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SOME NOTES ON LUBRICATION.

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The notes contained in this paper are mostly confined to that part of this very large subject which concerned the actual behaviour of the lubricant of the bearing. The various points had necessarily been touched upon very briefly, and nothing had been said about the composition, the extraction and purification, the chemical properties, the analysis, or testing of the innumerable varieties of lubricants on the market. Owing, also, to the very limited time in which this paper was written, no mention had been made of the many kinds of lubricating devices that were now in use, nor of the conditions which governed their application.

With these few remarks the author would now ask their permission to present the following notes:—

The special characteristics which distinguished oils from other bodies were:

1. For the most part they were liquid bodies having a specific gravity ranging between .730 and .980.

2. They all possessed, more or less, that peculiar property called oiliness or greasiness.

3. They left a greasy stain more or less permanent on paper.

4. They were all inflammable.

5. They were insoluble in water, but slightly soluble in alcohol.

Oils were divisible into two large groups:

1. Fatty oils and fats.
2. Hydrocarbon or mineral oils.

With regard to the first, it would be sufficient for the purposes of this paper to state that these oils were compounds of the three elements C, H, and O. All the fatty oils and fats were derived from the animal and vegetable kingdoms, the arbitrary distinction commonly given between oils and fats being that the former were liquid, and the latter solid.

The shales and crude petroleums of the mineral kingdom were the only source from which the second class of oils was derived. Chemically, they contained only the two constituents C and H. These two elements were capable of combining together in varying proportions and forming a large number of compounds known as hydrocarbons. Those hydrocarbons which were classed as oils had properties which could be graded in definite steps as they passed from the light, white volatile liquids to the heavy viscid and waxy substances. Only the heavier oils were used for lubrication purposes, the lighter ones being quite unsuitable. Mineral oils usually possessed a peculiar fluorescence or bloom.

It was very hard to buy two quantities of the same grade of mineral oil twice, i.e., unless one was prepared to pay a high price. This was owing to the complicated nature of the crude article and the difficulties met with in its refinement, which consisted of fractional distillation. Therefore, it was only waste of time and money to perform elaborate tests, unless very large quantities were to be used. A very rough practical test was to place some of the oil between the thumb and forefinger, to gradually move them apart, and to notice when the film broke. According to the distance the film could be stretched before breaking, they could judge whether that particular oil would be suited to their requirements. Further, if portions of various oils be placed in long tubes, say, 9in. long by ½in., in diameter, not quite filling them, and the tubes were inverted quickly, a rough estimate of their suitability might then be made by comparing the time of flow of each from one end to the other.

ANIMAL AND VEGETABLE OILS AND FATS.

Among the common animal oils and fats might be mentioned: Tallow, tallow oil, lard oil and neatsfoot oil. The chief of these was tallow, and its use was practically restricted to the lubrication of heavily loaded bearings and the manufacture of greases.

The principal vegetable oils were: Castor, olive, palm, and cocoanut oils. Since castor oil could resist better than most other oils, the great friction and heat which existed in very heavy and quick-running machinery it was still largely used in bearings of such machines. It would not mix with mineral oils, but only with other fatty oils. The other vegetable oils were not much used now as lubricants.

Lubricating greases were often given fancy names which gave no indication of their suitability for the purposes claimed by the makers. They were mostly made by treating certain oils and fats with caustic alkali, chiefly lime and soda, thus forming a soap. This was thoroughly mixed with unaffected oil, making a stiff greasy product. Greases were never used where oils would do, owing to their higher co-efficient of friction.

ACTION OF DESTRUCTIVE AGENCIES ON LUBRICANTS.

The action of these agencies was aided by the thinness of the films which necessarily existed in bearings. The oxygen and moisture in the atmosphere played the chief part in deteriorating the lubricating properties of oils.

Oxygen acted more or less on the fatty oils, but had no effect on mineral oils. The absorption of oxygen by the fatty oils to form a hard dry resinous mass, which stuck to the bearings, was technically known as "gumming." By mixing mineral with fatty oils this gumming was prevented to a certain extent. Water, especially when accompanied by heat, helped the splitting up of fatty oils into their constituent parts, viz., the base glycerine, and the peculiar fatty acids of the oil. Glycerine was a neutral substance, and had no corroding action on the metal. It was also devoid of any lubricating properties. The fatty acids, on the other hand, combined with the metal, forming a kind of greasy soap, which caked on the surfaces and led to rapid and unequal wear.

PROPERTIES OF LUBRICANTS.

It was generally conceded by leading authorities that the following properties should be possessed by lubricants:—

1. Enough viscosity or "body" to prevent the surfaces from coming into contact under the maximum pressure which was likely to be applied to them. Cohesion and adhesion both appeared to play a part in viscosity.

2. They should have as much fluidity as was consistent with the foregoing requirement.

3. They must be able to keep the bearing cool at the working temperature.

4. Mineral oils should have a suitable specific gravity.

5. A high temperature of decomposition or of evaporation, in other words, a high flashpoint; also, a low congealing temperature.

6. Freedom from tendency to gum or clog the bearings.

7. Freedom from acids (mineral or fatty), and any tendency to corrode the bearings.

8. Freedom from any suspended matter or other impurities.

FACTORS GOVERNING THE FRICTION IN BEARINGS.

Provided a bearing be well lubricated the friction followed the laws of fluid, rather than of solid friction; but, vice versa if the lubrication was defective. When choosing a lubricant for any particular purpose they must consider the speed, pressure and temperature at which it had to work.

The obvious rule with regard to the speed was that the faster it was the thinner and lighter the oil was required. The same rule also held for the pressure; as light pressures were usually associated with high speeds, and heavy pressures with low speeds. The thinnest oil that would reduce the friction of the machinery to the minimum amount should always be applied to bearings, as it was only waste of power to overcome the greater viscosity of too heavy an oil. The importance of temperature could not be overlooked either in buying oils. Every practical man knew how an oil became thinner as the temperature rose. The oil that would work well in a cold room might not give equally satisfactory results in a hot one. Therefore, the more viscous oils should be used at the higher temperatures. Theoretically, at least two oils should be used for machines which contain within themselves both fast and slow speeds, but few machinists worried themselves about such details.

On the score of both economy and cleanliness provision should be made where convenient to collect all oil after it had been used in bearings, to strain it, and allow it to stand, afterwards being used over again.

THE THEORY OF LUBRICATION.

It was convenient to group the notes on this subject under three headings:—

1. Static friction.
2. Slow speed lubrication.
3. High speed lubrication.

STATIC FRICTION.

Oils always had a smaller surface tension than the metal of the bearings they lubricated, hence they could spread over their surfaces, and, so to speak, "wet" them. Oils adhered to metallic surfaces very strongly, and it was to this property that their excellence as lubricants was mainly due. But, on the other hand, it was this same property which made them dangerous in boilers. Liquids in which surface tension was exhibited too strongly, e.g., water and mercury, were practically useless as lubricants. It was common knowledge how a drop of water or mercury, especially the latter, was scattered about when let fall on a horizontal surface; but most oils, if dropped from the same height, possessed sufficient cohesion to prevent "splashing." This particular strength of cohesive force or viscosity in lubricating oils thus enabled thin films to offer appreciable resistance to external mechanical agencies which tended to rupture or attenuate them. Owing to their insolubility in water (solution appearing to be a molecular phenomenon), oils, fats, greases, etc., could not be displaced from the surfaces of metals by water. At high temperatures, however, as in steam engines cylinder and valve chests, the film of lubricant might become very thin indeed, but, as far as the author was aware, the condensed water was never able to completely displace the oil and leave conditions of purely solid friction between the surfaces.

SLOW SPEED LUBRICATION.

This was of less general importance at the present day than high speed lubrication, but must be taken into account when starting up any kind of machinery and in hydraulic machines. Machinery that had been standing idle for some time, say over-night or a week end, generally groaned and creaked when started up, indicating that the oil had been forced out from between the bearing surfaces by the weight of the parts, leaving metal to metal contact.

As was well known to all, the most highly polished surfaces appeared under the microscope to be very irregular in contour, so that, when two metals were pressed together and impelled by a tangential force as well, for motion to ensue, the projections of one surface must shear off the elevated portions of the other, or else climb over them. This seemed to be the most acceptable theory of friction at present, hence, if it was a fact one could easily see how lubricants performed their function. Suppose that Fig. 1 represented a highly magnified section of two surfaces separated by a lubricating film. As one of the elevated portions, A, of the top surface approached a similar one, B, on the bottom the lubricant was squeezed out until the thickness of the film between them reached a minimum depending on the pressure and speel. On continuing the motion a suction effect was produced behind A, drawing in more oil from the thicker portion of the film, C. By increasing the speed they increased the resistance of the oil to this treatment, until such a thickness of film was reached that the size of the irregularities of the surfaces became negligible in comparison. Indeed, at this stage they were rather a help than a hindrance, because they aided the forcing in of the oil between the pressure points where it was most needed.

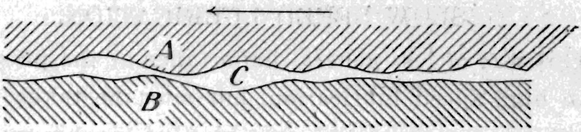

FIG: 1

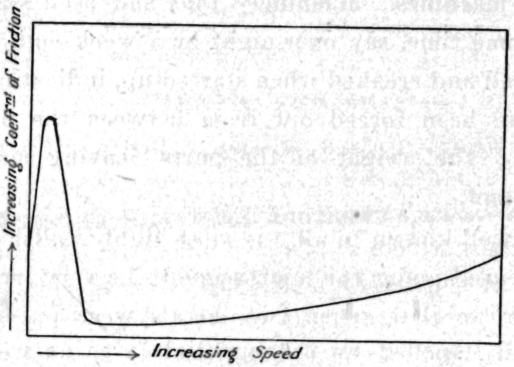

FIG: 2

The graph shown in Fig. 2 might be interesting to members, as it illustrated how the co-efficient of friction increased up to a certain speed (about two feet a minute) and then rapidly decreased till a speed of about four feet a minute was reached, when it very gradually got larger as the speed was augmented. This curve was very approximate and held for ordinary bearings under normal conditions, but the temperature, the hardness of the bearing surfaces, the manner of lubricating, and the plasticity of the lubricant all varied its shape.

Professor Goodman had plainly shown by his experiments how the co-efficient of friction at very low speeds was often greater than the static co-efficient.

Greases were largely used in slow speed lubrication. They would not flow without pressure being applied to them, and hence were not easily squeezed out from between the journal and its bearing. Their usefulness was further increased by their being able to be forced in at the higher velocities.

It might be interesting to mention that, according to experiments performed by Mr. T. G. Clayton in England, on an average 12.62 lbs. per ton was the force required to move a carriage when lubricated with grease, and 18.54 lbs. per ton when oil was used.

HIGH SPEED LUBRICATION.

As the bearing surfaces of machinery attained the higher speeds a thicker and thicker film of oil forced them apart and transmitted the pressure. The extent of this thickening depended not only on the load, the viscosity of the lubricant, the area of the bearing surfaces and their relative velocities, but also on their shape and inclination to one another. Since cylindrical surfaces were most frequently met with in practice he would like to limit his remarks to them.

PRESSURE OF THE OIL FILM.

Beauchamp Tower conducted a series of experiments in which he measured the pressure of the oil films with a pressure gauge connected with holes drilled in brasses. The graphs shown in Figs. 3 and 4 were drawn from his readings, and illustrated very clearly how the pressure varied at different parts of the bearing. Osborne Reynolds arrived at very much the same result by a mathematical route under similar conditions. The exact curve of pressures drawn from his figures was shown in Fig. 5.

Owing to the limited length of the brasses, all the oil did not go round the journal in planes at right angles to its axis, but some escaped laterally. This had the effect of reducing the pressure at the end to nil, leaving the full value at the centre only.

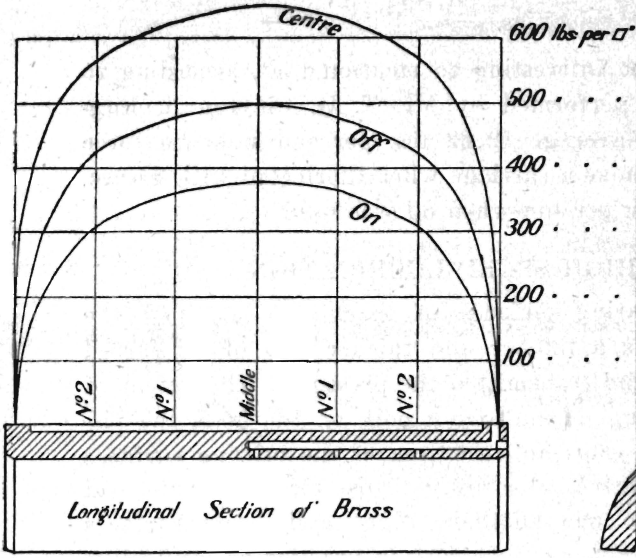

FIG: 3

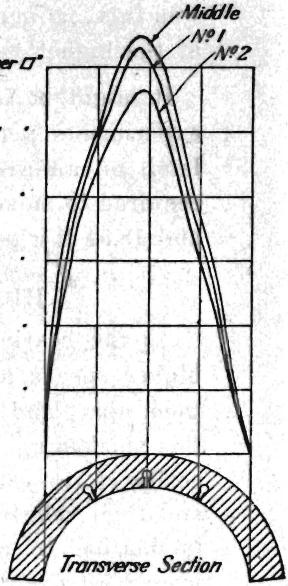

FIG: 4

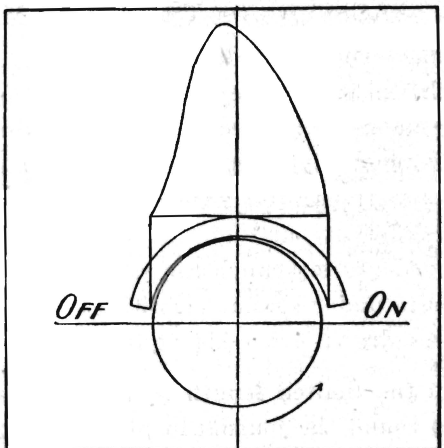

FIG: 5