

Interrelation of processing modes with the current parameters of the contact zone during thermofriction processing

Nikolay Pokintelitsa^{1,*}

¹Sevastopol State University, Department of Food Technologies and Equipment, 299053 Sevastopol, Russia

Abstract. The establishment of the interrelation between the processing modes and the current parameters of the contact zone during the thermofriction processing of flat surfaces of workpieces by a rotating disk tool is considered. Dependencies are presented allowing assignment of cutting modes, prediction of the size of the removed material layer, and determination of the control actions value.

1 Introduction

Mathematical modeling of workpiece processing operations allows solving many practical problems in the selection and design of the tool, the designation of methods and processing sequence, and optimal control of technological equipment [1-3].

Determination of the output technological parameters of thermofriction processing (TFP) by means of mathematical models makes it possible to simplify significantly the search for optimal modes and is a relevant task.

The operation is very often treated as a dynamic system during simulation [4]. One possible scheme for the decomposition of an operation as a dynamical system is considered in work [5]. According to the functional characteristics, the operation is divided into subsystems of the machine tool, fixtures, tools, workpieces. Each of the subsystems has its own set of properties, state parameters, development history, a vector of input and output variables, a vector of perturbing influences.

The central subsystem is the contact area of the workpiece with the tool. The zone state parameters [4] include its dimensions, shape, parameters of the chip formation process, material removal rate, wear parameters and tool material destruction. The dimensions of the zone are in direct connection with the dimensions and spatial arrangement of the tool and the workpiece, as well as the state of their surfaces. Due to changes in the size, spatial location and condition of the contacting surfaces, the parameters of the state of the contact zone and, as a consequence, the parameters of the quality and efficiency of the TFP, will change with each new rotation of the disk.

Therefore, the purpose of this work is to establish the inteconnection of processing modes with the current parameters of the contact zone.

* Corresponding author: nik.pokintelitsa@mail.ru

2 Main text

To establish the parameters of the contact zone, let us consider the scheme of the TFP process (Fig. 1).

In a section plane, perpendicular to the surface being processed, the contact zone has the form of two mutually intersecting rectangles. In TFP after leaving the zone, the thickness of the workpiece decreases by the amount of material removal Δh , the height of the disk - by the amount of wear ΔH .

The surface to be processed is faced with microprotrusions farthest from the base surface of the cutting blade. The shape of the zone also changes due to the appearance of elastic deformations of the disk and the workpiece.

Let us denote the maximum possible (nominal) depth of insertion of the microprotrusions of the tool into the workpiece material with t_f . The actual depth will be less than the maximum possible for the amount of material removal.

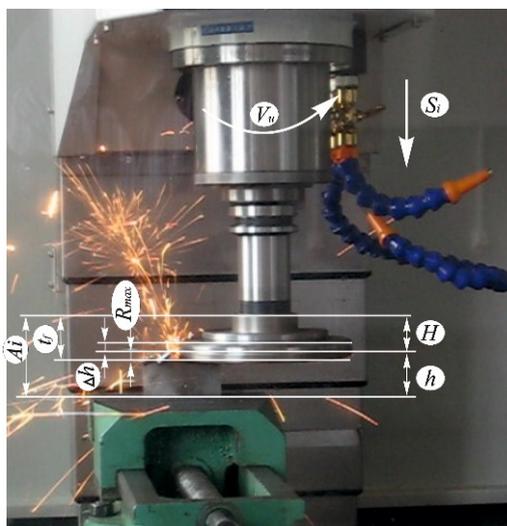


Fig. 1. Scheme for calculating the balance of displacements in the technological system.

After leaving the contact zone, the roughness remains on the surface of the workpiece, since the cutting blade has a cutting edge with microprotrusions. The surface roughness is distributed in a layer with thickness R_{\max} . The actual depth of cut is interrelated with the material removal and the depth of the roughness layer by the simple relationship [3]:

$$t_f = R_{\max} + \Delta h.$$

To derive a relation characterizing the balance of displacements, let us consider Fig. 1, according to which for the i th pass we have:

$$A_i = H_i + h_{i-1} - t_{fi}. \quad (1)$$

Accordingly, for the $i-1$ th pass we get:

$$A_{i-1} = H_{i-1} + h_{i-2} - t_{fi-1}, \quad (2)$$

where t_{fi}, t_{fi-1} – the actual depth of microcutting by the most protruding protrusion on the i -th and $i-1$ -th pass; H_i, H_{i-1} – disk heights on the i -th and $i-1$ -th pass; A_i, A_{i-1} – the distances between the base surfaces on the i -th and $i-1$ -th pass, respectively; h_i, h_{i-1} – the dimensions of the workpiece before the completion of the i -th and $i-1$ -th pass [6].

After subtracting the dependence (1) from (2), we get ΔA_i – the distances between the base surfaces A_i on the i -th pass:

$$\Delta A_i = \Delta H_i + \Delta h_{i-1} - \Delta t_{fi}, \quad (3)$$

where ΔH_i – change of tool height on the i -th passage, caused by linear wear of the disk; Δh_{i-1} – change of the workpiece thickness on the $i-1$ -th pass, Δt_{fi} – increment of the actual cutting depth.

Current distance between base surfaces:

$$A_i = A_{i-1} + S_{i-1} - S_i + \Delta A_{ti} - \Delta A_{yi},$$

or

$$\Delta A_i = \Delta S_i + \Delta A_{ti} - \Delta A_{yi}, \quad (4)$$

where ΔA_{ti} – increment of the distance between the base surfaces A_i on the i -th pass due to temperature deformations; $\Delta A_{yi} = \frac{\Delta P_{Yi}}{j_{TC}}$ – increment of elastic depressions in the technological system on the i -th pass.

Here P_{Yi} is the normal component of the cutting force; j_{TC} – rigidity of the technological system; ΔS_i – displacement of the disk for the i -th pass due to vertical feed.

After the joint solution of equations (3) and (4), taking into account the direction of the feed, we obtain the balance equation of displacements in the technological system in increments:

$$\Delta S_i = \Delta H_i + \Delta h_{i-1} + \Delta t_{fii} - \Delta A_{ti} + \Delta A_{yi}, \quad (5)$$

or

$$\Delta t_{fii} = \Delta H_i + \Delta h_{i-1} + \Delta S_i - \Delta A_{ti} + \Delta A_{yi}. \quad (6)$$

Dependencies (5) and (6) determine the change in the state of the technological system for any time moment in TFP [7-8].

Equations demonstrate that the state of the system under TFP depends on the current and previous stages of processing, depends on the state of the tool, elastic deformations, etc.

Analysis of the dependences (5), (6) shows that the vertical feed on the i -th pass is spent on incrementing the depth of microcutting, compensating for the removal of material from the previous passage, wear of the disk, increment of elastic and temperature deformations. The dependence differs from the known ones by the presence on the right of the increment of the depth of microcutting, which in some cases may be greater than the other summands [9-10].

A schematic diagram of the change in increments over the period of processing one surface is shown in Fig. 2.

So, for TFP on vertical milling machines with a workpiece size of 30×50×200 mm, the flexibility of the «milling head spindle-tool» system is 0,04 to 0,06 μm/N. When processing with disks with a height of 50 mm, the resultant cutting force is 800...1000 N. Consequently, the elastic depressions in the system lie in the range from 0,03 to 0,06 mm, the depth of microcutting varies from 0,05 to 0,2 mm, and the temperature deformation significantly exceeds the elastic ones (on average 2 and 2,2 times).

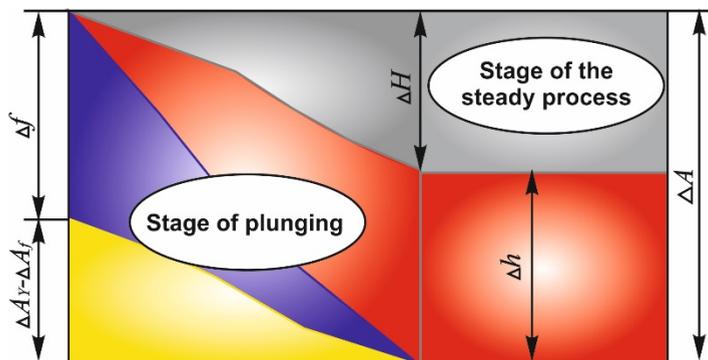


Fig. 2. Change of parameters of material removal, disk wear, increments of elastic deformations and depth of cutting during one cycle of TFP

In TFP without preliminary preload at the initial moment of time, almost the entire vertical feed goes to the increment of elastic deformations and the depth of microcutting. With the course of time, material removal and disc wear increase, so the increments of deformations and depth decrease for the further part of the process, and at the stage of the steady-state process they tend to zero. Vertical feed at this stage is almost completely spent on material removal and tool wear.

Analysis of the dependence (6) shows that the establishment of the parameters of the i -th contact is possible only if there is information about the i -th contact.

The use of the dependence (6) allows us to keep to the second principle of the analysis of the TFP operations. The equation of the balance of displacements (6) in TFP with changing cutting conditions and the parameters of the state of subsystems is the basis for predicting the spatial arrangement of the tool and the workpiece, the dimensions of the contact zone, and, consequently, the quality parameters of the processed surface.

To solve it, it is necessary to have dependencies for calculating the cutting force, material removal, disc wear, elastic and thermal deformation of the elements of the technological system.

3 Conclusion

The equation (6) allows us to assign modes, predict the value of the remote layer of the material, determine the value of control actions, for which it is necessary to determine the functions included in the equation (6), which is the task of the following studies.

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