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Evaluation of the time-varying mesh stiffness for gears with tooth spalls with curved-bottom features

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ABSTRACT

Gear tooth spalling is one of the most common defects in gear transmission. The loss of surface materials due to tooth spall reduces the Time-Varying Mesh Stiffness (TVMS) of the gear pair, and thus modifies the vibration response of the gear transmission. The evaluation of the TVMS of the gear tooth pair under gear tooth spalling conditions plays an important role in gear dynamic simulation and the corresponding fault feature analysis. Common approaches assume that the tooth spall has a flat bottom with a constant tooth spall depth. This assumption implies an abrupt change in dent depth and cliff-like material loss. However, in practice, the flake of the surface material usually results in a gradually changing dent depth with a curve-shaped bottom. Thus, the modelling of tooth spalls with a flat bottom may result in mesh stiffness differences. To address this shortcoming, this paper proposes a curved-bottom shaped tooth spall to model the tooth spalling geometric features as observed in practice. The proposed method is constructed based on an ellipsoid geometry which is capable of varying radii in three dimensions to best fit the shape of the tooth spall. The foundation stiffness within the double tooth contact area in the proposed method is corrected and the non-linearity of Hertzian contact stiffness is considered. The effectiveness of the proposed method on modelling single and multiple tooth spalls with different shapes and severity conditions is then validated.

1. Introduction

Due to excessive load, poor lubrication conditions and high rotational speeds, a gear tooth is susceptible to surface damage, such as tooth pitting and spalling. The loss of tooth surface material reduces the strength and durability (life) of the gear tooth. The Time Varying Mesh Stiffness (TVMS) evaluation under tooth fault conditions plays an important role in gear dynamic simulation and system vibration feature analysis. The Potential Energy Method (PE) has been widely accepted as an effective tool in gear TVMS evaluation [1–4]. The PE method was first utilized in [5] where only the gear Hertzian contact stiffness, bending stiffness and axial compressive stiffness were considered. Later, this method was improved by Tian et al. [6] and Wu et al. [7] by considering shear stiffness. Soon after, the deformation of the gear body (foundation stiffness) was also taken into consideration by Zhou et al. [8] and Wan et al. [9]. Recently, Ma et al. [10] reduced the calculation error of the fillet foundation stiffness during double-tooth contact zone.

Research has been carried out to investigate the gear TVMS with tooth spalling. Chaari et al. [11] modeled a localized tooth spall as a rectangular indentation and analyzed the effect of spalling on gear mesh stiffness and the dynamic response of a gear

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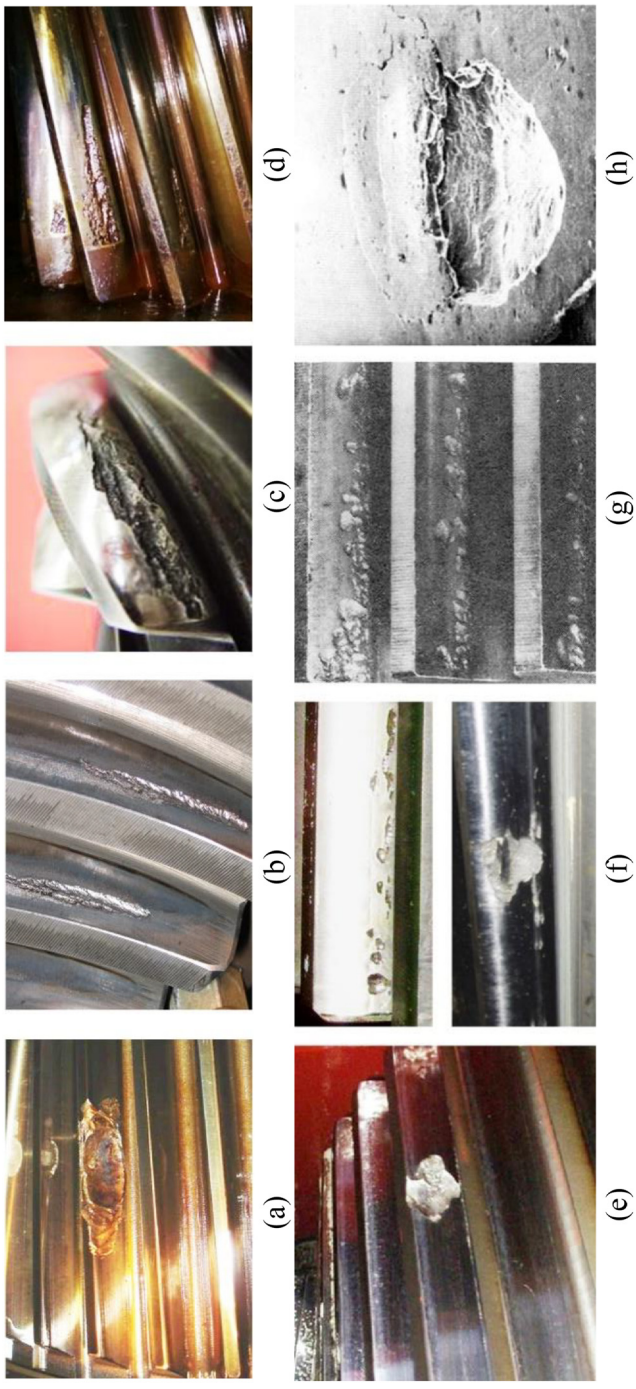

Fig. 1. Gear tooth spalling in practice [18–24].