Castor Oil as a Lubricant

By C. P. HARRIS, Ph. D.

AMONG oils, the product of the castor bean, *Ricinus Communis,* possesses several unique properties. It has a very high specific gravity and a viscosity of a magnitude far greater than that of any other known untreated oil. These very valuable properties have pointed to its use as a lubricant and it has met with success, especially in bearings carrying heavy loads. However, its tendency to become rancid when exposed to heat and air have militated against its use. But in cases where the lubricated surfaces are not exposed to air, its use should not only be unobjectionable but highly advantageous. Until a few years ago the only tests applied to an oil so far as lubricating properties are concerned were the viscosity and power consumption or friction test. All the other tests made referred to the purity and stability of the oil. It has recently been recognized, however, that two oils of the same viscosity may have quite different lubricating values due to another factor, which, for lack of a better name is called "oiliness." Castor oil is pre-eminent in the possession of oiliness and its use as a lubricant will doubtless be stimulated by consideration of this new factor. Oiliness has been defined as "the capacity of the oil to form on the bearing surfaces an absorbed film, which will resist rupture at low speeds and high loads and thus prevent *metal-to-metal contact and abrasion.*"[1] It seems quite clearly to be a function of the chemical constitution and largely independent of the viscosity. The viscosity, of course, is of great importance in this connection and viscosity and oiliness are the chief factors influencing lubrication.

Both of these properties depend upon the chemical nature and constitution of the oil. Mineral oils are hydrocarbons which are saturated and inert under ordinary conditions. Some mineral oils have measureable iodine numbers and they vary among themselves in this respect, but the magnitude of this property in mineral oils commonly used as lubricants is negligible compared with measurements of unsaturation in animal and vegetable oils. The former consist chiefly of paraffin hydrocarbons and the presence of other elements such as sulphur or nitrogen is accidental. Except for the very high flash point cylinder and engine oils the viscosities are lower than those of most vegetable and animal oils. In fact, it appears that in any given chemical series, such as the paraffin hydrocarbons, the viscosity is a function of and varies directly with the increase of the molecular weight. It has been observed that unsaturation of the molecule increases the viscosity and for purposes of comparison a paraffin base lubricating oil is a completely saturated substance. This partially accounts for the fact that of mineral and vegetable oils of similar molecular

---

[1] Parsons and Taylor. *Journal of the Institute of Engineering Chemists,* Vol. 18, 1926, p. 493.

[2] A. E. Dunstan and F. B. Thole. *Journal of the Institute of Petroleum Technology,* 1918, page 191.

weight, the vegetable oils usually have the greater viscosity. Another structural factor affecting viscosity is the symmetry of the molecule. Molecular symmetry tends to decrease the viscosity.[2] This is an interesting idea, as the viscosity is thought to be due to the "internal rubbing" of the molecules against each other. Apparently molecular symmetry makes for a small amount of internal friction of the molecules. And here is another reason assignable to the difference of observed viscosities in animal and mineral oils. Pure paraffin hydrocarbons are remarkably symmetrical, whereas vegetable and animal oils, besides containing various different radicals in the molecule often possess asymmetric carbon atoms, that is, carbon atoms, each of whose valence is satisfied by a different radical.

Vegetable and animal oils are closely related chemically and consist of triglycerides of fatty acids. They differ from one another according to the properties of their acids. Sperm oil is a mixture of waxes, that is, *mono*molecular compounds of fatty acids with an alcohol of high molecular weight. Castor oil stands out in this group with a viscosity approximately seven times as great as that of other members.

Probably all chemical compounds possess the property of residual affinity in some degree. By this term is meant the activity and capacity for further combination with other substances. Atoms are ordinarily in a highly active condition and combine readily to form molecules. Molecules, in turn while much less active combine with other molecules, indicating that a mutual force of attraction previously existed. In some cases these molecular combinations are so loosely held together, as, for example, in the formation of certain hydrates, that the existence of the compound must be detected by delicate changes in certain physical properties, such as the formation of maxima in freezing point curves. In other words, there are all degrees of activity of chemical combination varying from a comparatively strong and stable compound formation to an extremely loosely held and easily disintegrated substance.

Adsorption is, doubtless, not to be considered a form of chemical combination, but in many cases it exhibits phenomena similar to a very loosely combined compound. Adsorption of active gases by finely divided charcoal, occurs quantitatively under proper conditions and can be made to reverse like a chemical combination. The fact is, that at the border line, it is difficult to distinguish between an adsorbed surface phenomenon and a chemical reaction. At any rate, the more chemically active substances are more readily and avidly adsorbed. This idea is applicable to the property of oiliness of lubricants.

It has already been stated that vegetable oils in general, and castor oil in particular, have not only higher viscosities, but also greater degrees of oiliness for equal molecular weight. The difference in residual chemical activity seems to explain the observed differences in these properties. In each of the three acid radicals combined with glycerin in a triglyceride there are two atoms of oxygen which possess additional combining capacity. One of these atoms is assumed to be connected to the carbon atom of the carboxyl group by a double linkage, the other is represented as having one valence satisfied by the carbon of the carboxyl group and the other by one carbon of the glyceryl radical. But oxygen can and does exist in tetra valent form[3]. So that in a carboxyl radical the oxygen atoms have residual chemical affinity. This accounts for part of the activity of these oils.

If the carboxyl group is not combined in the form of ester the reactive capacity is increased by the presence of a labile hydrogen atom; and it is noticed experimentally that the presence of uncombined fatty acid in mineral oils or in vegetable oils has decreased the static coefficient of friction, which is considered to be a measure of the property of oiliness. Unsaturated linkages between the carbon atoms composing the acid radical of oils naturally increases their reactive power. The number of unsaturations has long been recognized as an important property of oils but more from the viewpoint of oils suitable for paint manufacture. The iodine number is a meaure of this unsaturation and it is found that the property of oiliness varies directly with the increase of unsaturation of carbon linkages. Small variations of iodine absorption cannot be detected by measurement of oiliness, however, and small differences in this constant in mineral oils are not noticeable.

The presence of the hydroxyl radical introduces another unsaturated group.[4] The oxygen of this group possesses the property of becoming tetravalent, a procedure which probably is antecedent to many of its customary reactions. The hydrogen of the group can be replaced by acid radical to form esters, as in the alcohols. Castor oil is the only common hydroxylated oil and some of its characteristic properties are due to the presence of this group. The property of forming "sulphonated" castor oil is due to the reaction of the hydroxyl group with sulphuric acid, resulting in what amounts to an ester of sulphuric acid. The carboxyl, hydroxyl and unsaturated group and the asymmetric carbon atom are all present in the acid radical of castor oil, which fatty acid is known as ricinoelic from its derivation. The formula for this acid is:

$$\mathrm{CH_3\ (CH_2)_5}\ \mathit{C}\ \mathrm{HOH = CH_2 = CH = CH\ (CH_2)_7 = COOH.}$$

The underlined carbon is asymmetric. The combination in one molecule of both carboxyl and hydroxyl groups seems to increase lubricating power to a marked degree[5]. Esters of lactic acid, $\mathrm{CH_3\ CHOH{=}COOR}$ although of a very low molecular weight demonstrate this property.

There are three types of friction. First, there is the friction between perfectly dry clean surfaces, either flat or balls and rollers rotating against a bearing; second, there is the friction of partial lubrication where the surfaces are covered with a very thin film of grease or oil, not enough to prevent metal to metal contact and third, there is

---

[8] Kendall, *Journal Amer. Chem. Society*, **36**, 1722 and **37**, 160.

[4] Faulk and Nelson. *Journal Amer. Chem. Society*, 37, 1732 (1915). Standinger, Ber. **46** 3520. H. Goldschmidt, Zeitschrift Electrochemie. **14**, 581.

[5] W. B. Hardy. Fourtn Report on Colloid Chemistry and Its General and Industrial Applications. British Association, 1922, p. 196.

the friction of completely lubricated surfaces, where there is always a film of oil separating the metals and where the friction is due simply to the vicosity of the lubricant.

Partial lubrication is likely to occur in bearings moving at low speed, or at high pressure or both. A high speed of rotation has a tendency to "drag" the lubricant around with the bearing, low speed the reverse. High bearing pressure, naturally, exerts a tendency to break the fluid film and cause partial lubrication and metallic contact. Any bearing can be operated with a given lubricant so that either partial or complete lubrication will take place. The point at which the change occurs is called the critical point and is indicated by a sharp rise in the frictional coefficient.

In the region of complete lubrication the viscosity of the oil determines its efficiency as a lubricant, assuming its safety and stability factors to be satisfactory. But in partial lubrication the oiliness is the dominant factor. An exaggerated case of partial lubrication is illustrated by the lubrication of cutting tools where a heavy cut is taken. Here, fatty oils only are found satisfactory. A mineral oil compounded with a fatty oil and which gives similar results in static friction tests does not work as well for this purpose, probably because the high temperature at the cutting point alters the lubricating property of the compounded oil to a greater extent than the straight fatty one.

As castor oil, possesses the most desirable lubricating qualities of the fatty oil group, compounded mineral and castor oils might be expected to have value. This has been found to be the case. However, the solubility curve of castor and mineral oil is a peculiar one. Castor oil in small percentages is insoluble in mineral oil and as little as 0.5 per cent causes turbidity at room temperature. Equal quantities of castor and mineral oil, however, give a homogeneous solution, and the characteristic insolubility of castor oil is lost even in small quantities if a small amount of soluble oil, or a mutually soluble oil is added. Patented methods exist which have for their purpose the rendering of castor soluble in mineral oil. These depend mainly upon heating the castor oil, either alone or with reagents.

Castor oil is distinguished chemically by its high acetyl number, about 150, a measure of its hydroxyl groups, its solubility in alcohol, in which one part dissolves in four at ordinary temperature and its high maumené test. Physically it is distinguished by its high gravity, high viscosity and low solidifying point. Within the last few years, however, new and important lubricating tests have been devised. These consist of (1) the surface tension, (2) the interfacial tension, and (3) the static coefficient of friction, the measurement of oiliness. The surface tension and interfacial tension between oil and water are measured by means of a Traube stalagmometer, by dropping water into oil through a capillary tube. The value of these two tests is somewhat in doubt as investigators disagree as to the relation of interfacial tension to coefficient of friction. It seems, at least possible, that low interfacial

(*Continued on page 37*)

---

[6] Report of Lubricants and Lubrication Committee, Department of Scientific and Industrial Research. London, 1920.