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Research on the theoretical tooth profile errors of gears machined by skiving

Zheng Guo [a], Shi-Min Mao [a,*], Xiao-E Li [b], Zhong-Yi Ren [a]

[a] State Key Laboratory for Manufacturing System Engineering, Xi'an Jiaotong University, Xi'an 710049, China
[b] Hanjiang Tool Corporation Limited, Hanjiang 723002, China

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ABSTRACT

This study focuses on the theoretical tooth profile errors of gears machined by conventional skiving. The influences of skiving cutter rake angle on tooth profile errors of gears are analyzed. It is found that the inherent error of skiving cutter and the longitudinal deviation of cutting edge contributed to the gear profile errors. The influences of skiving cutter resharpening are then analyzed, and it is found that the resharpening amount of skiving cutter has obvious influence on the tooth profile error of workpiece. Therefore, conventional skiving tools are defective in high accuracy gear machining.

1. Introduction

Skiving is an efficient and promising gear cutting technology, which can be used in cylindrical gear machining and is especially excellent in internal gear machining. In recent years, with the developments of CNC technology and tool material, skiving has gradually shown its great potential advantages [1]. The design and manufacture technologies of skiving cutter have made great progresses, and various new kinds of skiving cutters have been developed, such as stick blade cutting wheel which is composed of a base wheel and several cutter bars that are assembled on the base wheel [2,3] and cylindrical skiving tool [1,4,5]. Of all the skiving cutters, conventional skiving tool, with a shaper-cutter-shaped structure, is most widely used and studied [6–12]. However, researches on the tooth profile error of gears machined by the conventional skiving tools are deficient, and some opinions are inaccurate [7–10], in which the tooth profile errors are only ascribed to the inherent errors of the skiving tools, and the cutting edges longitudinal deviations of the skiving tools are ignored. Besides, it is also necessary to study the influence of the resharpening of skiving tools, which relates to the tool life and the machining accuracy maintenance of the gears.

Some research is carried in this paper in order to solve the problems described above. Firstly, the calculating method of tooth profile error of gears machined by conventional skiving is studied and the influences of skiving cutter rake angle on the tooth profile errors of the gears are analyzed. Secondly, the contributing factors of tooth profile error of the gears are investigated. Finally, the influences of skiving cutter resharpening on tooth profile error are analyzed, and the disadvantages of conventional skiving tools, compared with cylindrical skiving tools, are discussed in terms of high accuracy gear machining.

* Corresponding author. Tel.: +86 13279222220; fax: +86 029 82665204.
E-mail address: maoshm1@263.net (S.-M. Mao).

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2. Calculation of gear tooth profile error by skiving

In conventional gear skiving, the relative motion of a skiving cutter and workpiece, at skew axes, is that of rolling of the cutter pitch circle existing in its tooth-end transverse plane (as if it was of zero rake) on the gear pitch cylinder. The conventional skiving cutter resembles a gear shaper cutter. According to the cutting edge curves of the tool and the relative motion between the workpiece and the tool, the tooth profile coordinates of the workpiece and the tooth profile errors can be calculated [13,14].

2.1. Definitions of coordinate systems

As shown in Fig. 1, $S_1(x_1, y_1, z_1)$ is the fixed coordinate system of workpiece that rotates around and moves along axis of z_1. Coordinate system $S_w(x_w, y_w, z_w)$ is rigidly attached to the workpiece, and its original position is identical with S_1. Coordinate system $S_2(x_2, y_2, z_2)$ is the fixed coordinate system of cutter that rotates around axis of z_2. Coordinate system $S_c(x_c, y_c, z_c)$ is rigidly attached to the cutter, and its original position is identical with S_2.

If the angular speed of the cutter is ω_c and the axial feed speed of the workpiece along z_1 axis is f, the angular speed of the workpiece ω_w can be described as

$$\omega_w = Z_c \cdot \omega_c / Z_w + f/p \tag{1}$$

where, Z_c and Z_w are the numbers of teeth of the cutter and the workpiece respectively, and p is the helix parameter and can be expressed as

$$p = p_z/2\pi \tag{2}$$

where, p_z is the helix lead of workpiece on the reference cylinder.

The crossed axes angle $\sum$ between the axes of the cutter and the workpiece is equal to the sum of the workpiece helix angle β_w and the cutter helix angle β_c, and the center distance a is the difference between the workpiece reference radius r_w and the cutter reference radius r_c. $\sum$ and a can be expressed separately as:

$$\sum = \beta_w - \beta_c \tag{3}$$

$$a = r_w - r_c \tag{4}$$

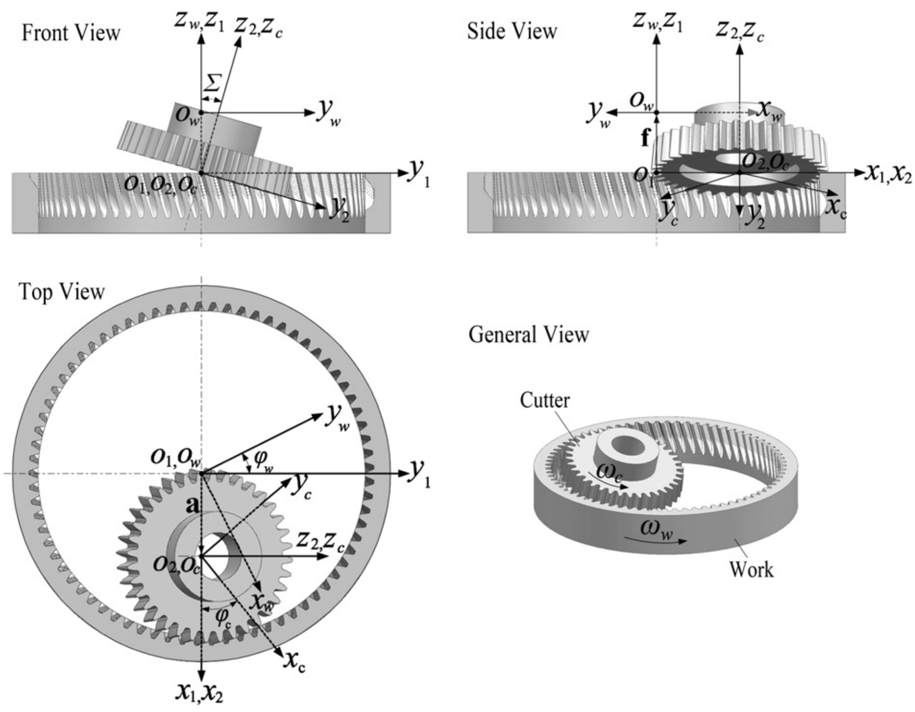

Fig. 1. Coordinate systems applied in skiving process.