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Experimental and theoretical investigation about reaction moments in misaligned splined couplings

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ABSTRACT

This paper deals with the uneven loads generated when splined couplings work in misaligned conditions. These loads are balanced by the shafts bearings and they have to be taken into account by designers during the calculation of splined transmission systems. In particular an experimental investigation about tilting moment has been carried on by means of a dedicated test rig, in order to better understand this phenomenon. Experimental tests have been conducted in order to investigate the effect of misalignment angle, transmitted torque and tooth stiffness on the tilting moment. Also a numerical model has been developed in order to obtain a preliminary quick estimation of tilting moment values.

1. Introduction

Spline couplings are mechanical components allowing to transmit torque by means of teeth.

Engaging teeth present a non-uniform, but substantially known, load distribution when working in theoretical conditions [1–5]. The load distribution becomes more complex in real components when manufacturing and assembly errors are considered [6]. As an example, parallel offset misalignments cause non uniform load distributions among teeth [7] and pitch errors cause an increase of the stress at the spline root and a decrease in the related life [8].

These components may also work with angular misalignments: this means that the shaft may not be coaxial respect to the hub, but its rotating axis has an angular misalignment α (see Fig. 1). The angular misalignment may be due to machining and assembly tolerances and it is allowed by the clearance between shaft and hub teeth [9]. It is supposed that the misalignment does not force the shaft inside the hub and so the maximum possible misalignment is really that allowed by the teeth clearance.

In aligned conditions the whole tooth flank surface is in contact (see Fig. 1 left), while in misaligned conditions only the tooth width extremities are in contact (theoretically only one point on the teeth width extremity is in contact, as shown in Fig. 1 right) generating a complex load behavior [10] that produces reactions moments as tilting moment and friction moment [11].

In particular, the tilting moment (investigated in this work) tends to realign the spline coupling and it is balanced by the reaction forces generated on the shafts bearings; this means that bearings could be overloaded if the effect of misalignment

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moments is not considered. So designers need to have some practical models allowing a quick and good estimation of these unshaven loads.

The literature is lacking about this topic. Simplified formulas may be found in [11] providing a quick, but not reliable estimation of misalignment loads. In particular, as will be further discussed, these formulas give a substantial overestimation of these loads and a consequent overdimensioning of bearings. The overestimation of the misalignment loads is mainly due to the fact that the simplified model [11] does not consider both tooth stiffness and misalignment angle value.

Moreover, in the literature, no evidence of any experimental tests about reaction moments in misaligned spline couplings can be found.

The first aim of this work is to perform an experimental investigation on misalignment loads in spline couplings and the second one is to provide an easy model to better approximate the tilting moment by considering both tooth stiffness and misalignment angle value.

Experimental tests have been done by means of a dedicated test rig [12] allowing to apply a torque on misaligned splined couplings and to measure the reaction titling moment.

Tests have been performed on two splined couplings with different dimensions.

Results have been compared with the corresponding theoretical values obtained by means of simplified formula found in the literature [11] and by means of the new calculation model developed in the present work.

2. Experimental set up

The test rig used in this work, shown in Fig. 2, has a power re-circulating scheme, that allows to reduce energy consuming [12].

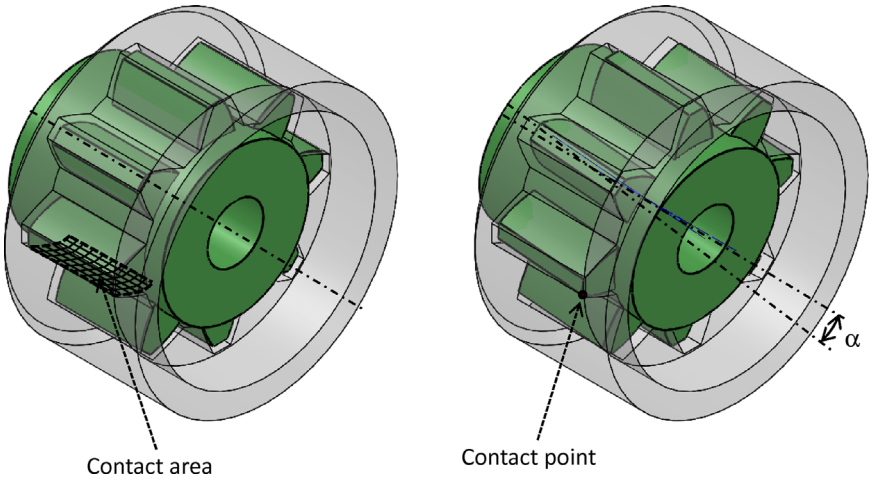

Fig. 1. Aligned (Left) and misaligned (right) spline coupling.

Fig. 2. Spline coupling test rig.