Friction Coefficient of Spruce Pine On Steel -- A Note on Lubricants

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ABSTRACT. Generally, the introduction of water and ethanol increased the friction coefficient for ovendry samples but decreased the coefficient when the samples were saturated. Octanoic acid decreased the coefficient when samples were wet. In the entire experiment, coefficients ranged from 0.14 to 0.78.

IN A PREVIOUS PAPER[1], the coefficient of kinetic friction of spruce pine wood (*Pinus glabra* Walt.) on steel was shown to vary with the wood's extractive content, specific gravity, and moisture content. In the research reported here, the friction coefficient between steel and two wood surfaces (radial and transverse) at two initial moisture conditions (ovendry and saturated) was studied in the presence of several lubricants.

Procedure

One-inch cubes of spruce pine wood were prepared to accurately expose a radial and a transverse surface. Cubes were first extracted in alcohol-benzene. Half were then dried for 48 hours in an oven maintained at 105°C.; the remaining half were saturated with water in a vacuum desiccator.

The horizontal force (F_h) required to slide a 1-square-inch surface subjected to a known vertical force component (F_v) was measured and the coefficient of kinetic friction (μ) calculated by the relationship

$$\mu = F_h/F_v$$

An Instron testing machine was used to slide the samples at a velocity of 2 inches per minute. Samples were connected to the crossarm of the machine by a thin copper wire, and a pulley converted the direction of travel from vertical to horizontal[1]. Horizontal force was measured with a load cell. A 1-pound weight was placed on the upper surface of each cube and it, plus the weight of the sample, was considered the total vertical force component.

The stationary surface was an oil-hardened, tool steel plate with a surface roughness of 9 microinches RMS. Specimens were pulled parallel to the grinding marks, and tests were conducted at 24°C.

Prior to testing, each wood surface was sanded in a figure-8 motion with a fresh sheet of 220-grit sandpaper and cleaned with compressed air. Radial surfaces were pulled parallel to the grain, while transverse surfaces were pulled parallel to the annual rings. Before each test, the surface of the plate was cleaned with acetone and lint-free laboratory tissue.

The horizontal force required to slide the unlubricated specimen was determined first. Several milliliters of liquids thought to have lubricating properties were then dropped ahead of the specimen and the change in the horizontal force noted. The liquids were water, ethanol, xylene, polyethylene glycol 1000, didecyl phthalate, and octanoic acid.

[1]Lemoine, T. J., C. W. McMillin, and F. G. Manwiller. 1969. Wood variables affecting the friction coefficient of spruce pine on steel. Wood Sci. 2(3):144-148.

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Results

Table 1 summarizes the information on coefficients of friction before and after application of water, ethanol, and octanoic acid. The other intended lubricants did not appreciably affect the friction coefficient and are therefore not tabulated.

Table 1. — FRICTION COEFFICIENT DETERMINATIONS.[a]

Lubricant	Radial surface		Transverse surface	
	Unlubricated	Lubricated	Unlubricated	Lubricated
	Ovendry samples			
Water	0.21	0.42	0.22	0.46
Ethanol	.23	.40	.26	.38
Octanoic acid	.21	.18	.23	.18
	Saturated samples			
Water	.60	.47	.72	.61
Ethanol	.64	.56	.78	.61
Octanoic acid	.61	.28	.71	.28

[a]Each numerical value is the average of three observations.

The general effect of the treatments may be compared from the ratios of μ after treatment to μ before treatment. In the following tabulation ratios greater than 1 indicate that the coefficient was increased by treatment, while ratios less than 1 indicate it was decreased; values are averaged over both surfaces:

	Ovendry	Saturated
Water	2.05	0.82
Ethanol	1.59	.82
Octanoic acid	.82	.42

The introduction of water and ethanol increased the coefficient for dry samples but decreased the coefficient when the samples were wet. Octanoic acid decreased the coefficient for both dry and wet samples.

Differences between the means in Table 1 were tested by variance analysis at the 0.05 level of significance. For untreated surfaces only two significant differences were observed. The coefficient was greater when the samples were saturated (avg. 0.68) than when dry (avg. 0.23). For saturated untreated wood, the coefficient was greater for the transverse surface (avg. 0.74) than for the radial surface (avg. 0.63).

There was a significant interaction with initial moisture content when the samples were lubricated with water. Water increased the coefficient of dry samples from 0.22 to 0.44 but reduced the coefficient of saturated samples from 0.66 to 0.54. With dry samples, the water increases wood moisture content at the interface, and thus an increase in the friction coefficient would be expected[1]. With saturated samples, a thin film of free water probably forms at the interface and acts as a lubricant.

For water-lubricated ovendry samples, the coefficient did not differ between surfaces (avg. 0.44). When saturated samples were lubricated with water, the coefficient was lower for a radial surface (avg. 0.47) than for a transverse surface (avg. 0.61).

Ethanol is slightly less polar than water. It also is a dehydrating agent and a solvent for surface extractives. As with water, ethanol interacted with initial wood moisture content. When the samples were dry, the coefficient of lubricated surfaces was significantly greater (avg. 0.39) than the coefficient of unlubricated surfaces (avg. 0.25). For saturated samples, the coefficient was less for lubricated (avg. 0.59) than for unlubricated surfaces (avg. 0.66). The coefficient did not differ between surfaces for lubricated ovendry samples (avg. 0.39). For saturated samples lubricated with ethanol, the coefficient was lower for radial surfaces (avg. 0.56) than for transverse surfaces (avg. 0.61).

Octanoic acid is a liquid whose molecule is nonpolar on the hydrocarbon end and very polar, with good hydrogen bonding capability, on the opposite end. For this lubricant, the interaction of initial moisture condition and presence of lubricant was again significant. With dry samples, there was no significant difference in coefficients between lubricated and unlubricated surfaces (avg. 0.20). With saturated samples, the coefficient was considerably greater for unlubricated (avg. 0.66) than for lubricated surfaces (avg. 0.28). The coefficient for wood lubricated with octanoic acid did not differ between radial and transverse surfaces in either ovendry or saturated samples.

Octanoic acid is adsorbed readily on ovendry wood but is immiscible with water. Thus, in water-saturated samples, it was possible to maintain a boundary layer of lubricant at the interface.

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