METHODS OF LUBRICATING HIGH SPEED BALL BEARINGS

by

A. F. BREWER

The Texas Co., New York, U.S.A.

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Ball bearings, unlike plain bearings, do not fail by reason of wear or abrasion. A change occurs in the surface of either the balls or races (or both) to cause minute particles to flake or spall off.

Lubrication, which keeps the rotating surfaces continually wet with a film of oil, reduces local temperature variations which would otherwise lead to metal fatigue. Obviously, it is most important to prevent metal fatigue in a high-speed bearing where hundreds of millions of revolutions are required between overhaul periods, or in some instances even between shut-down periods. Oil is the ultimate lubricant, regardless of whether the lubricating film is developed by some means of dispersing fluid oil, or whether the required oily component for the film is derived from the soap base of a grease which is so applied as to be in intimate contact with the rotating parts of the bearings.

Lubrication at the load-carrying surfaces which involve rolling contact, in the opinion of some authorities, is primarily for corrosion prevention. Any sliding velocity which occurs, due to the finite contact ellipse, is probably accompanied by such high contact pressure that oil film action seems unlikely. The major function of the lubricant in a high-speed ball bearing would seem to be to minimize friction between the balls and the ball separator.

Most effective lubrication of a high-speed bearing by means of oil is attained when the volume of lubricant circulated is just sufficient to wet the rolling surfaces. Obviously, an excess of oil, such as would result from flood lubrication, might seriously affect the maximum speed of rotation due to churning.

The oil-mist lubricator is a device for injecting oil drop by drop into a stream of low-pressure air which breaks it up into a fine mist. A regulator is provided in advance of the lubricator accurately to control the air pressure. A high-quality filter should also be inserted in the line ahead of the lubricator to ensure clean dry air. The oil-mist lubricator illustrated in Fig. 1 produces particles of oil so finely divided as to form a fog. In operation, a vacuum is created by the air stream which draws oil through the orifice. The rate of oil consumption can be limited to a few drops per hour. This fog is so finely divided that it can be distributed to bearings in many different locations. Also, by means of mist-producing fittings, this fog can be transformed back to mist or spray or even drops, depending on the requirements of particular bearings. All this is done from a single lubricator.

This type of lubrication assembly is widely used for the supply of oil to high-speed grinding spindles. Since it requires air under a certain amount of pressure, it is obviously mainly applicable to stationary machines.

Advocates of oil-mist lubrication claim that :—

1. The air portion of the air-oil fog provides a cooling medium which maintains uniform spindle temperature.

2. By permitting the fog to continue flowing for a short time after shutting

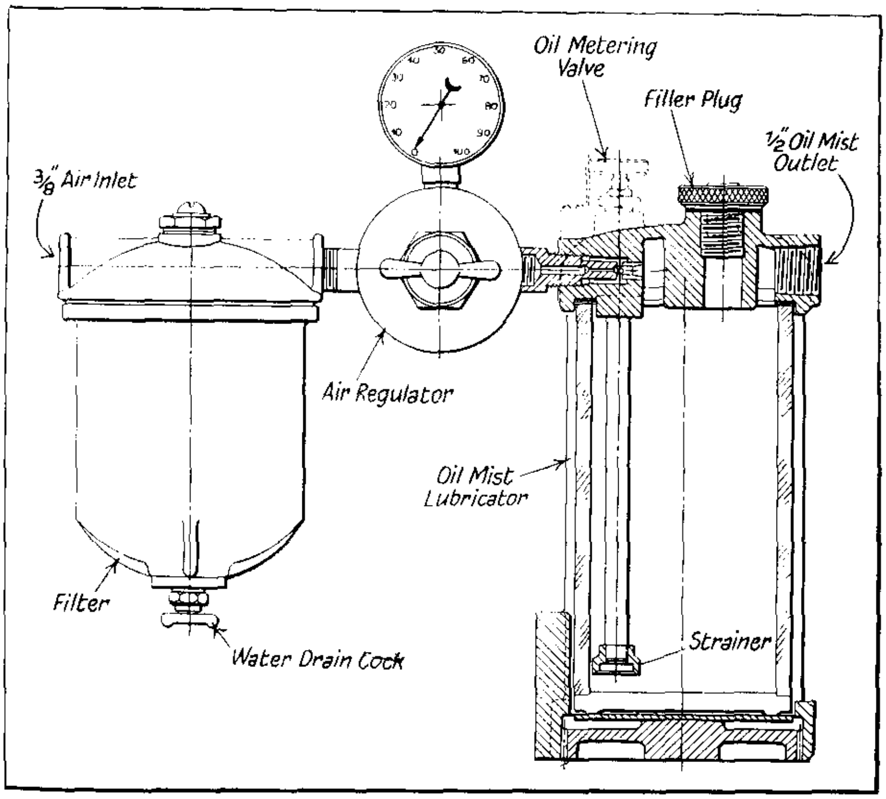

FIG. 1.—DIAGRAM OF AN SKF LUBRICATOR WHICH SUPPLIES A FOG OF LUBRICANT TO HIGH-SPEED BALL BEARINGS

down, the creation of a partial vacuum within the spindle housing as it cools is avoided, and consequently there is no risk of drawing in abrasive particles.

3. The particles of oil penetrate the hard core of air surrounding the rapidly rotating bearing to lubricate it without causing uneven rotation.

4. Only new oil is carried to the surfaces of the bearing.

5. Air pressure slightly above atmospheric is maintained inside the spindle housing to prevent entrance of abrasive and coolant.

Oil-mist lubrication is not measured lubrication in the true sense of the word, although the procedures adopted provide for very accurate control in terms of drops of oil delivered by an oiler or a wick.

Some aircraft designers, in seeking for a satisfactory method of lubricating the high-speed ball bearings of cabin refrigeration and pressurization equipment, have adopted wick lubrication. The desired oil mist is obtained by submerging one end of a wick in an oil reservoir, the other end being in contact with the high-speed rotating shaft. At the point of contact a spray of oil is thrown off and air draught draws this spray into the bearings. No attempt is made to throw the spray directly into the bearings.

The required air draught is developed by a slinger adjacent to the bearings at the opposite end from the wick contact point. Suitable grooves convert this slinger into an effective air pump. When this device is in operation at high speed, a stable oil mist fills the entire bearing space, and because it contacts all parts of the bearing, it provides a very dependable means of lubrication.

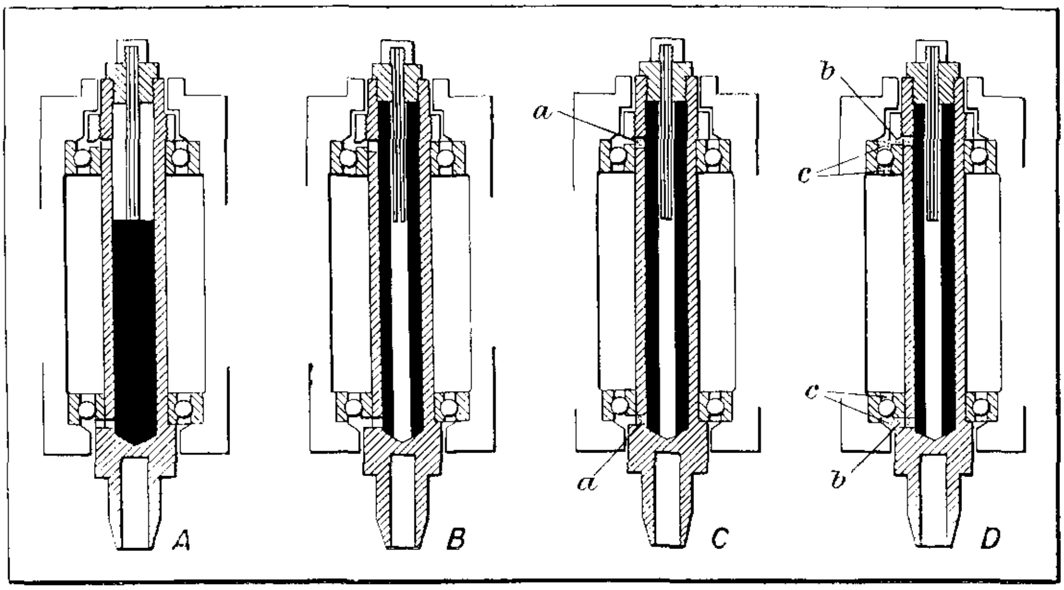

FIG. 2.—DIAGRAM SHOWING THE METERED-MIST LUBRICATING SYSTEM

No attempt is made to use the oil as a coolant, the desired cooling being secured by conduction through direct contact with the circulated air. This is a highly effective method of cooling when the heat rejection rates of the bearings permit. When it is not sufficient, oil cooling jets can be used.

Research has determined that the effective oil pumping capacity of such a wick is surprisingly high. The rate of oil flow through a ⅛-in felt wick in contact with a high-speed shaft is as much as 20 c.c. per hour.

Some atomization of oil is also obtained when high-speed bearings are lubricated by attaching oil slingers to the shafts. As the latter rotate, the slingers, which dip into an oil reservoir below, carry a continuous film into the upper part of the assembly, where it is thrown off. The oil passes to the bearings through apertures of varying size and number which have an atomizing effect.

Metered-mist lubrication is another interesting system devised for maintaining a dependable oil supply to high-speed spindle bearings, especially for wood-working machinery. This system employs the centrifugal force developed by spindle rotation as the means for maintaining the oil feed. Fig. 2 illustrates the principles of operation.

As shown at *A*, the hollow spindle is the oil reservoir. Air is trapped in the upper part by the feed-tube, preventing over-filling. As the spindle turns, centrifugal force drives the oil against the walls of the reservoir (see view *B*). The air that was trapped forms the core extending upward to the feed-tube, thus preventing oil leakage. The only points for oil escape, as seen at *C*, are through metering elements *a*. Being of predetermined porosity, these permit only the desired amount of oil to pass in a given time. They also break up the oil into very small particles. As the oil leaves the metering elements centrifugal force carries it through the spaces *b* into bearing chambers *c*, as indicated at *D*. Metered-mist oiling can be applied in any plane.

To provide a quickly available source of oil for high-speed motor spindle bearings during the first few seconds of operation, a priming cartridge has

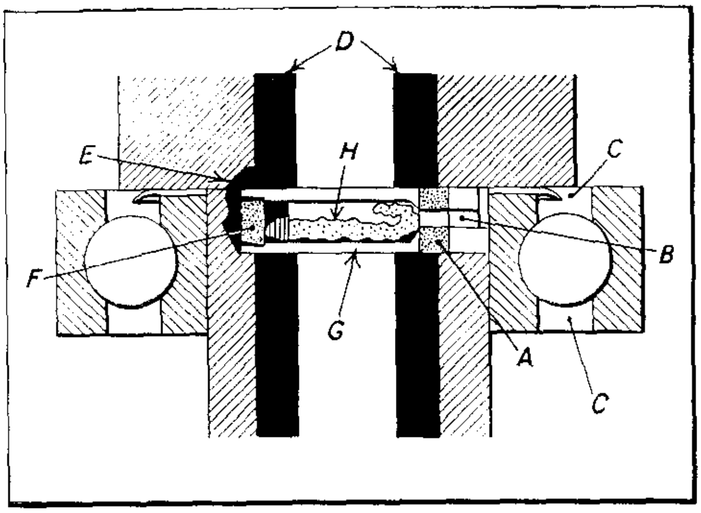

FIG. 3.—A PRIMING CARTRIDGE

been developed for use with a metered-mist system. The priming cartridge is shown in Fig. 3, where *A* is the porous metering plug ; *B* the open feed channel ; *C* the bearing chamber ; *D* lubricant on the walls of the reservoir ; *E* a recess in the wall ; and *F* a porous plug. The lubricant passes through this plug in the direction towards the axis of rotation. When rotation ceases, the priming wick *H* in the cartridge *G* absorbs the lubricant and holds it until the spindle begins to rotate again.

This provision for auxiliary lubrication during the start-up period is very desirable where the unit, when shut down, may develop enough heat to evaporate the existing oil film from the spindle bearings. High-cycle electric motors running for lengthy periods under severe operating conditions, when stopped for a few minutes, can become so hot as to cause their bearings to run dry until a new oil film is built up, unless means for oil priming are provided. Two or three drops of oil suffice to provide complete film coverage of each set of bearing elements, and to protect them until the main supply becomes available.

Requirements of Oil for Mist Lubrication

The oil for an oil-mist system should be a comparatively low-viscosity mineral oil (ranging from 100 to around 350 sec Saybolt Universal at 100°F). Stability is as important as viscosity, which only indicates the comparative fluidity. The highest degree of refinement is necessary, for the oil must be resistant to oxidation and gum formation. Conditions are favourable to oxidation due to the finely-atomized state of the oil as it is directed to the bearing and the fact that each particle is virtually surrounded by air. Furthermore, the warmer the air the greater the chances of oxidation.

The petroleum chemist has perfected a method of improving the resistance of mineral lubricating oils to oxidation by adding materials that will improve stability. Additives also are available which make mineral oils capable of forming rust-resistant films on steels. It is advisable to consider an oil of this type for use in an oil-mist system, particularly if moisture conditions are adverse and machines such as high-speed grinders are involved, which are periodically shut down. Condensation under such conditions may do serious damage to spindle bearings unless the oil is fortified to prevent rust.

High-speed ball bearings in gas turbines and jet-propulsion units carry thrust loads of such magnitude that considerable heat is generated in the bearings due to friction. Obviously, this heat must be dissipated in order to guard against bearing failure. In the jet-propulsion units, and, earlier, in turbo-superchargers, this was accomplished successfully by injecting solid jets of oil directly into the bearings, the oil striking either on the side of the ball separator or directly on the balls. Subsequently the oil is thrown off and scavenged out of the bearing housing as rapidly as possible, thereby carrying off the heat and transmitting it to the oil reservoir where it is, in turn, removed by conduction and radiation. For a bearing having a bore of about 110 mm (4.33 in), as much as 3 lb to 10 lb of oil per minute is injected. This enables heavy loads to be carried at high speeds.

In a recent test by an aero-engine builder, a bearing was run under about 12,000 lb thrust at 8,000 r.p.m. Careful observations of temperatures indicated that 3 lb of oil per minute was needed to cool the bearing. Increasing the oil flow beyond 5 lb per minute did not materially reduce the temperature. Where jet lubrication of this type is used, the primary purpose is to carry off heat, since very little of this large volume of oil is needed to lubricate the bearing. The system has been found to be more effective than using large volumes of air at low pressure to carry oil mist through the bearing, and depending on the flow of air for the cooling effect.

Grease Lubrication

The grease packing of ball bearings is successful where vertical spindles are involved, as on high-speed jig grinders and motorized wood-working shaper spindles, some of the former running at speeds as high as 60,000 r.p.m. Two high-precision ball bearings carry each spindle. In one very successful design applied to internal grinding, grease lubrication is provided from an annular space located above each bearing. At the time of assembly, grease is packed in by hand, and, on some machines, there is no provision for re-lubrication during the running life of the bearing. Other designs provide for pressure grease-gun replenishment. Lubrication from the original charge of grease is maintained by " bleeding " the grease just sufficiently to maintain a continuous wetting film of lubricant on the bearing parts. Those who favour this method claim the advantages of low-cost housings, infrequent lubrication, and cleanliness—all important factors in machine design.

Type of Grease Employed

Certain greases susceptible to shear " bleed " oil readily and are considered suitable for this purpose. It is assumed that, since such greases may contain a number of occluded oil pockets, the latter (plus shear susceptibility) tend to maintain a semi-fluid oily condition around the moving parts of the bearing. The fact that the grease is packed into an annular space above the bearing indicates the need for a quick-feeding medium-consistency grease.