLE SKIDDER EQUUS 175N

Orlovsky L., Ing.
Technical Univerzity in Zvolen
(Zvolen, Slovak Republic), e-mail: xorlovsky@is.tuzvo.sk

ВРЕМЕННЫЕ ИССЛЕДОВАНИЯ АНАЛИЗА ТРЕЛЕВКИ С ПОМОЩЬЮ ТРЕЛЕВОЧНОГО ТРАКТОРА CABLE-GRAPPLE EQUUS 175N

Орловски Л., инж.
Технический университет в Зволене
(Зволен, Словацкая Республика)

Abstract. This time study assesses time consumption and productivity of EQUUS 175N cable-grapple skidder. Within the time study 34 work cycles were measured, and 9 snapshots of work day were taken. In the study was used methods of continuous time study. The result show that the overall time consumption of the work cycle of the monitored cable-grapple skidder is influenced by skidding diatance and number of logs in a load. Non-operation times of the skidder operator shift represent 27 % with the highest pert taken by the machine defaults repair. The mean gross production rate of the monitored skidder was 5,85 $m^3.h^{-1}$. The aim of the present study was to: (i) assess the impact of production factors on the time consumption of individual partial work operations of EQUUS 175N cable-grapple skidder; (ii) find out and compare the productivity of monitored skidder.

Key words: time study; time consumption; cable-grapple skidder; skidding; production factors productivity

Аннотация. В этом исследовании оцениваются затраты времени и производительность трелевочного трелевочного трактора EQUUS 175N. За время исследования было измерено 34 рабочих цикла и проведен хронометраж 9 рабочих дней. При исследовании использовались методы непрерывного изучения времени. Результаты показывают, что общее время, затрачиваемое на рабочий цикл отслеживаемого трелевочного тракта с кабельным захватом, зависит от расстояния скольжения и количества бревен в нагрузке. Время простоев оператора трелевочного трактора во время смены составляет 27%, при этом наибольшее значение отмечается при ремонте машины по умолчанию. Средняя валовая производительность контролируемого трелевочного трактора составила 5,85 $м^3ч^{-1}$. Целью настоящего исследования было: (i) оценить влияние факторов производства на затраты времени на отдельные операции частичной работы кабельно-захватного трелевочного трактора EQUUS 175N; (ii) выяснить и сравнить производительность контролируемого трелевочного трактора.

Ключевые слова: время обучения; потребление времени; трелевочный трактор; трелевка; производственные факторы производительности

Introduction. Harvesting systems, such as those associated with cahinsaw and skidders, are quite common in Europe (Borz et al. 2015). The Slovak Republic is no exception. According to the 2007 Green Report, the share of tractor technologies in wood concentration i sup to 78%, of winch forest wheel tractors account for 47,6%. Present day performance standards for skidder technologies published in the proceedings no 24 of the Ministery of Agriculture and Rural Development of the Slovak are not current (last issue from 1992). They do not correspond to the current development of forestry equipment and requirements for modern skidders regarding ergonomics and ecology.

A number of authors from abroad have dealt with time studies of forest wheeled tractors (Behjou et al. 2008; Mousavi et al. 2012; Borz et al. 2013; Proto et al. 2018; Kulak et al. 2019). Kluender et al. (1997) studied the productivities of rubber-tired cable and grapple skidders in southern pine stands and found that grapple skidders were considerably faster and move productive than cable skidders. They also indicated that the productivity of this grapple skidding was sensitive to a skidding distance, sterm size, number of sterms in load and harvesting intensity. Proto et al. (2018) in his study assesses the productivity and cost effectiveness of John Deere 548H cable-grapple skidder, including a comparison of winch and grapple configurations. Najafi et al. (2007) carried out a time study to obtain a mathematical model and to calculate the production cost. Wang et al. (2004) mentioned that the skidding cycle time was mainly affected by volume load and skidding distance. Borz et al. (2013) presented in their study that teh time consumption of overall work cycle of the skidders (TAF 690OP , TAF 657) depends on the skidding diatnce, winching distance and in case skidder TAF 657 the number of logs was also another statististically significant factor. Behjou et al. (2008) in time study of the wheled skidder Timberjack 450C in Caspian forests indicated taht the skidding cycle time was mainly affected by skidding distance, winching distance and interaction between skidding distance and slope.

Material and methods. Study of the time consumption was carried out in the Univerzity Forestry Enterprise of the Technical University in Zvolen from 15 September to 25 October 2019. During the time study 9 snapshots of the work day were taken and 34 work cycles of skidders were measured. In the study was tested cable-grapple skidder EQUUS 175N. The working group consisted of two persons including logger and skidder operator. They had several years of experience with that type of machine and performed all service and most of repair works. Table1 presents the chrakteristics of the forest stands where the timber skidding was carried out, while Table 2 describes the chrakteristic parameters of individual momnitored skidder analysed within the study.

Table 1 – Characteristics of forest stands

Subcompartment	727a
Stand age (years)	110
Stand area (ha)	15.84
Stand density	0.81
Slope (%)	55
Species composition (%)	BK 78; JD 13; JH 5; JS 3; LM 1
Skidding distance (m)	110
BK- beech, JD- fir, JH- maple , JS- ash , LM- lime	

Table 2 – Specifications of the EQUUS 175N cable-grapple skidder

Parameter	Value
Engine power (kW)	125
Age of skidder in years	1
Lenght (mm)	6,678
Width (mm)	2,450
Height (mm)	2,870
,Mass (kg)	12,400
Total skidded volume (m^3)	360
Number of skidded logs (pcs)	199
Equipment of skidder	HC, RO,D, C
HC- hydraulic crane, RC- radio control, C-clambank, D-double drum winch	

Measuring the time consumption of cable-gapple skidder was carried out using the methods of continual time study. Net time work of the skidder operator and two further categories of time losses, i.e. technical-organisation and personal losses were recorded, as well. Overall work cycle wheeled skidder was dovided into several elements: travel unloaded, cable relasing, collecting time, winching the load, skidder travel to other logs, travel loaded, load unhooking, handling by the skidder operator and log piling. All work phases were recorded just as if the operator were in a normal working condition without any special arrangements. A number of variables including skidding distance, winching distance, number of trees per turn and load volume were measured. These factors were measured throughout all skidder work cycles. The skidding distance and winching distance were measurd using a digital laser range finder TruPulse 360B or using a GPS receiver. The number of logs in a load and wood species were recorded visually. To determine the logs volume and loading, Huber´s formula volume and collection logs volume in each time of skidding was used, respectively. In order to develop prediction model for the cable-garapple skidder EQUUS 175N multiple regresion analysis using the last square method was applied to test the correlation. STATISTICA 12.0 package was used for the statistical analysis. In order to examine the goodnessoffit of regression models and to test the co-significance of coefficiebnt, F-test was conducted. Each coeficient of the work phase models was also tested separately by t-test.

Findings. Table 3 presents the mean time consumption of individual monitored phases of a work shift of monitored skidder operator, as well as the mean time of the shift. The data indicate that the net time work is 73% on average, and the remaining 27% covers non-operation time of the shift (machine defaults repair, biological and recreational breaks etc.). The highest average percentage of non-operation time was recorded with the machine defaults repair 5.5% followed by technical-organizational losses 5.4%, whereas the lowest average percentage is represented by Personal losses 0.1%. The average shift lenght of monitored skidder operator in this study represents 461 minutes (7.68 h) being 19 minutes less than the lenght of a standard shift (8 h).

Table 3 – The balance of average consumption of elements shift time of skidder operator

Work shift components	EQUUS 175N	
	min.	%
Net time work	337	73
Preparation and termination of work	18	4
Work orders	7	1.5
Technical service of the workplace	15	3.3
Technical service of the machine	10	2.2
Machine defaults repair	25,5	5.5
Biological and recreational breaks	23	5
Technical-organizational losses	25	5.4
Personal losses	0,5	0.1
Average working time	461	100

The average time consumption for partial work operations, as well as corresponding average values of production factors of the skidder are illustrated in Table 4.

Table 4 – Descriptive statistics of mean time consumption of elements work operation of monitored skidder

Element of work operation	Mean	Minimum	Maximum	Standard Deviation
		(min.)		
Travel unloaded	7.56	1.47	12.78	2.60
Cable relasing	1.98	0.47	6.40	1.37
Collecting time	8.77	0.07	23.28	4.64
Winching load	8.06	0.40	14.13	3.12
Travel skidder to other logs	4.96	0.22	18.58	3.87
Travel loaded	9.83	1.58	15.80	3.66

Unhooking load	2.97	0.23	6.10	1.25
Log piling	17.18	1.35	36.95	9.32
Handling	8.05	1.02	23.70	5.50
Total cycle time	70.16	4.74	122.95	25.89
Factors of production				
Number of log in load (pcs)	6.00	1.00	12.00	2.28
Load volume (m^3)	10.96	0.79	15.68	3.20
Mean tree volume (m^3)	1.96	0.79	3.09	0.52
Skidding distance (m)	530.00	200.00	801.00	143.70
Winching distance (m)	18.56	3.00	33.00	6.68

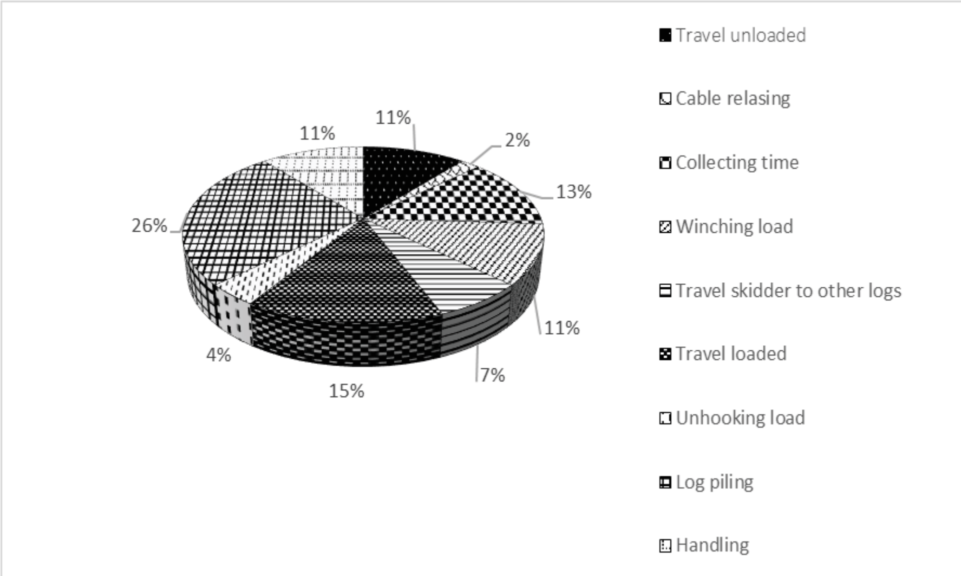

Figure 1 – The time distribution of elements work operation of cable-grapple skidder EQUUS 175N

The time distribution of different elements of work cykle cable-grapple skidder EQUUS 175N is presented in Figure 2. Log piling is the most timeconsuming element for EQUUS 175N cable-grapple skidder (26%) followed by travel loaded (15%) and collecting time (13%). The statistical chrakteristics of the regresion models for skidder EQUUS 175N are presented in Table 5. F-value and P- value show that presented models are statistically significant.

Table 5 – Statistical charakteristic of models EQUUS 175N cable-grapple skidder based on regression analysis

Elemental of working operation	R	Adj. R2	F-test		N	Term	b*	error b*	Constant	Std.error	t-test	
			F-value	p					coeficient		t-value	p
Travel unloaded	0.85	0.71	83.48	p<0.000	34	constant			-0.592	0.924	-0.641	0.526
						xsd	0.85	0.093	0.015	0.002	9.136	0.000
Collecting time	0.76	0.57	40.18	p<0.000	34	constant			-0.285	1.461	-0.195	0.850
						xn	0.76	0.114	1.548	0.233	6.646	0.000
Winching the load	0.72	0.48	15.83	p<0.000	33	constant			0.477	1.441	0.331	0.743
						xwd	0.57	0.132	0.268	0.062	4.352	0.000
						xn	0.30	0.132	0.433	0.192	2.258	0.031
Travel loaded	0.76	0.55	21.29	p<0.000	34	constatnt			-0.319	1.762	-0.749	0.460
						xsd	0.52	0.143	0.013	0.003	3.614	0.001
						xvl	0.33	0.143	0.379	0.164	2.301	0.028

Unhooking load	0.53	0.26	12.45	p<0.000	34	constant			1.281	0.513	2.497	0.018
						xn	0.53	0.150	0.289	0.082	3.532	0.001
Log piling	0.45	0.17	7.98	p<0.000	34	constant			6.517	4.044	1.611	0.117
						xn	0.45	0.160	1.821	0.645	2.825	0.008
Total cycle time	0.78	0.58	23.91	p<0.000	34	constant			-7.836	11.838	-0.662	0.520
						xn	0.45	0.119	5.692	1.358	4.192	0.000
						xsd	0.50	0,.119	0.081	0.022	3.739	0.000

Xsd – skidding distance, xvl – volume load, xn – number of logs in a load

Discusion. Methoodlogically, the emphasis of this study was on the comparative area with less attentation paid to the correlation aspects. The main problem of the correlation study is the multiplicity of influencing factors which was controlled by a detailed division of harvesting work phases into elements (Bergstrand 1991; Nurminen et al. 2006).

Non-operation shift times represent on average 27% for monitored skidder operator. For ilustration and comparison Sabo and Poršinsky (2005) in their study indicate higher percentage 32.15% of non-operation time for the Timberjack 240C skidder. The highest amount of non-operation times – 51 and 43% for cable skidders (TAF 690OP, TAF 657) are mentioned by Borz et al. (2013) Technical-organizational losses accounted for almost 98% of the delay time. Percentage of personal delay (0.1%) was low compared to the studies performed (Lotfalin et al. 2011, Mousavi et al. 2013, Borz et al. 2015). The amount of non-operation shift times of the skidder operator is affected mostly by the amount of time consumed for the machine defaults repair, occurrence of technical-organizational losses during the sift. These time losses can be avoided by planing and organising the work better. The average speed of EQUUS 175N in travel unloaded was 4.20 $km.h^{-1}$ for comparison the average skidding speed was 25% lower 3.23 $km.h^{-1}$. The average gross production rate of cable-grappple skidder was 5.85 $m^3.h^{-1}$ with the mean load volume 11.27 m^3. Most of the studies from abroad mention higher average gross production of cable-grapple skidders ranging from 6.2 $m^3.h^{-1}$ (Mousavi et al.2013) to 21.0 $m^3.h^{-1}$ (Medrski et al. 2010). With a decrease in the number of logs per load , the volume of each cycle decreases, which has a significant influence on skidding productivity (Nikooy et al. 2013).

The model travel unloaded cable-grapple skidder showed that it was highly dependet on the skidding distance (Table 5). These results are in accordance with other studies (Wang et al. 2004, Nurminen et al. 2006, Mousavi et al. 2012). The work elemets operation collecting time takes around 13% of the total time consumption of wok cykle (Figure 2) and it is influenced by the number of logs in load, wat is in accordance with the study of Mousavi (2012). Time consumption of winching the load is statistically significantly influenced by the winching distance and number of logs in the load, what is in accordance with the study of Mousavi (2012). The partial work operation- travel loaded is statistically significantly influenced by the skidding distance and load volume. These results are in accordance with the results presented in the study by Marčeta et al. (2014). The work element operation unhooking the load it is influenced by the only number of logs in the load Log piling is the last element of skidding and it is influenced by the number of logs in each turn. The overal time of the work cycle of the cable-grapple skidder (EQUUS 175N) operators is a affected by the following factors: skidding distance and number of logs in the load. Differences between the results of this study and those reported by other studies may be the consequence of local conditions and work patterns of the operators.

Acknowledgments. The paper has been prepared under the financial support of the Ministry of Education, Science and Sports of the Slovak Republic in the frameworks of the project KEGA 007TU Z-4/2019."

BIBIOGRAPHY

Behjou, F.K., Majnounian, B., Namiranian, M., Dvořák, J., 2008. Time study and skidding capacity of wheeled skidder Timberjack 450C in Caspian forests. Journal of Forest Science, 54(4): 183-188.

Bergstrand K.G. 1991. Planning and Analysis of Forestry Operation Studies. Skogsarbeten Bulletin 17. Skogsforsk Uppsala, Forest Operations Institute of Sweden: 63.

Borz, S. A, Dlnulca, F., Birda, M. Ignea, Ch., Clobanu, V. D., Popa, B., 2013. Time consumption and productivity of skidding Silver fir (*Abies alba* Mill.) round wood in reduced accessibility conditions: A case study in winthrow salvage logging from Romanian Carpathians. Annals of Forest Research, 56(2): 363-375.

Borz, S.A., Ignea, G., Popa, B., Spârchez, G., Iordache, E., 2015. Estgimating time consumption and productivity of roundwood skidding in grounp shelterwood system- a Case study in a broadleaved mixed stand located in reduced accessibility conditions. Croatian Journal of Forest Enginering 36(1): 137-146.

Kulak, D., Stańczykiewicz, A., Szewczyk, G., Wala, Ł., 2019. Wydajność zrywki drewna skiderem na terenach pochylych. Sylwan, 163(7): 601-609.

Kluender, R., Loretz, D., Mscoy, W., Stokes, B.J., Klepac, J., 1997. Productivity of rubber-tored skidders in southern pine stands. Journal of Forest Products, 47(11-12): 53-58.

Lotfalian. M., Moafi, M., Foumani, B.S., Akbari, R.A., 2011. Time study and skidding capacityof the wheeled skidder Timberjack 450C. Journal of Soil Science and Environmental Management, 2(7): 120-124.

Marčeta, D., Petkovič, V., Košir, B., 2014: Comparison of two skidding methods in beech Forests in Mountainous conditions. Nova mehanizacja šumarstva: Časopis za teoriji i praksu Šumarskoga inženjerstva, 35(1): 51-62.

Medrski, P.S., Bembenek, M., Erler, J., Giefing, D.F., Karaszewski Z., 2010: The enhancement of skidding productivity resultting from changes in construction: grapple skidder vs rope skidder. In Proceedings of FORMEC 2010, Forest Engineering: Meeting the Needs of the Society and the Environment, Padova, 11-14. July 2010. Padova, Formec: 1-7.

Mousavi, R., 2012. Effect of log lenght on productivity and cost of Timberjack 450C skidder in the Hyrcanian forest in Iran. Journal of Forest Science , 58(11): 473-482.

Mousavi, R., Nikooy, M., Nezhad, A.E., Ershadfar, M., 2012: Evaluation of full tree skidding by HSM-904 skidder in patch cutting of aspen plantation in Northern Iran. Journal of Forest Science, 58(2): 79-87.

Mousavi, R., Nikooy, M., Naghdi, R., 2013. Comparison of timber using two ground-based skidding systems: grapple skidding vs. cable skidding. International Journal of Forest, Soil and Erosion, 3(3): 79-86.

Najafi, A., Sobhani, H., Seed, A., Makhdon, M., Marvi Mohajer, M.R., 2007. Time study of skidder HSM 904.Journal Iran. National Research, 60: 921-930.

Nikooy, M., Esmailnezhad, A., Naghdi, R. 2013. Productivity and cost analysis of skidding with Timberjack 450C in forest plantations in Shafaroud watershed, Iran. Journal of Forestry Science, 59(7): 261-266.

Nurminen, T., Korpunen, H., Uusitalo, J., 2006. Time consumption analyses of the mechanized cut-to-lenght harvesting system. Silva Fennica, 40: 335-363.

Proto, A.R., Macrí, G., Visser, R., Russo, D., Zimbalatti, G., 2018: Comparison of timber extraction productivity between winch and grapple skidding: A case study in Southern Italian Forests. Forests, 9(2): 1-12.

Sabo, A., Poršinský, T., 2005: Skidding of fir roundwood by Timberjack 240C from selective forests of Gorski Kotar, Croatian Journal of Forest Engineering, 26(1): 13-27.

StatSoft (2012). STATISTICA 12.0 for Windows

Wang, J., Long, C., McNeel, J. Baumgras, J., 2004: Productivity and cost of manual felling and cable skidding in central Appalachian hardwood forests. Forest Production Journal, 54: 45-51.

Zborník výkonových noriem č.24 Výkonové normy pre sústreďovanie dreva univerzálnymi, pásovými a špeciálnymi lesnými kolesovými traktormi. Ministerstvo lesného, vodného hospodárstva Slovenskej republiky. Vydanie 1992, 32 p.

Zelená správa 2007. Ministerstvo pôdohospodárstva Slovenskej republiky: Bratislava 2007. ISBN 978-80-8093-018-9 164p.