Lubricants and Lubrication of Plastics Gears

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Surface measurement of any metal gear tooth contact surface will indicate some degree of peaks and valleys. When gears are placed in mesh, irregular contact surfaces are brought together in the typical combination of rolling and sliding motion. The surface peaks, or asperities, of one tooth randomly contact the asperities of the mating tooth. Under the right conditions, the asperities form momentary welds that are broken off as the gear tooth action continues. Increased friction and higher temperatures, plus wear debris introduced into the system are the result of this action.

The basic function of a lubricant is to provide an oil film that will separate two mating surfaces that move relative to one another. In metal gearing, it is imperative that an adequate lubricant and lubrication system be provided to prevent contact of surface asperities. Once failure of the lubricant or lubrication system is initiated, ultimate failure of the gearing is likely.

Plastics Reactions

In plastics gearing, both molded and cut plastics gears have the peak-and-valley surface contour. This is the result of manufacturing, inherent machining equipment inaccuracies and allowable tolerances. Some studies indicate that under the right conditions, momentary welding can occur in plastics gears. A compressive stress is present as a set of gear teeth come into contact. The stress moves from the initial point of contact along the tooth profile until the teeth are no longer in contact. The compression causes the same subsurface stress as in metal gears. When relative sliding takes place at the mating point of contact, heat builds up at a localized point and material is removed due to the shear stress. These factors contribute to:

1. New, exposed surface irregularities;
2. Free debris particles and erosion;
3. Increased energy requirements to maintain constant speed;
4. Increased friction and wear;
5. Increased heat generation;
6. Erratic, sluggish system response; and
7. Accelerated tooth contact surface change reflected in output load fluctuations or motion transfer problems.

Significant lubrication differences and similarities are found between lubrication of metal and plastics gears. Applications, materials and design situations range in plastics gearing from the extreme of plastics gearing with no lubrication and unfilled material to gears operating immersed in water, oil, or chemical baths. Present-day usage consists of many combinations of lube/no-lube, filled/unfilled materials and like/unlike materials. The ideal low-cost gearing system is that requiring no lubrication and unfilled materials.

In a gear set that is designed, manufactured, assembled and operated correctly, the use of a lubricant is recommended during the run-in period. Continued lubrication serves primarily to help reduce friction and assist in heat dissipation at the tooth contact surfaces, since even the best quality standard gears cannot avoid some degree of sliding contact during operation. Other uses of a lubricant in the application are flushing wear particles, dirt, and moisture, providing corrosion protection to adjoining parts and lubrication of those parts. As in all plastics gearing applications, gears should be tested to determine design suitability. The lubricant and lubrication method should be tested at the same time using the identical systems of the intended application at the required service conditions.

Coefficients of friction, temperatures, stress levels and wear factors of mating materials are an indication of the necessity for use of a lubricant. A low coefficient of friction indicates that relatively small amounts of input energy are necessary to overcome sliding contact conditions. Small wear factors for unit load will provide longer wear life. When coefficient of friction and wear data are not available, substitute materials may be considered. This is particularly advisable in plastics gearing because much data have been generated for the commonly used and most successful gearing materials.

It is important to remember that lubricants are chemicals. Plastics are susceptible to chemical attack, so a major consideration is the type of lubricant selected for a particular application. This selection process is aided by tables provided by plastics material suppliers and texts containing results of chemical compatibility tests. Test samples of candidate plastics materials are immersed in the chemical of interest at a certain temperature for a period of time. Test samples are then weighed, and that weight compared with pre-test weights. Chemical attack of the plastic material has occurred if the sample weight has been reduced or if crazing of the material is evident. If the test sample weight is increased, the indication is that absorption has occurred. Remeasurement of the test sample can sometimes indicate the severity of the fluid absorption. In gearing, moisture or chemical absorption can be as severe a problem as chemical attack, because small clearances for backlash can easily be eliminated and wear initiated.

Discussion of chemical attack on plastics is not an indictment of the lubricant. Practically all types of lubricating oils contain at least one additive, and some oils contain several different types of additives. The amount of additive used varies from a few hundredths of a percent to 30% or more (Ref. 1). It is usually the chemical action of the additives that is responsible for the failure of plastics materials when in contact for a period of time, under stress conditions, subjected to adverse temperatures or in contact with combinations of other system materials.

Chemical compatibility data will usually indicate exposure time and temperatures. The question confronting the design engineer is the applicability of the data for his or her application. Operating stress levels are usually never the same as the stress level of the test sample. The same is true for the temperature and the time of exposure. For this reason, some material suppliers provide data generated at wide ranges of temperatures for extremely long periods of time. Regardless, gear life tests should always be run unless significant experience with a particular lubricant dictates otherwise.

Plastics Stress Level

The fact that lubricant attack is influenced by stress level is sometimes overlooked. Often samples submitted for chemical compatibility testing will be at a specific stress level due to normal sample preparation procedures. When a gear is produced either by molding or cutting, stresses are set up in the parts. These residual stresses may or may not be relieved with subsequent manufacturing processes. Nevertheless, operating stresses are also present during running of the gears in their application. The problem is that the reaction of the gear materials to the residual or operating stress levels and operating temperatures may produce significant lubricant and material incompatibilities. Fortunately, experience has shown that some lubricants work better with certain materials used in gears of common sizes, with typical loads, and limited to reasonable temperature levels. The result is that many material suppliers and gear houses are aware of the lubricant/plastics gear compatibility concern and can be of assistance in providing recommendations. However, since stress levels and applications can be substantially different, the recommendation is to test the gears with the intended lubricant in actual situations. Where testing is impossible or impractical, all available experience and reported data should be consulted and analyzed.

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Plastics gear lubrication is accomplished using the following methods or in combinations of the various methods:

1. Dry with no external or internal lubricant;

2. Initial application of external lubricant, usually grease;

3. Initial application, replenished at random or fixed intervals;

4. Continuous coverage by liquid bath;

5. Fillers such as carbon, graphite or molybdenum disulfide;

6. Gears filled with silicone or similar lubricants; and

7. Gears both filled with lubricants and externally lubricated.

Other Considerations

A problem often encountered is adherence of the lubricant to the tooth-contacting surfaces. Squeeze-out and throw-off by centrifugal action has plagued gear users and is a continual problem in many applications. Some innovative housing designs have provided deflectors that channel the oil or grease back into the gear contact area. Selection of an adhering type lubricant may resolve the problem in some applications. Nonspreading and nonmigrating lubricants or oil creep barrier films may also be possible if carefully selected for particular problems.

There are times when lubricants may be considered to be contaminants. This may be particularly true where the lubricant is used on food handling equipment. Inadvertent contact with the food necessitates the use of certain types, such as the silicones.

Acetal (polyformaldehyde) is not vulnerable to solvation (attack by lubricant components) or crazing. However, it is quite sensitive to buildup of acidic constituents. The most popular gearing materials, acetal and nylon, are susceptible to chemical attack at temperatures above 150°F and in strong acids and strong alkalis, particularly at full strength (Refs. 3, 4).

The most versatile synthetic lubricant families are the silicones and hydrocarbons, where operating temperature ranges of -65°F to +250°F are not uncommon.

Chen and Juarbe (Ref. 5) discuss lubricants and MoS_2-filled nylon gears. Gear oils with an EP additive in the viscous range of 200-300cs at 40°C are suitable for nylon. This is equivalent to the AGMA mild EP lubricant #4EP. Loads tested were heavy and operation was low-speed.

Chemical equipment and chemical handling equipment can be sources of contamination by oils and greases. Lubricants can contaminate areas such as office equipment, where paper forms, bills and account ledger materials must pass through data processing machines. Care is necessary so that creep, splash-out, dripping or bleed do not become a problem.

What to Look For in a Plastics Lubricant

Items of importance are as follows:

1. *Correct viscosity.* Minimum oil film thickness, continual recreation of a lubricated surface, formation of a protective film, good distribution with minimum squeeze-out.

2. *Adequate temperature range.* Fluid film at low-temperature extreme, sufficient coverage and lubricating capability at high temperature extreme, minimum fluid breakdown at high temperature.

3. *Chemical stability.* Minimum oxidation under heat buildup may provide additional protection.

4. *Good lubricity.* Minimum friction that aids in control of operating temperature rise may have additive protection.

Lubricant and Plastics Compatibility (Ref. 2)

Materials not usually a problem are nylon, phenolic, diallyl phthalate, terephthalate polyesters, polytetrafluoroethylene, polyethylene and polypropylene.

Materials that can be a problem are polystyrene, polyvinyl chloride, ABS resins, polycarbonate, polysulfone, and polyphenylene oxides. ■

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