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STUDY OF THE IMPACT OF LUBRICANT TYPE ON SELECTED OPERATIONAL PARAMETERS OF A CHAINSAW USED IN BEECH TIMBER CUTTING

The focus of the study was to determine the influence of the lubricant used for greasing the cutting subsystem of a petrol chainsaw on selected operational characteristics. Three lubricating oils were studied, two of which were commercially available, while the other was a suitably modified rapeseed oil, prepared specifically for the study. It was shown that the application of selected lubricating components in the cutting subsystem of the chainsaw resulted in significant differences in the consumption of both the fuel and the lubricating agent.

Keywords: petrol chainsaw, chainsaw, oil consumption, fuel consumption

Introduction

The use of portable chainsaws carries the risk of environmental contamination. This is a result of the usual design of a chainsaw, featuring an open lubricating system. In a system like this, the oil is dispersed and released into the environment via a variety of channels. It is estimated that between 50 and 85% of the oil is absorbed by sawdust, while, during rough-hewing, depending on the type of work performed, anything between 10 to 35% of the oil goes directly into the soil [Skoupy 2004]. According to previous research data [Rudko et al. 2010], under Polish felling conditions, i.e. implemented working methods and the amount of harvested timber (30 million m³ per year), as much as 6 million dm³ of oil finds its way into the soil every year. However, this does not reveal the full scale of the problem, as chainsaws are now used extensively by non-professionals. The amateur application of chainsaws makes it impossible to monitor how they are used, which, with insufficient technical knowledge and a lack of environmental risk awareness, may result in dangerous practices. The existing literature on the subject identifies the danger caused by the application

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of used motor oils for the lubrication of the chainsaw cutting subsystem [Giefing 1991; Rudko and Rybczyński 2010].

Considering the scale of the potential risks, it is not surprising that new solutions are being sought to minimize the negative impact of chainsaw lubricants on the natural environment. In scientific studies, it has been suggested that only bio-degradable oils are appropriate for use as chainsaw lubricants, and ones which meet specific quality standards [Lauhanen et al. 2000; Zembrowski et al. 2010], rather than mineral oils, which are still widely used in the lubrication of chainsaws. Other research has been conducted to study the influence of design solutions and the operating parameters of chainsaws on their effectiveness [Gendek 2006; Maciak 2013]. The results of such studies may be considered in terms of pro-ecological recommendations, which might provide guidelines for the reasonable management of consumables (both lubricating oils and fuels). Particularly relevant to the matter under discussion is a study on the influence of lubrication intensity and type of lubricant on the movement resistance of the chainsaw [Wojtkowiak and Tomczak 2003; Wojtkowiak 2004; Nordfjell et al. 2007; Rudko and Rybczyński 2010]. Complementary data on both the durability of the chainsaw cutting subsystem and safety of the natural environment would be a desirable outcome of such a study.

An overview of the existing literature led to the conclusion that it was worthwhile conducting experimental research on the possibilities of the application of lubricating substances for chainsaws, which are safe for the environment and, at the same time, do not cause a deterioration in the operational parameters of these machines. With that in mind, the present study took the form of a field experiment and the adopted method in which the study was conducted made it possible to transfer the results to wood cutting in forests. In addition, it may also be applicable for the use of motor chainsaws in the preparatory processing of fuelwood, e.g. in individual households. It was considered that the use of chainsaws for the processing of fuelwood, combined with the increased interest in this method of processing wood in households, generates a problem of particular gravity, relating to the risk of environmental contamination in rural areas.

Materials and methods

The study intended to determine whether the application of various lubricating components of the cutting subsystem of the Husqvarna 357 XP chainsaw could significantly affect its operational parameters, and, in particular, the consumption of consumable supplies: fuel and chainsaw lubricating oil. Three oils were compared, two of which are available commercially, while the last, rapeseed oil, was modified by the authors of the study. In the case of those products dedicated to the lubrication of the chainsaw cutting subsystem, one was the result of the processing of crude oil (mineral base) and, according to the

manufacturer, it additionally contained an undisclosed percentage of vegetable oil. This oil is referred to in the study as “A”. The other lubricating component, marked with as “B”, was, according to the manufacturer's claims, composed of vegetable ingredients (the list of ingredients was not provided).

As mentioned earlier, the third lubricant was rapeseed oil modified with sulphur content at an experimentally determined level (purely for analysis). For this oil a number of measurements of lubrication parameters were conducted in a four-ball tribometer test, in accordance with the standard methodology [PN-76/C-04147]. An analysis of the results demonstrated desirable changes in the lubrication properties of the rapeseed oil, with only a 1% content of sulphur, which in turn suggested this type of oil was suitable for use as the lubricating component in the chainsaw's cutting sub-system.

The main study was performed in 2013. The wood material was beech wood, arranged in stacks, numbered accordingly and divided into research samples, 100 cylinders each. The cylinders were numbered according to their location in the stack, and their average diameter was established by measuring the smallest and the greatest diameter of the cylinders at each end of the cylinder (arithmetic average of the four measurements). The diameters established this way were used to calculate the surface area of the kerfs on each cylinder. As each cylinder was cut four times, the total cutting area for the studied sample was calculated as the ratio of the total surface areas of the kerfs and of the number of cuts made, as demonstrated below:

$$F_c = \frac{4 \cdot \sum_{i=1}^{100} \pi d_i^2}{4} \quad (1)$$

where: F_c – total surface area of the wood cut in the studied sample [m^2],
 d_i – diameter of the i -th shaft [m].

In relation to thus specified cutting surface, the mass fuel consumption was calculated, as well as the volume consumption of the oil lubricating the cutting sub-system of the Husqvarna 357 XP motor chainsaw. Field tests were carried out in two stages. Each of them included the cut test of one hundred wood cylinders used for each of the three lubricating oils (6 test samples in total). The results were not examined immediately after the first stage of the study. In view of a chance to repeat the tests, the second stage was regarded being suitable for verification of the assumed methodology for assessment of the functional qualities of tested oils. Repeating the tests also made it possible to assess, by comparing the results for the same lubricants, how the random distribution of the wood cylinder diameters used in the test samples affected the measurement results.

As a result of the research being carried out in field conditions, there was no control over a number of the parameters (e.g. ambient temperature and air humidity), as well as the execution of the cutting process at constant force values (e.g. chainsaw feed speed, chainsaw motor rotational speed). It should be noted, however, that although such conditions differ significantly from the laboratory trial regime, they resemble more closely the actual way chainsaws are used.

Due to a number of technical and operational factors determining fuel and lubricating oil consumption, the research was adapted so as to make it possible to draw conclusions on the basis of a comparative assessment of the results:

- the wood cutting was carried out using the same chainsaw, after prior maintenance activities (e.g. adjusting fuel and lubrication sub-systems, replacement of filters and of the chainsaw driving wheel),
- the individual study trials were performed using new chainsaws and guides (produced by the OREGON Company),
- on the basis of preliminary studies, the size of the study sample was adopted so as to make it possible to perform the scheduled work without the need to sharpen the sawing chain (successive sharpening operations, in particular when performed manually, do not ensure repeatability of chainsaw cutting blades geometry, which would result in a change in the parameters of the performance of the cutting sub-system),
- before commencing each study trial, the chain was initially tensioned in accordance with the PN-ISO 6535 [PN-ISO 6535:1999] standard,
- the wood processing was performed by a team of three, consisting of an experienced lumberjack who made the cuts, and two assistants who loaded the wood cylinders from the stack onto the sawbuck, resulting in efficient chainsaw use and a working pace comparable between individual study trials.

Results and discussion

In order to attain the major research goals, a number of indications were used and measurements taken, the results of which are presented in table 1. In accordance with the methodologies described above, the total surface area of the cuts in the study samples was determined, and in relation to this, the mass fuel consumption of the chainsaw and the volumetric consumption of lubricating oil were defined. During the field work, the fuel and lubricating consumption were assessed by weight, and because of the different specific gravities of the oils used, their consumption was calculated in laboratory conditions following a determination of their densities using the pycnometer method. Table 1 also shows the dynamic viscosity measurements of the oils used, measured using a Bookfield viscometer, in accordance with DIN 53019 (DIN 53019-1: 2008]. Parameters such as the viscosity and lubricity of oils (the tendency of the lubricating agent to form durable adsorption films on friction surfaces) can affect

the resistance of the cutting system to motion, and therefore constitute determinants of fuel and lubricating oil consumption. However, the study did not focus on the assessment of tested lubricants with respect to their viscosity and lubricity, but the aim was to determine the differences in the chainsaw's consumption of working fluids depending on the lubricating oil used in the cutting system. It was concluded that the investigated variables directly determined the usefulness of the oils used, indirectly pointing to the differences in their rheological characteristics.

Table 1. Summary of primary test results

Tested parameter	Cutting sub-system lubricating oils in the Husqvarna 357 XP chainsaw					
	Oil "A"		Oil "B"		Rapeseed oil modified with sulphur	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
Surface area of the wood cut in the studied sample F_c [m ²]	13.41	13.92	12.62	13.53	13.83	14.02
Chainsaw fuel consumption [g]	1553.3	1513.0	1249.9	1381.6	1225.2	1290.6
Lubricating oil consumption [g]	626.72	682.85	476.36	572.27	554.85	618.76
Volume consumption of oil [cm ³]	699.14	761.68	517.89	626.16	600.76	669.85
Oil consumption relative to the area of the cut [cm ³ ·m ⁻²]	52.13	54.72	41.03	46.27	43.45	47.78
Fuel consumption relative to the area of the cut [g·m ⁻²]	115.82	108.73	99.03	102.15	88.62	92.05
Density at a temperature of 293 K [g·cm ⁻³]	0.896		0.920		0.924	
Dynamic viscosity at a temperature of 293 K [mPa·s]	209.21		147.63		93.84	

The temperature, at which the density and viscosity of the oil (293 K) was determined, was selected from the range of the variability of the thermal environmental conditions in which the experimental tests were carried out. The assumption was also made that the variability of the ambient temperature within a range of several degrees which characterized the existing thermal conditions should not be a factor influencing the objectivity of the research. The fact that the cutting of the wood was conducted with periodically repeated short breaks, in order to refill the operation fluids, favoured a stabilization of the thermal

loads of the sawing machine. Taking into account that the oil reservoirs had relatively low volumes and the effect of heat transfer from the structural elements to the oil, this should have led to temperature stabilization. These considerations, although not verified experimentally, became the basis for calling into question the comparability (as regards temperature) of the working conditions of the lubricating oils. On the basis of these assumptions, it was considered possible to interpret the differences in the amount of fuel and lubricating oil consumed by the saw as a result of the variability in working qualities (including rheology and lubricity) of the lubricants used in the cutting system. In the following part the study focused exclusively on identifying the impact of the lubricating agents used in the cutting system on the consumption of consumables, that is, on verifying the main postulate of the research.

As is clear from the data presented in table 1, in the case of the “B” oils and the rapeseed oil modified with sulphur, a similar level of consumption was found, expressed in $\text{cm}^3 \cdot \text{m}^{-2}$ of the wood cutting area. In the 1st and 2nd study trials, a higher rapeseed oil consumption was registered, by 5.8% and 3%, respectively, in relation to the “B” oil. In light of this, oil “A” (with a mineral base) fared rather unfavourably, and its consumption in the first study trial was nearly 21% higher than that of oil “B”. The fuel consumption measurement results indicated that the rapeseed oil modified with sulphur had the best operational properties of all the lubricating agents used for the chainsaw cutting sub-system. With this oil, the fuel consumption was lowest, expressed as $\text{g} \cdot \text{m}^{-2}$ of the cutting surface area, and in relation to oil “A”, it was lower by 24% and 15%, respectively, in the first and second study trials. In relation to oil “B”, the use of rapeseed oil as the chainsaw lubricant resulted in a reduction in fuel consumption by approx. 10%, in both the study trials performed.

The test results were statistically analyzed, with the intention of establishing whether the random variability of the cylinder diameters in the individual trials could have affected the reported differences in the consumption of the lubricating oils and the fuel consumption by the chain saw. Parametric tests for significance by t-Student were carried out to verify if there were significant differences between the diameters of the cylinders cut in individual study trials. For the adopted significance level $\alpha = 0.05$, there was no evidence to reject the null hypothesis of the equality of averages, which indicated a lack of statistically significant differences between the mean diameters of the wood cylinders used in the test samples. The test results, however, did not specify the distribution of the variable tested in the research trials, which was considered an interesting supplement to the statistical analysis. For this purpose, figure 1 shows the frequency histograms and the corresponding distributions of the density of the average diameters of the cylinders.

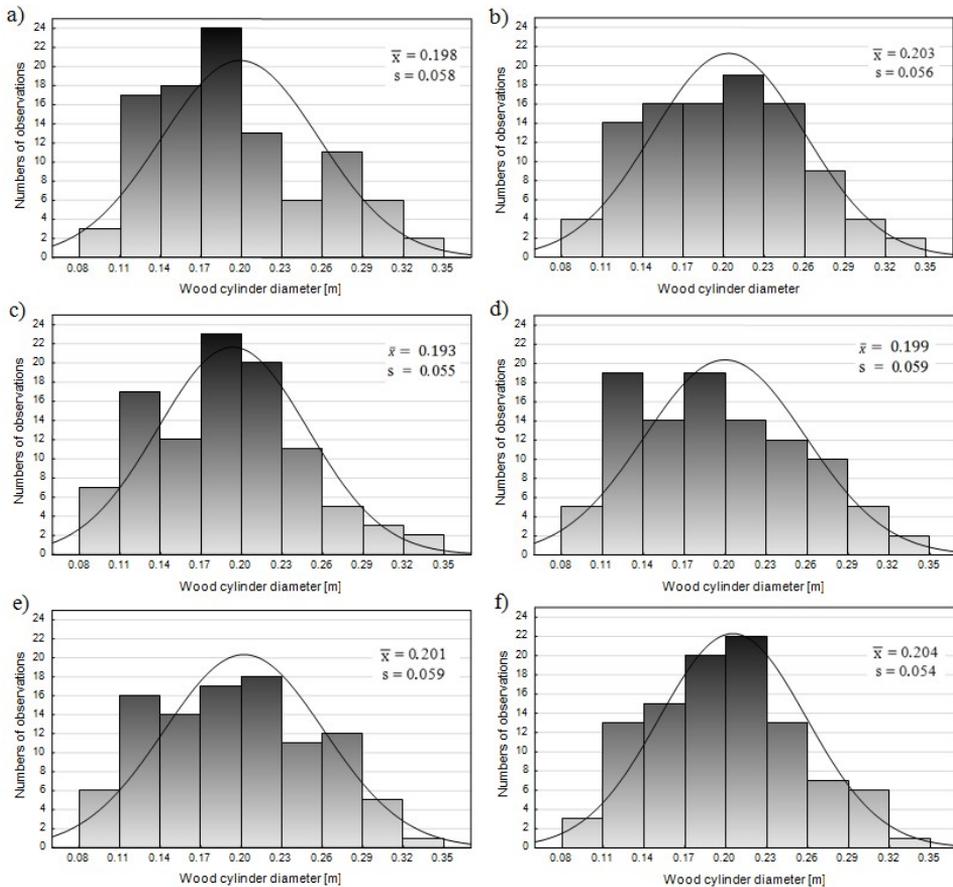


Fig. 1. Histograms of distribution of wood cylinders diameter frequencies in study trials: a, b – oil “A” (trials 1 and 2), c, d – oil “B” (trials 1 and 2), e, f – modified rapeseed oil (trials 1 and 2), s – standard deviation [m], \bar{x} – average cylinders diameter in the study trial [m]

In the first study trial, in which oil “A” was used to lubricate the cutting sub-system (fig. 1a), the greatest asymmetry in the distribution of the variable under examination was found, tending towards values lower than the trial average $\bar{x} = 0.198$ m. The demonstrated variability of diameters resulted in a relatively higher, than in other cases, percentage of works performed with lower cutting resistance and higher chainsaw motor rotational speed. As a result, this could have translated into an increased consumption of fuel and lubricating oil, relative to the unit surface area of the saw cuts. It should be noted that in the case of the second study trial, all the histograms of the distribution frequency of the cylinders cut with the application of individual lubricants were closer to the normal distribution. In spite of this, in this case also, the application of oil “A” resulted in the highest consumption of oil and fuel relative to the surface area of

the cut. The statistical analysis performed provided the basis for the recognition of the adopted research methodology as one that enabled an objective evaluation of the operational parameters of the lubricating oils based on a comparative assessment of the results.

Conclusions

The analysis of works performed when cutting the beech wood cylinders demonstrated significant differences related to the consumption of both fuel and lubricating oil by the cutting sub-system of the Husqvarna 357 XP chainsaw, depending on the type of lubricant used. The highest consumption of oil and fuel, relative to the surface area of the wood cut, was observed when using the mineral oil, which constituted useful practical information for operation of chainsaws. This means that the use of lubricating components produced from plants may be justified not only from an economical, but also from an ecological perspective. One aspect of vegetable oil-based lubricants deserving particular attention is the reduction in the risk of environmental contamination, particularly soil and water contamination during work in the forest and when preparing wood for heating, and air pollution, which may occur when the sawdust resulting from wood processing is burned, as is often the case. The results achieved in this study should encourage further research on the suitability of rapeseed oil for all-year-round application, both for individual usage, as well as for timber extraction in forests. It would be particularly useful to confirm the desirable operational characteristics of rapeseed oil in cold temperatures, and its physico/chemical stability in storage, as this information would influence the use of chainsaws.

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List of standards

- DIN 53019-1:2008-09.** Viskosimetrie – Messung von Viskositäten und Fließkurven mit Rotationsviskosimetern – Teil 1: Grundlagen und Messgeometrie
- PN-76/C-04147.** Badanie własności smarnych olejów i smarów (Research into the lubricating properties of oils and greases)
- PN-ISO 6535:1999.** Pilarki łańcuchowe przenośne – badanie hamulca piły łańcuchowej (Portable Chainsaws – Chain Brake Performance)