The effect of surface roughness and lambda ratio on micropitting damage

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Micropitting is a type of rolling contact fatigue surface damage that occurs in lubricated rolling-sliding contacts as a result of cyclic stresses on the roughness asperity level. Lambda ratio has historically been used as the main factor to assess the risk of micropitting but there are currently no universally agreed design criteria for its prevention. This study uses controlled triple-disc fatigue tests to separate the influence of lambda ratio and surface roughness in order to provide new insights in to the mechanisms of micropitting and provide better guidelines for its prevention.

Keywords: micropitting, gears, rolling contact fatigue, roughness, lambda ratio

1. Introduction

Micropitting is a type of surface damage that occurs in contacts operating in thin oil film conditions where cyclic asperity stresses lead to surface fatigue damage and eventual formation of small pits. Micropitting is distinct from the more common pitting damage, which occurs due to cyclic Hertzian stress on a macro-contact level. The occurrence of micropitting has been increasing, particularly in gears, due to current trends aimed at using less viscous lubricants and increasing machine power densities, both of which lead to thinner lubricating films and hence more surface asperity interactions. With the lack of established design criteria, contact lambda ratio has traditionally been used on its own as the main means to assess the risk of micropitting. However, multiple other factors play an important role in micropitting, including slide-roll-ratio [1], lubricant formulation [2], contact pressure and, particularly, surface roughness of the components. This study assesses separately the influence of lambda ratio and surface roughness on the onset and progression of micropitting with the aim of providing improved criteria for its prevention.

2. Methods

A triple-disc contact fatigue rig (PCS MPR) is employed to generate micropitting under controlled conditions deigned to isolate the influence of lambda from that of surface roughness. The rig consists of a central roller specimen in contact with three counterface rings so that roller sees three contact cycles per revolution allowing for fast fatigue tests. Test specimens were made of case carburised 16MnCr5 gear steel. The roller is made slightly softer than the counterface rings to ensure damage is preferentially formed on the roller while the surface roughness of the counterface rings is preserved. In addition, custom made lubricant consisting of PAO base oil with ZDDP blended in at a phosphorus concentration of 1000 ppm is used. This approach minimises surface wear which has been shown to compete with micropitting [2] and minimises the variations in asperity level stresses as test progresses. Tests are conducted with different surface roughness while keeping lambda constant and with different lambda while keeping surface roughness constant. This is achieved by using different viscosities of the exact same PAO base oil. Importantly, the progression of micropitting damage with time is established by pausing tests at regular intervals to inspect the extent of damage on the roller surface using an optical microscope and surface profilometer. This also allows the micropitting initiation time to be established.

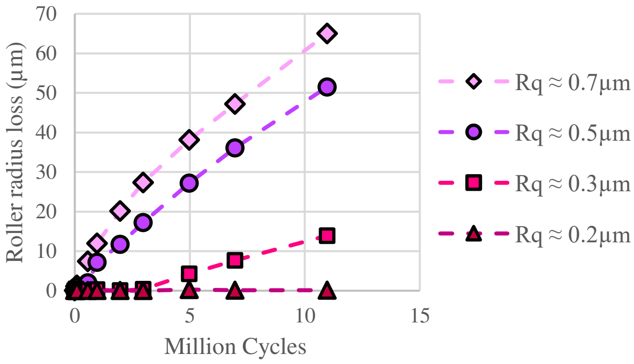

Figure 1. Evolution of micropitting damage for different values of R_q at $\Lambda = 0.3$.

3. Results and Discussion

Figure 1 illustrates the effect of surface roughness on micropitting at a constant lambda value. Clearly, higher roughness causes more micropitting even if the lambda ratio is kept constant. Roughness affects both the micropitting initiation period and the rate of its progression. It also appears that below certain roughness level micropitting damage is unlikely to occur at all.

The results clearly show that using the lambda ratio on its own as the micropitting risk criterion is inadequate. Any criterion for prevention of micropitting must also independently include surface roughness as a major factor. In addition, the results show that the surface roughness parameter that best corelates with micropitting is the reduced peak height (R_{pk}) which is a hybrid parameter derived from the material ratio curve.

References

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