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A novel design for enhancing the surface durability of the spur gear systems

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Abstract

In this study, a general mathematical model for defining the gear tooth profile and its geometrical aspects that meet a desirable sliding contact during the meshing cycle is built. This model is based on the path of contact shape predefinition. In the contact path, a straight-line segment through the pitch point and a universal transition curve for the other segments are combined to create a free-form tooth profile with desired radius of curvature in the designed gear. The maximum pressure angle during the meshing cycle and the involute curve length parameter are only introduced to characterize this model. The designed gear in this study is given the title "free-form-gear" since it provided a universal manner of establishing the path of contact that provides desirable sliding conditions during the meshing cycle. The proposed tooth form, interference condition, contact ratio, contact stress, sliding coefficient, and meshing efficiency are derived and investigated in this study. The fillet stress and torsional mesh stiffness of the proposed gear pair are obtained using the finite element method (FEM). The performance of the new gear is compared to that of the standard involute and non-involute gear types. The results indicated that the method proposed in this study can be utilized to construct a gear pair with higher surface durability and strength than typical involute gear of the same size.

Keywords

spur gear, non-involute gear, contact ratio, contact strength, sliding velocity, gear efficiency

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Introduction

Background

The power-to-weight ratio in the gearing systems has been enhanced throughout the years. Improvements in gear design, materials, lubrication, and manufacturing processes all contributed to this enhancement. In the industry, gears using the involute curve as a tooth profile are widespread. The involute gears offer numerous advantages, including ease of manufacture and low sensitivity to assembly and manufacturing errors. However, through the involute gear-pair, the motion is transferred over convex-convex surfaces. As the contact point between the two gears approaches the base circle of the involute curve, the radius of curvature of the tooth profile approaches zero, which means that there is a lot of contact stress on the gear pair surfaces, causing pitting failure. Another problem with the involute gear is that the dedendum is shorter than the addendum. This causes a lot of sliding during the meshing cycle, which leads to a lot of wear. Moreover, interference problems in low tooth count gear.[1–4] All of these drawbacks result in reduced surface durability and fracture strength of the gear teeth.

Many attempts were made by the researchers to eliminate these shortcomings, such that the involute teeth have reached a point where achieving a meaningful gain in strength or surface durability using the current involute gear design is either impossible, costly, or difficult. Therefore, in the last few years, designers have seen a rise in the use of non-involute gear drives to get around these kinds of shortcomings.

Using the theory of gear meshing and differential geometry, a known rack cutter or the tooth profile of a mated gear can be used to construct the pinion tooth profile and the contact path during the meshing cycle. The contact path is defined as the locus of the contact point between the mating tooth profiles in a fixed frame of reference.[5,6] Since the path of contact governs the kinematic characteristics of the gear drive, in the last few years, a few researchers have tried to design the gear tooth profile based on how this path looks to get desirable gear tooth characteristics. In this regard, L. Jing[7] proposed a mathematical model for planar gears that used a pressure angle function (PAF) to describe the geometries and meshing features of the gear tooth profiles. The model has been used to construct circular and non-circular gear pairs. The constant, linear, and quadratic PAF forms were examined in this research. A method for designing a high contact ratio (HCR) spur gear was proposed

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