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CALIBRATION CHARACTERISTICS AND EQUATIONS OF A DYNAMOMETER – DETERMINED WITH IEMI TYPE ELECTRONIC BRIDGE

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Abstract: *An important aspect in manufacturing is that of determining the characteristics of implied forces. It’s known that both in machining and cold pressing processes, the modulus of the forces has great influence on geometric precision and roughness of the obtained surfaces. The literature presents various types of dynamometers, but most of them are special or specialized ones. That’s why, was designed and realized a dynamometer for measuring forces, both in machining and cold pressing process. For proper use it is necessary to determine its calibration characteristics and equations.*

Key words: *dynamometer, calibration, characteristics, equation, force, experiment.*

1. INTRODUCTION

The most common used materials machining procedures are cutting (turning, milling, drilling, etc.) and cold pressing (punching, bending, drawing, etc.).

The formulae which enables the determination of machining forces (determined either theoretically, or theoretic-experimentally) are various and the choice of the one that provides values close to real ones involves both, thorough research and experience.

The measuring of machining forces, usually takes place in laboratory or production conditions – when the goal is that of determining its analytical expressions, or while machining – in continuous command of the technological system.

The most important specific element of a measuring system is the forces pick-up – the dynamometer.

There are a lot of machining forces dynamometers, but most of them are specific for a certain machining procedure. So, there was a serious need of designing and manufacturing a dynamometer, very sensitive and accurate, which could be used for forces’ measuring in various machining procedures.

A dynamometer [1, 3] is defined by its characteristics, some of the most important being: calibration curves, fidelity, rigidity, etc.

The systems for measuring of forces are calibrated by using an etalon dynamometers and mathematical processing of experimental obtained data, which depend on direction of force and mutual influence of signals.

The designing of elastic element – one of the most important part of dynamometer, has proved to be efficient if done with Finite Element Method (FEM) [2, 5]. The same method, can be used in order to establish the optimum position of transducers (resistive electric ones), so that the components of specific complex deformation are able to be separated (along each of the *Ox*, *Oy* and *Oz* axes).

2. EXPERIMENTAL STAND

The experimental stand used (dynamometer and IEMI electronic bridge), and its schematic representation [4], are presented by the figures below.

The direction of loading force is, successively, F_x (Fig. 1), F_y (Fig. 2) and F_z (Fig. 3) and its modulus increases

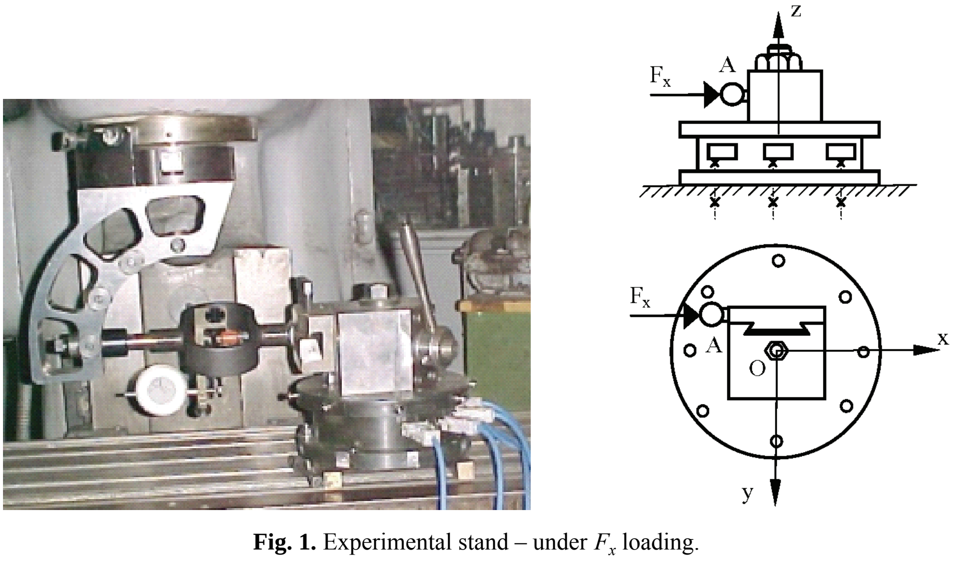

Fig. 1. Experimental stand – under F_x loading.

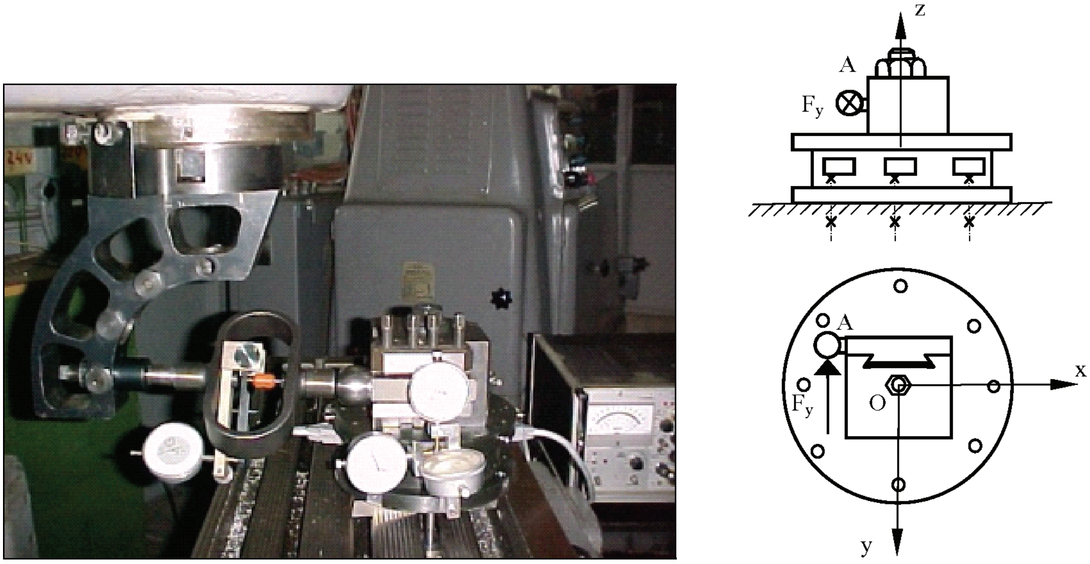

Fig. 2. Experimental stand – under F_y loading.

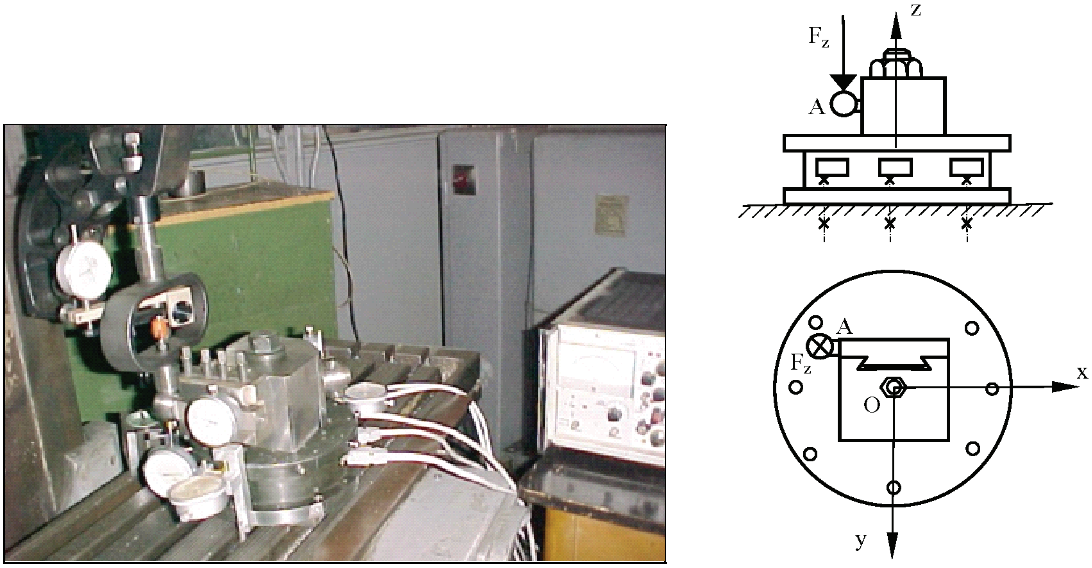

Fig. 3. Experimental stand – under F_z loading.

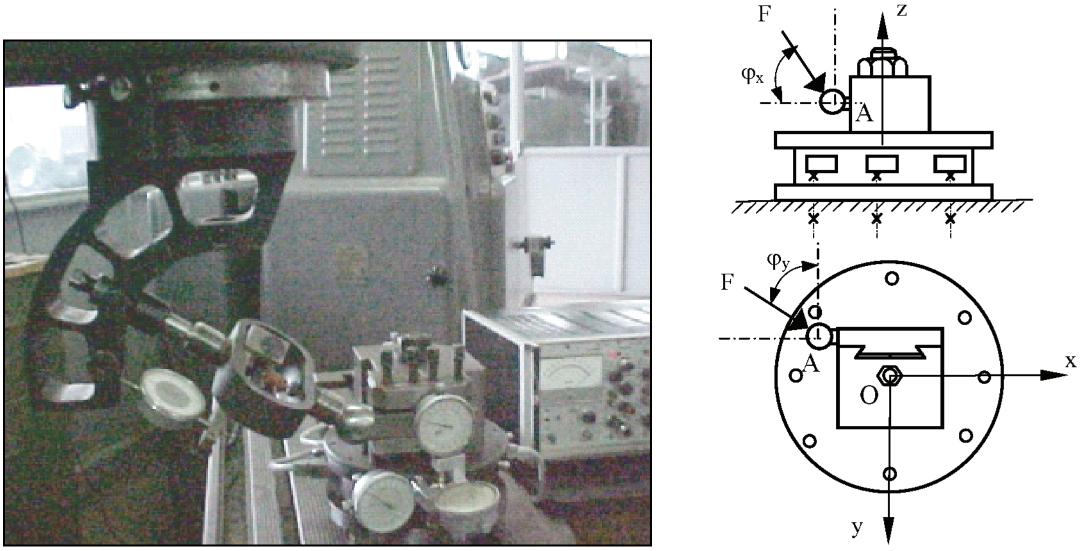

Fig. 4. Experimental stand – under F spatial loading.

and then decreases, step by step, in between the 0÷200 daN interval.

In order to calibrate, the forces application point is considered to be A.

Under the F_ρ ($\rho = x, y, z$) force, there are generated the $\varepsilon_{\rho x}$, $\varepsilon_{\rho y}$, $\varepsilon_{\rho z}$ signals at the strain-measuring bridge's channels connected to the dynamometer's exits.

The simultaneous action of F_x, F_y and F_z forces, on A point, is equivalent to the action of a spatial force (Fig. 4) on the same point, that generates the ε_θ ($\theta = x, y, z$) at the C_θ channel of the bridge.

3. EXPERIMENTAL DATA

An exemple of the experimental data obtained is presented in Table 1, the significance of the notations being:

i – the force increases step by step, from 0 to 200 daN;
d – the force decreases step by step, from 200 to 0 daN.

4. CALIBRATION CHARACTERISTICS

Using CurveExpert 1.3 program (a computer program allowing to determine regression equation coefficients and to plot the corresponding curves) there have been determined the regression linear equations coefficients.

The equations considered, pointing out the dependence relation of the relative deformation, $\varepsilon_{\rho\theta}$, to the application force, F_ρ (supposed to be linear) are as follows:

$$\varepsilon_{\rho\theta} = a_{\rho\theta} \cdot F_\rho + b_{\rho\theta}, \qquad (\rho = x, y, z \quad \theta = x, y, z). \qquad (1)$$

The coefficients' values are presented in Table 2 and some calibration characteristics are presented by Fig. 5, Fig. 6 (under F_x force) and Fig. 7, Fig. 8 (under F_z force).

Table 1

Experimental data

Load			**Deformation** $\varepsilon_{\rho\theta}$ **[μm/m]** ($\rho = x, y, z$, $\theta = x, y, z$)								
			F_x			F_y			F_z		
Direction	*F* [daN]	i, d	I	II	**m**	I	II	**m**	I	II	**m**
$\varepsilon_{\rho x}$ ($\rho = x, y, z$)	0	i	0	0	**0**	0	0	**0**	0	0	**0**
		d	–8	–10	**–9**	0	0	**0**	8	10	**9**
	50	i	–224	–220	**–222**	0	0	**0**	23	25	**24**
		d	–234	–236	**–235**	0	0	**0**	27	29	**28**
	100	i	–466	–468	**–467**	0	0	**0**	47	47	**47**
		d	–472	–474	**–473**	0	0	**0**	48	52	**50**
	150	i	–668	–670	**–669**	0	0	**0**	61	63	**62**
		d	–676	–678	**–677**	0	0	**0**	65	67	**66**
	200	i	–844	–846	**–845**	0	0	**0**	80	80	**80**
		d	–844	–846	**–845**	0	0	**0**	80	80	**80**
$\varepsilon_{\rho x}$ ($\rho = x, y, z$)	0	i	0	0	**0**	0	0	**0**	0	0	**0**
		d	0	0	**0**	–2	–4	**–3**	–6	–8	**–7**
	50	i	0	0	**0**	–20	–22	**–21**	–206	–208	**–207**
		d	0	0	**0**	–24	–26	**–25**	–217	–219	**–218**
	100	i	–4	–4	**–4**	–43	–45	**–44**	–496	–498	**–497**
		d	–5	–7	**–6**	–46	–48	**–47**	–496	–496	**–496**
	150	i	–4	–6	**–5**	–52	–54	**–53**	–680	–682	**–681**
		d	–6	–6	**–6**	–58	–58	**–58**	–702	–704	**–703**
	200	i	–5	–7	**–6**	–58	–60	**–59**	–876	–878	**–877**
		d	–5	–7	**–6**	–58	–60	**–59**	–876	–878	**–877**

Table 2

Coefficients' values

$\varepsilon_{\rho\theta} = a_{\rho\theta} \cdot F_\rho + b_{\rho\theta}$ $\rho = x, y, z, \quad \theta = x, y, z$					
F_ρ **[daN]**	$\varepsilon_{\rho\theta}$ **[μm/m]**	$a_{\rho\theta}$		$b_{\rho\theta}$	
		loading	**unloading**	**loading**	**unloading**
F_x	ε_{xx}	4,274	4,228	13,200	25,000
	ε_{xy}	0,202	0,188	5,200	2,000
	ε_{xz}	0,034	0,036	-0,400	3,782
F_y	ε_{yx}	0	0	0	0
	ε_{yy}	4,148	4,122	3,400	15,200
	ε_{yz}	0,300	0,290	5,400	9,400
F_z	ε_{zx}	0,396	0,360	3,000	10,600
	ε_{zy}	0,370	0,316	1,600	11,600
	ε_{zz}	4,456	4,450	6,800	15,200

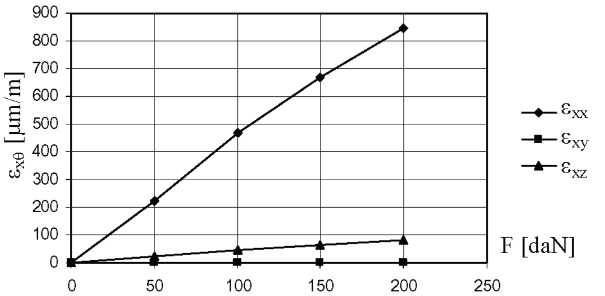

Fig. 5. Calibration characteristics – loading under F_x force.

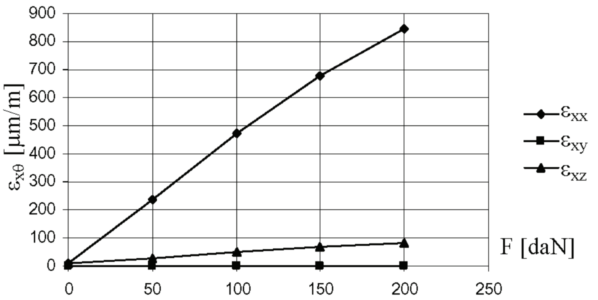

Fig. 6. Calibration characteristics – unloading under F_x force.

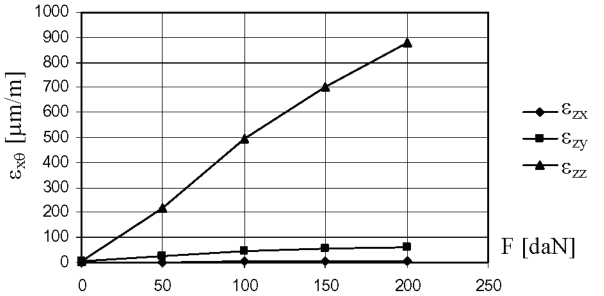

Fig. 7. Calibration characteristics – loading under F_z force.

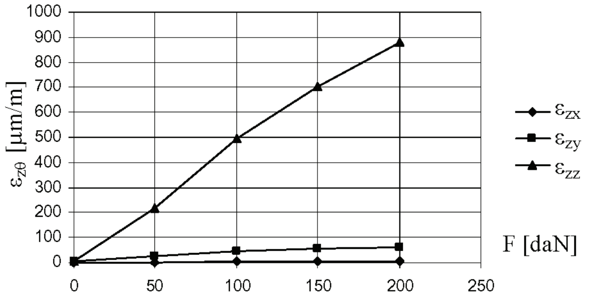

Fig. 8. Calibration characteristics – unloading under F_z force.

5. CALIBRATION EQUATIONS

As a result of the above mentioned, there have been obtained the calibration equation, as follows:

- in loading

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} 0,2341 & 0,0015 & -0,0209 \\ -0,0113 & 0,2425 & -0,0191 \\ -0,0010 & -0,0163 & 0,2859 \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_x - 16,2000 \\ \varepsilon_y - 10,2000 \\ \varepsilon_z - 11,8000 \end{bmatrix} \quad (2)$$

- in unloading

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} 0,2366 & 0,0014 & -0,0192 \\ -0,0107 & 0,2438 & -0,0164 \\ -0,0012 & -0,0159 & 0,2860 \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_x - 35,6000 \\ \varepsilon_y - 28,8000 \\ \varepsilon_z - 28,3820 \end{bmatrix} \quad (3)$$

where: F_x, F_y, F_z represent machining force's components [daN]; ε_x, ε_y, ε_z – relative strain [μm/m].

6. CONCLUSION

a. In order to obtain the calibration characteristics and equations of a designed dynamometer, there were carried out a lot of experiments whose results pointed out its good behaviour (the largest deformations registered were along the same direction as the forces).

b. There have been plotted the calibration characteristics and the calibration equations determined, both in loading (the force increases) and unloading (the force decreases). The values considered for forces' modulus varies from 0 to 200 daN, with an increment of 50 daN.

c. Because of the dynamometers calibration characteristics and equations, thus determined, it is possible to determine each of machining force components.

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