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Surface characterization of spline coupling teeth subjected to fretting wear

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Abstract

Splined couplings are mechanical components subjected to fretting phenomena above all when they are working in misalignment conditions and so the teeth surface morphology may change according to the corresponding working parameters (misalignment amplitude, presence of lubrication, etc). Aim of this work is to use the surface roughness to identify the fretting wear damage on spline coupling teeth. Experimental tests have been performed by means of a dedicated test rig, using steel made specimens. Teeth roughness has been measured before and after tests. In order to emphasize the different surfaces status, the measured roughness values have been processed considering both traditional and sophisticated parameters as kurtosis and skewness. The effect of transmitted torque and angular misalignment have been investigated. Preliminary results show that roughness values may change according to the working conditions.

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1. Introduction

Fretting is a phenomenon affecting components subjected to contact stress and relative displacements. Fretting occurs commonly in clamped connections and demountable couplings and involves surfaces in contact subjected to cyclic small amplitude relative displacements [1]. The role of debris is critical in fretting wear; generally, once debris accumulates on the contacting surfaces, it forms compacted oxide beds and the wear rate is reduced

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significantly [2, 3] but, if debris remains inside the contact region, it forms with the lubricant a kind of abrasive paste which speeds up the wear phenomenon. The debris oxidizing forms very small abrasive particles (order of microns), which are deposited and cause the worsening of wear process. The resulting damage may consist in a simple surfaces discoloration, in the formation of surface craters (the most common case) or in the removal of a considerable amount of material. The oscillating movement causes the surface layers erosion, exposing new areas to the phenomena of welding and breaking parts.

Fretting strength varies strongly because of the materials in contact and the lubricant characteristics: lubricants characterized by low viscosity tend to reduce the intensity of fretting maintaining the oxygen away from the area of interface and generally they carry away the debris created by wear; on the contrary lubricants that have an high viscosity tend to increase the fretting wear damage.

Fretting is currently an interesting field of research, also considering that there is not a consistent standard giving a best practice about both fretting design and testing [2].

Researchers aim to identify the surface aspect being different according to the fretting wear mode [3].

A common goal is to characterize a damaged surface by means of a suitable parameter, as an example the roughness. Surface roughness evaluation is very important for many fundamental problems such as friction, contact deformation, heat and electric current conduction, tightness of contact joints and positional accuracy [4].

Regarding the analysis of fretting phenomena, some authors utilized the variation of roughness parameters. As an example, Kucharski et al. investigated the evolution of the contact zone, by means of both wear scar depth and surface roughness in the contact zone [3]. Kubiak et al. presented an experimental study about the influence of the finishing surface and the machining process on the fretting damage arising in both partial and full sliding regimes [5].

Aim of this work is to use some surface roughness parameters to identify the fretting wear damage in a real engineering application like spline coupling teeth [6]. Splined couplings are mechanical components used to connect two rotating shafts; these components find applications in many industrial sector and in particularly in the aerospace field. One of the main cause splined couplings failure is the fretting wear caused by the relative motion between engaging teeth; as a matter of fact, these components are subjected to fretting phenomena above all when they work in misaligned conditions [7] and so the teeth surface morphology may change according to the corresponding working parameters (misalignment amplitude, presence of lubrication, etc). Experimental tests have been performed by means of a dedicated test rig [10,11]; specimens are steel made splined couplings (see Figure 1a).

The main feature of this test rig is to apply and to monitor a specific angular misalignment between shaft and hub and it is able to reproduce the real operating conditions to which the component is subjected.

In this work some roughness parameters available in literature [4] have been chosen to identify the teeth surface topography variation due to the wear phenomena. Particular attention has been paid in using not only traditional [4] roughness parameters, but also the more sophisticated ones as kurtosis and skewness [10]; parameters have been measured before and after each tests. The effect of both transmitted torque and angular misalignment on the surface damage aspect have been investigated.

2. Experimental set up and data processing techniques

The test bench used in this work has a mechanical power recirculation scheme [8], since the external power to be applied offsets only the power dissipated in friction [8]. Splined couplings specimens are steel made (42CrMo4) nitrogen-hardened; they have crowned tooth profile and the main characteristics are: 26 teeth, 1.27mm modulus, 30° pressure angle, 200 mm crowing radius and 12 mm face width. The surface of all teeth of each specimen has been analyzed before and after the wear tests with a Alpha SM RT-70 profilometer; the roughness trend of the teeth surface has then been obtained. To guarantee the correspondence of the same profile measurement before and after each tests, a dedicated device has been realized (see Figure 1b); in this way a perfect parallelism of the specimen axis has been obtained respect to the support plane of the profilometer touch probe.