

A Study on the Transmission-tribology Design Based on Existing Problem of the Gear Drive and Tribology

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We propose a new concept of transmission-tribology design based on the investigation of development and existing problems of the gear drive and tribology. The content of transmission-tribology and transmission-tribology design is probed. Some effective methods of transmission-tribology design is probed. Some effective methods of transmission-tribology design are put forward. Partial achievements in this research are introduced tersely. Mechanical transmission, which is represented by the gear drive, and tribology are two main branches of mechanical engineering. They have their own definite research field. In recent years, we have been doing our utmost to suggest combining mechanical transmission-tribology and transmission-tribology design. Partial achievements in this research area are obtained

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1. Introduction

It is widely known that an executive committee chaired by H. Peter Jost was set up by the Education and Science Ministry of UK in the 1960s. The term tribology was creatively put forward by the committee of tribology and the research scope of this subject was first determined by the committee: lubrication, friction, wear and contact mechanics were combined. This initial action raised the status of the whole tribology subjects, and made people believe that tribology is really a science with profound significance in the field of engineering technology.

But tribology is not at period of full bloom of its development and application in all over the world. The situation could be described as follows:

Although people have realized the importance of tribology, they are not guiding the engineering actively with the help of tribology.

Tribology still only belongs to tribologists. Because of the lack of tribology guidance in mechanical engineering, large amounts of resources are being wasted by the improper wear and accidents of mechanical plants at every moment. Because tribology is not being applied actively, the new epoch of tribology design has not come yet.

The development of tribology lacks a breakthrough. Because of the reasons above, we first put forward transmission-tribology design and consider that the huge economical effect can be obtained only by combining tribology with mechanical transmission and realizing guiding role of tribology in mechanical transmission.¹⁻⁶

Another important reason for putting forward research into transmission-tribology is that the development of mechanical transmission urgently requires the guidance of tribology.^{7,8}

As mechanical equipment becomes larger and larger, it is urgently required to raise integrity and reliability of key parts of large equipment.

It is an important basis and key measure to design correctly, solve the problems of lubrication and improve anti-wear ability for reducing resource consumption and prolonging the span-life in high power plants.

In addition, an important aspect of tribology design is to optimize design on work interface in the eyes of modern tribology. It is widely known that the contact surfaces of mechanical transmission(especially the gear drive) are not simply curved surfaces such as the bearings or cylinders, but complicated conjugate meshing curved surfaces with three dimensions for which contact elastic deformation must be considered. It is difficult for these people who are only engaged in tribology to make work surface design for the gear drive. On the other hand, the lubrication state between the surfaces of the gears(or the worm and wheel) belongs to the most complicated and the most difficult changeable curvature contact and unsteady thermoelastic hydrodynamic problem with three dimensions in the lubrication theory; the classical theory does not fit. Thus, the analysis and optimal design of lubrication property to the work interface of the drive counter are the most difficult, complicated and important work. The two subjects, tribology and mechanical transmission, are forced to combine so as to solve this complex and important problem. It is another important reason for we put forward transmission-tribology and transmission- tribology design.

The study of transmission-tribology design takes the drive mechanism(especially the drive components of modern large mechanical equipment) as its object, and takes the operation of drive counter under the optimum and the most reliable state as its aims. Therefore, transmission-tribology lays emphasis on considering every sort of question concerning tribology during the period of designing for transmission mechanism, rather than asking for help only after some problems have appeared in the transmission mechanism. This is the characteristic of transmission-tribology.

In the early 70s, Sakai and Zhang are the firsts in the world to put

forward the plane double enveloping hourglass worm gear with better lubrication property respectively⁹⁻¹¹. Then scholars who are engaged in this field around the world started their researches into double enveloping hourglass worm gear with different generating surface. The emergence and thorough researches into the plane double enveloping hourglass worm gear have prompted the formation of transmission-tribology. It not only makes the researches in transmission-tribology necessary but also possible.

2. The Research Content of transmission-tribology

The following is the research content of transmission-tribology:

1. Studying the interaction, changes and tearing on the friction surfaces in the course of mechanical kinematics transfer, power transmission and in the mechanical transmission system by combining the two important branches of mechanical engineering, mechanical transmission and tribology.

2. Setting up modern lubrication theory and taking the large mechanical transmission plants as its objects.

3. Setting up lubrication control theory related to the appearance of surfaces of friction pair, the relative movement and the lubrication oil.

4. Making transmission-tribology design aiming at creating new type of gear drive with high anti-wear and lubrication property.

The following should be specially emphasized.

- 1) The search for new approaches to solve the complicated theoretical lubrication problem of the tooth surfaces of the gears and worm wheels with low speed and high load at the curvature-changing contact and unsteady thermoelastic hydrodynamic state. The modern lubrication theory will be built up with large mechanical transmission plants as its objects based on the coupled researches of meshing theory and lubrication theory.

- 2) Set up lubrication control theory between work surfaces guided by space meshing theory. According to it, design and control the thickness of oil film, the pressure distribution and flowing direction of lubrication oil between the tooth surfaces by intentionally changing the appearance and topography of drive contact surface and the relative movement relationship, and adjusting lubrication oil quality.

- 3) Make a working surface design for the drive mechanism under the guidance of tribology and meshing theory. It emphasizes making the reversal-design that takes the better lubrication property as object function to optimize the meshing geometry parameters of the drive counter. Make component design of lubrication medium and that of contact pair interface, aiming at reducing friction, and enhancing load ability and anti-wear ability.

- 4) Study the heat effect and the countermeasure to the heat dissipation of the drive contact surface directed by the space meshing theory.

3. About the Coupled Research of Meshing Theory and Lubrication Theory

The coupled research of meshing theory and lubrication theory is an important content of transmission-tribology. In the past, the meshing property and lubrication property were researched by scholars who were engaged in mechanical transmission and scholars who were engaged in tribology respectively in the analysis of the gear drive. Scholars who were engaged in tribology often simplified contact of tooth surfaces as that could be analyzed under the traditional lubrication theory, then they did not consider its meshing characteristic in the lubrication analysis of the gear drive. This cannot reach accurate results. The same is that how scholars engaged in mechanical transmission obtain a gear drive with high lubrication ability if they do not design it from the standpoint of enhancing lubrication property. The coupled research of meshing theory and lubrication theory will investigate combining of meshing theory with lubrication theory, and new problems and methods caused

by this combination.

The theory and method of lubrication analysis are established according to the lubrication characteristics of the gear drive based on adequate researches into the characteristic of meshing and contact property in analysis of lubrication mechanism of the gear drive. Some preliminary achievements have been obtained by the coupled research of meshing theory and lubrication theory.

3.1 A method of calculating gap between tooth surfaces by use of theory of the moving coordinate system

According to the lubrication theory, the shape of gap between conjugating tooth surfaces near contact line in normal plane, which is a shape of oil wedge, has a key influence on the forming of lubrication film between them when they move relatively. It is important to calculate this gap correctly for lubrication analysis. So we propose a method of calculating the gap between tooth surfaces, which is based on theory of the moving coordinate system.

As shown in Fig. 1, curve C is the contact line between conjugate tooth surfaces

4.1 The interface design of mechanical transmission under the direction of tribology

The factors of friction, wear and lubrication are not always considered in tooth profile design of spare parts in mechanical transmission. The research achievements in tribology are not used for designing the tooth form, namely the design foundation and criterion generally based on the requirement of kinematics transmission, stiffness and strength.

Fig. 7 shows a flow chart of worm gear design. The tooth number of worm

reaction and permeation of other metal and nonmetal elements by tribo-catalysis. It provides a special method of tribochemistry treatment according to the special requirements of surface property of spare parts, and makes composition design of tooth surfaces by tribochemistry treatment at the worksheet possible.

With this method, fine surface treatment is not necessary during its manufacture, so as to obtain better running-in ability, and adding some element into the oil to improve its running-in ability during running-in time. After running-in, add some proper elements into the oil, then some of the oil composition permeates into surfaces of parts by tribo-catalysis reaction to strengthen interfaces and obtain the property similar to that obtained by heat-chemistry treatment. The effective composition design of surfaces' material is implemented by this procedure.

5. Conclusions

There are two essential aims to advocate the theory of transmission-tribology and transmission-tribology design. One is to make scientific researchers and technicians consider the problems related to tribology, and make coupled research on the meshing theory and the lubrication theory in research and design for the transmission pans (especially for the gear drive). Another is to urge people engaged in tribology design to keep their eyes on the characteristics of a gear drive.

The theory of transmission-tribology design and the method of transmission-tribology design were discussed in this paper. It can be regarded as the preliminary attempt of applying transmission-tribology.

Developing of tribology is the responsibility not only of tribologists, but also of also scientific researchers and technicians. It can be predicted that the mechanical industry will develop greatly as important achievements are obtained in tribology

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