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Calculation method of the contact area in flank machining for continuous generating grinding

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ABSTRACT

The results of grinding processes like surface roughness or grinding burn are often characterized by the usage of the tool specification and process parameters but also by the geometrical contact. Whereas the calculation of contact length or contact area as well as the specific removal rate is clearly defined for processes like plane or cylindrical grinding, they are still a field of research in context of continuous generating gear grinding. In the scientific environment the contact parameters for continuous generating grinding have been already computed via numerical simulations. But the dependency of the contact parameters on the simulation software restricts their industrial usability. One of the focuses in the actual gear machining analysis at the Institute of Production Engineering and Machine Tools is the analytical modeling of the geometrical contact values for continuous generating grinding. In this paper the geometrical model of the contact area is presented and validated via numerical simulation. Thereby, a high degree of correlation between calculated and simulated values arises.

1. Introduction

Results of grinding processes and experiments like surface roughness or the residual stress state are commonly interpreted by specific parameters, which are related to the contact width or contact area. Specific grinding forces and grinding power often correlate with tool wear and the generated subsurface characteristics.

Usually, the contact area is calculated by the multiplication of contact width a_p and contact length l_g. Thereby, the contact length l_g has the same direction as the grinding speed v_c and the contact width is directed at right angle to l_g. This calculation approach is applicable for orthogonal grinding processes like plane grinding, external cylindrical grinding or internal cylindrical grinding [1,2]. For continuous generating gear grinding this approach is not applicable since the contact area cannot be represented by a rectangle with side lengths l_g and a_p. Contrary to orthogonal grinding processes, the contact width a_p and contact length l_g are not clearly defined for continuous generating grinding. Moreover, the contact area geometry is not describable by any basic geometric form. Due to that fact, it was not possible to calculate the common contact area related parameters for continuous generating grinding yet.

The fundamental problem of the contact area calculation, for continuous generating gear grinding, results from the complex process kinematics as well as from the complex geometry of the gear and grinding tool. The continuous generating gear grinding kinematics is similar to the worm gear pair (Fig. 1). Thereby, the abrasive worm (grinding tool) and the gear rotate with gear transmission ratio defined by the number of worm starts z_0 and gear teeth z. Additionally, the grinding worm

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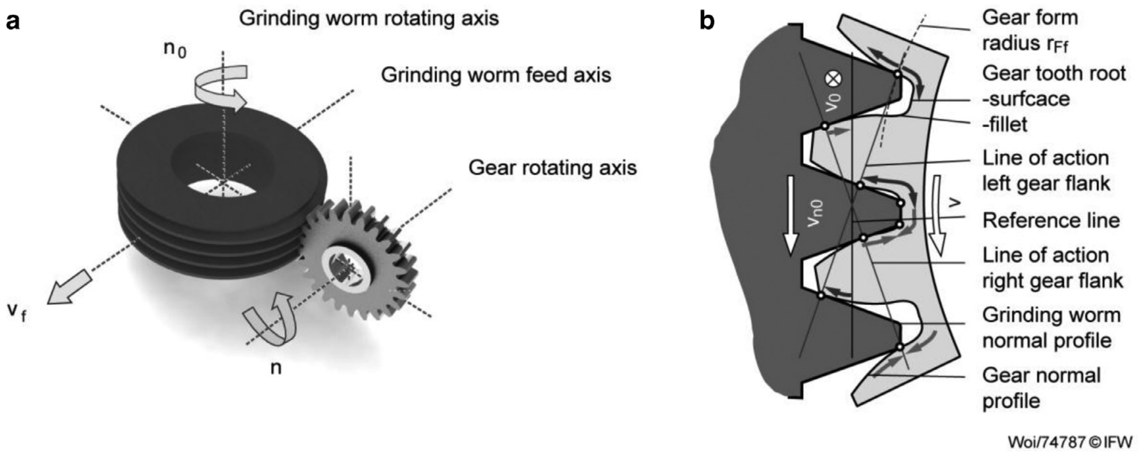

Fig. 1. Continuous generating grinding: (a) process kinematics (b) multipoint worm-gear contact.

Nomenclature of gear geometry

C	contact point (pitch point)
m	module mm
n	number of revolutions min^{-1}
q	allowance mm
r	reference circle radius, circle radius mm
z	number of teeth
α	pressure angle
β	helix angle
ρ	radius of curvature mm

Indices of gear geometry

0	grinding wheel
a	tooth tip
b	base
f	tooth fillet
g	path of contact
n	normal section
t	transverse section

Nomenclature of grinding process

A_k	contact area mm^2
$a_{\alpha ti}$	1. contact area dimension mm^2
a_p	cutting trace width mm
a_{pi}	2. contact area dimension mm^2
a_{gti}	3. contact area dimension mm^2
l_g	geometrical contact length mm
f	feed per gear revolution mm/min
Q'_w	specific removal rate (width related) mm^2/s
Q''_w	specific removal rate (area related) mm/s
v_c	cutting speed m/s
v_f	feed rate mm/min
$v_{f\,res}$	resulting feed rate mm/min
$\#p$	number of passes

moves with the feed ratio $\boldsymbol{v_f}$ in the direction of the gear tooth width. Thereby, the grinding worm penetrates the gear at several contact areas which are moving along the involute from addendum to dedendum on the one flank and contrariwise on the other [3]. Especially the electronic coupling of two rotational axes in the machine tool hinder the simple analysis of the contact area using real gears. The required freezing of two cogged parts during the grinding process including two rotational and at least one translational motion are theoretically possible, but may cause damages on the machine tool or