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Bifurcations of Deep Hole Drilling Process

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Abstract

Modern control of the cutting process can only be based on the thorough study of the dynamics of the technological system that allows revealing different mechanisms of the processes occurring in the cutting zone. The article shows the bifurcations inherent in the process of deep drilling that allows explaining a number of phenomena that affect the tool breakdown and development of typical defects of the deep holes mechanical processing. The formation of bifurcations in the deep drilling process is shown based on the mutual influence of the cutting force and the force of the contact interaction between the surface of the hole and the side face of the drill. The forces, appearing in the cutting zone create the non-linear dynamic characteristics of the cutting process which depend on the radial float of the tools. The radial floats of drill are characteristic of the deep drilling of small-diameter bores.

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Keywords: Bifurcations; drilling dynamics; deep hole.

1. Introduction

Drilling of deep holes of small diameter is used for internal cylindrical surfaces of critical parts of machines [1], for example, channels of fuel injection equipment of heat engines. The main difficulties in the operation of drilling of deep holes of small diameter are associated with the stabilization of the drill in a radial direction. Deviations of a drill from the ideal axis of the hole is a cause of irreparable defect of the processing of parts and breakage of the drill. These defects appear both during the processing of metals and processing of details made of polymeric materials [2-11]. One of the promising directions of radial stabilization is a dynamic control [12, 13]. The applicability of this approach of drill stabilization is dictated by the achievements of the machine tool industry - the use of the machines in modern systems of automatic control and diagnostic of the system state. However,

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fundamental knowledge of the process under consideration is needed to create the programs of control of the dynamics of the drilling process. This article describes a mathematical model and the results of modeling the dynamics of the process of deep drilling, in the case of elastic deformation shifts of the tool tip in the radial direction.

Nomenclature

m	reduced mass of the tool subsystem, N·s^2/mm
h	the rate of the dissipation of the tool subsystem, N·s/mm
c	rigidity rate of the tool subsystem, N/mm
y	the radial shift of the drill tip, mm
f_1	area of the cutting layer №1, mm^2
f_2	area of the cutting layer №2, mm^2
F_{Y1}	radial component of the cutting force to area №1, N
F_{Y2}	radial component of the cutting force to area №2, N
F_Y	total radial component of the cutting force, N
F_R	reaction force from the surface of the hole, N
κ	cutting rate, MPa
α_i, β, γ	approximation coefficients of nonlinear force functions

2. The mathematical model

The following basic assumptions [14-16] have been adopted in the preparation of a mathematical model:

- the drill is not totally rigid in the radial direction;
- cutting force is determined by the following

$$F_{Yi} = \kappa f_i \tag{1}$$

- the cutting process is fundamentally disturbed [17].

During the drilling the tool may experience elastic deformations in the radial direction, which cause nonlinear change of f_1 and f_2 areas in the cutting layer. The scheme of change of the area of the cutting layer is shown in Fig. 1.

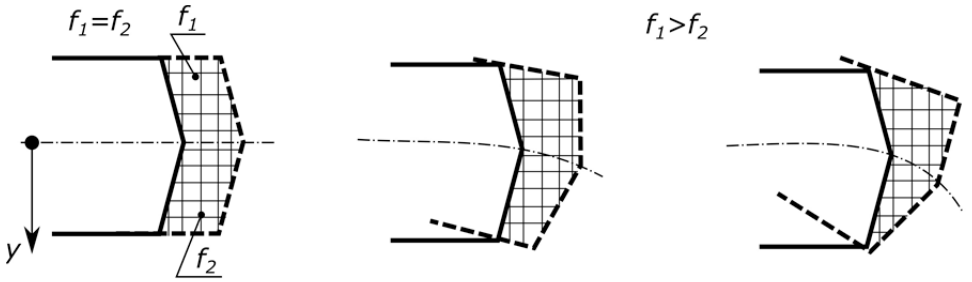

Fig. 1. The scheme of change of the area of the cutting layer, resulting in deformation of the drill.

The total radial component of the cutting force is determined by the equation (2):

$$F_Y = F_{Y1} - F_{Y2} \tag{2}$$