

Polytetrafluoroethylene lubrication in highly loaded rolling contacts

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Extreme environmental conditions, such as high temperature or vacuum, require the use of solids as alternative lubricants. Unlike liquid lubricants, solid films do not replenish themselves once they break down. Therefore, they must be constantly resupplied to maintain an equilibrium of wear and relubrication. While PTFE is widely used in sliding contacts due to its low coefficient of friction, a lack of knowledge of the lubrication mechanism has so far prevented its use in rolling bearings. This work illuminates the processes in a PTFE lubricated rolling contact by in situ measurements of film thickness and friction.

Keywords: solid lubrication, polytetrafluoroethylene (PTFE), film formation, highly loaded rolling contacts

1. Introduction

Highly loaded tribological contacts ($p > 1000$ MPa) occur in many machine elements, such as rolling bearings or gear wheels. To ensure low friction and wear rates, lubricants are used to separate the interacting surfaces in tribological contacts. Solid lubricants are used as alternative lubrication media as soon as the use of oil or grease is no longer possible (e.g. in vacuum) or undesirable (e.g. food industry). There are different concepts of supplying solid lubricant into the contact zone through coatings or sintered materials. These solutions are not suitable for highly loaded rolling contacts due to the high contact pressures. Alternative approaches to provide the solid lubricant in the vicinity of the rolling contact and to transfer it into the contact zone by transfer processes are still little researched. The mechanisms of provision and lubrication in rolling contacts have so far not been sufficiently investigated. This work describes the lubricant film formation in a highly loaded rolling contact which is supplied by PTFE relubrication.

2. Methods

A ball-on-disc tribometer is extended by a PTFE pin pressed on the rotating disc. Due to the sliding contact between pin and disc, a PTFE transfer film is formed on the disc, which lubricates the rolling contact between disc and ball.

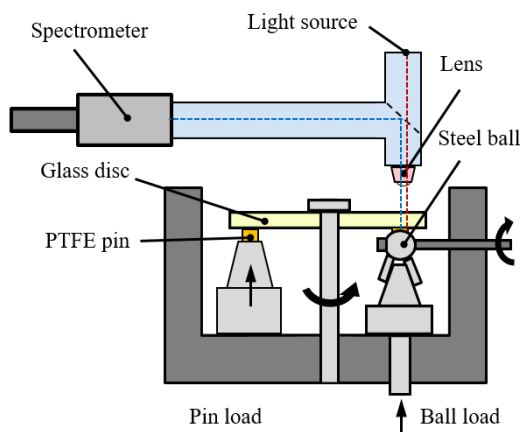


Fig. 1: Schematic sketch of the extended tribometer for film thickness and friction measurements

After the formation of an initial lubricating film, the PTFE pin is either removed or left in place to investigate the lubrication effect with or without relubrication, respectively. The rolling contact pressure is varied in a range of 400 to 1000 MPa and the rolling velocity in a range of 50 to 1200 mm/s. By applying different velocities to disc and ball, the slide/roll-ratio can be varied from pure rolling to pure sliding.

The lubricating film formation is analyzed by in situ microscopy and film thickness measurements using optical interferometry. Simultaneously the lubrication effect is evaluated by means of friction measurements in the PTFE lubricated rolling contact. This allows to determine the effect of relubrication on the film formation and its influence on the coefficient of friction considering the operational conditions.

3. Results

The results show the necessity of relubrication for an effective PTFE lubrication in rolling contacts.

The initially applied PTFE transfer film consists of a thin layer, which is well adhered to the disc surface, and thick wear particles, which are only slightly bonded to the disc. Without relubrication the initial film is removed within short time by shear and compressive stresses in the rolling contact inducing high friction, which is in good accordance to the results of other authors.

In contrast, a stable friction regime is established by continuously supplying small amounts of PTFE into the rolling contact. In this way, the coefficient of friction can be reduced up to 65 % compared to the unlubricated conditions. Shear stresses in the rolling contact are further required for the formation of an effective lubrication. The stresses seem to enhance the adhesion of the lubricating film on disc and ball leading to the separation of the two surfaces. High pressure and shearing in the rolling contact seem to form a new type of film from the wear particles, which are constantly transferred through the sliding contact. The newly formed lubricating film differs in structure and thickness from the initially applied transfer film.

These results establish an advanced understanding of the physical mechanisms of PTFE lubrication in rolling contacts and demonstrate that permanent lubrication of a highly loaded rolling contacts using PTFE is possible.