GEAR COUPLING LUBRICATION

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When connecting two pieces of rotating machinery, the main problem is not so much how to transmit the motion and power, but how to cope with the misalignment between the two shafts. This misalignment has formed the subject of many papers and many heated discussions, simply because it is an unavoidable evil. Couplings can, to a certain extent, take care of misalignment. There are only two ways to handle misalignment; through flexing one or more of the coupling elements, or through the relative sliding motion between the coupling's elements. Each method has advantages and disadvantages. The need for lubrication is one of the disadvantages of the second method. Gear couplings accommodate misalignment through the relative sliding between the hub and sleeve teeth, hence they require lubrication.

Why are gear couplings still used? Among other reasons, because:

- Gear couplings can transmit more power per pound of steel, or per inch of diameter, than any other coupling.
- Gear couplings are forgiving, they accept errors in installation and mistreatment more readily than other types of couplings.
- Gear couplings are reliable and safe; they do not throw around pieces of metal or rubber even when they fail, and they can work longer in corrosive conditions than many other couplings.

A gear coupling consists of two sets of meshing gears, each mesh having an internal and an external gear, with the same number of teeth. The relative motion between the meshing gears is in the axial direction, is oscillatory, and has a low amplitude and a relatively high frequency. This type of motion is unlikely to help in forming a hydrodynamic film of lubricant. Lubrication, however, exists and it is generated by the centrifugal forces present in a coupling.

In order to understand not only why lubrication is necessary but also how the lubricant works inside the coupling, one must first be familiar with the particular motions between the coupling teeth. Figure No. 1 is a developed pitch circle.

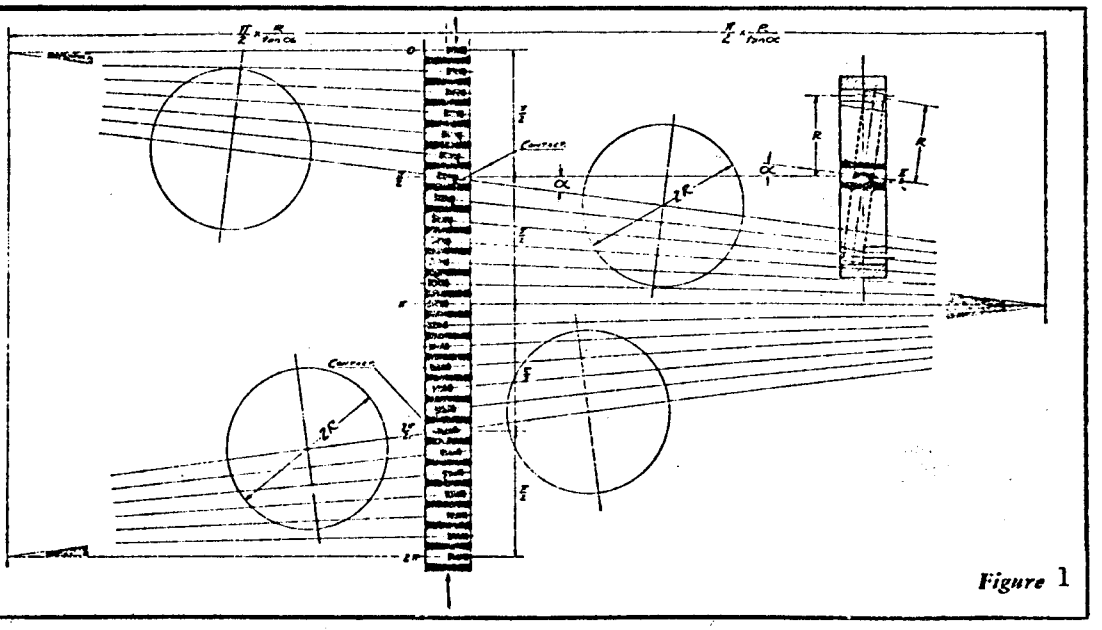


Figure 1

When the angle of misalignment is large, the torque is theoretically transmitted by only two teeth, 180° apart. This does not mean that the same two teeth continuously transmit the torque; on the contrary, each tooth transmits the torque over a small distance only, the tooth behind it takes over the torque transmission, then the next one, and so on. In other words, two matching teeth come in contact for a short period of time, then gradually separate, then approach each other, and after half a revolution come in contact again. In the period between two contacts, the lubricant has a chance to penetrate between the teeth. When the teeth come in contact they try to expell the lubricant from between them, but three things prevent this:

a. The duration of contact is short.
b. The contact pressure between the teeth is small.
c. The viscosity of the lubricant is high.

The condition in which only two teeth transmit the torque happens only theoretically; in practice, many more teeth participate in the torque transmission because:

- The misalignment is never large enough to create such an extreme condition, and
- under the influence of the torque, the loaded teeth flex slightly and thus allow the adjacent teeth to share the load.

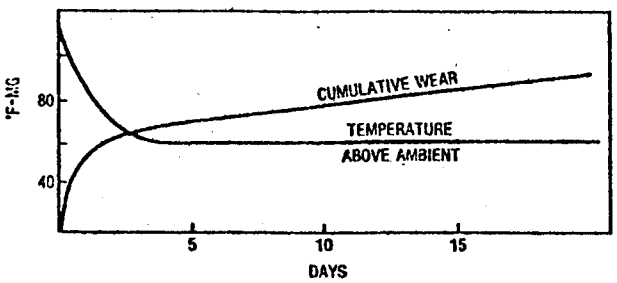
Let us carefully analyze the three conditions that prevent the lubricant's expulsion from between the teeth:

a. As the misalignment decreases the duration of contact between two teeth increases, which means that there is more time to expell the lubricant and less time for new lubricant to be introduced between the teeth. Both these conditions worsen the lubrication; however, as the misalignment decreases so does the need for lubrication. Indeed, at zero misalignment there is no relative motion between the teeth, hence no need for any lubrication! But zero misalignment is difficult to accomplish even in laboratory conditions so the the need for lubrication will always be present.

b. It takes a given pressure to expell the lubricant from between the teeth. We design the couplings for a maximum contact pressure which will not allow the teeth to expell the lubricant. The contact pressure is influenced not only by the coupling design, but also by the transmitted torque. It is easy to see that if the torque in the coupling exceeds the rated torque, then the contact pressure between the teeth becomes too high, and metal to metal contact will occur. Under such conditions the coupling will wear rapidly.

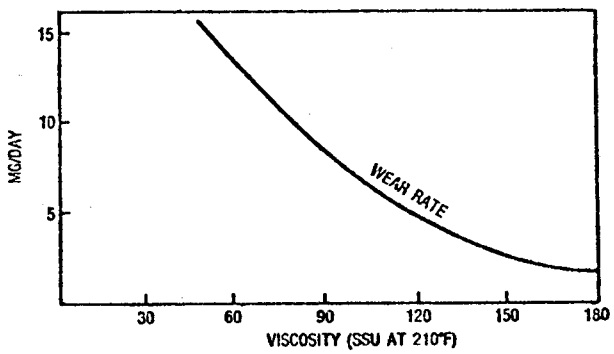
   There is one period in a coupling's life when the contact

pressure between the teeth is always high; during the breaking-in. One has to understand that although we manufacture high quality couplings, it is virtually impossible that all the teeth would be in contact with their mating teeth when the coupling is brand new. Slight variations in tooth-to-tooth spacing will cause some of the teeth to carry a much larger share of the torqu than the rest of the teeth, for the very first few hours in the life of a coupling. During breaking-in the loaded teeth will wear rapidly, but in doing so they gradually share the load with the other teeth. Eventually all the teeth will be in contact and will be evenly loaded. It is not unusual for a compling to operate "hot" during breaking-in, but, if the conditions are normal, the temperature should drop quickly after only a few hours.



—Coupling condition during break-in.

c. The more viscous a lubricant is, the more it resists the force of expulsion from between the teeth. However, the more viscous a lubricant is, the more difficult it is for it to repenetrate between the teeth. This subject will be discussed further on. All other conditions being the same, the wear-rate of a coupling decreases with an increase in lubricant viscosity.



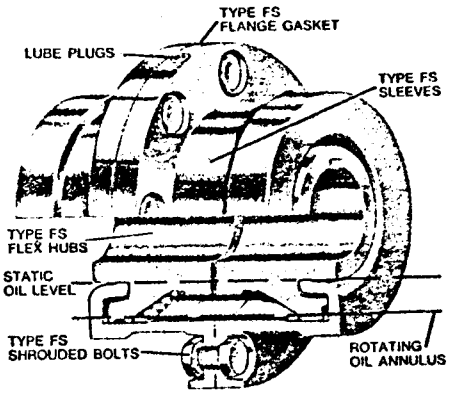
—Effect of lubricant viscosity on coupling wear.

There are two basic methods for coupling lubrication; batch and continuous flow. In the batch method, the coupling is filled either with grease or with oil; the continuous flow uses only oil, and almost exclusively light turbine oil. Standard couplings seldom use the continuous oil flow method, which requires an oil circuit with an oil tank, pump, piping, filters, etc. The continuous oil flow is used primarily in special applications, where either the oil circuit is available, or where the coupling must operate within an enclosure.

When should oils be used and when should greases be used?

A grease is mainly oil, often over 90% oil. The rest is a soap (aluminum, calcium or lithium base) which, similarly to a sponge, retains the oil. The soap of a grease does not participate in the process of lubrication. If we could make a leak-proof coupling then we would not even talk about greases today. Our "Forged Steel" coupling, although not leak-proof, is

designed so that it can operate with oil. The secret is in the design of the end-ring and in the large lubricant capacity of this type of coupling. Other couplings, such as the H type, although equipped with an "O" ring seal, cannot retain enough oil under stationary conditions, to insure proper lubrication.



Why should we bother with oil at all, if a grease is mainly oil? Because even the small amount of soap in a grease can cause many unpleasant problems, as we shall see. A good oil is also much easier to find than a good grease. Actually, any good grade "gear" oil (SAE 140) is an excellent coupling lubricant. It is not necessary to recommend brand names, or even viscosity index. Quite to the contrary, we are very careful when recommending greases.

Manufacturing greases is not a science, it is an art. Each oil company has its own secret recipe and only seldom do they disclose the ingredients used. For coupling applications a grease must have two main qualities:

- to be a good lubricant and
- to maintain its solid state.

In order to provide adequate lubrication the oil used in blending the grease should have a high viscosity. For instance, one of the greases we found to give excellent results has 94% mineral oil with a viscosity of 4213 SSU at 100°F and 174 SSU at 210°F (1000 centistokes at 38°C and 35 centistokes at 100°C). Let us warn you that very few greases have oils with such a high viscosity.

What about the requirement that a grease should maintain its solid state? Just as when one squeezes a sponge all the liquid is lost, a grease will lose the oil when subjected to centrifugal forces. Actually, some greases lose their oil even under earth gravity; when opening a container we can see oil floating on the surface. Separation of the grease into oil and soap is detrimental for couplings. Because the soaps used are heavier than the oil, under centrifugal force they would go toward the teeth; if the grease contains enough soap then the teeth are completely immersed in something which is not a lubricant. This is why sometimes a coupling wears rapidly although it is full of grease.

Because oil companies do not supply information about the resistance to centrifugal separation of their greases, Koppers decided to develop

these data. In 1960 we bought a powerful centrifuge that can subject grease samples to up to 36,000 times the earth's gravity! Since then we have conducted hundreds of tests, and we used the results to screen the best greases available from each oil company. This program is continuing and we are testing grease samples sent by customers or oil companies.

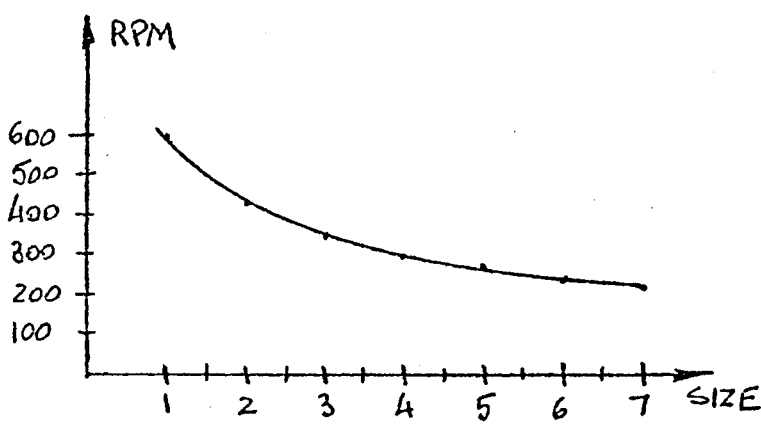
One important point which is, unfortunately, missing from our instruction sheets is the requirement to clean the coupling before re-lubrication. When a coupling is re-lubricated without being first opened and cleaned, the additional grease pumped into the coupling brings in more soap, and expells some of the separated oil. If this process is repeated many times, then the coupling ends up filled with a very high soap concentration grease and wears out quickly. This is more likely to happen if an improper grease is used.

If someone is faced with the problem of selecting a grease from an oil company not listed in our instruction sheets, here are a few basic rules:

1. Select the grease that has the smallest percent of soap.
2. Avoid greases with more than 8% soap, if possible.
3. Select the grease that has a high viscosity base oil.
4. Select a grease with an NLGI classification 1 (one).
5. If possible, send a sample (1/2 kg) to Koppers for testing. However, discretion should be used in sending samples, considering that testing is expensive.

Couplings that operate at high speeds require not only dynamic balancing, but also high quality greases. In such cases Koppers should be notified which greases are available at the location so that the best one can be selected. Again, to simplify both your and Koppers' work, you should first attempt to use one of the many greases listed in our instruction sheet.

A thicker grease (such as NLGI No. 2 or No. 3) is preferable at high speeds, but <u>should not</u> be used at low speeds. It should be remembered that it is the centrifugal force that helps the lubricant to penetrate between the teeth. With a thick grease the coupling needs a larger centrifugal force to have adequate

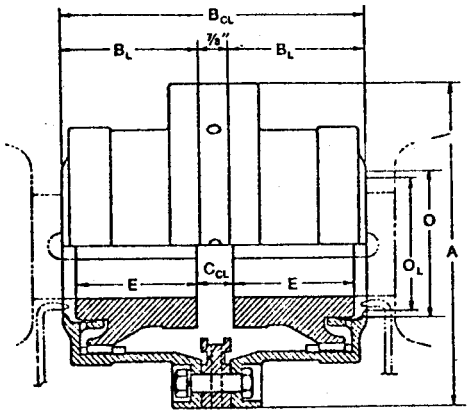


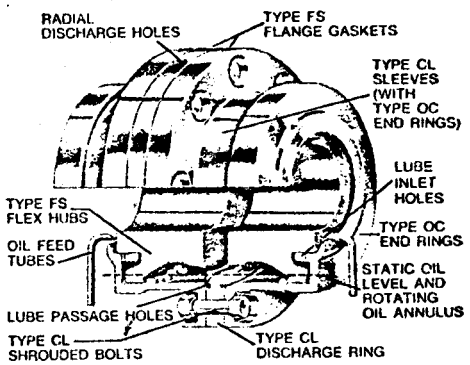
lubrication. In order to estimate what is low speed (for lubrication purposes) we recommend this graph, or the formula

$$RPM = \frac{850}{\sqrt{2 \times size.}}$$

Although used very seldom, the "continuous lube" system has one advantage that appeals to some users; a continuously lubricated coupling does not require servicing. When the equipment cannot be stopped for re-lubrication, and in particular when the coupling is located within an enclosure, the continuous oil flow is very advantageous.

Continuous Lube Type FSCL





The gear coupling is a very efficient element in the power transmission system. Because of this, the windage generated by the coupling is sufficient to dissipate all the heat generated by the friction between the teeth. This may not be true when the coupling must operate in a closed housing; it is then recommended that continuous oil flow be supplied, not only for lubrication, but also for cooling.

Because the oil flows continuously around the teeth, the coupling can operate with a less viscous oil than we recommend when it is filled with oil. A minimum viscosity of 40 SSU at 210°F (4.5 centistokes at 100°C) is recommended. The flow of oil required depends on the size and rotating speed; this information can be found on Page 7 of our Bulletin 4000.

The centrifugal force that separates the greases into soap and oil has also a negative effect on oils; it separates the dirt that the oil might contain. It is true that the oil leaves the coupling slightly cleaner, but the coupling slowly accumulates all the dirt. This oily

dirt, which we call "sludge", is not pleasant to look at and does not do any good to the coupling. The dirt accelerates the coupling wear and reduces the amount of oil that can flow through the coupling.

Even worse than dirt is water. Very seldom is an oil circuit free of water. The coupling separates and retains the water and corrosion and wear are the results.

For continuously lubricated couplings we recommend:

- a fine filter (5 micron) in the system
- a clean oil to start with
- regular purging of the oil tank
- fine filters at all the breathers.

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