APPLICATION OF HYDROMECHATRONICS FOR STUDYING THE MOTION ACCURACY OF THE WORKING PARTS OF TECHNOLOGICAL MACHINES

Vladas Vekteris
Machine Building Department, Vibroacoustic Tests and Diagnostics Research Laboratory, Vilnius Gediminas Technical University, Vilnius
LT2009, Lithuania
e-mail: vekteris@me.vtu.lt

Mindaugas Jurevichius
Machine Building Department, Vibroacoustic Tests and Diagnostics Research Laboratory, Vilnius Gediminas Technical University, Vilnius
LT2009, Lithuania
e-mail: vekteris@me.vtu.lt

ABSTRACT

Hydromechatronic Programmable Load Equipment is used for workload simulation while testing technological machines to determine their dynamic characteristics. The structure and principles of operation of the created equipment are described and equations of balances of the hydrostatic bearings of the slider and boring bar and equations of motion of the boring bar have been formed in the article. Analytical and graphical dependences of motion of the slider and boring bar have been determined after entering digital data into the computer.

INTRODUCTION

Hydromechatronic Programmable Load Equipment (HMPLE) is used for technological equipment workload simulation in order to measure the accuracy of motion and parametrical reliability of the working parts thereof [1, 2]. When HMPLE is used the loading force is applied by noncontact method which enables to avoid any additional inadequate mechanical links between the working appliances (e.g. the table and spindle) and increases their reciprocal mobility. The loading force value is set by the control computer according to the following formula

$$F = F_0 + \sum_{i=1}^{n} F_i \sin \omega_i t,$$  \hspace{1cm} (1)

where $F_0$ – static component, $F_i$ – frequency of the i-th dynamic component, $\omega_i$ – amplitude.

The motion parameters of the working parts of technological machines are measured by programming variations of the loading force (1). The operational quality of the working parts of a technological machine is determined according to the measurement results.

TESTING STAND

The testing stand consists of the following basic parts: body, hydraulic station, vibrator, pressure controller, linear throttles, valves and connecting pipes.

Pressure controllers are used for changing the loading force by all three coordinates in accordance with the computer preset program, which controllers are based on the throttling hydraulic distributors and their opening control circuit. If necessary, a variable component of the loading force is given by means of a vibrator, which consists of the throttling hydraulic distributor with a distributing hydraulic cylinder and which is independently connected for each coordinate (x, y, z) through the valves.

DYNAMIC TESTS OF THE LOAD EQUIPMENT

The trough-shaped body (3) is fixed to the machine-tool table (Fig.1). The ends of the body feature two built-in hydraulic cylinders (4) with plungers (5) fixed to the slider (2), which can slide in the body by x-coordinate only within the table's travel range. Eight hydrostatic pockets are milled on the sides of the slider to center it in the body to prevent it from moving by y-coordinate. Further, there is a hole with four radial pockets in the centre of the slider to centre it in relation to the boring bar (1) vertically fixed in the machine-tool spindle with a hydrostatic step bearing. To create hydrostatic force in the pockets pressurized lubricant is fed through the linear throttles.

The following initial conditions were selected for the calculation: pressure $p_C$ in the right end of the hydraulic cylinder (4) is determined according to the lubricant flow balance equation for this end of the hydraulic cylinder:

$$\frac{p_n - p_C}{R_{1C}} + S_3\dot{\theta} + S_3x_2 = \frac{p_C}{R_{2C}},$$  \hspace{1cm} (2)
where: $p_H$ - lubricant pressure in the main line; $p_C$ - pressure inside the hydraulic cylinder; $R_{1C}$ and $R_{2C}$ - hydraulic resistance at the entry into, end exit from, the hydraulic cylinder; $S_3$ - inner space of the hydraulic cylinder; $V$ - machine-tool table (feed) velocity.

Slider and boring bar's radial bearing balance equations:

\[
\begin{align*}
\frac{p_H - p_1}{R_0} &= 2 \frac{p_1 - p_2 - p_3 - p_4 + RL_{12}^2(x_1 - x_2)}{R_{12} r_{12} r_{14}}; \\
\frac{p_H - p_2}{R_0} &= 2 \frac{p_2 - p_3 - p_4}{R_{23} r_{23} r_{34}} + \frac{S_1 J_1(t) - RL_{12}^2(x_1 - x_2)}{R_{12} r_{12} r_{14}}; \\
\frac{p_H - p_3}{R_0} &= 2 \frac{p_3 - p_4}{R_{23} r_{23} r_{34}} + \frac{S_1 J_1(t) + RL_{12}^2(x_1 - x_2)}{R_{12} r_{12} r_{14}},
\end{align*}
\]

(3)

where $p_i$ - pressure in the radial pockets ($i = 1, 2, 3, 4$); $R_i$ - output hydraulic resistance of the i-th pocket; $r_{ij}$ - hydraulic resistance of the lubricant flow between the i-th and j-th pockets; $S_2$ - cavity space of the hydraulic cylinder shaft of the vibrator; $R$ - radius of the boring bar; $L_E$ - effective length of the radial pocket; $x_1$ and $x_2$, $y_1$ and $y_2$ - boring bar and slider's velocity components; $l_x(t)$ and $l_y(t)$ - velocity of the hydraulic cylinder shaft of the vibrator transmitting pressure pulsation into the radial pockets; $R_0$ - output hydraulic resistance when the boring bar is centered in relation to the slider ($h(\phi) = h_0$).

After solving these equations the following was obtained:

displacement of the boring bar $\bar{x}_1 = \sqrt{x_1^2 + x_2^2}$,

displacement of the slider $\bar{x}_2 = \sqrt{x_2^1 + x_2^2}$.

Diagrams of these dependences are presented in Fig. 2.

**CONCLUSIONS**

1. HMPLE tests of technological machines have been created, methods of valuating the relationship of the table sliding and spindle rotating motions have been prepared, means of testing technological machines by program method and forecasting parametric reliability have been planned.

2. HMPLE analytical computation methods, which enable to simulate its operation under various conditions, have been prepared. Equations of motion of the slider and boring bar have been formed for determining the dynamic characteristics of a technological machine. After entering digital data into the computer analytical and graphical dependences of motion of the slider and boring bar have been determined.

**REFERENCES**
