The Effect of Lubricating Oil on Temperature of Chainsaw Cutting System

Miroslav Stanovský, Ján Schürger, Martin Jankovský, Valéria Messingerová, Richard Hnilica, Marian Kučera

Abstract – Nacrtak

Portable chainsaw is a basic operational instrument in forestry. To ensure long-lasting performance of a chainsaw, it is necessary to perform the necessary maintenance of its cutting system. The basis of this maintenance lies in the lubrication of the chain, which protects it from excessive wearing and deterioration. Various lubricating oils are used for lubricating the chain. Biodegradable oils are promoted nowadays, with their main advantage being shorter decomposition time in the environment, and the same lubricating properties as conventional lubricants. This paper is aimed to evaluate and compare the ability to lubricate and cool the cutting system of a portable chainsaw filled with biodegradable oil and oils commonly used for its operation. Conditions of measurements were specified to simulate the actual operating conditions. During the evaluation no major differences between these oils were observed.

Keywords: biodegradable oil, portable chainsaw, temperature, thermograph

1. Introduction – *Uvod*

At present, forestry machinery used on forest roads and in forest stands or other areas presents an ecological threat due to oil and petrol leakage. It is therefore logical that much effort is put into developing environmentally friendly fuels and lubricants, which are biodegradable or of biological origin. The decomposition time varies and depends on many factors, such as: temperature, humidity, quantity and type of bacteria, quantity of oxygen, etc. (Stanovský et al. 2012a). As Stanovský et al. (2012b) states, in the state forest enterprise of Slovakia (Lesy SR) alone, 1.8 million liters of oil were spilled into soil from chain saw operation (Lesy SR manages approximately 50% of the forest area in Slovakia). Finland forestry workers discharge about 2 million liters of oil per year, in Croatian forestry the number is 420 thousand liters (Oršanić et al. 2008). In Germany, the gap between oil consumption and oil purchase in forestry alone is 2 million liters, which implies the possibility of toxic oils being used in logging operations (Hartweg and Keilen 1989).

Based on many studies, it is safe to say that every lubricant is harmful to the environment. However, lubricants and fuels produced from biological matter are significantly less harmful than those of fossil origin and are preferred over mineral or synthetic lubricants with similar characteristics in forest management (Schaffer and Buchschacher 2002). Based on empirical data, there are some apparent problems with using bio-oils. These are mainly shortened lifespan of the saw and thickness of the oil at lower temperatures.

Current legislation (Nature Protection Act 543/2002 Z.z., act 326/2005 Z.z., 360/2007 Z.z.) defines zones with different environmental protection intensity, which range from zones with almost no restrictions (1st level of protection) to zones with forbidden human intervention (5th level of protection). When logging in zones with higher levels of environmental protection, typically there is a requirement to use bio-oils in the operation. Forestry workers usually say that they avoid bio-oils because their lubricating characteristics are not as good as those of conventional lubricants. We tried to test this claim in conditions that simulate the conditions in practice.

2. Material and methods – *Materijal i metode*

Two lubricants were selected for the evaluation – STIHL BioPlus (BP) and SHELL Helix Ultra VX 5W-30

(HU). BP oil is a lubricant designed for chain lubrication in chainsaws. It is a bio-oil and as such it is less harmful to the environment than conventional lubricants. The HU lubricant is synthetic motor oil and although when new it could be designed to protect the environment in case of spill in the nature, used motor oils are hazardous to the environment. The HU lubricant was drained from a combustion engine after the recommended mileage and then used in the measurements. This kind of lubricant (used motor oil) was selected because it is disturbingly commonly used in Slovak forestry. The basic characteristics of the lubricants can be seen in Table 1.

Two chainsaws were selected for measurements – Husqvarna 346XP and STIHL MS440. These chainsaws are commonly used in forestry for different purposes – the Husqvarna chainsaw is mainly used in thinning and the STIHL is most commonly used in regeneration felling. Their main characteristics are shown in Table 2.

Table 1 Main characteristics of lubricants used in research
Tablica 1. *Glavne značajke ulja korištenih pri istraživanju*

Characteristic *Značajke ulja*	BioPlus	Shell HU VX 5W-30
Melting point, °C *Točka taljenja,* °C	-2 – 10	-39
Flash point, °C *Točka zapaljenja,* °C	>230	230
Density (at 15°C), g/cm^3 *Gustoća (pri 15°C),* g/cm^3	0.92	0.848
Kinematic viscosity (at 40°C), mm^2/s *Kinematička viskoznost (pri 40°C),* mm^2/s	37	67.1

Table 2 Chainsaw characteristics
Tablica 2. *Značajke motornih pila korištenih pri istraživanju*

Characteristic *Značajke*	STIHL MS440	Husqvarna 346XP
Cylinder volume, cm^3 *Obujam,* cm^3	70.7	50.1
Performance, kW *Snaga,* kW	4	2.7
Weight, kg *Masa,* kg	6.3	5
Oil tank volume, l *Rezervoar za ulje,* l	0.33	0.28
Idle speed, rpm *Minimalni broj okretaja,* min^{-1}	2500	2700

2.1 Instrumentation – *Mjerni uređaji*

The measurements were made with a FLUKE Ti25 thermal imager for temperature data collection, a stopwatch for time measurement of the operational cycles, a caliper for roundwood diameter measurements and a thermometer for outdoor temperature measurements. Specifications of the thermal imager are presented in Table 3 below.

Table 3 Thermal imager specifications
Tablica 3. *Tehnički podaci termalne kamere*

Specifications – *Tehnički podaci*	
Temperature measurement range, °C *Raspon mjerenja,* °C	–20 to +350
Temperature measurement accuracy, °C *Preciznost mjerenja,* °C	±2°C or 2%
Detector type *Vrsta senzora*	160x120 uncooled microbolometer
Infrared spectral band, µm *Raspon infracrvenoga spektra,* µm	7.5 to 14
Minimum span, °C *Minimalni raspon,* °C	5
Operating temperature, °C *Radna temperatura,* °C	–10 to +50

The thermal data was subsequently evaluated by the SmartView 3.1 software. Statistical evaluations were carried out in Statistica 9 program and MS Excel 2010.

2.2 Measurements – *Mjerenja*

The measurements took place on the grounds of the university campus and in a log conversion depot of the University forest enterprise in Lieskovec (approx. 5 km from the University). During the measurements, the following characteristics were measured: time of chainsaw operation during measurements, temperature of the cutting system (the center of the bar, chain on the upper side of the bar, the tip of the chainsaw bar), diameter of processed wood, number of cuts made with the chainsaws, outdoor temperature. Also the tree species was taken into consideration. The outdoor temperatures during individual measurements were taken into account. They were recorded in 2 hour intervals and then used during the evaluation. The SmartView program contains algorithms to compensate the temperature difference.

The measurements were divided into two parts:

A) Measurements without the cutting load,

B) Measurements under cutting load.

2.2.1 Measurements without the cutting load *Mjerenja bez prerezivanja drva*

One measurement cycle, during which thermal images were taken, consisted of the following intervals:

1) A snapshot of the cutting system without prior movement of the chain, in operational temperature of the chainsaw engine,
2) The second snapshot was taken after one minute of chainsaw movement in full engine load and maximum chain revolutions per minute (RPM),
3) The third interval lasted for two minutes. The chainsaw was in full engine load and maximum chain RPM, the snapshot was taken after finishing the interval,
4) The fourth interval lasted for three minutes. The chainsaw was in full engine load and maximum chain RPM, the snapshot was taken after finishing the interval.

There was a minimal pause (ranging from 30 to 40 seconds) between individual measurement intervals during which the snapshots were taken. Measurement cycles were carried out three times for both chainsaws and lubricants. Between the measurement cycles, the chainsaws were at rest to ensure their cooling down.

2.2.2 Measurements under cutting load – *Mjerenja s prerezivanjem drva*

One measurement cycle, during which the thermal images were taken, consisted of the following intervals:

1) A snapshot of the cutting system without prior movement of the chain, in operational temperature of the chainsaw engine,
2) The second snapshot was taken after one minute of cutting in full engine load,
3) The third interval lasted for two minutes. The chainsaw was under cutting load and in full engine load, the snapshot was taken after finishing the interval,
4) The fourth interval lasted for three minutes. The chainsaw was under cutting load and in full engine load, the snapshot was taken after finishing the interval.

Measurements under cutting load were divided into two subgroups – hardwood and softwood cutting. Hardwood used in the measurements consisted entirely of beech, softwood used during the measurements was mostly spruce, and on three occasions fir wood was used. The cutting process is presented in Fig. 1.

Fig 1 The cutting process
Slika 1. *Prikaz prerezivanja drva*

Again there was a minimal pause (ranging from 30 to 45 seconds) between individual cutting intervals during which the snapshots were taken. Measurement cycles were carried out three times for both chainsaws, lubricants and wood type. Between the measurement cycles, the chainsaws were at rest to ensure their cooling down.

3. Results – *Rezultati*

During the measurements, 144 snapshots of the cutting system were taken. The average diameter of processed wood was 45.6 cm and on average 5.49 cuts were made into the wood (average cut area was 0.9 m^2) in one measurement interval.

The STIHL MS440 chainsaw reached lower temperatures while cutting with the BP oil, on average 0.27 °C lower. The average temperature difference was 3.57 °C in favor of the HU oil on the chain. The overall temperature difference of the bar and tip of the bar was 1.35 °C in favor of the BP oil, but the reason for that is that the BP oil rendered better results in measurements without cutting load (-10.50 °C on average). As for measurements under cutting load, the chainsaw bar temperature was on average 3.23 °C lower when filled with the HU oil. The overall difference in temperatures of the bar tip was 3.03 °C, but again this was mainly due to better results of the bio-oil without the cutting load, where the difference was 14.37 °C in favor of the BP oil. In measurements under cutting load, the HU oil proved to be better reaching 2.64 °C lower temperatures than the BP oil.

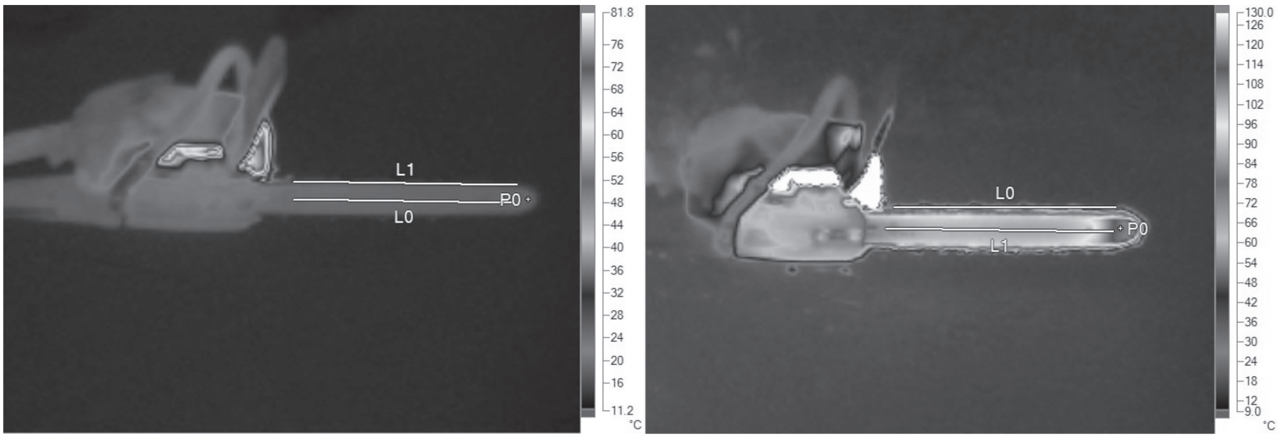

Fig. 2 Infrared snapshots of the Husqvarna cutting system, left – 1st interval, right – 4th interval

Slika 2. *Infracrvene slike reznoga mehanizma Husqvarna, slika lijevo 1. interval, slika desno 4. interval*

The results of measurements carried out on the Husqvarna 346XP chainsaw had similar outcome. The BP oil performed worse with this chainsaw than with the STIHL chainsaw. The temperatures of PB oil were on average 2.68 °C lower than the temperatures of the HU oil. The chain temperature difference was 6.80 °C in favor of the BP oil. The only measurement group where the bio-oil tested worse than the synthetic oil was cutting softwood, where the HU oil reached 0.18 °C lower temperatures. The overall average temperature of the bar was also lower with the BP oil, but the difference was not as big as on the chain (0.71 °C). The temperatures of the bar, while operating with the BP oil, were higher in measurements without the cutting load (2.92 °C) and while cutting softwood (3.20 °C). This pattern was visible on the tip of the bar as well, where overall temperature difference was 0.51 °C in favor of the BP oil. On average the BP oil reached 8.26 °C higher temperature without the cutting load and 5.48 °C when cutting softwood. In hardwood cutting, the tip reached 15.26 °C lower temperatures when filled with the BP oil.

The development of temperatures in the cutting systems of particular chainsaws is shown in Fig. 2 and 3. It is clear, that the highest temperatures are reached at the tip of the chainsaws and on the periphery of the bar, where there is friction between the chain, chain saw bar and material cut.

The average temperatures of the bar, tip and chain for both chainsaws and all measurement groups can be seen in Table 4 and 5.

Although more wood was processed with the STIHL MS440 chainsaw, it reached lower temperatures than the Husqvarna 346XP chainsaw, as can be seen in Fig. 4. Fig. 4 also shows variation of temperatures of the chainsaws.

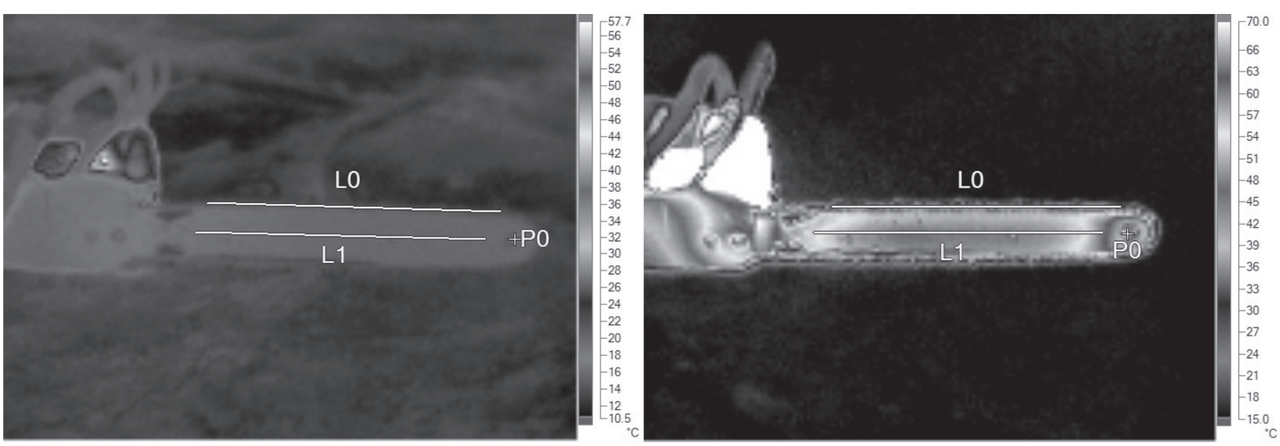

Fig. 3 Infrared snapshots of the STIHL cutting system, left – 1st interval, right – 4th interval

Slika 3. *Infracrvene slike reznoga mehanizma STHIL, slika lijevo 1. interval, slika desno 4. interval*

Table 4 Results of measurements with the Husqvarna chainsaw, average temperature in °C

Tablica 4. *Rezultati mjerenja s motornom pilom Husqvarna, prosječne temperature u °C*

Husqvarna 346XP							
Oil – *Ulje*		BioPlus			Shell Helix Ultra		
		Chain – *Lanac*	Bar – *Vodilica*	Tip – *Vrh vodilice*	Chain – *Lanac*	Bar – *Vodilica*	Tip – *Vrh vodilice*
Without cutting *Bez prerezivanja*	1. interval	17.53	19.77	19.63	19.67	19.30	19.33
	2. interval	49.33	53.77	83.10	54.73	49.83	72.87
	3. interval	61.70	81.70	108.00	75.13	77.73	100.50
	4. interval	65.47	92.40	119.30	82.57	91.53	112.27
Beech cutting *Prerezivanje bukve*	1. interval	18.20	19.77	20.20	21.97	23.23	22.17
	2. interval	47.87	55.53	83.63	52.97	58.67	91.67
	3. interval	54.03	68.47	94.97	55.53	78.13	113.20
	4. interval	53.87	72.67	102.90	73.10	84.67	122.40
Spruce cutting *Prerezivanje smreke*	1. interval	16.77	18.67	17.67	16.37	17.00	17.37
	2. interval	46.83	52.87	81.83	49.43	51.50	77.33
	3. interval	61.13	74.50	104.57	58.47	74.57	100.57
	4. interval	69.13	85.87	112.53	68.67	77.57	104.60

Table 5 Results of measurements with the STIHL chainsaw, average temperature in °C

Tablica 5. *Rezultati mjerenja s motornom pilom STHIL, prosječne temperature u °C*

STIHL MS440							
Oil – *Ulje*		BioPlus			Shell Helix Ultra		
		Chain – *Lanac*	Bar – *Vodilica*	Tip – *Vrh vodilice*	Chain – *Lanac*	Bar – *Vodilica*	Tip – *Vrh vodilice*
Without cutting *Bez prerezivanja*	1. interval	23.10	21.97	22.47	27.40	30.17	28.80
	2. interval	47.60	39.40	54.13	52.07	49.90	66.70
	3. interval	60.47	58.97	76.70	66.97	69.03	90.17
	4. interval	65.40	67.57	85.30	68.67	78.50	102.37
Beech cutting *Prerezivanje bukve*	1. interval	20.67	22.90	22.43	17.87	18.87	17.27
	2. interval	44.60	42.50	52.90	40.03	40.37	50.53
	3. interval	52.93	54.33	69.27	49.87	53.73	70.80
	4. interval	58.60	58.77	73.00	49.40	58.90	69.67
Spruce cutting *Prerezivanje smreke*	1. interval	12.07	12.73	12.13	16.67	18.33	17.07
	2. interval	47.07	41.83	50.13	32.47	38.27	47.03
	3. interval	55.33	58.93	69.03	42.83	51.27	64.13
	4. interval	48.97	63.20	75.90	46.50	57.67	72.20

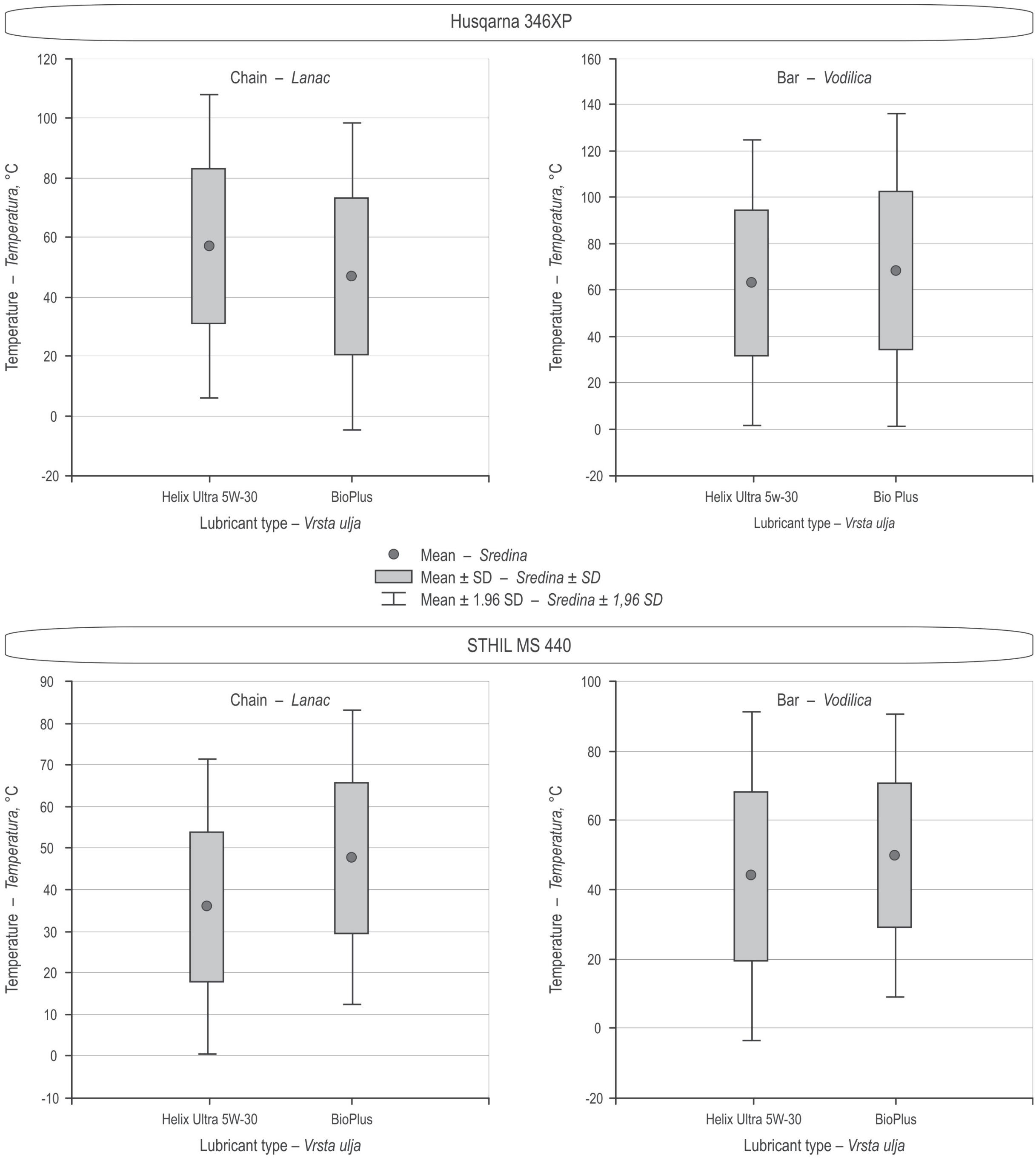

Fig. 4 Box charts showing temperature variability of cutting systems with both chainsaws and lubricant types
Slika 4. *Slikovni prikaz varijabilnosti temperature reznoga mehanizma obiju motornih pila i obiju vrsta ulja*

4. Discussion – *Rasprava*

The infrared snapshots, as seen in Fig. 2 and Fig. 3, show that the heat is mostly produced in the areas with most friction (tip of the bar and periphery of the bar) from where it spreads to the center of the bar. The highest temperatures were recorded on the tip of the chainsaw, where the bearing that enables chain revolutions, is located. Typically, the temperature of the bar was higher than the temperature of the chain.

Several biodegradable oils with some characteristics similar or better than those of mineral oils are available in the market (Lauhanen et al. 2000). The data acquired show that STIHL BioPlus oil and used

Shell Helix Ultra synthetic motor oil can both lubricate the cutting system and reduce friction between individual components and between the cutting system and cut wood. The results also show that the bio oil performed worse than the used synthetic motor oil in softwood cutting. This is possibly due to characteristics specific to softwood (e.g. higher volume of resins, lower density, different structure, etc.). Furthermore as Klvač et al. (2002) states, thin layers of rapeseed oil easily oxidize when exposed to air. An oxidized rapeseed oil is sticky and may cause chain blocking. Residual oxidized oil can also restrict piston movement during oil pumping, resulting in damage to the drive wheels of the transmission system.

Both oils are suitable for use in chainsaws but only regarding friction reduction. From the environmental point of view, the use of used motor oils has vast negative effects on the soil and water in the ecosystems. Skoupý (2004) states that 12–16% of oil sets on the surface and most of it is washed into underground or groundwater (Skoupý et al. 1990; Skoupý and Ulrich 1994). Used motor oils typically contain traces of metals (lead, iron, zinc, copper, etc.) and complex carbohydrates (Lengyel and Cvengroš 2008). It takes decades and/or a lot of financial resources to remediate soil from oil pollution.

5. Conclusion – *Zaključak*

The data collected during measurements fail to show significant differences in temperature of the cutting system that would be dependent on the type of lubricating oil. Our research disproves the assumption of forestry workers that bio-oils have a highly negative impact on the wear of the chainsaw cutting system. However, it is necessary to understand that the measurements carried out during our research were only short-term, meaning that some differences in lubricating characteristics were not able to show. The bio-oil studied does not provide significantly better lubrication for the chainsaw and in some cases it performs worse than the used synthetic motor oil. Its main advantage lies in its rapid degradation in the soil and very low ecotoxicity, which is a sufficient reason, in our opinion, to use it in practice.

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Sažetak

Utjecaj maziva na temperaturu rezne garniture motorne pile

U slovačkim šumama godišnje se u okoliš prospe 1,8 milijuna litara ulja za podmazivanje lanaca motorne pile. Od ulja koje se upotrebljava za podmazivanje lanaca motornih pila najštetnije je sintetičko motorno ulje kojim se još uvijek većinom podmazuju lanci motornih pila. Okolišno prihvatljivije bilo bi ulje koje se, usprkos svim naporima, koristi u manjim količinama. Šumski radnici sjekači tvrde da bioulje ima negativan učinak na tehničku ispravnost motornih pila.

Cilj je ovoga istraživanja bio usporediti svojstva bioulja i sintetičkoga ulja kako bi se teze šumskih radnih sjekača potvrdile ili opovrgnule. Pri istraživanju je korišteno iskorišteno sintetičko motorno biorazgradivo ulje Shell Helix Ultra VX 5W-30 i bioulje STHIL BioPlus. Mjerenja su obavljena na dvjema motornim pilama – Husqvarna 346XP i STHIL MS 440.

Termalne su fotografije snimane pomoću termalne kamere FLUKE Ti25, a preciznost termalne kamere je +/- 2 °C s »uncooled moicrobolometer« *senzorom. Mjerenje je provedeno tijekom rada motorne pile bez prerezivanja drva i tijekom prerezivanja bukova i smrekova drva.*

Mjerilo se u četiri režima rada:

1. Snimanje temperature motorne pile prije upotrebe

2. Snimanje temperature motorne pile nakon 1 minute rada

3. Snimanje temperature motorne pile nakon 2 minute rada

4. Snimanje temperature motorne pile nakon 3 minute rada.

Ukupno su snimljene 144 fotografije. Prosječan je promjer prerezanoga drva bio 45,6 cm, u svakom režimu rada prosječno je napravljeno 5,5 rezova, a prosječna prerezana površina iznosila je 0,9 m^2. Na temelju prikupljenih podataka sa sigurnošću možemo reći da obje vrste ulja, korištene u istraživanju, osiguravaju dostatno podmazivanje lanca motorne pile i smanjuju trenje između rezne garniture motorne pile i materijala koji se prerezuje. Pri prerezivanju mekoga drva (drva četinjača) sintetičko ulje pokazalo se boljim nego bioulje.

Istraživanje pokazuje da vrsta ulja nema značajniji utjecaj na trošenje rezne garniture. Bioulje nije se pokazalo boljim (ni lošijim) nego iskorišteno sintetičko motorno ulje, a njegova je glavna prednost smanjen negativan utjecaj na okoliš i brza razgradnja u šumskim ekosustavima, što je dovoljan razlog za povećanjem korištenja bioulja u šumarskoj praksi.

Ključne riječi: biorazgradivo ulje, motorna pila, temperatura, termograf

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