An experimental investigation of surface behaviour of ground steel gear surfaces in mixed lubrication conditions

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1. ABSTRACT

This paper presents a detailed experimental investigation into the effects of contact pressure, slide/roll ratio, and entrainment velocity on the micropitting of ground steel surfaces operating under mixed lubrication conditions, representative of heavily-loaded power-transmission gearing.

The individual and interaction effects of these three variables were investigated using a two-level factorial test program, with the test conditions being systematically varied over the course of nine separate endurance tests conducted on a power-recirculating twin-disk test rig, with a fully-formulated naval gear lubricant.

The disks were case hardened to around 750 Hv, and finished using a grinding technique which produces a nominally axial roughness lay, meaning that the orientation of roughness to the rolling/sliding direction mimics that found in ground gear teeth. A series of in-situ profile measurements were taken prior to operation, after a brief period of operation, and then at regular intervals during the experiments. Detailed replicas were also taken of the surfaces at intervals throughout the experiments, from which three-dimensional roughness measurements could be evaluated.

A range of parameters were calculated to quantify the progression of micropitting over the full two-million fast disk cycle endurance test. Micropits were detected using an automated detection algorithm developed by the authors, allowing the progression of micropitting to be evaluated over a representative area of the surface rather than relying on two-dimensional line measurements. Figure 1 shows the pits detected by the algorithm on a one millimetre square portion of the surface.

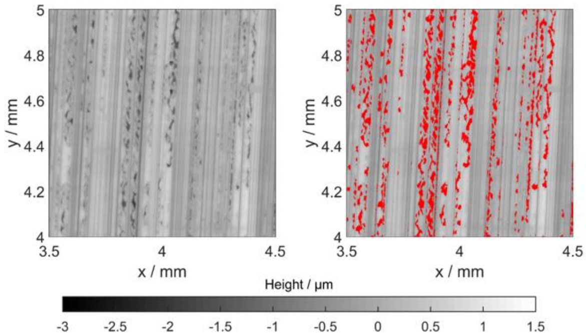

Figure 1: Areal measurement of disk surface showing micropits (highlighted in red in right hand image)

The amount of micropitting on each surface at the end of the test was evaluated, together with parameters quantifying the rate at which micropitting became established in the early phases of the test. It was found that pressure showed the strongest influence of the three variables on micropitted area, micropit depth, volume removed, and rate of micropitting later in the test for both the fast and slow surfaces. Pressure acted to increase micropitting in all cases. Slide/Roll ratio had a particularly strong influence on micropitting initiation in the early phase of the tests, with greater sliding leading to increased micropitting. Increased entrainment velocity opposed micropitting for both surfaces. However, extensive two- and three-factor interaction effects were observed for both the fast and slow surfaces, showing micropitting to be influenced by a complex network of interconnected effects. Potential mechanisms for the observed effects are discussed in detail in the paper.