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Research paper

Research and improvement of the cutting performance of skiving tool

Zheng Guo[a], Shi-Min Mao[a,*], Liang Huyan[b], Dong-Sheng Duan[a]

[a] State Key Laboratory for Manufacturing System Engineering, Xi'an Jiaotong University, Xi'an 710049, China
[b] Qinchuan Machine Tool & Tool Corporation, Baoji 721008, China

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ABSTRACT

Skiving is an efficient and promising gear cutting technology. For further improvement of the reliability and the cutting performance of skiving tool, fundamental research is conducted. Firstly, mathematical model of skiving is derived based on the theory of gearing, and the working rake and relief angles are analyzed. It is found that the top-recess nose is the weakest part of skiving tool tooth. Secondly, mathematical model of cutting force in gear skiving is presented, and the mechanical performances of the tool in skiving with different commonly used feeding techniques are investigated. The results show that the multiple-side-feeds technique is more advisable in gear skiving, but it is still futile for the wear reducing of the up-recess edge. Finally, an improvement of the multiple-side-feeds technique is proposed for wear reducing of the up-recess edge of skiving tool.

1. Introductions

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, and many kinds of high-end skiving machine tools have been developed by famous manufacturing enterprises [1–4].

More recently, the design and manufacture technologies of skiving tool have made great progresses, and various new kinds of high-performance skiving tools have been developed, such as cylindrical skiving tool [1,4–6] and assembled skiving tool [2,7–9]. Li et al. [10,11] proposed a design method of error-free spur skiving tool for internal helical gear and show the grinding method of the tool major flank. Guo et al. [12] propose a method to design and calculate the skiving tool for machining involute gears. Guo et al. [6] analyzed the theoretical tooth profile errors of gears machined by conventional skiving. Tsai [13] proposed a mathematical model of the cutting edges of power skiving tool and analyzed the working rake, relief angle and wedge angles.

Skiving technologies are improved at the same time. Aiming at improving the skiving performance, many feeding technologies of skiving have been proposed and applied, such as Semi-completing skiving [14] and multiple-feeds skiving technology [4]. Guo et al. [15] analyzed the influences of tool setting errors on gear skiving accuracy and proposed methods for improving the skiving quality.

* Corresponding author.
E-mail address: maoshm1@263.net (S.-M. Mao).

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Nomenclature

Σ	shaft angle
a	center distance
L	offset distance
$S_1(x_1, y_1, z_1)$	fixed coordinate system of workpiece
$S_w(x_w, y_w, z_w)$	attached coordinate system of workpiece
$S_2(x_2, y_2, z_2)$	fixed coordinate system of tool
$S_c(x_c, y_c, z_c)$	attached coordinate system of tool
ω_c	angular speed of tool
f	axial feed speed of workpiece
ω_w	angular speed of workpiece
Z_c	number of teeth of tool
Z_w	number of teeth of workpiece
p	helix parameter of workpiece
P_z	helix lead of workpiece
A	approach edge
R	recess edge
T	top edge
φ_c	rotation angle of tool
i	transmission ratio
γ_p	Top rake angle of tool
Ψ	tooth thickness half angle
γ_n	normal working rake angle
α_n	normal working relief angle
m_n	normal module of workpiece
α	normal pressure angle of workpiece
β_w	Helix angle of workpiece
α_p	Top relief angle of tool
$S_n(x_n, y_n, z_n)$	attached coordinate system of cutting plane
$S_s(x_s, y_s, z_s)$	attached coordinate system of shear plane
$S_r(x_r, y_r, z_r)$	attached coordinate system of rake face
P_s	cutting plane
P_{sh}	shear plane
η_c	chip flow angle
η_s	shearing direction angle
μ	mean friction angle
Φ_n	normal shear angle
λ_s	inclination angle
v_n	normal cutting speed of cutting point
τ	material shear strength of workpiece
A_c	area of the chip section
F_s	shear force
F_r	friction force of chip
N_s	normal force from shear plane to chip
N_r	normal force from rake face to chip
W	cutting work done by cutting edge element
d	distance between flank cuts

Skiving is an efficient gear cutting technology, but the deficiency is the poor durability of the tool if a defective skiving technology is used [5,16]. So the research on the improvement of skiving technology should be enhanced, especially in the cutting performance of skiving tool, and the present research related to the wear reducing of skiving tool should be focused. Spath and Hühsam [5] analyzed the cutting conditions of the skiving tool, including the working rake angle, the relief angle, the cutting depth and the cutting force. Schulze et al. [17] show their research results of gear skiving kinematics and chip formation mechanisms. Li et al. [18] proposed a calculation method of cutting force in gear skiving. Klocke et al. [16] pointed out chip welding can be a problem in power skiving and provided suggestions of skiving process optimization regarding productivity as well as quality.

The aim of the study is to propose an analytical model of cutting performance of skiving tool and make improvements to the skiving techniques. Firstly, mathematical model of gear skiving is derived based on the theory of gearing, and the