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Tribology In Gear Drive

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Abstract- The correct tribological design will have a considerable effect on a gear's service life and efficiency. The purpose of this paper is to clarify the impact of variation in the gear tooth flank tribological system on the gear contact load capacity to increase the understanding of how surface topography and lubricant interact. In this thesis the variation in surface topography inherent in the manufacturing method has been shown, by experimental work and computer simulations, to be an important factor for the contact condition in the early life of gears. Surface analysis revealed that the formation and composition of surface boundary layers depends strongly on the chemical composition of the lubricant, but also on pre-existing surface boundary layers. Additionally, surface boundary layers play a major role in frictional behavior, wear and in allowing the lubricant to react properly with the surfaces.

Keywords: Lubrication, Friction, wear

INTRODUCTION

Gears are one of the most important means of mechanical power transmission, partly thanks to their high efficiency, which can reach over 99% for a gear pair. The earth's limited resources have forced us to use fuel more efficiently, and so there are increasing demands for even higher efficiency, longer service life and more power-density. In addition, customers have begun to make demands relating to environmental aspects such as noise pollution, full recycling and lubricant properties that may affect humans or the environment for a very long time after the product has been taken out of service. To meet these demands, designers and manufacturers have been forced to become aware of phenomena that were previously of less importance. The principles behind these phenomena affect friction, wear and lubrication, which are all covered in the science of tribology. For example, today it is not just the presence of lubrication in a machine application that is of importance, but also the type of lubricant, where it is intended to act and how to apply it.

LITERATURE SURVEY

Vijayarangan and Ganesan:-In 1992 studied static contact stresses including the effect of friction between the mating gear teeth. Using the conventional finite element method the element stiffness matrices and the global stiffness matrix [K]of the two gears in mesh were obtained. If the external forces at the various nodes are known, then the system of equations is written as: [K]{U} {F} (2.1) where {U} is the nodal displacement vector and {F}is the nodal force vector. The system of equations is solved and {U} is obtained. Then the stress can be calculated. Each gear is divided into a number of elements such that in the assumed region of contact there is equal number of nodes on each gear. These contact nodes are all grouped together.

David and Handschuh:- Investigated the effect of this moving load on crack trajectories. The objective of this work was to study the effect of the moving gear tooth load on crack propagation predictions. A finite element model of a single tooth was used to analyze the stress, deformation and fracture in gear teeth when subjected to dynamic loading. At different points on the tooth surface impulsive loads were applied. Moving loads normal to the tooth profile were studied. Even effective designs have the possibility of gear cracks due to fatigue. In addition, truly robust designs consider not only crack initiation, but crack propagation trajectories. residual stresses have beneficial effect for the improvement of the fatigue life of the peened component.

Kasuba:- determined dynamic load factors for gears that were heavily loaded based on one and two degree of freedom models. Using a torsional vibratory model, he considered the torsional stiffness of the shaft.

Kelenz:- investigated a spur gear set using FEM. The contact stresses were examined using a two dimensional FEM model. The bending stress analysis was performed on different thin rimmed gears. The contact stress and bending stress comparisons were given in his studies.

TRIBOLOGY

Tribology, derived from the Greek word tribosmeaning rubbing, is the science and technology of interacting surfaces in relative motion and of related subjects and practices. It includes friction, wear, and lubrication. Friction can be directly correlated to gear contact power losses and temperature rise. Gears generally have a slow continuous wear process which eventually causes loss of gear accuracy. Lubrication is the most common way to reduce friction and wear in terms of building up easily-sheared boundary layers; it is also a common way to transfer heat from the contact zone. Choices made during design and manufacturing affect all these aspects. Over the years, tribology has focused towards smaller and smaller scales in the investigation of these phenomena. This progress goes along with the tools of surface science. In any machine there are lots of component parts that operate by rubbing. Eg.Bearings, gears, cams and tappets, tyres, brakes, and piston rings.

GEAR

Gears are machine elements, which are required to transmit power between shafts rotating at different rotational speeds. By adding teeth of the proper shape on disk, power can be transmitted without slip at uniform rate. These types of geometrics are known as external gears. Internal gears are generally more efficient since the sliding velocity along the profile is lower than equivalent external gears. It operates at closer center distance with its mating pinion than external gears of the same size, which often permits a more compact design. The internal gears eliminate the use of an idler gear, where it is necessary to have two parallel shafts rotate in the same direction. In manufacturing point of view also, external gears are simpler than internal gears.

Fig4.1 Internal & External gearing

GEAR FAILURE MODES

There exist at least four major types of tribological failure modes: macro-pitting or spalling, micro pitting or gray staining, scuffing, and mild wear. The following section defines each failure mode and describes the physical phenomenon that causes the failure.

Wear

Wear can be defined as the removal or displacement of material from surfaces in contact as a result of mechanical, chemical, or electrical action. Wear can be classified as mild, moderate, or severe. Wear can include several wear mechanisms (e.g. adhesive wear, abrasive wear), and the predominant wear mechanism gives rise to a specific failure mode. Generally, the failure mode of scuffing is based on a critical contact temperature at which the lubricant film fails and micro-welding between asperities takes place. Gears mostly have a slow continuous wear process, but gear life is usually deliberately limited by surface fatigue, since a tooth breakage will immediately stop the gear function. Pitting occurs when the limits of the surface durability of the meshing flanks are exceeded and particles break out of the flanks leaving pits.

Types of wear

A) Macro-Pitting

Contact between surfaces of gear teeth leads to shear stresses which reach a maximum value just under the contact surface. The relative motion between gears in the form of rolling, sliding, or both, creates a band of material that is repeatedly stressed. Eventually, cracks form at subsurface stress concentrations and work upward until they reach the surface. Once they reach the surface, a flake of material is released and a pit is formed in the gear tooth. Pitting can appear anywhere on the gear tooth that experiences contact, however most pitting in spur gears has been shown to occur near the pitch line. Macro-pitting is shown to be greatly reduced with the use of lubrication. Lubrication reduces the intensity of the near-surface stresses by spreading the area of contact. Many gears also utilize case hardened materials so that the area that experiences the maximum contact stress is more suited to withstand the stress without cracking.

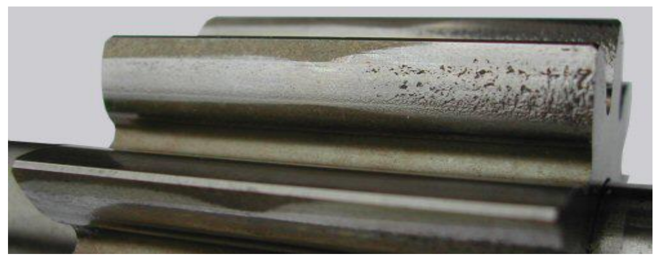

Fig.7 pitting (surface fatigue)

Scuffing

The tip and root of the gear tooth, where the slide-to-roll ratio is the highest, temperatures can elevate and break down the lubrication. Once the lubrication is broken down to a point where it is no longer able to keep asperities on the surface of the gears from contacting, the asperities plastically deform. Failure can occur due to the rapid wear and transfer of material between gear teeth and in severe cases scuffing can cause seizing of the gears. Figure shows a spur gear experiencing substantial scuffing at the tip and the root of the gear teeth.

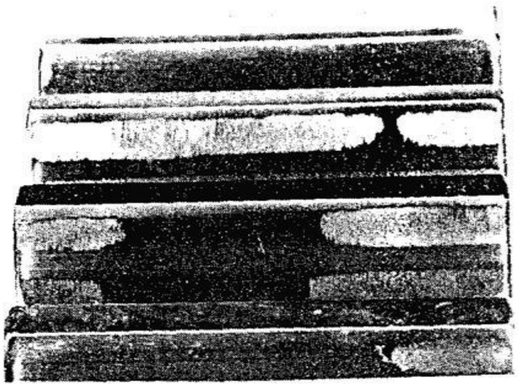

Fig.8 Typical Scuffing on a Spur Gear

C) Mild Wear

Operating conditions that do not cause pitting and scuffing may still slowly remove material from the gears through mild wear. Mild wear exists due to the adhesion, abrasion, and corrosion that slowly remove surface asperities while sliding across one another. The rate at which the asperities are adhered, sheared, and removed depends on the asperity contact temperatures. If the un-lubricated area reaches a critical temperature, scuffing will begin to occur.

Another type of mild wear is called corrosive wear in which lubricant additives slowly corrode rough asperities. The result of the corrosion is a smooth polished surface. If the corrosive wear is controlled so that material is not abraded away too quickly, it is desirable to have a polished surface between gears contacting. Doing so increases the lubrication film thickness and reduces the risk of pitting and scuffing.

D) Adhesion

Adhesive wear is classified as mild if it is confined to the oxide layers of the gear tooth surfaces. If however, the oxide layers are disrupted and bare metal is exposed, the transition to severe adhesive wear occurs. Severe adhesive wear is termed Scuffing. Gears operating at low speed and high load are especially prone to adhesive wear because of lubricant operating in the boundary or mixed lubrication mode. For low speed gears increased lubricant viscosity will decrease significantly low speed adhesive wear. Chemically active EP additives (sulfur-phosphorous) can be detrimental in low speed and high load gears causing high wear rate.

E) Abrasion

Abrasive wear in gear sets is caused by contamination of lubricants by hard, sharp-edged particles. Contaminants in gear set can be internally generated, ingested through breathers and seals or added during maintenance. Internally generated particles are wear particles in the system. These wear particles are especially abrasive because they become work hardened when they are trapped between gear teeth. Abrasive sand and dirt particles can be ingested through breathers and seals. Abrasive wear due to foreign contaminants or wear debris is called three-body abrasion and is a common occurrence. Inspection of gear tooth surface in case of abrasive wear mode will show scratching of the surface. The use of filtration in cases where circulating-oil systems are used will greatly reduce particle contamination. The use of oil-tight seals and filtered breather vents will minimize ingested contaminants.

LUBRICATION FOR GEARS

Lubricants perform a number of functions: transferring heat, controlling wear, reducing friction, carrying away contaminants and debris, preventing corrosion, and reducing noise and vibrations. The gear pairs in a gearbox rotate even if they are not transmitting any load. These load independent losses are an important source of the total transmission losses, and are most easily decreased by lowering the viscosity. Gear lubrication requires oil that can reduce wear, protect against corrosion and rust, resistOxidation degradation and shear down of itself inhibit the formation of foam and separate water easily.

APPLICATION

let us draw the different kind of configurations, gears are classified you can see that there is a straight trip whatever the motion transmitted from one or say smaller gear will be known as pinion to the gear, the axis are parallel; it is a parallel transmission however, there is a possibility of some sort of 90 degree bend, 60 degree bend or angle of inclination may be changing from 30, 45, 60 degree, then we need to change the profile then we use bevel gears, this is the bevel gear. There is some sort of helical shape also, you see often we use the helical gear for the smooth motion, what we know as contact ratio, effective contact ratio then helical profile is more than two, what is the meaning of that, see when you see this per gears, there is a contact between the one trip pair, because the second trip comes in contact naturally they need to be disengagement of first trip pair and there is no disengagement then there will be motion and this kind of variation changes the stiffness of the gear. And that induce some sort of additional vibration to avoid that, that kind of impact loading, that kind of vibration we use helical profile, so this is a smoothing engagement, smooth disengagement. Contact ratio is high, what is the contact ratio is that when we say two, contact ratio more than two, effectively two pair of teeth are in contact; sometime we require a high torque ratio shall we use, we use a warm gear, the torque ratio can be you mean up to 40 to 1. So, depends on the kind of profile which we use for kind of applications which we use we can classify this gears are pro gears, helical gear, bevel gear, warm gear or hair bend gear when gearing of the helical gears, but whatever the gear, their value of phenomena to some extent is factor of a tooth and greater extent is a surface for teeth. Mostly happens, because of the variable rolling to sliding ratio, even though I said this need to be rolling motion, but leg of the lubricant, change of the profile, change of the clearance, some sort of misalignment introduced more and more sliding, and it has been observed. Sliding to the rolling ratio many times happened to be 9 percent, this should show good performance, good efficiency, may be say 98 percent efficiency then sliding should be lesser than 2 percent, but the change in condition, change in clearance, environment change in different performance.

ADVANTAGES

Here are the advantages of gear drive:-

It provides large range of speed and torque for same input power.It is compact and need less space.

It offers more accurate timing than a chain system does, less friction loss and less noisy.It provides precise velocity ratio. It is used to get various speeds at different load conditions.There are different geometry of gears which offers different advantages for varied applications.

In general it is useful for power transmission between two shafts.

CONCLUSION

Considering tribological failure modes is a requirement for the design of any gear system. Most gear teeth are loaded with a very large number of cycles, and each cycle consists of a combination of sliding and rolling. The relative motion of the gear teeth give way to several failure modes that are each caused by different phenomena. Contact pressure causes pitting under the surface, contact between asperities only causes micro-pitting, high friction-induced temperatures create scuffing and the removal of gear tooth asperities causes general wear.

All of these failure modes can be controlled with the correct material selection, material treatment, and lubrication. Material treatments and material selection ensure that if gear teeth are not precision machined, that they will be able to either distribute the load over more area or be able to withstand more load. The use of lubricants also helps to better distribute the load between surfaces by creating a film between surface asperities. Lubricants have also been shown to reduce the temperature of gear systems which reduces the risk of scuffing and creates more separation between surfaces.

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