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A computerized method for loaded tooth contact analysis of high-contact-ratio spur gears with or without flank modification considering tip corner contact and shaft misalignment

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ABSTRACT

High-contact-ratio (HCR) spur gears have the advantages of reducing the acting loads on the teeth, as well as noise and vibration. However, the phenomenon of tip corner contact and the influence of shaft misalignments can cause unexpected damage and vibration. Flank modification is a solution for these influences. An efficient computerized tool for loaded tooth contact analysis (LTCA) is proposed in this paper that can be used to design HCR gears, while taking into consideration the conditions of tip corner contact and shaft misalignment. The LTCA method is developed based on the influence coefficient method and considers both the deformation of the loaded teeth and the twist deformation of the shaft. The variations of the shared loads and contact stress of a HCR spur gear pair with lead crowning and relieved profiles are analyzed considering the influence of the amount of shaft misalignment and relief. The contact patterns as well as the stress distribution on the engaged flanks in various cases are also simulated.

1. Introduction

Increased demand for less vibration and noise in gear transmission has led to a focusing of attention on the development of different design concepts. One strategy is to design gear drives with a high contact ratio (HCR), i.e., greater than 2. Although the loading characteristics of spur gears are poorer than those of helical gears, they are the simplest among the cylindrical gears to design, so they are still applied widely for various power transmission tasks, e.g., in planetary gear drives. It might also be meaningful to transfer the research results obtained for some critical issues related to spur gears to helical gears, especially related to the interference contact of tooth pairs due to tip corner contact or shaft misalignment which will not only cause rapid damage to the flanks due to concentrated stress and unfavorable tooth lubrication [1], but also vibration and noise due to high-frequency harmonics of the transmission error. In order to avoid the occurrences of these problems which are often found in spur gear drives with a high contact ratio, flank modification is applied. Developing a loaded tooth contact analysis (LTCA) method to explore the influence of the flank modification on the contact characteristics in such a gear drive is hence essential, especially for consideration of the tip corner contact and the shaft misalignment.

A high contact ratio, i.e., greater than 2, in a spur gear drive means that the number of contact tooth pairs during meshing will be at least either 2 or 3. The variation of the shared load and the contact stress during the gear mesh is quite different from those of the normal spur gears (where the contact ratio is less than 2). In the past few years, many research studies have been carried out analyzing the contact characteristics of multiple contact tooth pairs. The methods can be divided into three categories: analytical, numerical and finite element methods. For example, Elkholy developed a stiffness approach for the calculation of shared loads in HCR gears based on analytical equations for the deformation of the loaded teeth [2]. Pedrero et al. [3] proposed a load distribution model based on the minimum

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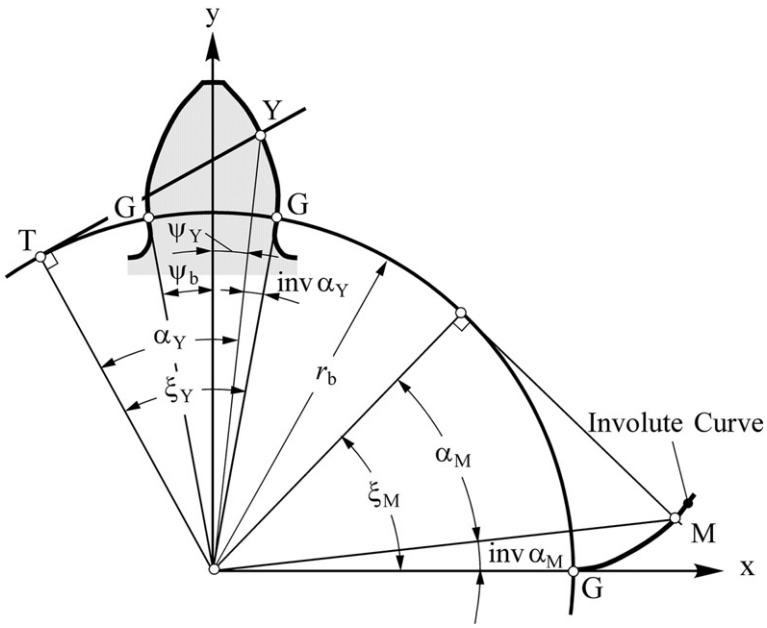

Fig. 1. Definition of unmodified tooth flank.

elastic potential criteria for the calculation of tooth bending strength and surface durability. Based on this model, Sánchez et al. [4] further developed a method for the calculation of the contact stress along the line of action. However, none of the methods mentioned above can deal with the case of flank modification. Apart from the application of finite element method (FEM) for the calculation of the tooth bending and contact stress of HCR spur gears [5,6], Li combined FEM with calculation programs to develop a face-contact model and a 3D geometry model of engaged teeth with which to conduct LTCA for the spur gears with different addendums and contact ratios [7]. Some calculation programs based on various numerical methods for load distribution have also been developed, e.g. LVR at the TU Dresden (Germany) and LDP at the Ohio State University (USA). Wu and Tsai proposed a computerized LTCA approach based on

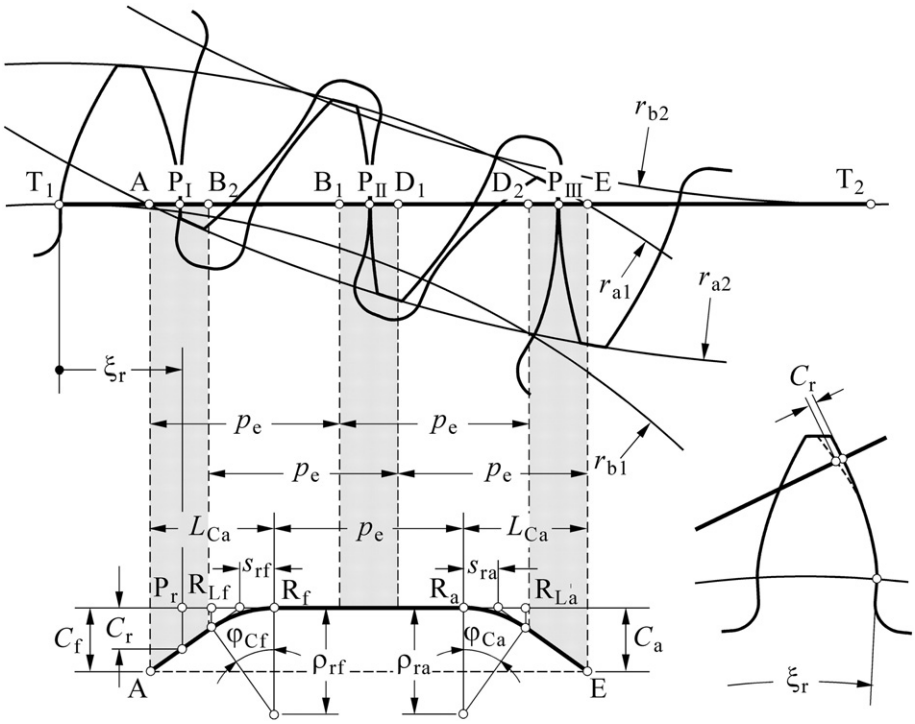

Fig. 2. Definition of linear tip and root relief with smoothing.