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MOVEMENT STABILITY STUDY FOR THE COMPONENTS OF THE DYNAMIC SYSTEM OF HIGH SPEED INTERNAL GRINDERS.

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Abstract: The paper presents an analysis of the movement stability of the dynamic system elements using the Nyquist's stability criterion, which requires construction of the frequency characteristics of the equivalent "open" system.

1. INTRODUCTION

For this purpose it is required knowledge of the dynamic system structure of the high speed grinding machine it has to meet a series of requirements:

a. The dynamic system of high speed grinding machines is represented as a closed system with circuits that contain delay elements with respect to waves on the tool edge and on the workpiece surface.
b. The elastic system is considered to be placed in the plane determined by the axes of the piece and tool, having one or more freedom degrees.
c. Within the elastic system of high speed grinders there are the partial elastic systems of the tool and the workpiece.
d. The structure of the elastic system can be simplified in accordance with the proposed goal. Simplification is usually desirable, with the requirement to keep all elements that influence the dynamic phenomena in the system. The simplification must be justified experimentally, if possible.
e. In order to decrease the number of variable parameters, researchers study the dynamic process considering that the machine does not perform axial advance.
f. Transition from the stable to the instable state of the work process is performed in stages, without distinct limits as in case of other types of machine tools.
g. The contact rigidity between tool and workpiece can be approximated by the parabolic characteristic of a soft spring and only in specific cases it can be considered having linear variation.
h. The study of dynamic systems which contain non-linear elements (curves, play, hysteresis, saturation) is performed using adequate mathematical instruments.
i. Theoretical study of dynamic systems must be performed in narrow frequency ranges, since the vibrations are larger in case of high speed grinders than in case of other machine tools and variable in time.
j. The study begins with analysis of dynamic phenomena at offload functioning.
k. Processing must not be interrupted until all phenomena have been recorded, since resuming would require ensuring of identical conditions, which is impossible in case of high speed grinders.

l. Forces are measured using tensometric transducers mounted on the elastic elements of the measurement captors. Vibrations are recorded using inductive, tensometric and, less frequently, capacitive and piezoelectric transducers for piece, tool spindle and tool bearer.

Grinding is one of the most complex cutting processes due to the fact that the tool (in rotation) presents a large number of cutting edges whose placement and grinding capacity are completely random.

By grinding, very small chips are removed at high frequency, allowing generation of very smooth surfaces with high dimensional and shape precision.

Consequently, the dynamic phenomena that accompany the grinding process play an important role among the factors that influence the quality parameters of the finished surface.

In the study of dynamic phenomena at grinding machines most difficulties arise from the complexity of the dynamic system of the machine tool, due to the highly non-linear characteristics [1] of the components, the unpredictable connections between the elements of the equivalent elastic system [1], variation in time of dynamic parameters and randomness of excitation factors [2, 3].

2. STABILITY ANALYSIS OF DYNAMIC SYSTEM ELEMENTS MOVEMENT

The stability of the dynamic system movement in the absence of self vibrations or intermittent sliding movements is evaluated in accordance with known stability requirements. Using Nyquist's stability criterion requires construction of the frequency characteristic of the equivalent "open" system. The equivalent "closed" system is stable if the amplitude-phase frequency characteristics do not contain the point with coordinates (-1,i0).

In offload conditions the dynamic system of high speed internal grinders becomes a typical friction system which can be met inside various machines and mechanisms. In fig. 1a is presented the schematic of the equivalent dynamic system in case of auxiliary and mounting movements obtained by unifying the elastic system (SES) and motor processes (PT) into an equivalent system SEE. In fig. 1b is presented the equivalent open system.

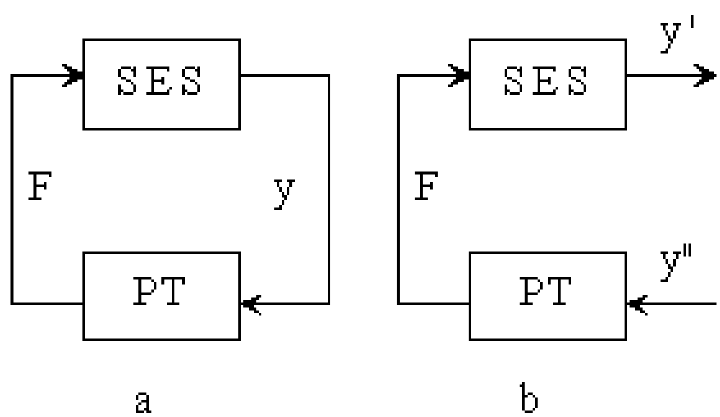

Fig. 1

The transfer function is given by:

$$W_{SEEd} = W_{SES} \cdot W_T \quad (1)$$

where: $W_{SES} = y/R_E$ (2)

$W_T = R/y$ (3)

in which:

y – contact deformation of friction bodies with respect to the sliding surface normal

R_E – equivalent SES force of reaction R due to friction which acts on the elastic system

$$R = F\sqrt{1 + 1/\mu^2} \quad (4)$$

where: F – sliding contact friction force

μ - friction coefficient

Corresponding to fig. 2 the frequency characteristic of SES can be presented as sum of the single degree of freedom [4] frequency characteristics SES_1, SES_2 constructed along main system directions.

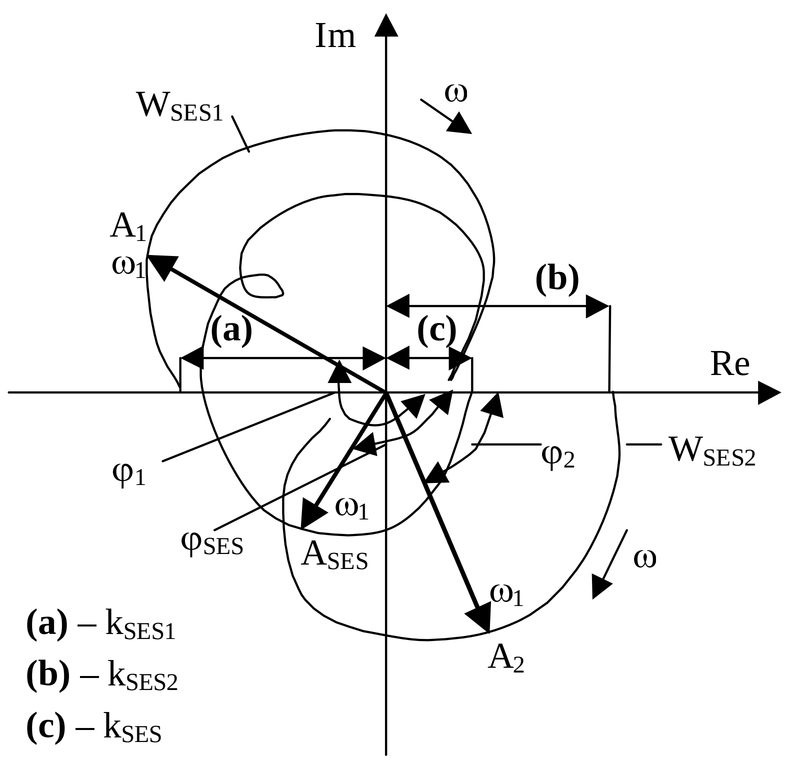

Fig. 2

We have:

$$W_{SESj} = y_j / R_e = R_{e_{SESj}} + iIm_{SESj};\ j = \overline{1,2},\ j \text{ – main direction index} \quad (5)$$

Also:

$$Re_{SESj} = \frac{k_{SESj}(1 - T_{j1}^2\omega^2)}{(1 - T_{j1}^2\omega^2)^2 + T_{j2}^2\omega^2} \tag{6}$$

$$Im_{SESj} = \frac{k_{SESj}T_{j2}\omega}{(1 - T_{j1}^2\omega^2)^2 + T_{j2}^2\omega^2} \tag{7}$$

In which: k_{SESj} – static characteristic; $k_{SESj} = 1/c_j$
c_j – static rigidity
T_{j1} – time constant; $T_{j1} = \sqrt{m_j/c_j} = 1/\omega_{cj}$ (8)
ω_{cj} – proper frequency
T_{j2} – fading time constant; $T_{j2} = \lambda_j T_{j1}/\pi$ (9)
λ_j – logarithmic decrement of the vibrating system

In fig. 3 there are presented the frequency characteristics in which the static coefficient $k_{SES}>0$ represents the normal case of sliding friction and $k_{SES}<0$ represents the case of approaching bodies.

The sliding friction is a complex technological process that includes elastic and plastic deformation of superficial layers of the friction bodies. The friction process has its own stability in absence of gripping.

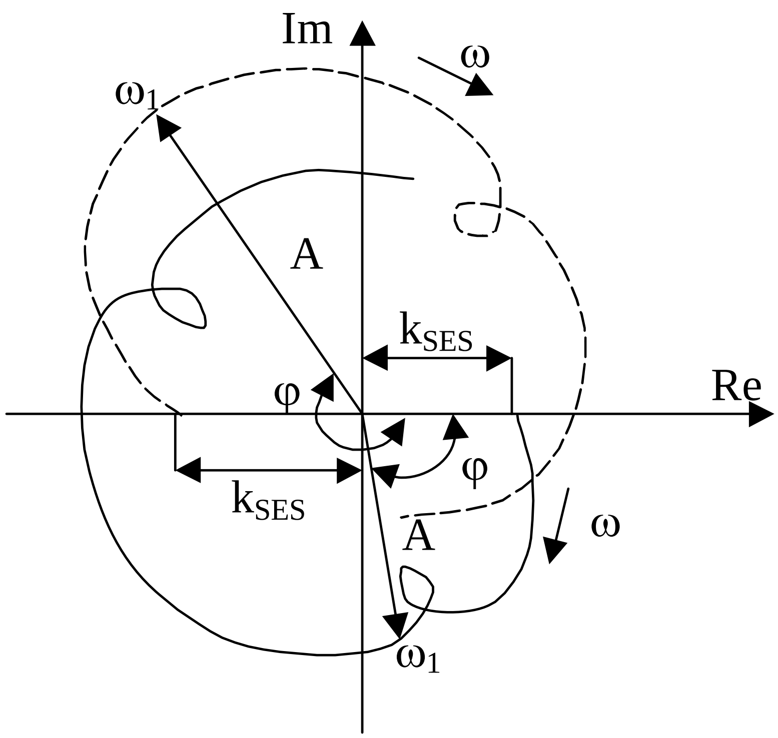

Fig. 3

Usually the friction force is proportional with the active load, namely with the normal contact deformation (z) of friction surfaces. The friction force is formed during probable tangential displacement. The dynamics of the sliding friction process relates the modification of the normal contact deformation with the friction force modification:

$$W_T = R/y = Re_T + iIm_T \tag{10}$$

where:

$$Re_T = \frac{k_T}{1 + T_T^2 \omega^2} \tag{11}$$

$$Im_T = -\frac{k_T T_T \omega}{1 + T_T^2 \omega^2} \tag{12}$$

in which: c_k – normal contact rigidity of friction bodies

$$k_T = c_k \mu \tag{13}$$

T_T – time constant of probable displacement

$$T_T = \zeta / v \tag{14}$$

3. CONCLUSIONS

The sliding friction is a complex technological process that includes elastic and plastic deformation of superficial layers of the friction bodies. The friction process has its own stability in absence of gripping phenomena.

The stability of the dynamic system movement in the absence of self vibrations or intermittent sliding movements is evaluated in accordance with known stability requirements, such as Nyquist's criterion.

The SES frequency characteristic can be presented as sum of SES_1, SES_2 single freedom degree system frequency characteristics constructed along main system directions.

The frequency characteristics in which the static coefficient $k_{SES}>0$ represents the normal case of sliding friction and $k_{SES}<0$ represents the case of approaching bodies.

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