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Full Length Research Paper

Time study and productivity analysis of chainsaw mounted log debarker in southern pine forests of Turkey

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In timber harvesting process, the debarking activity time covers more than 50% of the total production time especially for coniferous trees. The debarking operations are usually carried out by forest villagers with an axe because of the abundance of labor force and subvention applied for forest villagers. Recently, in the face of labor shortage, in order to shorten harvesting time and to accelerate the operations, chainsaw mounted log debarking attachments has also been used. The aim of the study was to obtain information about time consumption and productivity of debarking with log debarker. Debarking time with log debarker belonging to Brutian pine logs was found to be 11.71 min/m^3 and the work productivity was 5.12 m^3/h. It was determined that the use of log debarker could be achieved; the time saving by 80% compared with conventional debarking method (with axe) and increased the work productivity up to 5 times. It can provide various advantages in terms of prevention of bark beetles damages, fast and fresh product supply, reduce dependence on the number of human resources and improvement the production rate.

Key words: Debarking, log debarker, productivity, time study, chainsaw attachments, log wizard.

INTRODUCTION

The debarking operation is the elimination process of bark from sapwood stem on a falling tree (Gürtan, 1969). This can be carried out in stump, strip or forest road, and wood storage or factories. The purpose and reason of the debarking is to reduce the weight of the log by providing quickly dry, to minimize the coefficient of friction on the ground (wood can lose own weight quickly dried up, the rate of 35 to 40%, by debarking), to facilitate the process of transport along skidding and hauling distances, to prevent damage caused by insects and protect the health of forest, to reduce storage defects, to contribute to the needs of organic matter in the forest by leaving bark residues, to reduce eradication of bark debris by way of facilitating wood manipulation (Gürtan, 1969; Grammel, 1988; Engür, 1996). The place, time, and order of debarking operation are variable dependent on tree species, age, ecological conditions of stand, debarking technique, and so on.

Debarking is carried out by means of various methods such that: (1) Manuel with hand tools (axe, debarking spade, debarking knife, and debarking spud); (2) Debarking machines; (3) Chemical matters, and (4) Water pressure and friction techniques (Gürtan, 1969). Recently, log debarker (LD) is being used for peeling bark of coniferous in Turkey, as well (Eker, 2004). For example, a forest administration in Mediterranean region paid attention to importance of LD usage to speed up debarking activities for reducing bark beetles impacts (GDF, 2010a). In other countries, LD can be also used in debarking for fighting bark beetles (McAvoy, 2004; Michele, 2010). Furthermore, in Turkey, pneumatic debarking spade with manual orientated has been used in peeling of broad level tree species like that beach tree (GDF, 2010b).

The amount of bark covers 10% of whole stem volume of a tree. Thirty-three percent of productive time is consumed per cubic meter for debarking in a logging operation (Gürtan, 1964, 1969; Yıldırım, 1979). Previous

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Table 1. Some characteristics of the study site.

Compartment no.	Area (ha)	Slope (%)	Aspect	Stand Development Stage	Closure (%)	Litter and shrub density	Elevation (m)	Total allowable cut volume (m^3)	Age class	Site Index
92	23.5	38-42	South	Çzcd3*	71	Disability does not	1050-1080	1352	60-80	I

*Çzcd3 symbolizes that *Çz* is brutian pine, *c* is thin sawtimber, *d* is sawtimber, *3* is variable closure degree as 70%, and the diameter at breast height of majority of the tree in stand has covering stand is over 20 cm.

studies often addressed only traditional method (that is, axe or debarking spade) in various tree species. Gürtan (1969) put forward that time consumption was 71 min by axe and also 92 min by debarking spade for debarking one cubic meter log including diameter class from 26 to 35 cm. Geray (1978) determined the required time for debarking of one tree having 20 cm^2 bark surface area and 56 to 60 cm mean diameter was about 90 min for brutian pine species, which was 80% of total harvesting time. Ilter et al. (1986) stated that the debarking time with axe was 86.4 min/m^3 for coniferous tree species, which was 81% of total harvesting time, as well. Karaman (1997) defined the ratio of debarking time was 65.3% for coniferous within whole harvesting process. However, Çoban (1975) exposed that the debarking time was dependent on drying time of bark, debarking place, tree species, tree diameter, and length. Eker (2004) determined that the cutting process time including debarking activity with axe was 86.1 minute per one cubic meter in brutian pine forest. It was calculated without doing any time analysis, when the chainsaw mounted LD was used in debarking, the total cutting time was to be 47.78 min/m^3. It was empirically estimated that time saving was to be 44% and productivity increasing was to be 81% by using of LD in debarking activity. Eker and Acar (2004) assumed that time savings could be achieved at least 1/3% compared with an axe for debarking.

Timber harvesting operations including cutting, extraction and hauling (Eker and Acar, 2006) constitute 65% of all forestry workmanship in Turkey (Dingil, 1991). Debarking activity time also covers more than 50% per unit time belonging to cutting process (IPDB, 2010). This situation clearly point out to importance of debarking activity in the harvesting operations and emphasizes the need to increase the productivity and shorten production time.

In this respect, the hypothesis of the study is based on, if the number of workforce is less than and more production is necessary in a short time, the use of LD in bark peeling can be more suitable solution. However, changes on average debarking time and work productivity of LD due to partial technological improvement from manual to motor-manual has not been investigated yet. Therefore, the objective of the study was to determine and evaluate average debarking time and debarking productivity of LD for debarking of pine tree bark and was realized in the frame of the time study and productivity analysis method with the use of chainsaw (Kluender and Stokes, 1994; Lortz et al., 1997; Olsen et al., 1998; Behjou et al., 2009). The study was limited by only debarking activity with the use of LD and which was not compared to other debarking technologies. However, hypothetical data generated by traditional bark peeling work with axes was used to highlight the performance of the LD in bark peeling.

MATERIALS AND METHODS

Study site

This study was carried out in forest land belonging to Forest State Enterprise (FSE) of Ağlasun in Isparta Regional Directorate of Forestry (FSE, 2008). The debarking activity was studied during extraordinary harvesting process on brutian pine (*Pinus brutia Ten.*) trees overturned by snow damages that occurred in February 2010. The characteristic of the study area was abstracted in Table 1. The logs to be debarked which mentioned as study material localized on compartment numbered 92 where located in between 4169124 to 4169233 m in North latitudes and 296008 to 296666 m in East longitudes, within UTM Zone-36 N. There was 1352 m^3 extraordinary allowable cut volume. The surface of the land studied was small rock terrain; in some places, there was usually alive disability cover. However, surface sinuosity was not uniform in terms of forest operability. The field works were realized in the beginning of April 2010. Average temperature in the region was 15 to 20°C within seasonal normality.

Study materials

Objects of the study are 110 unit brutian pine log having bark that were already bucked and debranched and LD used in bark peeling. The logs to be debarked were in stump or near, and were lined up one after another as parallel to land slope. They were often allocated in perpendicular to contour curves, and thick part of which was from top to bottom ends. The logs studied were mostly smooth form and semi-dry because the thrown trees were uprooted with medium root contact to moisture in the soil.

The chainsaw mounted log debarker was driven by an experienced male operator for 15 years; co-worker was also male experienced for over 40 years. The coworker helped the operator for turning over the logs around the long axis, cleaning the knots forgotten in delimbing, and so on. It was accepted that the operator had min/m^3 worked in a standard tempo.

Chainsaw mounted log debarker (LD)

The log debarker is a one of chainsaw attachment turning chainsaw

Figure 1. The general view of log debarker.

into a new tool as debarker to peel tree bark, produced by a variety of international and national firms, as well. It can be simply attached to any chainsaw and it manages into action as a log debarker. The power transmission is provided with the help of a strap (V-type) connected to the chainsaw drum gear. Made of various types of fasteners for chainsaws are mounted to the chainsaw body by removing the plate and closing the chain lubricating system (Figure 1). Assembly can be made directly to the body of chainsaw with the help of carrying handle of debarker attachment and/or to plate for low volume of chainsaw (Anonymous, 2010; BASEH, 2010; TrioAgri, 2010).

Peeling the bark is carried out quickly by rotating two pairs of fixed steel blade to the knife body (Eker and Acar, 2004). The body of the blade connection of LD is rectangular prism-shaped and there are two knifes on one sides and also two knife on opposite side. The knives cuts both ends of a rectangular shape and the dimensions of them are 3 × 4.7 cm. Blade depth adjustment is made for debarking tree barks according to the alidate with the 14 mm for thick barks and the 12 mm for thin barks. The distance between the drum and rotor strap for Huqvarna 272 XP chainsaw was measured as 28 cm. Husqvarna 272 XP chainsaw of the cylinder volume was 72.2 cm^3, power output was 3.6 kW, fuel tank volume was 0.75 L, oil tank volume was 0.4 L and the weight of (without attachments) was 6.3 kg (Husqvarna, 2010) which was a medium weight chainsaw (Grammel, 1988).

Method

This study follows the work steps as respectively: (1) The time study was realized by the direct and indirect observation technique of field measurements; (2) It collected data on the location and studied objects; (3) Work and time analysis was carried out; (4) The volume of logs object of study and therefore debarking surface area were calculated by thickness of the bark, and (5) The total time spent and the amount of work done per unit of time and work productivity were calculated, respectively.

Data

In this study, the data that were factors and operational variables were previously collected from the logs waiting for debarking and having 1.4, 2-, 2.5, 3 and 4 m log length. A total of 110 work cycles for debarking of the logs with the use of LD was observed in the field. On each debarked log, the over barked diameter of logs including the head and end portions with 1 m intervals were measured with the help of caliper diameters and also recorded. At this stage, the bark thickness was measured according to reciprocal double-sided bark thickness technique (Carus and Çatal, 2010; Durkaya and Durkaya, 2003) on head and end parts of a log by using of the precision compass. The log lengths were measured using the measurement beam with 1 m length and tape meter. Log forms, according to the state log on the relative curvature (curved or right) were determined (Acar, 1998). The position of the logs were determined and recorded according to location of a log on upright, in parallel or cross to contour curves. The slope of the study area, in the form of the mean slope, was determined with the help of clinometers.

In the field study, it was recorded that the elemental time data with digital chronometer and video camera beginning from assembling of apparatus to chainsaw to end of operations. The cumulative time measurement technique (Olsen and Kellogg, 1983; MPM, 1997; Karaman, 1997) one of direct work measurement methods (Ilter et al., 1986) was applied according to common methods of REFA (MPM-REFA, 1984) for each work cycle, due to taking advantage of the functionality of digital chronometer (Gürtan, 1969; Ilter et al., 1986; MPM, 1997) to prevent loss of time in the measurement of the supportive activities in a very short period of log rotation, walking and so on. The workplace elemental time was recorded to field survey forms had been prepared in advance.

Active or effective debarking time was the main time when the log debarker was being applied to log surface without turning to peel the bark; rotation time was a auxiliary time (rotating of unpeeled bottom surface to upward around the long axis of a log when the LD was running); walking time was the reaching from one log to another log; cleaning time was to prepare the log for debarking with cleaning its environment, the rest and personal time, fuel supply and the total working time were measured and recorded. Communiqué No. 288 belonging to General Directorate of Forestry (GDF), about harvesting of essential timber products, was utilized in order to calculate the chainsaw and worker operating time (GDF, 1996).

Analysis

The debarking activity in the scope of the cutting process was evaluated according to business (Şahin, 1983; Yıldırım, 1987; Yıldız, 1989; Mucuk, 2001; Çelikten, 2005) and time study analysis methods (Björheden, 1991; Abeli, 1996; Wang et al., 2004; Şentürk et al, 2007; Eroğlu et al., 2009).

Table 2. Descriptive statistics for variables.

Variable	Units	N	Minimum	Maximum	Mean	Std. deviation	Std. error
Diameter	cm	110	10.00	39.50	23.82	7.516	0.716
Length	m	110	1.40	4.00	2.77	0.554	0,053
Bark thickness	mm	110	2.00	60.00	17.53	15.337	1.462
Knot number	Piece	110	0.00	17.00	5.97	5.154	0.491
Direction		110	1.00	3.00	1.58	0.734	0,070
Log form		110	1.00	2.00	1.19	0.395	0,037
Log volume	m^3	110	0.02	0.56	0.22	0.137	0,013
Debarking area	m^2	110	0.97	7.21	4.14	1.520	0.145
Debarking volume	m^3	110	0.00	0.35	0,087	0,092	0,087
Rotate time	s	110	0.00	29.00	7.1636	5.757	0.549
Rotate number	Piece	110	0.00	4.00	1.9455	0.966	0,092
Delivered time	s	110	0.00	25.00	4.0433	4.167	0.397
Active debarking time	s	110	33.00	308.00	97.327	54.818	5.227
Basic debarking time		s				104,5	
Total debarking time		s				108,5	

Total debarking time: Cumulative debarking time (basic debarking time + delivered time). Basic debarking time: active debarking (activity) time + Rotate time. Active debarking (activity) time: main time when the log wizard is being applied to log surface without rotation. Delivered time: supplementary time (refuel, etc.) + work related delay time.

The elemental time functions' data recorded for debarking of each log were transferred from land survey form to MS Excell spreadsheets in order to be prepared for analysis and evaluation. The relationship between the work and the amounts of time spent for the work was taken into consideration in the analysis and evaluation. The related factors that were the number of log, log volume (m^3), debarking surface area (m^2) and bark volume (m^3) for debarking were used as a measure of the amount of debarking work. The log volume was used in valuation of time efficiency because it has been possible to compute by means of mean diameter and length of a log and that in practice due to the generally preferred measure of volume. The log volume was determined according to Smalian formula (Ozcelik et al., 2008) by using of top and end diameter with length of a log. Merchantable tree length obtained by the sum of lengths of logs, stem length, and mean diameter of the tree/stem was used in Huber formula (Carus, 2002) to calculate the volume of the stem wood.

The debarking surface area for each log was calculated by means of log circle, obtained mean log diameter, and length with the help of the method used by Geray (1978) and Karaman (1997). The bark volume to be debarked was computed by adding of bark thickness measured as double-sided.

Time spent in performing the work was measured and analyzed in seconds by sharing work segments to calculate the work productivity per unit of time. The standard working time was estimated according to the workplace time by using of the time study and analysis method referenced by FAO (1992), İlter et al. (1986), Yıldırım (1989), Karaman (1997), MPM (1997), Winkler (1999) and Baumgrass (2003) . Time measurement during work cycle and evaluation in the workplace, along with chainsaw operator and his assistant has been accepted as a system.

The elemental times were basic debarking, delivered and supportive times with the rest of the time were taken into consideration in the calculation.

The independent variables that were log diameter, length, bark thickness, log form, log position, log volume, debarking surface area, debarking volume, rotation time, delivered time and dependent variable that was active debarking time values, were calculated according to the weighted average and general arithmetic average method in using of the overall statistical analysis and evaluation. During the assessment process, log diameter levels were classified according to forest management plan (FSE, 2008).

SPSS 15 version (SPSS, 2010) package program was used in statistical analysis of data. Required data set by editing the basic descriptive statistics were summarized in Table 2. The data except for log length, number of knots, and delivered time showed normal distribution with the one sample Kolmogorov-Smirnov test. However, the log form and location of logs on land, was not included into test due to no showed normal distribution. Data reliability analysis conducted with Cronbach's alpha coefficient was calculated and data sets was reliable for analysis (α = 0.9) were determined. According to the parametric methods, respectively, correlation analysis (Pearson correlation) was applied for the relationship between variables to determine the direction and intensity, and the regression analysis to find the cause-effect relationship (Stepwise regression) (Eymen, 2007) was applied.

RESULTS AND DISCUSSION

The log volume was preferred for calculation of work productivity in this study. The descriptive statistics per log was summarized in Table 2 so that the debarking productivity with LD could be explained.

Average debarking time that was basic time for peeling the pine bark was sum of the active debarking and the rotate time was found amount 104.5 s per log (1.7 min / log). The results mentioned in Table 2, active debarking time was found as 97.3 sper log. On the condition of the workplace, the total debarking time of a log among log community in the stand was calculated 108.5 s/log by addition delivered time to working duration.

The unit times required for debarking of a log consisted

Table 3. The correlation between debarking time and variables.

Dependent variable	Independent variable	Diameter	Length	Bark thickness	Knot number	Direction	Log form	Rotate time	Rotate number	Delivered time	Log volume (Smalian)	Debarking area
Debarking time	Pearson correlation	0.733	0.272	0.656	-0.588	0.088	0.270	0.665	0.574	0.177	0.836	0.783
	Sig. (2-tailed)	0.000	0.004	0.000	0.000	0.359	0.004	0.000	0.000	0.065	0.000	0.000
	Reliability level	0.99	0.99	0.99	0.99	-	0.99	0.99	0.99	-	0.99	0.99

of active debarking time (89.7%), rotate time (6.6%), and delivered time (3.7%). Time elements for debarking a log, may vary depending on many factors such as operating conditions, tree species, the working peoples used to translate the tool, log characteristics, and so on. For example, Karaman (1997) determined that debarking with an axe had 5.1% share of time to rotate. In this study, the rotate times of logs were often made with an axe and usually the making stable of axe by sticking to log top and rotation time of the log has been wantonly prolonged.

In Table 2, the summary of the values of variables may differ for each log. In the statistical analysis (t-test), it was determined that the differences between log diameter, bark thickness, the number of knots, rotation time, the volume of bark, and debarking surface area values for each log was significant with $p<0.01$ confidence level, and the differences among log length was also significant with $p<0.05$ confidence level. The differences between land position of logs, timber form and delivered time for a log values were not statistically significant.

The factors caused changes in time for debarking, which were topography, climate, tree species, operator, equipment and machinery used, stand structure and so on were assumed to be constant, then the correlation between the effective variables and debarking time was abstracted in Table 3.

Positive and significantly correlation between debarking time and log diameter, bark thickness, rotate time, rotate number, log volume, debarking surface area, and bark volume with $p<0.01$ confidence level, and a significant negative correlation with the number of knots was determined. The correlation between debarking time and log length and log form was significant but weak. There was no significantly correlation between debarking time and log position in land and delivered time with 95% reliability level. Therefore, in some of analysis, these variables were excluded from evaluation. Although Çoban (1975) determined that the debarking time with conventional method was dependent on tree length, the weak correlation between debarking time and log length was found out in this study. The reason of the situation resulted from majority of the logs were taken place in the same length range (average 3 m length).

The log volume bark outside was the variable that showed the strongest and significantly correlation ($R = 0.836$; $p<0.01$) with debarking time. Furthermore, bark volume, debarking surface area, log diameter, rotate time, and bark thickness had a significantly correlation with debarking time. The effect of a combination of all variables associated with the formation of debarking time with LD was tested by multiple regression analysis. As a result of the analysis, four different model explaining relationship between debarking time and the effective variables on debarking was obtained (Table 4).

As defined in Model-1, 69.9% of the debarking time was dependent on log volume. In forestry practices, Model-1 could be available for estimating the time of debarking a log. The reason which resulted is that it is sufficient to know the log diameter and log length for the calculation of debarking time.

In Table 2, the calculation of the average debarking time without any diameter categories were evaluated together through thick and thin log diameter values. But the log diameter has changed the values of the variables and the debarking time per log has changed, as well. However, the required working time and unit costs per cubic meter in the harvesting process have been calculated according to diameter classes (GDF, 1996). Therefore, the log diameter was distributed into diameter classes used in forest management plans, to reveal the effects of change in diameter on the debarking time and to calculate average debarking time corresponding to each diameter class in practice (Table 5).

Table 5 explained that the weighted average values of the variables in each group varied in diameter. In the result of statistical analysis, it was found that the variables number of knots and bark volume showed significantly differences according to their diameter with 95% reliability level, the other variables with 99%. However, it was determined that the average debarking time corresponding to each diameter class had no correlation with log length and log form (Table 6). The reason of which based on that log length had been taken into account as the mean value for each diameter class and average length values of the each diameter class were found similar as 3 m. In addition statistically significant was found relationship between, the log direction (position) and delivered time and the average debarking times, because of the direction and distribution of the logs on forest land and delivery time including

Table 5. The average values of variables according to levels of diameter distribution.

Diameter class (cm)	Frequency (Piece)	Mean diameter (cm)	Mean length (m)	Bark thickness (mm)	Number of knots (piece)	Log direction	Log form	Log volume with bark outside (m^3)	Debarking surface area (m^2)	Bark volume (m^3)	Rotate time (s)	Rotate number (piece)	Delivered time(s)	Active debarking time(s)	Total debarking time [s (min)]
38-41.9	5	40	3	42.29	0	2	1	0.502	6.431	0.278	20.20	3	8.40	212.20	232.40
34-37.9	7	36	3	37.40	0	1	1	0.436	5.931	0.251	12.29	3	4.00	181.86	194.14
30-33.9	15	32	3	35.80	0	2	1	0.330	5.147	0.184	10.67	2	4.40	125.00	135.67(2.26)
26-29.9	14	28	3	23.96	3	2	1	0.296	5.135	0.123	6.29	2	4.14	118.00	124.29(2.07)
22-25.9	20	24	3	13.90	7	1	1	0.222	4.479	0.062	7.25	2	3.55	83.95	91.20(1.52)
18-21.9	22	20	3	8.64	9	2	1	0.144	3.476	0.030	5.09	2	2.95	71.82	76.91(1.28)
14-17.9	16	16	3	4.38	11	2	1	0.094	2.890	0.013	3.56	1	6.06	58.94	62.50(1.04)
10-13.9	11	12	3	3.18	10	1	1	0.046	1.882	0.007	3.55	1	0.91	58.45	62.00(1.03)

Table 6. The summary of correlation analysis designed for diameter classes.

Dependent variable	Independent variable	Diameter	Length	Bark Thickness	Knot number	Direction	Log form	Rotate time	Rotate number	Delivered time	Log volume (Smalian)	Debarking area	Debarking volume
Debarking time	Pearson correlation	0.943	-	0.922	-0.898	0.082	-	0.945	0.909	0.624	0.975	0.913	0.964
	Sig. (2-tailed)	0.000	-	0.002	0.000	0.847	-	0.000	0.002	0.098	0.000	0.002	0.000
	Reliability level	0.99	-	0.99	0.99	-	-	0.99	0.99	-	0.99	0.99	0.99

Table 7. Model summary of regression analysis for diameter groups.

Predictor	R	R^2	Adjusted R^2	Std. E.E.	Model	
1[a]	0.975	0.950	0.941	15.243	DT = 24.537 + 378.173 V	5
2[b]	0.996	0.992	0.989	6.479	DT = 105.646 + 763.568 V - 40.899 DA	6
3[c]	0.999	0.998	0.997	3.427	DT = 107.151 + 883.258 V - 43.201 DA - 1.052 BT	7

a Predictors: log volume; b Predictors: log volume, debarking area; c Predictors: log volume, debarking area, bark thickness, DT= total debarking time (s) ; V = log volume (m^3); DA = debarking surface area (m^2); BT = bark thickness (mm).

also walking time to reach the distributed logs was incidental.

On the other hand, all of the variables corresponding to each diameter class, associated with the formation of debarking time (that was total debarking time without non-work time) were summarized in Table 7 in order to explain the relation.

Accordingly, Model-7 could explained the

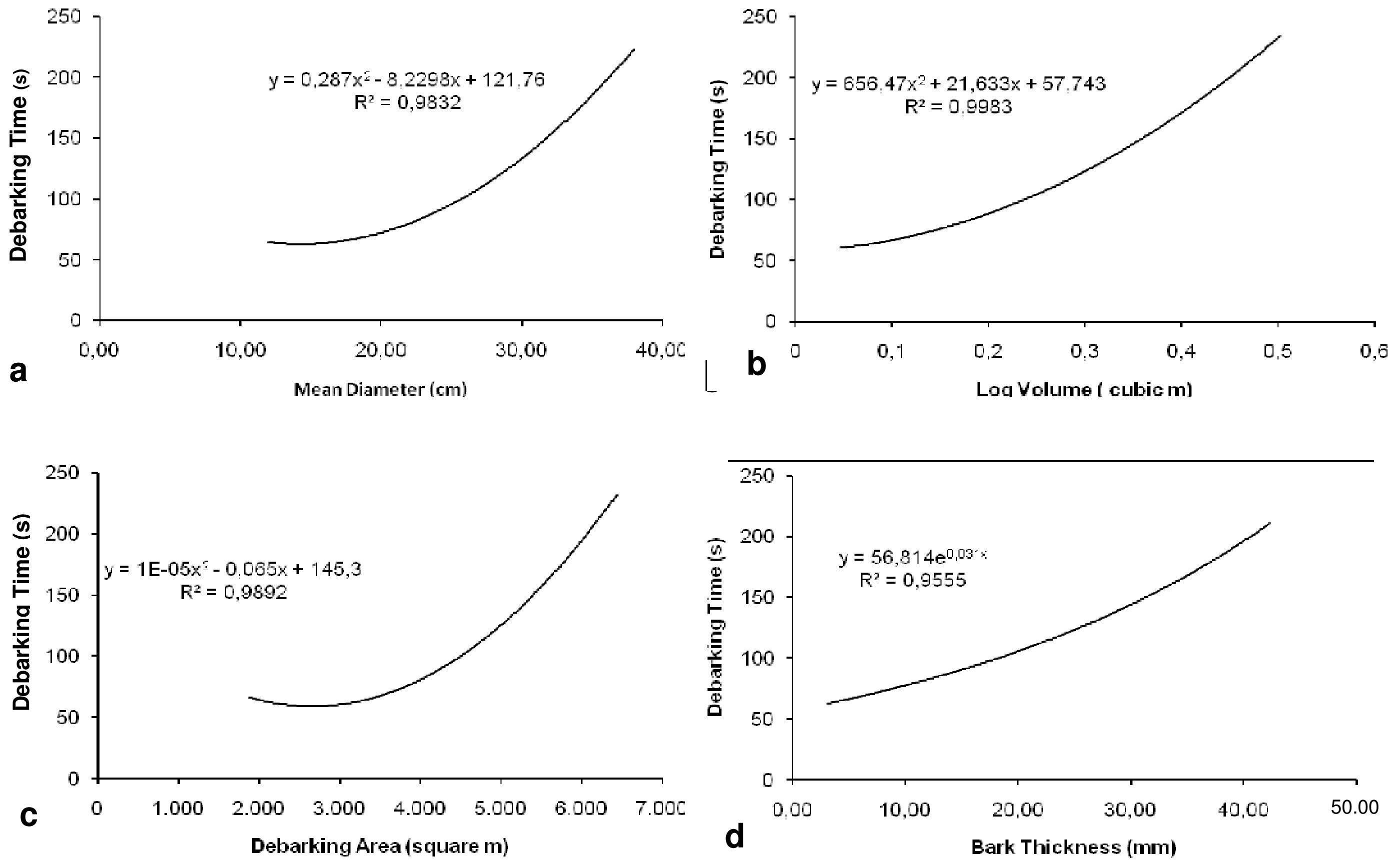

Figure 2. The relation between debarking time and average log diameter (a), log volume (b), debarking surface area (c), and bark thickness (d).

relationship with 99.8% ($p<0.01$) ratio between the debarking time corresponding diameter class and log volume calculated with diameter and length measures, debarking surface area, and bark thickness. As well, the log volume and debarking surface area to be effective in determining the debarking time is also consistent with literature. Geray (1978) pointed out that the debarking time had an exponential correlation with debarking surface area while other conditions were steady. Karaman (1997) indicated that debarking surface area was the most influential variable on debarking activity. In this case, it was clarified that all models in Table 7 could be surely used to estimate the debarking time. However, Model-5 (R^2 = 0.950; $p<0.01$) dependent on log volume with bark outside have a successfully capability to calculate the debarking time in practical application because there is sufficient only in diameter and length measurements.

Furthermore, the pair wise comparison models was separately derived to analyze the relationship between debarking time and independent variables that were log volume, debarking surface area, bark thickness, and average diameter in each diameter class (Figures 2a to d). Accordingly, a polynomial relation between debarking time and average log diameter (R^2 = 0.983; $p<0.05$), log volume (R^2 = 0.998; $p<0.05$), debarking surface area (R^2 = 0.989; $p<0.05$), and exponential relation (R^2 = 0.955; $p<0.05$) with bark thickness was determined.

Both linear regression models based on multiple relationship mentioned in Table 7 and polynomial and exponential models based on bilateral regression mentioned in Figure 2 could similarly explain the equations to calculate total debarking time of the logs at least 95% reliability level (R^2 = from 0.950 to 0.998). Therefore, these models were found successful and available for estimating average log debarking time.

In forestry operations engineering, the unit measurement has been usually focused on one cubic meter of forest product. Therefore, the debarking time per tree (merchantable stem) was estimated in order to calculate average debarking time of unit amounts of forest product. Additionally, the length of logs obtained from each tree was calculated as stem length. Mean diameter of the logs was added one to another and average diameter per stem was estimated. In commercial timber harvesting operations, the top section of a tree length such as 2 to 3 m, is cut off and separated as fiber-chipboard or firewood whose barks does not peel. Therefore, the merchantable stem length was used in terms of tree length. Furthermore, it was found out that

Table 8. Structure of standardized workplace time for debarking of 1 m^3 pine log (in second per m^3).

Basic time		Delivered time		Non-work time	Total unit time
Activity time	Auxiliary time	Supplementary time (Refuel)	Work related delay time	Rest and personal time	
441	50	89	25	98	
491		114		98	703

average 5 short logs could have been produced from a tree/stem having 13.3 m stem length and 23.9 cm mean diameter. Using of whole length and mean diameter of the stem, the stem volume bark outside was calculated by Huber formula for each tree because of the reason quoted by Carus (2002). As a result, average basic time of debarking was found out 542.7 s (9.05 min) for one cubic meter per stem wood. By adding of delivered and non-work time to basic debarking time, total debarking time for 1 m^3 of brutian pine stem was calculated as 705 s (11.75 min). However, according to the weighted average total debarking time per tree, 526.4 s (8.77 min) were found, as well.

During harvesting process in real conditions, the whole body of a stem can be bucket with variable length and diameter, thus debarking time can take different values. In addition, debarking activities are carried out on a lot of logs having the different characteristic of independently distributed trees. In this regard, standardized time required for debarking was calculated with LD mounted chainsaw used by operator and coworker working with normal tempo in workplace time within 8 h per day, for 1 m^3 of log wood having different diameters. The standardized debarking time for 1 m^3 log volume with bark outside was computed according to weighted average values of log debarking time and abstracted in Table 8.

In Table 8, the standardized debarking time that means total unit time for 1 m^3 product was determined as 11.71 min/m^3 and work productivity was 5.12 m^3/h. The calculated standard debarking time was harmonious with average debarking times per stem wood with 0.3% a margin of error rate.

Standard time included all activities that occurred within working time in workplace (Table 8). For example, the chainsaw with a full tank could conduct the activities of debarking a period of 28 to 32 min. Accordingly, a tank of fuel at an average of 15 pieces log (having average 24 cm diameter and 3 m length) could be debarked. Although the refuel time did not exceed 30 s, because of the preparation time such as walking time consumed to oil drum could take a long time ranging from 1.5 to 4 min.

The debarking time and work productivity might be varied according to many variables such as working conditions, operator, chainsaw power, tree properties, and so on. The relationship and variation between work productivity and log volume, debarking surface area, bark thickness, and mean diameter were described with following Figures 3a to d.

In Figure 3, the similar shaped, polynomial, and significant relationship between work productivity and log volume, debarking surface area, bark thickness, and mean diameter with 95% reliability level was determined. The work productivity level increased up to 30 cm log diameter in polynomial form, and fell down after 30 cm. Because the thin-diameter logs (less than 22 cm) generally corresponded to parts of the tree end. In the end of tree; diameter, bark thickness, log volume, and debarking surface area decreased whereas the number of knots increased. Therefore, the amount of the debarking work performed in unit time decreased, and this caused to lessen work productivity. At the same time, increasing of mean diameter by over 30 cm, the work productivity decreased as well. Because, provided that the same log length, as the log diameter was becoming thick; the bark thickness, log volume, debarking surface area, and active debarking time increased as polynomial. It was stated that the work productivities of thin and thick diameter logs obtained from bottom and end of a tree/stem was low. However, it was concluded that if the log diameter was between 25 and 35 cm, the work productivity could have been the highest. The significant and polynomial relationship between work productivity and log diameter (R^2 = 0.9839; $p<0.01$) supported the conclusion that the lower the work productivity for the thin and thick diameter logs, the higher the normal diameter logs were. On the contrary to Gürtan (1969), for the traditional debarking methods, as the log diameter was decreased, the productivity was also decreased. It was estimated that the reason of the difference resulted from work techniques used for debarking. Although, the barks have been debarked through strip and tablet by using traditional methods such as axe and debarking spade, the log debarker has shaved and sharpened the bark layer from outside to sapwood. On the other hand, the consumed working time increased when the log diameter become thick as result of the study. As dependent on the result, the debarking productivity lessened because the amount of the debarking work decreased in the unit time.

It is possible to achieve a significant time savings with LD for debarking activity. As a result of the study, the unit debarking time (11.71 min/m^3) spent for debarking of 1 m^3 forest product showed that time savings in 80% could be provided compared with traditional methods specified by Gürtan (1969), Geray (1978), İlter et al., (1986), Karaman(1997), and Eker (2004).

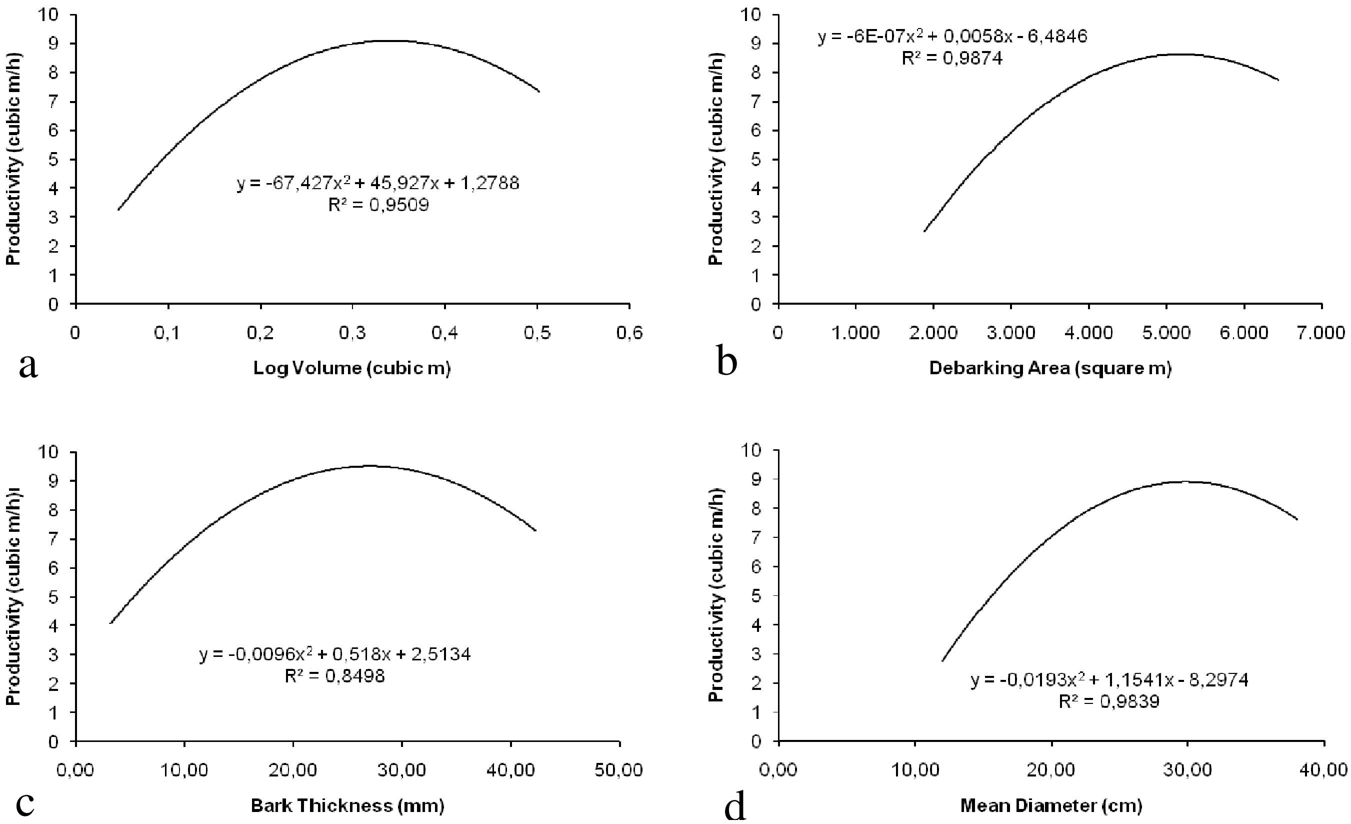

Figure 3. The relationship between work productivity and log volume (a), debarking surface area (b), bark thickness (c), and mean diameter (d).

Taking into account the characteristics of the study area, the manually working time with manpower for cutting process of 1 m^3 of forest product was identified as 73.81 min/m^3 by Forest State Enterprise (FSE), and 22.87 min/m^3 for working time with chainsaw. The manual debarking time with axe in the traditional cutting process was estimated as 59.05 min/m^3 (1.02 m^3/h) by using of hypothetical and empirical data drawn from previous studies, field observation, literature, and FSE records. The share of debarking time with axe within cutting process was found in proportion 61%. In the case of using LD for debarking in terms of axe, it was found that the debarking time could be relatively reduced in proportion of 80% and augmented the work productivity in 5 times.

In addition, using of LD for debarking, the share of the debarking activity time within cutting process could be lessened to rate of 33.8%. In contrast, the operating time of chainsaw due to log debarker would be increased by 11.71 min for one cubic meter debarking activity. However, when the log debarker was used in debarking operations, the cutting process could be shortened in the rate of 58% and productivity could be increased in the rate of 72%. These results clearly demonstrated the superiority of the use of LD in comparison to traditional method in terms of work speed and productivity.

CONCLUSION AND RECOMMENDATIONS

This study has the function of being a base for calculating the standard working time and work productivity, which is based on work and time analysis for the log debarker mounted to chainsaw. It is different from previous studies related to log debarker in Eker (2004) and Eker and Acar (2004) in terms of study site, time, material and method, analysis, and results. However, in this study, work techniques, economy, ergonomics, energy balance, and work quality of debarking with LD was not dealt with. These topics will be evaluated in another study. On the other hand, this study is focused on debarking of only brutian pine in a certain condition with LD. Additional researches about LD usage should be conducted to determine complete performance of the use of LD on different pine species or coniferous, and various site and operating conditions.

As a result, by using of LD for debarking of pine tree species' barks in commercial timber harvesting operations, the shortening average unit time and total debarking time, and increasing of work productivity can be provided. Thus, the duration of total harvesting process can be reduced and then, the logs having bark harvested do not wait for debarking a long time. In this way, the damages can be minimized resulting from bark beetles originating on logs with bark. When it is required, the debarking is to be quickly operated, on exceptional circumstances such as wind or snow damages and fire destroy; the LD can be efficiently and easily used in debarking activities. Furthermore, when the other conditions of debarking work phase is fixed, the technological improvement with motor- manual tools such as log debarker can make the work productivity effective and can facilitate the debarking operations.

It is possible to practically estimate the average debarking time (DT) and thus work productivity of chainsaw mounted log debarker, in similar circumstances and similar tree species in the study, by using of log volume bark outside (V) to be debarked with the Model-5 mentioned earlier that was; DT = 24.537 + 378.173*V ($R^2 = 0.941$; $p < 0.01$).

The utility of the LD requires the use of a chainsaw; therefore, a short training is necessary to safely operate chainsaw with LD. Thus, the work productivity can be increased by the experienced operators.

Taking some precautions, it is possible to shorten the unit debarking time and to promote the work productivity, as well. For example; the sequence of debarking activity in the work flow can be taken front of cut-to-length process and then performed, thus, the top surface (at least, 1/3 proportion) of the whole stem can be debarked at once to shorten work time.

Furthermore, the blade depth of the log debarker can be extended from 12 to 14 mm for debarking the butt logs having high bark thickness bucked from bottom of a tree, or the section of the a tree can be debarked with by axe. In particularly, both log debarker and axe can be used in combination for debarking the parts of a stem with thick diameter and bark, after clear-cutting that is latest allowable cut for the regeneration. Two log debarker attachment can be separately mounted to different two chainsaws, one of which has short blade depth (12 mm) and the other one has long (14 mm), or firstly, thick barks can be debarked with long blade and then the depth of blade may changed to peel the thin barks. However, the LD should not be lean to log surface to avoid damage on sapwood while debarking of the thin logs having also thin diameter and fine bark surface.

In addition, the allocation of the logs to be debarked in the right place with appropriate manner, cleaning the surrounding of each log, and using of turning hook, crank or sappie to rotate the logs can help shorten the rotating time and thus indirectly provide for shortening the unit active debarking time.

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