

TIMKEN TAPERED ROLLER BEARINGS

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Abstract: The paper concerns the use of polymer additives for improving different characteristics of lubricants required in running of mechanical systems – especially tapered roller bearings. The macromolecular matter dispersed into the oil contribute to increase of lubricant film thickness and reduce the risk of damage by scuffing of the contacting surfaces. The purpose of this paper is to investigate the performances obtained in lubrication of concentrated contacts by using polyethylene as additives for the lubricant oil used for an four-high mill.

Key words: EHD lubrication, additives, polyethylene, rolling mill.

1. INTRODUCTION

The chemical and mechanical action of lubricants additive with polymers is complex and not yet clearly understood. The polymer properties and the processing concentration affect the lubricant performances. The macromolecular content depends on the chemical nature of the lubricants and additives and on the type of application.

Polymers as additives for the lubricant oils prolong the life of equipment by performing some important functions: viscosity improves, dispersants, antiwear and extreme pressure agents, friction modifiers, pour-point depressants, oxidation and corrosion inhibitors, emulsifiers and demulsifiers, foam inhibitors, etc. The additive lubricants in use are more resistant to oxidation, thermal degradation, microbial attack, and contamination. As polymer-in-lubricant dispersions, the polymer-thickened lubricants can be an efficient solution at lubricant transport, storage and processing.

Polyolefins, and particularly polyethylene, have some particular properties [1,2] that make them useful for some applications. Their characteristics depend on a great number of parameters, such as molecular structure, molecular weight, molecular weight distribution and morphology.

Experimental tests performed recently on tapered roller bearings [3,4] showed that there is an optimum concentration of polymer dispersed into the oil, which assures a maximum film thickness. This concentration was found in the dilute regime of concentration, where the rheological units are the individual particles formed by macromolecular matter dispersed into the oil.

2. EXPERIMENTAL RESULTS

The chosen oil has a paraffin structure and also contains a low amount of iso-paraffins, cycloparaffins and aromatics. Low-density polyethylene (PE) was used as additive for the lubricant mineral oil. The polymer properties are shown in (Table 1).

There are experimented these lubricants for the working tapered roller bearings used in an four-high mill equipment for milling ultrafine straps.

The intrinsic viscosity (η , dl/g) of dilute solution of polyethylene in the lubricant oil was determined by using an Ubbelohde suspended level viscometer. Calculation of intrinsic viscosity was made by simultaneous extrapolation of η_{sp}/c vs. c and $\ln(\eta_r)/c$ vs. c plots to infinite dilution so that both plots gave the same intercept (c is concentration in g/dl and η_{sp} is the specific viscosity, $\eta_{sp} = (\eta_{suspension} - \eta_{oil})/\eta_{oil}$).

The low-voltage electrical resistance method was used to estimate the degree of contacts taking place between the rolls and the raceways. The bearing insulating resistance was measured in stabilised thermal regime for different bulk lubricant temperatures. Corresponding to each bulk lubricant temperature, when the bearing electrical resistance was monitored, the average film thickness at the raceway contacts was computed. The calibration curve representing an electrical resistance - minimum film thickness relationship was obtained by applying the last mean square method on the semiempirical dependence $R_b^{experimental} = f(h_{av}^{theoretical})$.

Table 1

Physical properties of base oil and polyethylene		
MINERAL OIL		
Parameter		Value
Density (g/cm ³)	at 20°C	0.898
Kinematics viscosity (m ² /s)	at 40°C	173.45
	at 100°C	15.38
Pour point (°C)		-20
POLYETHYLENE		
Parameter		Value
Average molecular weight (g/mol)		120.000
Methyl groups per 1000 C atoms		46
Density (g/cm ³)		0.925
Glass transition temperature (°C)		-80 to -90
Melting point (°C)		110
Melt flow index (g/10min)		2.5
Cristallinity (%)		48

Table 2

Tapered roller bearing tested	
Parameter	Value
Geometry	
Outside diameter (mm)	157.48
Bore diameter (mm)	91.6
Width (mm)	85.6
Roll length (mm)	22
Number of rolls	36
Material	
Young's modulus of elasticity (N/mm ²)	2.1·10 ⁵
Poisson's ratio	0.3

For the film thickness measurements, the electrical circuit is connected between the driving shaft and the bearing housing of tapered roller bearing. In this system there are three zones where the lubricant film is formed: between cone and roller, between rib and roller, and also between cup and roller. Using the calibration curves for each lubricant system, the minimum film thickness versus bearing speed at different temperatures and polymer concentrations was plotted.

3. DISCUSSION

The intrinsic viscosity $[\eta]$ is related to the hydrodynamic radius R_H by the following relation:

$$R_H^3 = 0.0955 \cdot [\eta] \frac{M_w}{N_A}; \quad (1)$$

where N_A is the Avogadro number and M_w/N_A is the weight of one polymer chain.

The theoretical radius of gyration is given by:

$$R_G = a \cdot \sqrt{\frac{N}{6}}; \quad (2)$$

where a is the length of the monomer and N is the number of monomers.

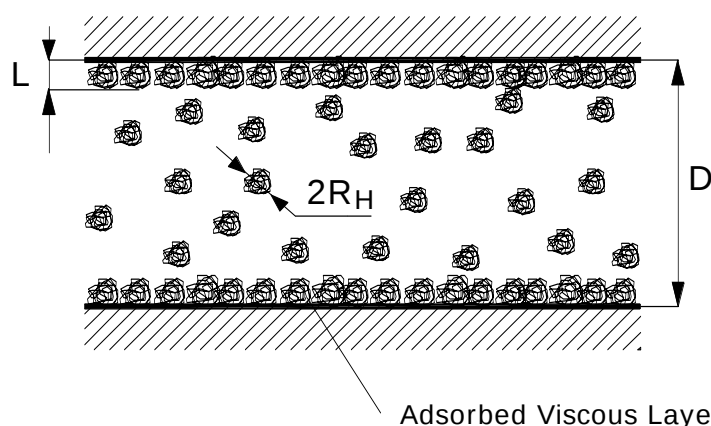


Figure 1. Lubricant flow of additive lubricant and oil through two surfaces.

For the studied system, the radius of gyration was calculated as being 7.478 nm. The ratio hydrodynamic radius to gyration radius R_H/R_g is considered as a criterion for the solvent quality. According to the literature, it has a value close to one for a θ -solvent and more (1.7 - 2.5) for a good solvent - here it is found to be 1.75 - 1.9. It is concluded that the base oil is a good solvent for polyethylene.

The dissolved polymer adopt a progressively more open molecular conformation in solution as temperature is raised, so that it makes a larger contribution to the overall viscosity of the system at high than at low temperatures. This behaviour determines an improving of the film forming properties when such dilute solutions of polyethylene are used as lubricants.

The thickness of polymer layer adsorbed on the solid surfaces corresponds to a diameter of the polymer ($2 \cdot R_H$) shown in Fig. 1. The boundary of the flow appears at the top of layer thickness L , showing that the small molecules of solvent are removed from the polymer layer or solvent.

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The layer structure is controlled by the polymer adsorption and the solvent quality

The basic relation for the electrical resistance of a lubricated contact is: $R = \frac{\rho \cdot h}{A}$, where ρ is the electric resistivity of the lubricant, h is the average lubricant film thickness at the contact interface and A is the effective area (Hertzian contact area). As a consequence, the ratio between electrical resistance of the rib - roll end and roller - raceway contact, respectively, is approximately 18:1. If the film thickness at the rib - roll end is twice that of the film thickness in the raceway contact, the ratio R_0/R_{rib} is approximately 0.02 and we consider that this value can be neglected reporting to the unity.

In Fig. 2 is presented the dependence of the minimum film thickness on the temperature for the base oil and for samples having different concentration of polyethylene. The maximum value of the minimum film thickness is reached for 0.58 % of polymer in the base oil, value close to the concentration at which the polymer coils begin to overlap (0.5 - 0.6 % for the studied system).

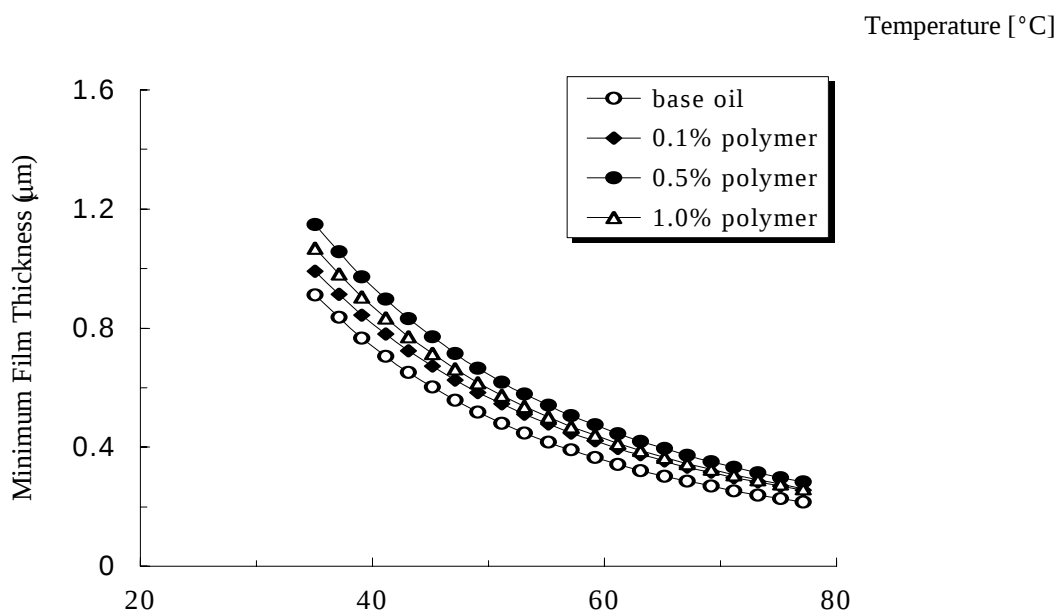


Figure 2. Film thickness as a function of temperature for different concentration of polyethylene.

4. CONCLUSIONS

The additive lubricant oil becomes able to form reasonably thick hydrodynamic and elastohydrodynamic films. The macromolecular coils dispersed into the oil contribute to the increase of the lubricant film thickness and reduce the risk of damage by scuffing of the contacting surfaces.

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