Effects of gear modification and surface finish on planetary gear systems efficiency

PUBLISHER

TriboUK

VERSION

VoR (Version of Record)

Effects of Gear Modification and Surface Finish on Planetary Gear Systems Efficiency

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1. Introduction

Planetary gear systems offer desired speed and torque variation with a compact and lighter construction than traditional gear trains. Transmission losses are one of the main concerns. Modification of gear teeth geometry is one of the remedial actions to reduce friction.

Ideal spur gears with line contact are very sensitive to misalignment and manufacturing errors which cause the edge loading contact of gear drive and increase gear noise. The simplest way to avoid the edge loading contact is to localize the mesh contact by crowning gear tooth surfaces. Several investigators such as; Seol and Kim [1] and Simon [2] have investigated improvements in the meshing contact stress distribution for misaligned spur gears through crowning. Additionally, planetary gear systems for off-highway applications are subject to high contact pressures up to 1.2 GPa, which can result in asperity interactions within the mating teeth pair contacts. Therefore, better surface finish helps to reduce boundary friction.

This study aims to ascertain the overall system effects of different extent of crowning of planetary spur gears with varying surface roughness.

2. Methodology

The devised methodology enables prediction of frictional losses. The method integrates TCA (Tooth Contact Analysis) to determine the instantaneous contact geometry, kinematics of contact and load distribution, which are used in an analytical EHL model for prediction of meshing power losses.

The lubricant film thickness under the instantaneous operating conditions is obtained using Chittenden et al. [3] extrapolated lubricant film thickness formula. Predicted film thickness is then used in Evans and Johnson [4] approach to analyse viscous friction in EHL contacts. With the high loads experienced by gears in off-highway planetary spur gear systems, the lubricant operates in the Eyring traction regime. Consequently, the coefficient of friction is calculated using [4]:

$$\mu = 0.87\alpha\tau_0 + 1.74\frac{\tau_0}{\bar{p}} ln\left[\frac{1.2}{\tau_0 h_{co}}\left(\frac{2K\eta_0}{1+9.6\xi}\right)^{\frac{1}{2}}\right]$$

where,

$$\xi = \frac{4}{\pi}\frac{K}{h_{co}/R}\left(\frac{\bar{p}}{E'RK'\rho'c'U_r}\right)^{1/2}$$

The generated friction due to viscous shear of the lubricant film is expressed as:

$$f_v = \mu W$$

Thin lubricant films in the meshing contacts of loaded gear teeth pairs in off-highway applications are comparable to the height of surface asperities. Consequently, asperity interactions, and therefore boundary friction is to be expected. Greenwood and Tripp [5] method is used to obtain boundary friction within the contact.

Finally, the instantaneous power loss is determined by taking into account the calculated viscous and boundary friction contributions as:

$$P_{loss} = (f_v + f_b)U_s$$

where, U_s is the instantaneous contact sliding velocity determined through TCA.

3. Results

The effect of gear crowning with different surface roughness on power loss is investigated. Figure 1 shows the predicted instantaneous total power loss during a typical meshing cycle for the sun-planet contact.

Considering two identical planetary gear hubs with three planet gears, Table 1 depicts the average total power loss for different values of surface roughness.

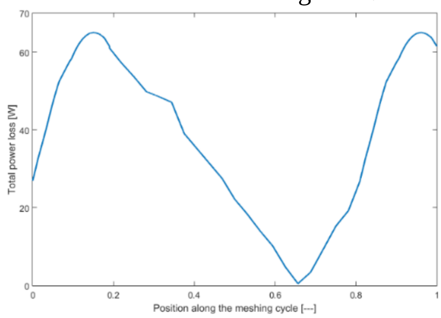

Figure 1: Total power loss, Sun-Planet Contact

Table 1: Total power loss of two planetary gear hub

Surface Roughness (μm)	0.4	1.2	2	2.8	3.6
Average Total Power Loss [W]	267.8	272.3	273.2	273.6	273.9
% increase in total power loss compare to 0.4 μm roughness	-	1.66	2.02	2.17	2.26

4. Acknowledgement

The authors would like to express their gratitude to JCB transmission and Innovate UK for their support of this research.

5. References

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