STUDY ABOUT THE MODES VIBRATIONS ANALYSIS OF CNC SPINDLE STRUCTURAL ELEMENT USING NUMERICAL METHOD

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Abstract

The vibrations problems of numerical machine tools control, is actual even today given the fact that the structure is oscillating in the presence of forces caused by the cutting process, with stiffness-elasticity variable, depending on the own frequency (pulsation) of cutting forces. Numerical determinations for knowing the problems of rigidity elasticity of components flexible CNC machine tools is precisely the objective of this paper.

Key words: spindle, method, analytical, vibration, free, forced.

INTRODUCTION

Mechanical Wood Processing machine tools with CNC knows at present widely used in the processing industry because of the multitude advantages it presents, including: precision and high efficiency, high capacity, easy use and no preliminary adjustments (Albu A., 1995). Woodworking is influenced by increasing productivity so will increase cutting forces and one of its components will lead to a move away between the tool and the workpiece and therefore a decrease in accuracy of process. In the cutting process such forces are present and will cause vibration leading to a decrease of the processing accuracy and in reducing the duration of the machine tool (William M., 2005).

MATERIAL AND METHOD

For vibration analysis of machine tool spindle of CNC, it is considered to be elastic system dynamic model as represented by a beam having distributed mass (Albu A., 1986).

The elastic system considered consists of an infinite number of material particles thus formed into a system characterized by an infinite number of degrees of freedom.

The calculation algorithm to forced axial vibration is presented in the paper with the dynamic analysis of vibratory for the spindle of CNC machine tools.

The dynamic model considered the spindle as a homogeneous beam with constant density of the material, length and cross section. The free vibrations study is made for infinitesimal element of beam length, taking into account the principle of D'Alembert's (Stanciu C., 1986).

Where:

$\rho -$ density of material

$\rho = 7,85[g/cm^3]$

$l -$ length of spindle

$l = 300[mm]$

$d -$ diamter of sectional area:

$d = 30[mm]$

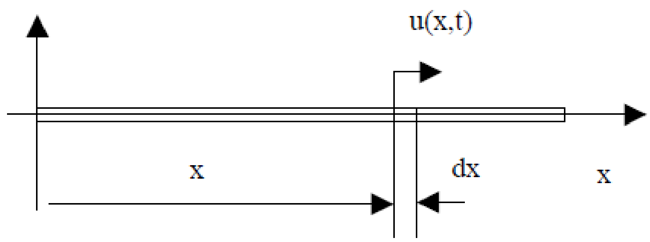

Fig. 1. infinitesimal element of beam length

In the case of the forced vibration of the spindle of the machine tool with numerical control is considered that it is acting on the free end of a cutting concentrated disruptive harmonic force of the form (Albu A., 1995; Bratu P., 1986; Fetea M., 2010).

$$F = F_0 \sin \omega t$$

Where:

$F -$ harmonic cutting force;

$F_0 -$ the module of harmonic force;

$\omega -$ pulsation of harmonic force.

Was chosen for the engine $n = 3000\ [rpm]$

Where (Morar L., 1998):

$$\omega = \frac{\pi n}{30} \approx 300[rad/\sec]$$

Dynamic analysis of forced vibration of the axial spindle CNC machine tool is performed for the case the drilling operation. Cutting force that manifests its action on structure composed of spindle - fixing and drill head has three main components, namely:

- Axial component of the cutting force having the same direction as the movement of advance and oriented by the outward normal and meaning for the purposes of advancing the drill;

- The radial component that acts on the edge of the drill;
- Tangential component, whose effect is negligible.

We consider the following technical aspect regarding physico-mechemical and elastic characteristics of considered system:

- it was used Matlab numerical calculation program;
- the spindle material is OLC 45.

The calculation algorithm to forced axial vibrations include the following steps (Bratu P., 2000).

1. Calculation axial component modulus cutting forces for the cases of static and dynamic loadings.

$$F_x = C_F \cdot D^{qF} \cdot s^{XF} \cdot k \qquad (1)$$

Where:

$F_x -$ the axial component modulus of the cutting force in case of the static model.

$D -$ drill diameter.

$C_F, k -$ drilling operations coefficients.

$s -$ drill advance.

$C_F = 60$;

$D = 8[mm]$;

$qF = 1$;

$s = 0{,}12\left[\frac{mm}{rot}\right]$.

It is determined

$$F_x = 136{,}0123[daN]$$

Taking into account the the dynamic action of the axial component of the cutting force, this can be expressed by the equation [2]:

$$F_{xd} = F_x \cdot \cos \omega t \qquad (2)$$

Are determined numerical value of the harmonic axial cutting force, at the moments

$$t_1 = 0{,}1[\sec],$$

$$t_2 = 0.5[\sec],$$

$$t_3 = 1[\sec]$$

using the the expression (2):

$$F_{xd1} = F_x \cos \omega t_1 = 117{,}79[daN]$$

$$F_{xd2} = F_x \cos \omega t_2 = -117{,}79[daN]$$

$$F_{xd3} = F_x \cos \omega t_3 = 68[daN]$$

The characteristics of the mechanical and elastic properties of the material (OLC 45) from which is made the principal spindle of the machine tool with numerical control are:

$$E = 2{,}1 \cdot 10^5 [N/mm^2], \sigma_{adm} = 120[N/mm^2]$$

σ_{adm} – allowable stress of the material.

2. Determination of own pulsations and spindle shape functions vibrations.

It took into account three normal modes of vibration. The calculation algorithm of spindle pulsations of the machine tool with numerical control is based on the following equation for calculating (Ispas C., 1986; Stanciu C., 1975).

$$p_i = (2i-1)\frac{\pi}{2l}\sqrt{\frac{E}{\rho}} \qquad (3)$$

i – number of axial vibration normal modes;

It was drafted the following program to determine the own pulsations spindle using a version of Matlab software.

```
E=2.1*(10^5) % Young's modulus [daN/cm2]
d=30 % spindle diameter [mm]
L=30 % spindle length [mm]
ro=7.85 % material density
pF=300 % disruptive force pulsation
F0=136.0123 % the disruptive cutting forces modulus
t1=1
t2=2
t3=3
F01=F0*cos(pF*t1)
F02=F0*cos(pF*t2)
F03=F0*cos(pF*t3)
Aria=(pi*d^2)/4
c=sqrt(E/A)
x=0:50:300
for i=1
ppr1=(2*i-1)*((pi*c)/(2*L))
end
for j=2
ppr2=(2*j-1)*((pi*c)/(2*L))
end
for k=3
ppr3=(2*k-1)*((pi*c)/(2*L))
end
```

Determining the shapes functions for the three normal modes of vibration considered was achieved through establishment of a program in Matlab. Expression of computation for clamped - free spindle is inserted in the program as (Morar L., 2006):

$$X_i(x) = \frac{(2i-1)\pi}{2l} x \qquad (4)$$

It was drafted the following program to determine the shapes functions of spindle using a version of Matlab software.

```
E=2.1*(10^5) % Young's modulus [daN/cm2]
d=30 % spindle diameter [mm]
L=30 % spindle length [mm]
A=7.85 % material density
pF=300 % disruptive force pulsation
F0=136.0123 % the disruptive cutting forces modulus
t1=0.1 % time [sec]
t2=0.5
t3=1.0
F01=F0*cos(pF*t1)
F02=F0*cos(pF*t2)
F03=F0*cos(pF*t3)
Aria=(pi*d^2)/4
c=sqrt(E/A)
x=0:50:300
% Shape functions determination
for i=1
Fpr1=sin((2.*i-1)*((pi)/2*L).*x)
end
for j=2
Fpr2=sin((2.*j-1)*((pi)/2*L).*x)
end
for k=3
Fpr3=sin((2.*k-1)*((pi)/2*L).*x)
end
```

RESULTS AND DISCUSSION

It have obtained the following main shaft's own pulsations shown in Table 1.

Table 1

Spindle pulsations

SPINDLE MODES VIBRATIONS	OWN PULSATION p_i
VIBRATION MODE NR. 1 $i = 1$	p_1=8.5639
VIBRATION MODE NR. 2 $i = 2$	p_2=25,6918
VIBRATION MODE NR. 3 $i = 3$	p_3=42,8197

Spindle values pulsations determined by the author using Matlab software and presented in Table 1 corresponding to the first three normal modes of vibration lead to the following conclusions:

- the ratio pulsations is:

$$\frac{\omega}{p_1} > 1{,}4\,, \frac{\omega}{p_2} > 1{,}4\,, \frac{\omega}{p_1} > 1{,}4\,,$$

So, dynamic multiplier Ψ is smaller in absolute value than unity, indicating that the system is moving in the opposite direction of the disturbing of harmonic cutting force.

-it also establishes that disruptive force pulsation is different from values of spindle own pulsations, therefore there is no danger for resonance phenomenon.

In table number 2 are presented the values of shapes function determinated using numerical methods.

Actually, the functions represent the static displacements values in sectional area considered.

Table 2

Shape function values

Sections	0	50	100	150	200	250	300
Shape functions Mode 1	0	-0.0127	-0.0255	-0.0837	-0.0510	-0.2001	-0.1674
Shape functions Mode 2	0	-0.1746	-0.3493	-0.4330	-0.6985	-0.6003	-0.8659
Shape functions Mode 3	0	-0.0182	-0.0364	0.1273	-0.0729	-0.2730	0.2545

CONCLUSIONS

As a conclusion to this study can be considered the following:

For the harmonic cutting force there is no danger for resonance phenomena at the machine tool CNC. Regarding natural shapes function values forms is found that:

- for vibration mode 1 the maximum value is obtained in section x = 250 [mm];

- for vibration mode 2 the maximum value is obtained in section x = 300 [mm];

- for vibration mode 3 the maximum value is obtained in section x = 250 [mm];

Maximum function appears in section x=300[mm], corresponding to mode number 2.

Can be noticed that the maximum displacements corresponding to mode 1 represent 23,1 % from the maximum displacements corresponding to mode number 2.

And also, can be noticed that the maximum displacements corresponding to mode 3 represent 31,5% from the maximum displacements corresponding to mode number 2.

The graphs presented shapes functions variations for normal modes of vibration considered relative to the the spindle sections in figures 2, 3, 4.

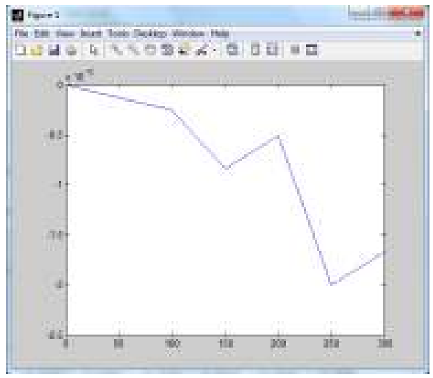

Fig. 2. Shapes functions variations - mode number 1

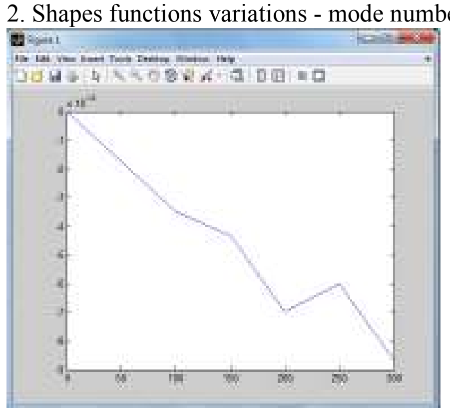

Fig. 3. Shapes functions variations - mode number 2

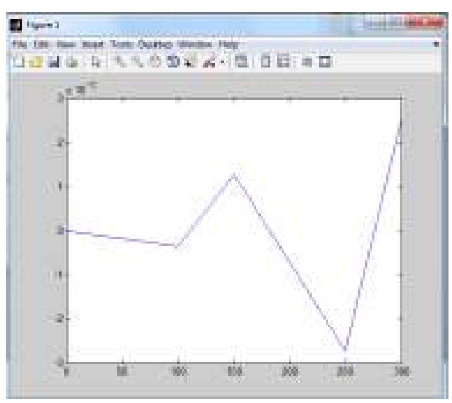

Fig. 4. Shapes functions variations - mode number 3

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