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Dynamics Analysis of the Starting and Braking of the Table of CNC Machine Tool

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ABSTRACT

The aim of the paper is a dynamic analysis of the starting and braking of the table of a numerically controlled CNC machine tool during idle motion. The experimental test was performed on the vertical table of the FV580A machining centre using the Phantom v1610 high-speed vision camera. The dynamics characteristics of the table movement were registered and the dynamics estimates of the movement were determined. The influence estimation of the parameters of the machine tool table motion on the value of the determined estimates was made. The results of measurements were discussed and in order to minimise disturbances, the guidelines were formulated. The test results were summarised and discussed in the form of charts and tables. The directions of further research in the discussed subject area were also defined.

Keywords: dynamics analysis, vision systems, table of CNC machine tool, feed rate.

INTRODUCTION

CNC cutting machines constitute a very important and widely used group of machines in the industry. The current trends related to obtaining better dimensional and shape accuracy of manufactured parts, with the continuous increase of their production efficiency, imply the need to use precise machine tools [1]. The manufacturers of cutting machines have to improve the solutions used so far and to ensure the possibility of using grater technological parameters, including rotational speed and the related cutting speed as well as feed rate. At the same time, the machining conditions represented by the technological parameters are strongly related to the geometric accuracy and the surface condition of the machined parts. For this reason, it is justified to study the dynamics phenomena affecting the machine tool behavior and manufacturing accuracy [2]. Continous improvement and development of machine tools and devices are desired due to enable to the cost-effective production of high-quality parts with high productivity and reliability [3, 4, 5].

Numerically controlled machines have a different structure. Machine tools with a movable table are milling machines and vertical machining centres. The dynamics of the table is associated with a number of processes. CNC machine tables can move in three, four or five axes [6, 7].

Milling machines and machining centres are complex mass-dissipative-elastic systems, which include many modular executive units that fulfill strictly defined tasks. The basic ones include: bodies, guides, drives as well as measurement and control systems, construction modules that independently performed individual movements or activities. Such modules usually have their own drive and the interaction in the machining process results from the operation of the CNC system connected with electrical control signals with individual modules. Modular construction and unification of design solutions facilitate the creation of various variants of machine tools tailored to the customer's requirements, as well as obtaining variability of production tasks in terms of mechanical construction [8, 9, 10].

The machine table movements result from the systems used to convert electrical energy into mechanical energy. The dynamics of the systems cause the table movement in the given directions and it is possible to create errors in the machine tool systems, so an important issue in modern industry that produces complex details is the minimisation of errors. Constantly control and reduce the possibility of errors are required in precise processes. Apart from the selection of appropriate tools, parameters and machining strategies, it is significant to pay attention to the control of individual modules and parts that may cause errors. The research shows that in the construction of machine tool tables, the formation of errors largely depends on the linear guides, which are responsible for the table movements in individual axes. The guide is an important element in the construction of the machine tool, but it has the movement errors, the occurrence of which affects the quality of the machining process [11, 12, 13]. It is worth noting that the friction process in such systems and cutting forces during machining may interfere with the work of the machine tool and negatively affect its accuracy [14]. The simplified linear dynamics diagram of a conventional feed drive is shown in Figure 1.

The various mechanical transmissions also play an important role in the construction of the machine tool. There are many types of mechanical transmissions and the parts often, included in the structure of the system, have strictly defined tolerances and small dimensions. Therefore, their proper quality control is important during the production process of such elements. The research related to mechanical transmissions shows that poor quality of the gears may cause errors in subsequent systems [15, 16, 17].

Through the diagnostics of the machine tools, it is possible to recognise, whether the machine tool has errors greater than the permissible errors in the table movements. Appropriate diagnostics can lead to the elimination or minimisation of the resulting movements errors. The measurement method that will be fast and precise is also important. One of such methods is the use of a simple conventional method, which is measurement with a laser interferometer [18, 19].

The cooperation of the control system can be especially noticed by starting and braking of the machine table. How the operation of individual units translates into movements of the table from the full stop position and braking the table to a complete stop may be another factor affecting the quality of the produced detail. Particularly during manufacturing parts that have close tolerances and high manufacturing accuracy, attention is paid to every aspect causing non-conformities. The current trends in the development of numerically controlled machines lead to an increase in the accuracy of machine tools in each field [20, 21].

METHODOLOGY

The methodology of experimental research included the dynamics analysis of the starting and braking moments of the CNC machine table. To achieve the aim of the study, different approaches and the type of work methods were analysed as well as on the basis of which the test conditions were defined. For the most appropriate method, the best possible equipment was taken into account. A vertical machining centre FV580A, shown in Figure 2, was used for the tests.

A comprehensive study of the dynamics of the machine tool is presented in Figure 3, which describes the relations between the real object, its behavior during work and experimental

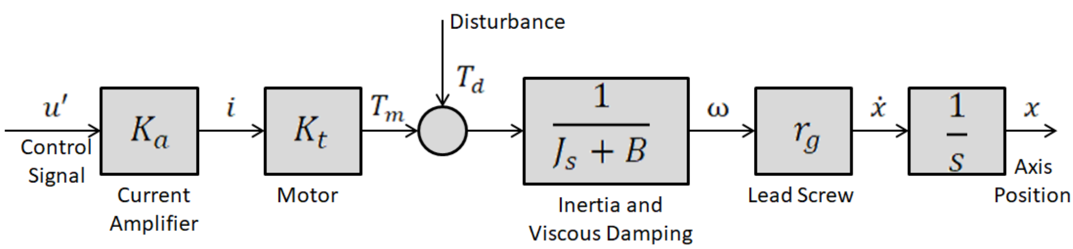

Fig. 1. A simplified diagram of the linear dynamics of a typical feed drive [22]

measurements as well as the determined indicators of the dynamics quality of the machine on the basis of empirical calculations and modeling.

The FV580A machine tool was subjected to diagnostics. To identify the parameters of the movement of the working table of the machine tool, a special high-speed vision camera, presented in Fig. 4a, was used. It allows to record photographs in high resolution of high-speed movements. Additionally, it is able to record the observed image at a speed of 16 Gpixels per second. In conversion it means that for the full recorded resolution of 1 Mpixel it is possible to register 160,000 frames in one second, while for the reduced speed even up to 1,000,000 frames/sec [23].

Additionally, the Nikon ED AF NIKKOR 80–200 mm f/2.8D lens shown in Fig. 4b, was used for the Phantom camera. The application of

Fig. 2. Vertical machining centre FV580A with measuring equipment

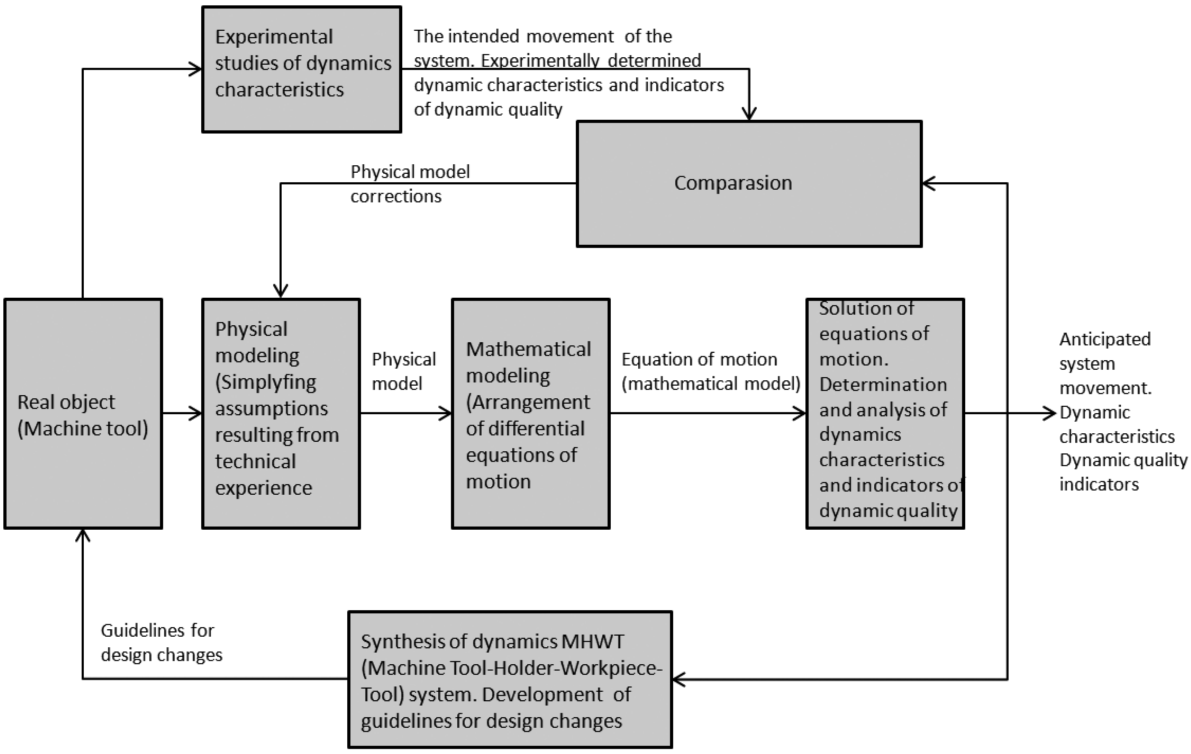

Fig. 3. Comprehensive study of the dynamics of the machine tool system [24]

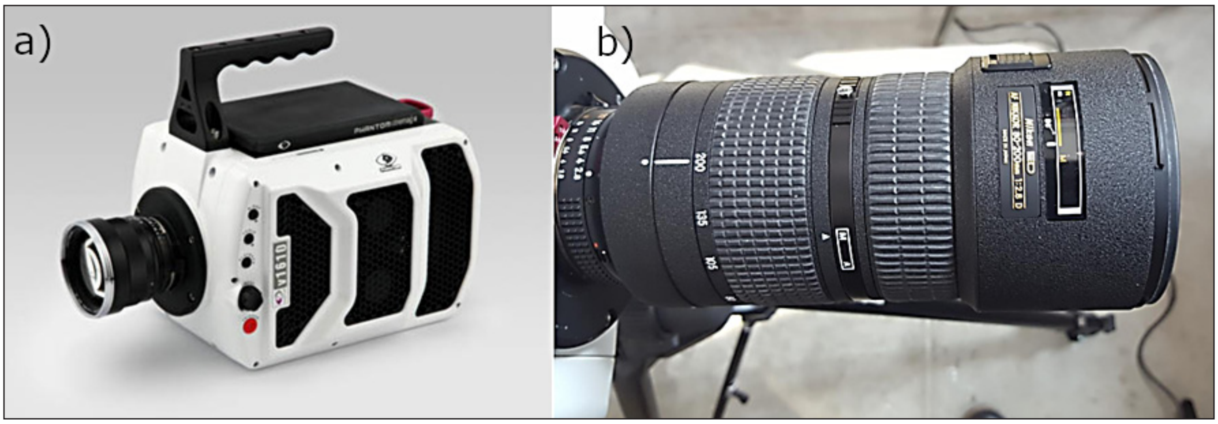

Fig. 4. Vision system used in experimental research: a) camera Phantom Ultra-High-Speed v1610, b) lens Nikon Nikkor AF 80–200 mm f/2.8D

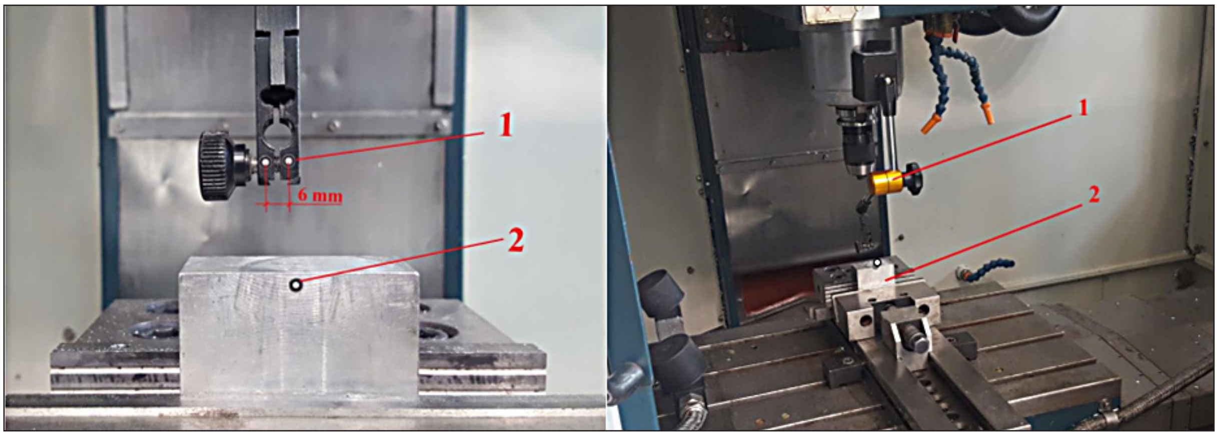

Fig. 5. Test stand: 1 - precise stand, 2 - sample

above-mentioned lens allows for high of image quality in the frame centre. The lens was chosen especially for experiment. The advantage of this choice was also that the lens is ideal for working with objects with a strongly intensified luminous flux. In the experiment under consideration, such type of a beam light was directed at the tested milling table [25].

The complete test stand, in addition to the above-mentioned research means, additionally consisted of a Manfrotto MN117B tripod, on which the camera was placed, as well as additional lighting in the form of two Helder C12 halogen lamps by Helder Systemlight was used.

In order to properly preparation the stand for experimental research a program that implements a specific trajectory of table movements was developed. The experiment was performed with the table idle motion. The table linear movement path was defined in the program and was assumed at the level of L = 100 mm. A sample in the form of a cube was mounted in the vice reference point for measurements and were glued to the sample. Additionally, the reference points were also glued on a precision stand mounted with a magnetic base on the headstock (Fig. 5).

The camera was set at a distance of 1 m from the machine tool table and the axis of lens was

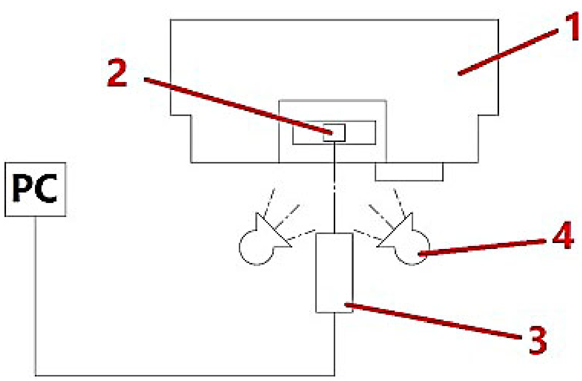

Fig. 6. Scheme of test stand: 1 - vertical machining centre table, 2 - sample with reference points, 3 - camera, 4 - additional lighting

between reference points of sample and precise stand. The scheme of the test stand is presented in the diagram in Figure 6.

The measurement results in the form of recording of the sequence of milling table movements were saved on the computer. A special PCC software was used for the analysis of the recordings. It is possible to adjust the camera by set its parameters. A fragment of the program is presented in Figure 7.

The Tema Motion Test program was used to analyse the results. It is an advanced software that enables movements analysis based on visual information. It is possible to analyse movements based on characteristic points, because of a number of algorithm used. This program enable to measure object displacement, velocity, acceleration, etc. The Tema Motion Test interface is shown in Figure 8.

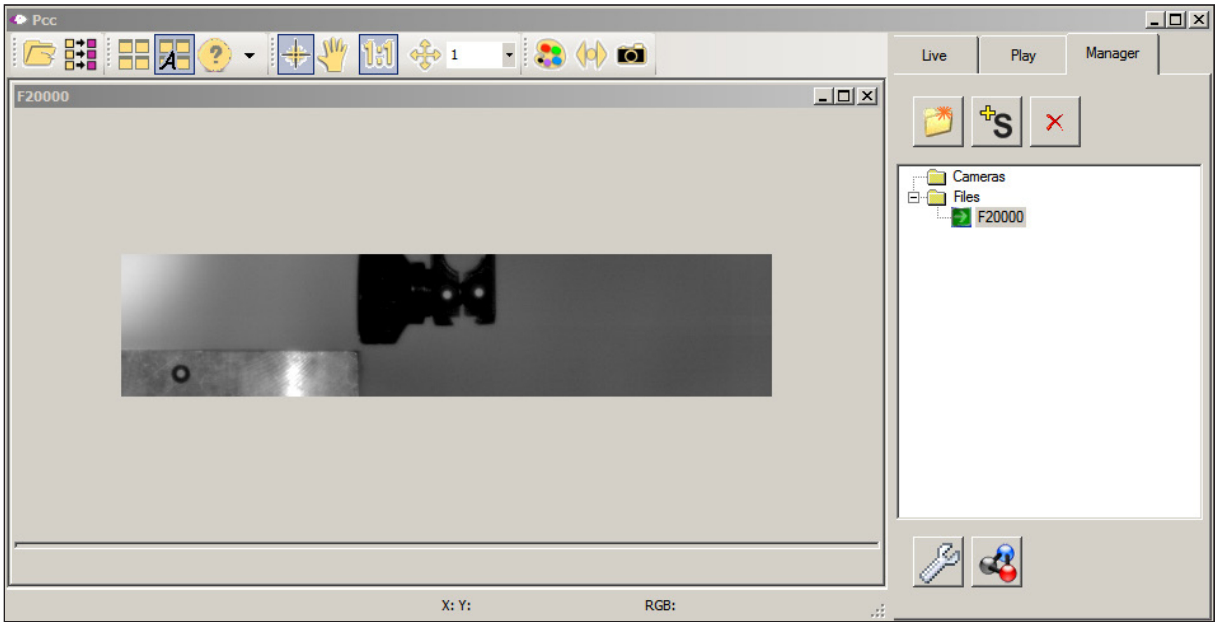

Fig. 7. PCC software used for camera settings and recording

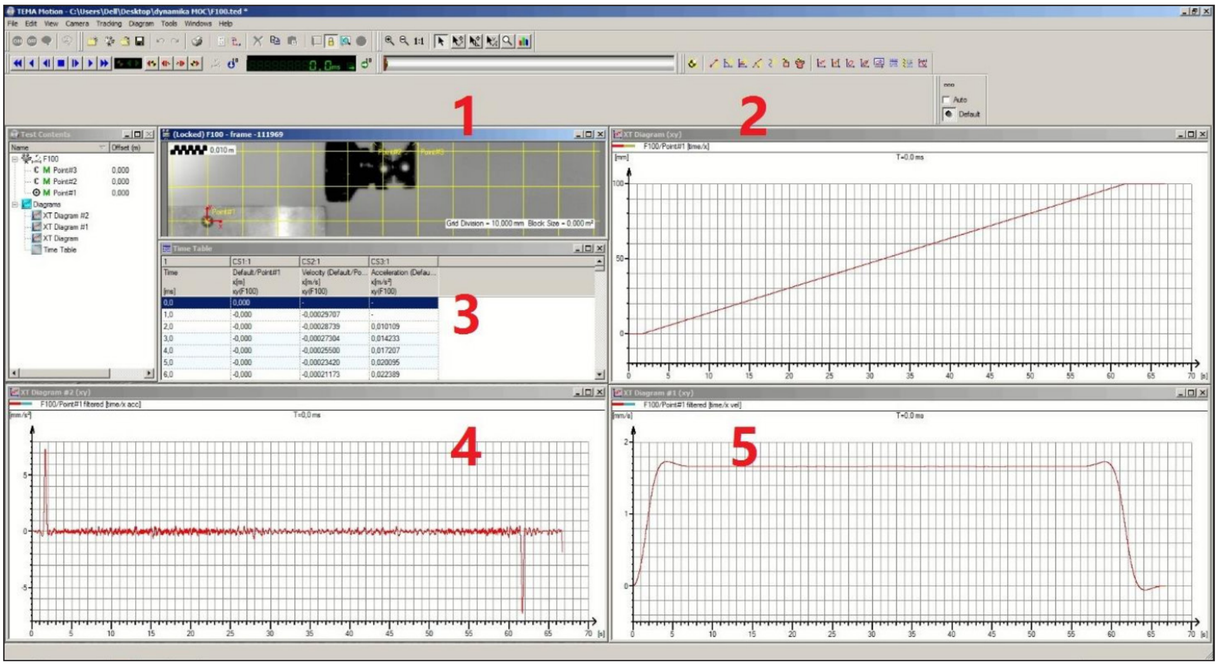

Fig. 8. Tema Motion Test interface during dynamics analysis: 1 - window of the analysed displacement, 2 - graph of displacement as a function of time, 3 - table of values from the graphs, 4 - graph of acceleration as a function of time, 5 - graph of velocity as a function of time

The experiment consisted in video recording of the table movement of a CNC machine tool for 16 different feed rates. The test was performed during idle motion. For each of the set feed rate, the recorded image was loaded into the Tema Motion test program and analysed. Finally, the time courses of displacement, velocity and acceleration of the tested point were obtained.

The signal was filtered in the Tema Motion Test program to obtain correct results. Lack of filtration leads to illegible graphs of the real waveforms. The software allows the use of three types of filters: FIR filter, CFC filter, and spline filter. For the analysis of the results, the CFC filter was used, which did not affect the graph of the object displacement as a function of time, which was linear in each of the analysed cases. The CFC filter is a 4^{th} order phaseless Butterwoth filter. The Butterwoth filter, compared to other filters, has the flattest course for the amplitude characteristic in the bandwidth. Therefore, at the end of its passband, the curve breaks down. Using this filter, the most important goal is to obtain the maximum flatness for the amplitude characteristics. For zero frequency, the characteristic starts as flat as possible and the bending occurs only at the cut-off frequency (it is usually 3 dB) [26]. The use of signal filtering also required setting the appropriate value. The defined value of the filter parameter determines the frequency of its cut-off, therefore, for different feed rates, the cut-off frequency of the CFC filter was corrected.

RESULTS

The obtained results for 16 different feed rates of the linear displacement of the milling machine table allowed for a comparative analysis. The main feature of the obtained time courses was the fact that for small values of the table feed rates, the characteristic spike was occured on the graph of the displacement velocity as a function at the moment of starting and braking. The spike is so-called peak in the main phase of movement (after the starting), this movement was stabilised. The same noticeable peak appears at the moment of speed reduction (deceleration), until the linear motion was stopped. At greater feed rates of the idle running, the rapid transition during starting and braking was reduced. The changes of velocity and acceleration at different feed rates were presented in the Figures 9–11. The charts are shown successively for the feed v_{f1} = 100 mm/min, v_{f6} = 2,000 mm/min and v_{f16} = 20,000 mm/min. The characteristics in Figures 9–11 showed the nature of changes in displacement, which was marked by red colour, velocity by green and movement accelerations by blue. The acceleration characteristics with clearly reflected dynamics motion features, represented by unambiguously and clearly defined acceleration peaks in the initial phase of motion and deceleration in the braking phase are especially significant. Figure 9 presents the nature of changes in the dynamics of motion registered for the base feed rate v_{f1} = 100 mm/min. Figure 10 shows the nature of changes in the *Y* displacement, velocity v_y and acceleration a_y as a function of time

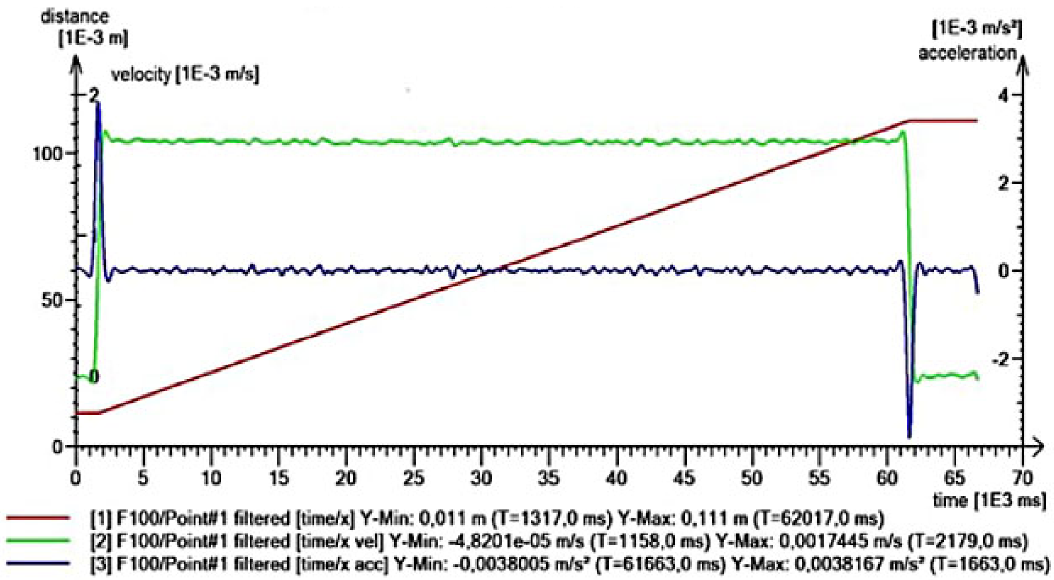

Fig. 9. Nature of *Y* displacement changes, speed v_y and acceleration a_y as a function of time, for the linear movement of the milling machine table with feed rate v_{f1}= 100 mm/min

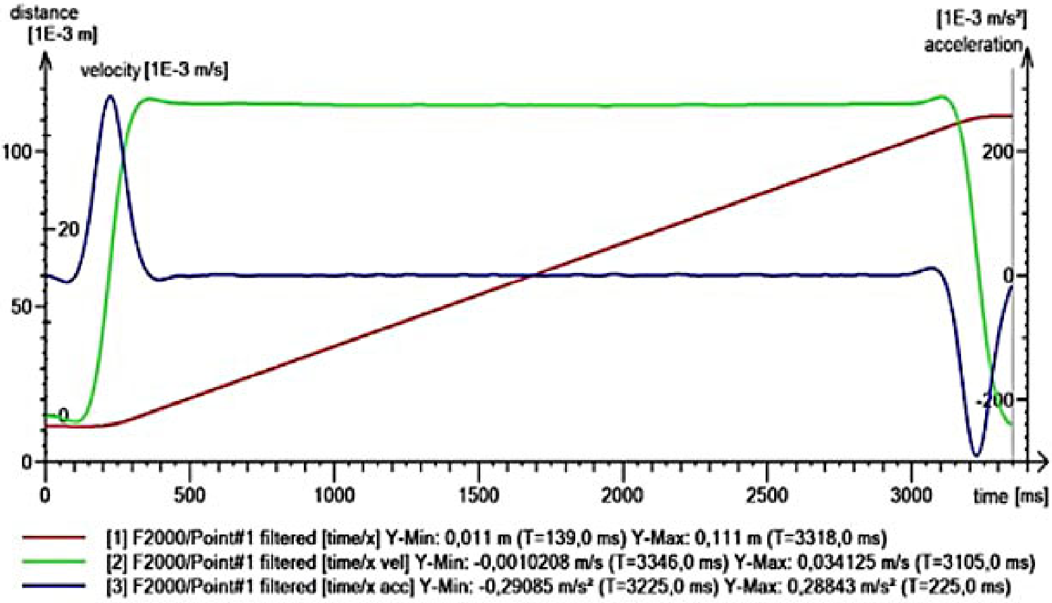

Fig. 10. Nature of Y displacement changes, speed v_y and acceleration a_y as a function of time, for the linear movement of the milling machine table with feed rate v_{f6}= 2000 mm/min

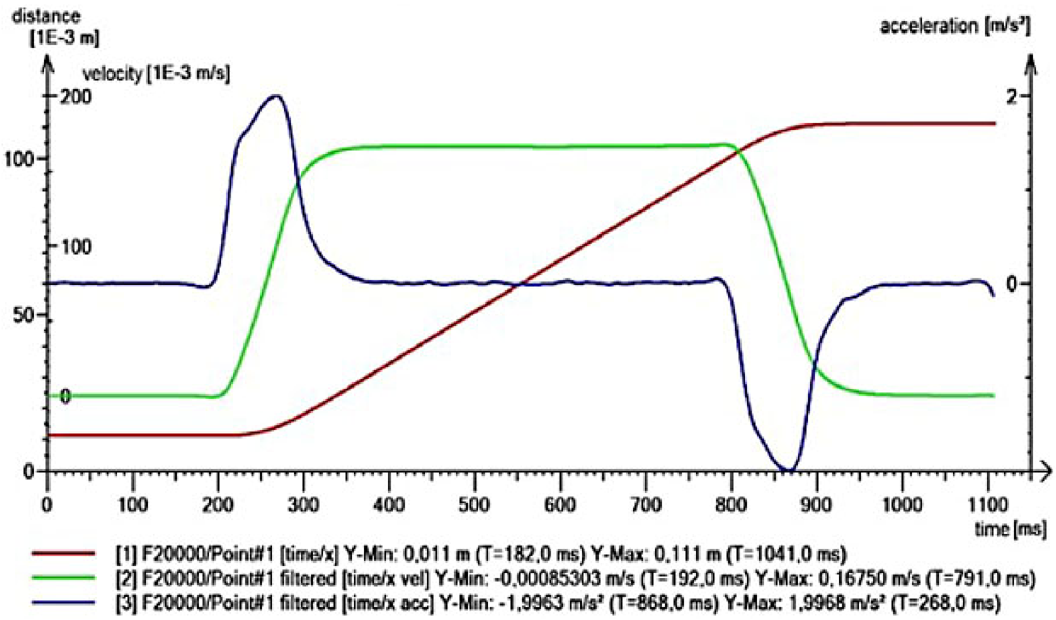

Fig. 11. Nature of Y displacement changes, speed v_y and acceleration a_y as a function of time, for the linear movement of the milling machine table with feed rate v_{f16}= 20,000 mm/min

t, for the linear movement of the milling machine table with the feed rate v_{f6} = 2000 mm/min, and Figure 11 presents the nature of changes in the dynamics of the movement along the Y axis for speed base feed of v_{f16} = 20,000 mm/min.

The above-mentioned characteristic peaks resulted from the dynamics of movement at the moment of changing the nature of the movement and changes in its speed, as well as also from physical phenomena accompanying the movement at low speeds, such as the stick-slip phenomenon.

Analysing the graphs of the time courses, it can be noticed that at the time of start, the recorded values of speed and acceleration had the positive values, while the value of the linear displacement increased in relation to them with a delay up to several hundred milliseconds. Depending on the given feed speeds, this difference ranged from about 800 ms for the speed v_{f1} = 100 mm/min to 35 ms for v_{f16} = 20,000 mm/min. This phenomenon occured because the energy supplied by the servo-drive was not enough large to overcome static friction. The graphs of displacement, velocity and acceleration in a function of time were generated using the Tema Motion Test software. On the characteristics obtained, a legend from the time courses were displayed, from which information about characteristic points were read. All such values for each of the analysed feed speeds are presented in Table 1.

Due to the possibility of exporting the values read from the recorded video file, position, velocity and acceleration data for each point were transferred to the MS Office Excel program. It allowed for the reconstruction of all the graphs presented in the program and a more detailed analysis of individual characteristic points was done. The nature of speed changes and its amplitude-time parameters for different table v_f was presented in Figure 12.

Table 2 summarises the results of the points characteristic for the analysed rates of feed movements of the milling machine table. It was visible that it was not possible to read all the values, because of some of the tested table speeds, the speed function changed much more regularly.

On the basis of the data imported to the MS Office program, it is possible to determine the values of speed and acceleration at the time of starting and braking of the milling machine table. All dependencies were calculated for all tested feed rates. The results were calculated using the formulas (1)–(15) presented below as an example for the given feed rate of the milling machine table v_{f4} = 1,000 mm/min. Table 3 presents the successive feed rates given to the table for idle running.

$$V_{s1,000} = \frac{\Delta s}{\Delta t} \quad (1)$$

$$\Delta s = s_1 - s_0 \quad (2)$$

$$\Delta t = t_1 - t_0 \quad (3)$$

$$V_{s1,000} = \frac{s_1 - s_0}{t_1 - t_0} \quad (4)$$

$$a_{s1,000} = \frac{\Delta V_{s1,000}}{\Delta t} \quad (5)$$

$$\Delta V_{s1,000} = V_{s1,000_1} - V_{s1,000_0} \quad (6)$$

$$\Delta t = t_1 - t_0 \quad (7)$$

$$a_{s1,000} = \frac{V_{s1,000_1} - V_{s1,000_0}}{t_1 - t_0} \quad (8)$$

where: $V_{s1,000}$ - the average speed obtained by the milling table when starting at a given feed rate v_f= 1,000 mm/min;

Table 1. Summary of the results of the points characteristic for the analysed rates of feed movements of the milling machine table

No.	v_f [mm/min]	T [s]	Filtr CFC	L [m]	V_{max} [m/s]	T_{Vmax} [s]	a_{min} [m/s²]	T_{amin} [s]	a_{max} [m/s²]	T_{amax} [s]
1	100	62.0	0.5	0.1	0.0017	2.17	-0.0038	61.66	0.0038	1.66
2	250	24.8	0.8		0.0043	0.92	-0.0147	24.62	0.0149	0.61
3	500	12.3	2		0.0085	0.37	-0.0617	12.22	0.0648	0.22
4	750	8.3	2		0.0012	8.10	-0.0937	8.23	0.0955	0.24
5	1,000	6.3	2		0.0171	6.12	-0.1257	6.26	0.1280	0.26
6	2,000	3.3	2.5		0.0341	3.10	-0.2908	3.22	0.2884	0.22
7	3,000	2.4	4.5		0.0507	2.04	-0.5642	2.12	0.5652	0.12
8	4,000	1.9	4		0.0676	1.62	-0.7205	1.70	0.7247	0.21
9	5,000	1.67	5		0.0843	1.41	-0.9567	1.49	0.9584	0.29
10	6,000	1.36	8		0.1007	1.04	-1.1831	1.12	1.1844	0.12
11	7,000	1.33	8		0.1173	1.02	-1.3887	1.09	1.3794	0.24
12	8,000	1.14	10		0.1337	0.08	-1.5936	0.09	1.6025	0.21
13	9,000	1.01	10		0.1504	0.07	-1.7783	0.08	1.7855	0.19
14	10,000	1.13	10		0.1672	0.08	-1.9915	0.09	2.0235	0.03
15	15,000	0.94	10		0.1673	0.06	-1.9937	0.07	2.0075	0.01
16	20,000	1.04	10		0.1675	0.08	-1.9963	0.08	1.9968	0.02

Note: v_f [mm/min] – feed rate, T [s] – displacement time from starting to braking, L [m] – path traveled through the milling machine table, v_{max} [m/s] – max speed, $T_{V_{max}}$ [s] – time during which the maximum speed was recorded, a_{min} [m/s²] – minimum recorded acceleration, $T_{a_{min}}$ [s] – time during which the minimum acceleration was recorded, a_{max} [m/s²] – maximum recorded acceleration, $T_{a_{max}}$ [s] – time during which the maximum acceleration was recorded.

Table 2. Summary of the results for the analysed rates of feed movements of the milling machine table

No.	Feed rate v_f [mm/min]	Feed rate v_f [m/s]	Time from start to braking *T* [s]	τ_1 [s]	τ_1' [s]	*h* [m/s]	a_1 [m/s]	τ_2 [s]	τ_2' [s]	a_2 [m/s]	*h*' [m/s]
1	100	0.0016	62	0.767	0.425	0.001745	0.000075	0.595	0.831	0.000068	0.001745
2	250	0.0042	24.8	0.523	0.672	0.004343	0.000156	0.228	0.524	0.000108	0.004304
3	500	0.0083	12.3	0.24	0.13	0.008573	0.000236	0.165	0.253	0.000245	0.008557
4	750	0.0125	8.3	0.249	0.144	0.001286	0.000307	0.13	0.259	0.000329	0.012858
5	1,000	0.0167	6.3	0.209	-	0.016687	-	0.097	0.22	0.000338	0.016928
6	2,000	0.0333	3.3	0.224	0.194	0.033909	0.000584	0.155	0.213	0.000811	0.034125
7	3,000	0.0500	2.4	0.184	-	0.05006	-	0.056	0.249	0.000761	0.050788
8	4,000	0.0667	1.9	0.18	0.058	0.066825	0.000161	0.077	0.207	0.001045	0.067659
9	5,000	0.0833	1.67	0.276	-	0.08339	-	0.076	0.26	0.001164	0.084378
10	6,000	0.1000	1.36	0.192	-	0.099857	-	0.037	0.235	0.000921	0.10078
11	7,000	0.1167	1.33	0.226	-	0.11654	-	0.036	0.246	0.00084	0.11732
12	8,000	0.1333	1.14	0.187	-	0.13293	-	0.032	0.248	0.00063	0.13376
13	9,000	0.1500	1.01	0.199	-	0.14964	-	0.032	0.195	0.00067	0.15049
14	10,000	0.1667	1.13	0.182	-	0.16599	-	0.042	0.255	0.00087	0.16726
15	15,000	0.2500	0.94	0.184	-	0.16598	-	0.033	0.246	0.0009	0.16736
16	20,000	0.3333	1.04	0.208	-	0.1662	-	0.053	0.261	0.00098	0.1675

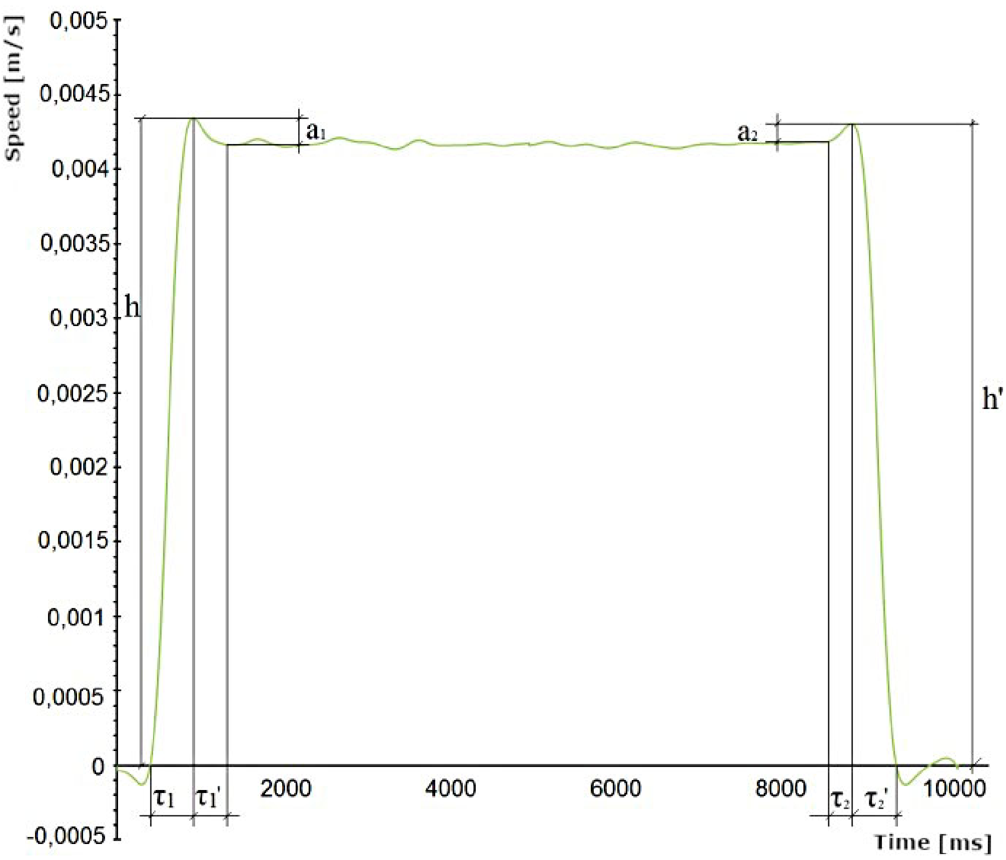

Fig. 12. Graph of velocity changes and its time-amplitude parameters, where: τ_1 – time from start to reaching the maximum speed value, τ_1' – time from reaching the maximum speed value to the achievement of the acceleration constant value, τ_2 – time from the constant acceleration value to the start of the beginning of the braking moment, τ_2' – time from the start of braking to complete deceleration, *h* –value of maximum speed at start, *h'* – value of the maximum speed before the start of braking, a_1 – acceleration amplitude value, a_2 – braking amplitude value

Table 3. Calculated results of speed and acceleration during starting and braking of the milling table

No.	Feed rate v_f [mm/min]	Feed rate v_f [m/s]	Avarage speed v_s during starting [m/s]	Avarage speed v_h during braking [m/s]	Avarage acceleration a_s during starting [m/s²]	Avarage acceleration a_h during braking [m/s²]
1	100	0.0016	0.0006	0.0012	0.0004	-0.0013
2	250	0.0042	0.0027	0.0018	0.0025	-0.0033
3	500	0.0083	0.0042	0.0039	0.0173	-0.0156
4	750	0.0125	0.0080	0.0077	0.0325	-0.0301
5	1,000	0.0167	0.0096	0.0103	0.0803	-0.0503
6	2,000	0.0333	0.0179	0.0188	0.0804	-0.0889
7	3,000	0.0500	0.0317	0.0198	0.1679	-0.0797
8	4,000	0.0667	0.0389	0.0289	0.2164	-0.1401
9	5,000	0.0833	0.0658	0.0269	0.2163	-0.1035
10	6,000	0.1000	0.0681	0.0297	0.3563	-0.1267
11	7,000	0.1167	0.0841	0.0367	0.3719	-0.1499
12	8,000	0.1333	0.0872	0.0309	0.4471	-0.1062
13	9,000	0.1500	0.1024	0.0567	0.4997	-0.2922
14	10,000	0.1667	0.1104	0.0535	0.6104	-0.2391
15	15,000	0.2500	0.1093	0.0487	0.5696	-0.1982
16	20,000	0.3333	0.1207	0.0463	0.5834	-0.1788

s_1 – the path of the table when a constant speed is reached;
s_0 – the path of the table at the beginning of the movement;
t_1 – time during which the table when the constant speed was reached;
t_0 – time the table started to move;
$a_{s1,000}$ – the average acceleration obtained by the mill table when starting at a given feed rate v_f=1,000 mm/min;
$V_{s1,0001}$ – table speed obtained after reaching the average speed;
$V_{s1,0000}$ – initial speed at the time of start.

$$V_{s1,000} = \frac{\Delta s}{\Delta t} \tag{9}$$

$$\Delta s = 0.002\, m - 0\, m = 0.002\, m \tag{10}$$

$$\Delta t = 410\, ms - 202\, ms = 208\, ms = 0.208\, s \tag{11}$$

$$V_{s1,000} = \frac{0.002\, m}{0.208\, s} = 0.0096 \frac{m}{s} \tag{12}$$

$$a_{s1000} = \frac{\Delta V_{s1000}}{\Delta t} \tag{13}$$

$$\Delta V_{s1,000} = 0.016687\, \frac{m}{s} - 0\, \frac{m}{s} = 0.016687\, \frac{m}{s} \tag{14}$$

$$a_{s1,000} = \frac{0.016687\, \frac{m}{s}}{0.208\, s} = 0.08\, \frac{m}{s^2} \tag{15}$$

Similar calculations were made for the braking torque of the milling machine table. The speed and acceleration of braking were described as: $V_{h\text{-}n}$ and $a_{h\text{-}n}$ where n – feed rate.

On the basis of Table 3 the graphs were prepared concerning changes in the average speed and acceleration of the table of the tested vertical machining centre. Figure 13 shows the nature of changes in average starting and braking as a function of the milling table feed rate v_f, while Figure 14 presents the mean starting and braking accelerations as a function of the milling table feed rate v_f.

The presented graphs show the nature of changes that take place in relation to the average values of speed and acceleration during the starting and braking of the milling machine table. It can be conducted that the average speed during the start and stop of the linear displacement of the milling machine was comparable in terms of the value for the speed from v_{f1} to v_{f6}. Subsequent higher feed rates resulted in their average braking speed was about half of the value of the average starting speed. In the case of acceleration for each of the tested feed speeds, the starting acceleration was greater than the braking acceleration.

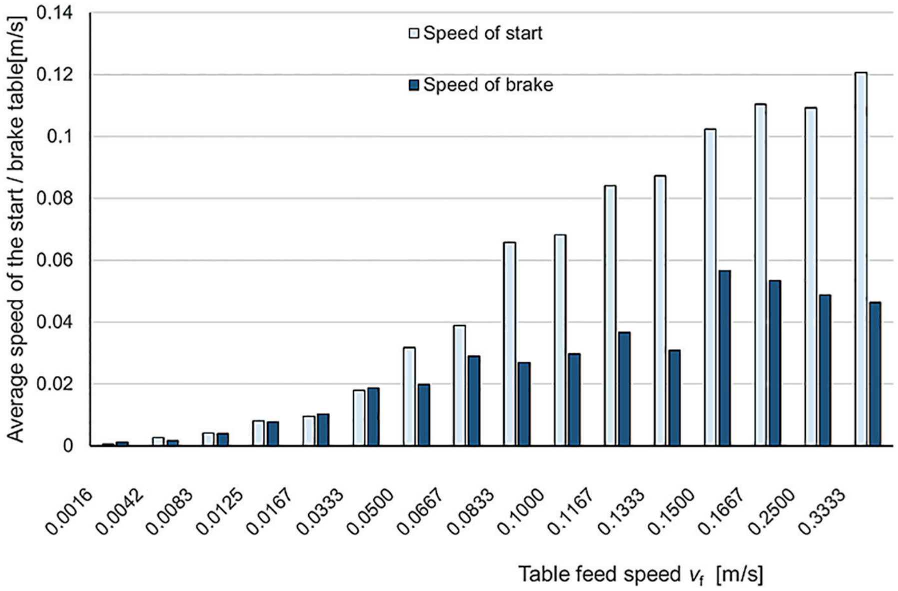

Fig. 13. Change of average starting and braking speeds as a function of the feed rate v_f of the milling machine table

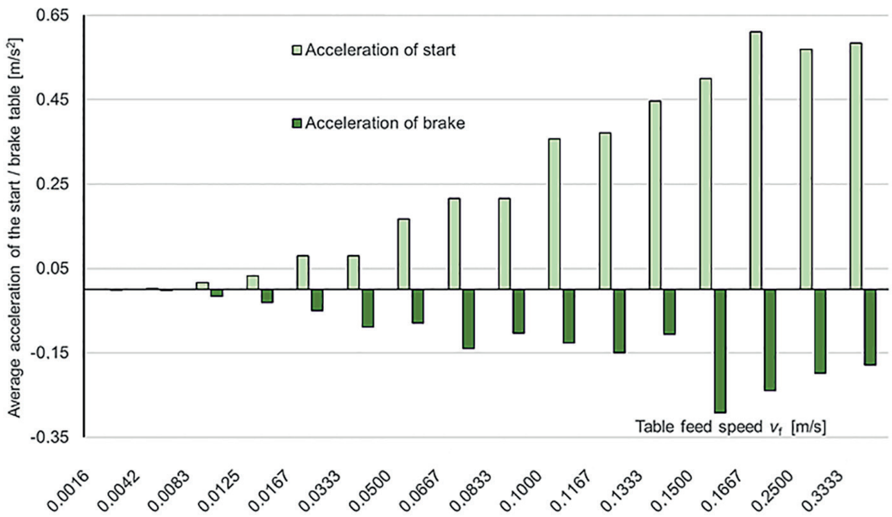

Fig. 14. Change of average accelerations of starting and braking as a function of the feed rate v_f of the milling machine table

DISCUSSION

The article presents a dynamics analysis of the starting and braking of the milling machine table for established feed rates in the range from 100 to 20,000 mm/min in idle running. The experiment was performed using the Phantom Ultrahigh-Speed v1610 camera and Tema Motion software. The test allowed to collect detailed information of displacement, speed and acceleration of movement in each of the recorded moments of time. The obtained results were presented in the form of graphs and the most important points for each of them are highlighted. An exceptionally advantage was also the ability to export the collected data to MS Office Excel which spreadsheet, where more activities were performed. For the experiment performed, the data were transferred to the Excel and the dynamics value analysis. The dynamics analysis confirmed that for low table feed rates (in the range from 100 mm/min to 750 mm/min), there was a noticeable increase in the registered speed of the measured points on the sample during the starting and before the start of the table braking. This conclusion is based on the assumption of the sick-slip phenomenon, characteristic for low feed rates of elements rubbing against each other. For higher feed rates, this error is reduced to zero because of the power supplied by the drive system is enough large to give the desired feed rate, and at the same time it is able to overcome the static friction resistance of the milling table at the starting. After compiling the average speed data during the starting and braking for each speed, it can be concluded that the table is working properly, and the stick-slip phenomenon does not have a negative effect on the table's linear shift for the idle running. Another information resulting from the analysis of the obtained experimental data is the fact that both the speed and acceleration during starting reach values greater than during braking. The assumed maximum table feed rate for the FV580A vertical machining center is 10,000 mm/min. During the experiment, two more rates were given, i.e. v_{f15} = 15,000 mm/min and v_{f16} = 20,000 mm/min. However differences were not visible for the speed v_{f14} = 10,000 mm/min.

CONCLUSIONS

The analysis of the research was performed for various feed rates of the idle running of the milling machine table proved the stick-slip phenomenon. The preparation of the graphs of displacement, velocity and acceleration of the table movement proves that for higher feed rates the error is reduced to zero, while for low speeds, it increases. The reason of its occurrence is probably the fact that for low feed rates the drive system does not provide sufficient power to overcome the resulting static friction force. There may be temporary tacking of surfaces rubbing against each other for the units cooperating in the machine. Another variant that may cause this phenomenon is the possible occurrence of local damage to the elements of the guides, resulting in the presence of undesirable resistance to motion. It is also possible that there is no proper lubrication for the guides' bearing arrangement. The experiment clearly shows the usefulness of this type of research. The highest quality equipment and appropriate software that have been used for this purpose allow for obtaining precise information on the condition of the machine during its operation. The information obtained also shows the user whether for the idle running of the table feed, the dynamics parameters do not deviate from the norm in the form of random speed jumps, and thus allow preventive measures if there is a need to service or replace the elements. After conducting the test on the FV580A vertical machining centre, it can be concluded that the work of the linear shift of the machining table is correct, and the deviations of smoothness in the speed change visible in the graphs occured only for low feed speeds of the idle running (i.e. 100–750 mm/min), which do not endanger the correct operation of the machine. By default, during the execution of a machining cycle, idle running should be defined as the fastest possible movement in order to reduce machining time to a minimum. The performance of the experiment may be the basis for further research for the feed of milling machine tables in other axes or dynamics analysis during the tool's work in the material.

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