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Fundamentals on face milling processing of straight shafts

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Abstract

The face milling could be applied for generating cylindrical surfaces in ingot peeling or heavy-shaft rough out. The practical application of the process requires special technological conditions. The design of technological equipment and of the machining parameters requires a knowledge of fundamental elements regarding surface generation, process kinematics and functional geometry of cutting tool. These are analysed and discussed in this paper, in a systematic unitary fashion. The theoretical model created by the authors is simulated on the computer, yielding very useful results. The experimental researches carried out confirm and validate the conclusions of the theoretical analysis. The results presented in this paper could increase the interest of industry for applying the process, given that it shows remarkable technical and economical performance.

Keywords: Face milling; Heavy-shafts; Machining accuracy; Cutting kinematics; Tool geometry; Chip shape

1. Introduction

Studies on face milling have been developed in connection with diverse processes associated mostly to generation of flat surfaces ([6,7], etc.).

The machining process of straight shafts by face milling was described for the first time in [1], and later in [2–5].

The cylindrical surface of workpiece (Fig. 1) results from the interaction of two rotative motions. First motion is made by the workpiece, with the number of revolutions n_1, and the second is made by the tool, with the number of revolutions n_0, respectively.

The tool consists of a body in which are mounted several blades that execute a pure face cutting. Because of distance e between the axes of tool and workpiece (Fig. 1), a distance called adjustment eccentricity, the cutting develops progressively as the point of contact between tool and workpiece moves continuously. Every elementary edge of the tool reaches the workpiece only twice during of one tool rotation.

As a result of a proper design of the tool, the progressive cutting executed by every edge is made on the entire length of the shaft, giving the process the advantage of high productivity.

For an optimum development of processing straight shafts using face milling [2], it is necessary to research the following areas: correlation between shaft length, tool diameter and adjustment eccentricity; correlation between cinematic parameters of cutting; fundamental elements for cutting kinematics; tool functional geometry and it's influence on cutting process.

2. Correlation between shaft length, tool diameter and eccentricity

For certain values of shaft length, L, tool diameter, d_0, and eccentricity, e, and for the sense of tool rotation as shown in Fig. 1, the cutting process begins in point A and, as tool turns, the tool contact point with workpiece moves progressively to point B. When the cutting edge has a perpendicular poisition against workpiece axis, all points of edge, between A and B, have made contact with the material subject to cutting. As tool

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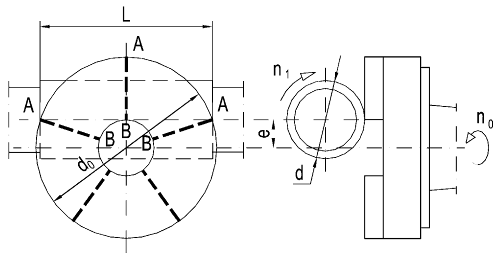

Fig. 1.

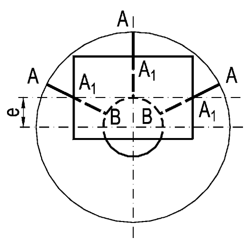

Fig. 2.

continues to turn, the contacts between edge and workpiece are made from B to A, after the edge ends to cut.

The analysis of correlation between L, d_0 and e (Fig. 1) leads to the relation:

$$L \leq L_{\max} = \sqrt{d_0^2 - 4e^2} \tag{1}$$

where $L_{\max}$ is the maximum length of shaft surface that could be generated for given d_0 and e.

When a shorter shaft ($L < L_{\max}$) is processed (Fig. 2) only a part of edges length are actively (between points A_1 and B). Decreasing the adjustment eccentricity, the active contact is moving along edge.

The value of adjustment eccentricity considerably determines the variation of cutting speed on tool cutting edges. If the value of adjustment eccentricity is little, the difference between maximum and minimum cutting speed will be great. For this reason, it is recommended that adjustment eccentricity should be set at the highest values. But this recommendation can not be always accomplished, because it leads to the use of over-sized tools.

3. Elements of machining accuracy

The profile of workpiece, in transverse section, can be approximated to a polygon with k sides (Fig. 3), one side being generated by one tool cutting edge. Considering this hypothesis, the deviation Δd from prescribed diameter, d, is defined as the double of circular segment a, i.e.

$$\Delta d = 2a = d\left(1 - \cos\frac{\pi}{k}\right) \tag{2}$$

It can be observed that as k increases Δd decrease and at limit, when k trends towards ∞, Δd towards zero.

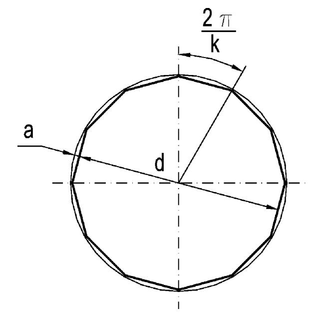

Fig. 3.

One of the important problems is to determine the correlation between workpiece revolution and tool revolution for having a certain established deviation.

The circular distance between two blades, s_0, is

$$s = \frac{\pi\, d_0}{z} \tag{3}$$

where z is the number of blades.

The time τ between cutting engagements of two successive blades is

$$\tau = \frac{s}{v} = \frac{\pi d_0}{z v} \tag{4}$$

where v is cutting speed.

If it is necessary that workpiece has k facets in transversal section, then the distance between engagement points of two successive blades is (Fig. 3):

$$s_1 = \frac{\pi\, d}{k} \tag{5}$$

So, the time for one face generation is:

$$\tau = \frac{s}{v_1} = \frac{\pi d}{z v_1} \tag{6}$$

where v_1 is rotational speed of workpiece.

From comparison of relations (4) and (6),

$$\frac{v_1}{v} = \frac{d}{d_0}\frac{z}{k} \tag{7}$$

The above relation allows the determination of workpiece revolution as a function of tool revolution, number of blades and number of facets:

$$n_1 = \frac{z}{k} n_0 \tag{8}$$

For an interval (k', k''), considered optimum, the optimum interval of workpiece revolution (n_1', n_1'') is a function of tool revolution (Fig. 4).

On the other hand, the number of facets k is a function of deviation Δd.

From Eq. (2), it results:

$$k = \frac{\pi}{\arccos(1 - (\Delta d/d))} \tag{9}$$