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Computerized design of modified helical gears finished by plunge shaving

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ABSTRACT

Among the several types of gear shaving operations, plunge shaving is used for finishing gears in mass-production due to the low cost and short machining time. Plunge shaving may be used to apply surface modifications with the purpose of reducing noise and vibration by the predesign of favorable functions of transmission errors, and modify gear tooth surfaces to avoid edge contacts and increase gear endurance, safety, and service life. A new geometry for helical gear tooth surfaces that combine the advantages of gear drives with lineal and localized contacts is proposed and obtained by plunge shaving. The shaver tooth surfaces are conjugated to those of an ideal helical gear with surface modifications. In this way, the to-be-shaved gear and the shaving cutter will be in line contact, and only a radial feed motion of the shaver is needed to generate the required pressure for the shaver to cut the excess of material on the gear tooth surfaces. A numerical example of design illustrates the advantages of the proposed geometry.

1. Introduction

Gear shaving is a finishing process for gear manufacturing. It is applied after the processes of cutting or roughing of the gear teeth by common generating tools are over. The shaving process consists of the removal of tiny particles of metal from the tooth working surfaces of the gears. For that, the shaver tooth surfaces are provided with special serrations in the flank area of the teeth that work as cutting edges.

Among the several types of gear shaving operations, plunge shaving is used for finishing gears in mass-production due to the low cost and short machining time [1]. In plunge shaving there is no translation of the shaver. Instead a radial feed motion of the to-be-shaved gear against the shaver takes place. The shaver and the to-be-shaved gear are in line contact so that the process of plunge shaving has shorter times than other gear shaving processes based on the achievement of point contact between the shaver and the to-be-shaved gear [2]. In recent years, the study and the determination of the tooth profile of plunge shaving cutters, as well as the improvements of the characteristics of the technological process have been the subject of study for many gear researchers and manufacturers [3–8].

The main advantages of gear shaving are the improvement of the tooth surface finish and the quality of a hobbed gear. The process of gear finishing can be also used for surface modification with the purpose of:

(i) Reducing noise and vibration of gears by the predesign of a favorable function of transmission errors.
(ii) Modifying gear tooth surfaces to avoid edge contacts and increase gear endurance, safety, and service life.

A new geometry for helical gear tooth surfaces that combine the advantages of gear drives with lineal and localized contacts [9] may be achieved by plunge shaving. The basic idea is to consider the shaving cutter tooth surfaces as conjugated to the ones of the to-be-shaved gear tooth surfaces, taking into account the surface modifications that we want to apply for the to-be-shaved gear. In this way, the to-be-shaved gear and the shaving cutter will be in line contact, and only a radial feed motion of the shaver is needed to generate the required pressure for the shaver to cut the excess of material on the gear tooth surfaces.

The advantages of the new geometry are: (i) total controllability of gear tooth profiles for favorable tooth contact patterns; (ii) avoidance of edge contacts when errors of alignment occur; (iii) favorable function of transmission errors that allows to absorb the lineal functions of transmission errors caused by errors of alignments; (iv) favorable load and unload cycles of the gear tooth surfaces; and (v) increase of the gear endurance and the service life of the gear drive. A numerical example of design will illustrate the advantages of the proposed geometry.

2. Generation of ideal geometry of the to-be-shaved helical gear

The concept of generation of a helical gear by an imaginary rack cutter of modified geometry as shown in Fig. 1(a) is applied for

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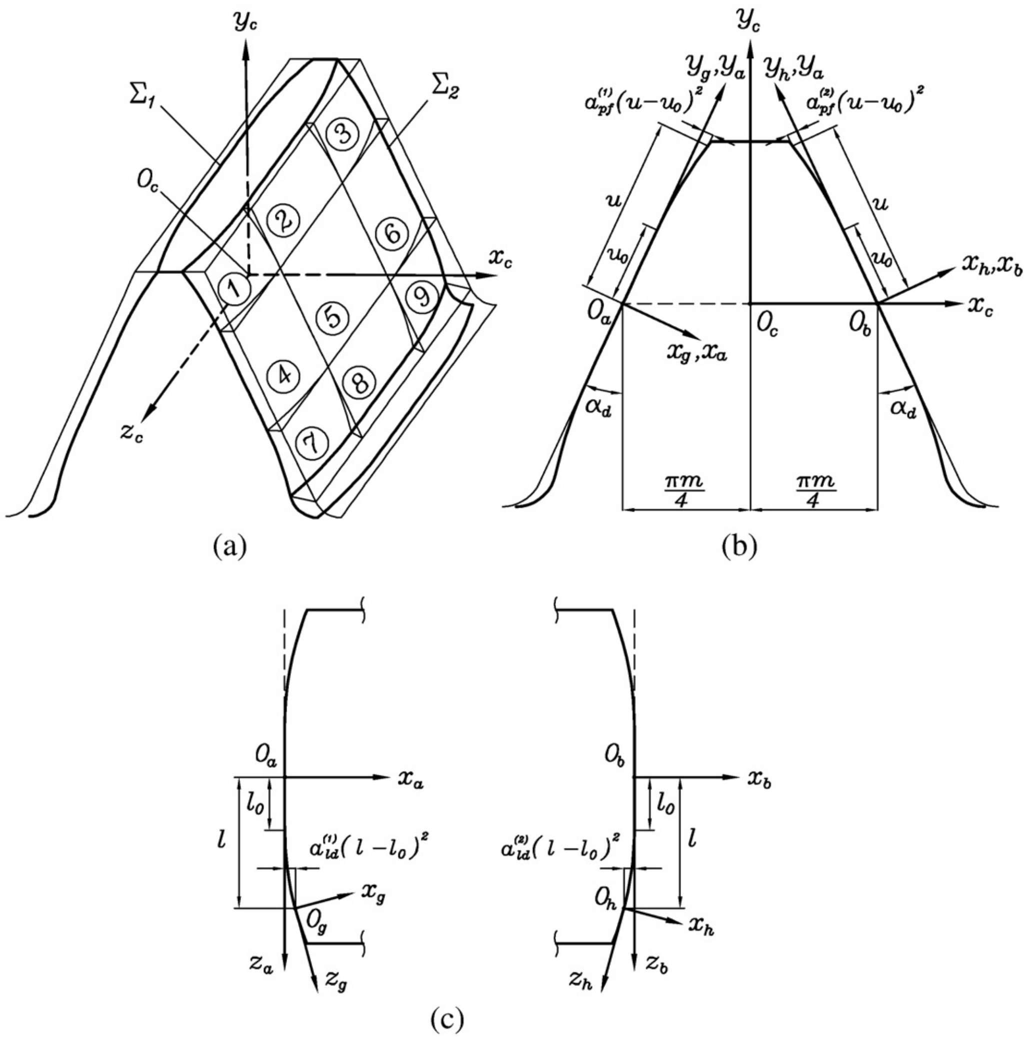

Fig. 1. Geometry of generating rack cutter: (a) 3D schematic view of the rack cutter; (b) geometry of rack cutter in profile direction; and (c) geometry of rack cutter in longitudinal direction.

determination of the ideal geometry of a modified helical gear. By considering one of the members of a helical gear drive with such a geometry, the above-mentioned advantages will be achieved.

2.1. Geometry of the generating rack-cutter

Fig. 1(a) shows a 3D schematic view of the generating rack cutter. Fig. 1(b) and (c) shows the geometry of the rack cutter in profile and longitudinal directions, respectively.

Coordinate systems S_a and S_b (see Fig. 1(b)) are rigidly connected to the rack cutter surfaces Σ_1 and Σ_2 that generate the driving and coast side of the helical gear, respectively. Coordinate system S_c is rigidly connected to the rack cutter and located on the rack cutter pitch plane as shown in Fig. 1 (b). Coordinate systems S_g and S_h (see Fig. 1(c)) are auxiliary coordinate systems to take into account the longitudinal crowning of the rack cutter.

Rack-cutter generating surfaces consist of nine zones as shown in Fig. 1(a) wherein:

(i) Zone 5 is a non-modified surface (planar) corresponding to the standard geometry of a rack cutter. No modifications are provided in this zone.
(ii) Zones 1, 3, 7, and 9 are areas of crowning in profile and longitudinal directions.
(iii) Zones 2 and 8 are areas of crowning in profile direction.
(iv) Zones 4 and 6 are areas of crowning in longitudinal direction.

Profile of rack cutter is represented in coordinate systems S_g and S_h (see Fig. 1) for left and right sides as

$$\mathbf{r}^{(i)}_{g,h}(u) = \begin{bmatrix} \pm a^{(i)}_{pf}(u-u_0)^2 \\ u \\ 0 \\ 1 \end{bmatrix}, \ (i = 1, 2). \quad (1)$$

Here, u is the surface parameter in profile direction, $a^{(i)}_{pf}$ is the parabola coefficient for profile crowning, and u_0 denotes the point of tangency of the parabolic profile with the corresponding y_g or y_h axes. The upper and lower signs of $a^{(i)}_{pf}$ correspond to representation of profile geometry in coordinate systems S_g and S_h for the left and right side, respectively.

The following conditions are established in order to divide the rack cutter generating surfaces in three areas in profile direction:

- If $u > u_{0_{top}}$, then $a_{pf} = a_{pf_{top}}$ and $u_0 = u_{0_{top}}$ (area A of zones 1, 2, and 3)
- If $u \le u_{0_{top}}$ and $u \ge u_{0_{bottom}}$, then $a_{pf} = 0$ and $u_0 = 0$ (area B of zones 4, 5, and 6)
- If $u < u_{0_{bottom}}$, then $a_{pf} = a_{pf_{bottom}}$ and $u_0 = u_{0_{bottom}}$ (area C of zones 7, 8, and 9).