Proceedings of the International Conference on Manufacturing Systems – ICMaS
Vol. 4, 2009, ISSN 1842-3183

University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

MONITORING OF VIBRATIONS DANGEROUS LIMITS IN MACHINING PROCESS OF BÖHLER M 201 MATERIAL

Jaromír MURČINKO, Zuzana MURČINKOVÁ

Abstract: *The vertical machining centre VMC 650S is a machine tool belonging to the Department of manufacturing technologies in Prešov. The problems of applied research AV 2/2022/08 are investigated through use of the mentioned machine. Such problems are for example verification of undesirable influence of vibrations for manufacturing of chosen materials intended for production of so called "soft" moulds. At the same time, the optimization of technological parameters for new kinds of tools is made. Article deals with description of measuring vibrations methods, measuring device, sensors and results of measuring.*

Key words: *monitoring, vibration, CNC machine, soft mould, amplitude, frequency.*

1. INTRODUCTION

The present requirements of quality and the increasing of labour productivity are not possible to make through the use of present conventional methods in manufacturing process. The confirmation of mentioned fact is computer integration manufacturing and control where are implemented the diagnostic systems based on the artificial intelligence elements.

2. DYNAMICS OF MACHINING PROCESS

The oscillating movement is the side-effect of working machine operation. In metal milling, the different kinds of vibrations are appeared. They can be divided into following groups:

- autooscillations,
- forced vibrations,
- self-excited oscillations.

The one of research AV2/2022/08, aims is to monitor influence of self-excited oscillations that are caused by cutting force in cutting process of material and follow by vibrations creation that influence final quality of milling machined surface. Non-linear character of vibrations in cutting process is regarded by watching the tool marks on machined surface. The tool marks have character of waves with profile of sinusoid. The self-excited oscillations can be almost harmonic or relaxation. The relaxation oscillations are created also in cutting zone, mainly in case if cutting tool has low stiffness. The time distribution of oscillations is not a profile of sinusoid. [2]

In specific working conditions, the vibrations between tool and workpiece reach the magnitude of resonance limit despite the fact that cutting force is not periodic variable. If the self-excited oscillations are appeared in cutting process, it is necessary to change the cutting conditions (chip thickness, feed, spindle speed etc.). The mentioned fact influences the final productivity of working machine and its energy balance of service. The chip formation process and machining surface process are the complex processes which involve the elastic and plastic deformation in cut layer. At the same time the internal friction is acting in chip and external friction among contact surfaces of cutting edge, chip and transition surface of workpiece. The state of stress is initiated by external force of tool which penetrates the workpiece material.

3. THE MACHINE SPINDLE VIBRATIONS SCANNING

The main aim of monitoring the vibrations of rotating machines is provided the information about working and technical state of equipment in order to provide strategic planning and maintenance management. The vibration diagnostic is used as diagnostic parameter of vibrations which are cased by dynamic machine stress. This diagnostic parameter gives information of objective technical state estimation for rotating machines.

1st measuring method: Acceleration – the method of measuring the acceleration of vibrations. The method estimate: cutting tool state, bearing spindle state, cutting process.

2nd measuring method: Velocity – method of measuring the velocity of vibrations; the measured values are viewed through the norm STN ISO 108 16-3 in which are determined velocities of vibrations. Fig. 1 shows the mentioned norm.

In such case the scanning of spindle vibrations and workpiece by means of accelerometers is performed. Signal is changed into digital through the analog-digital converter. The vibrations of individual scanned members are evaluated from signal in digital form and afterwards the orders are made in order to prevent the failure of system.

Fig. 2 depicts members of vibrations measuring for CNC machine: 1 - spindle vibration sensor, 2 - workpiece vibration sensor, 3 – machine spindle, 4 – workpiece, 5 – work table machine, 6- analog-digital converter, 7 – CNC machine working environment, 8 – computer +SW.

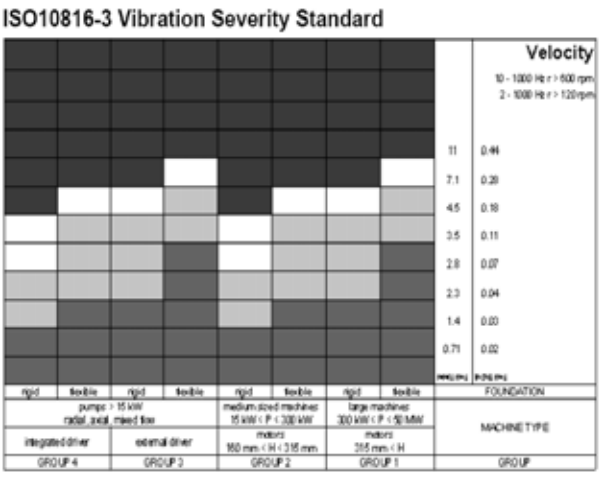

Fig. 1. The norm STN ISO 108 16–3.

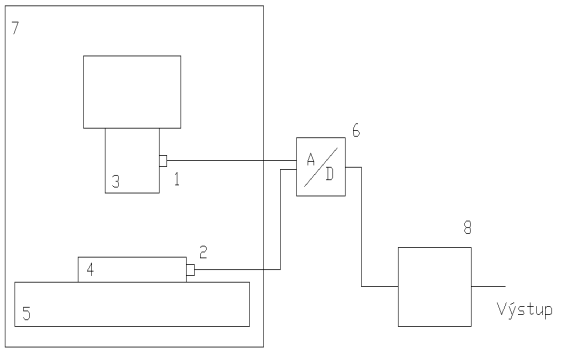

Fig. 2. Principle of vibration scanning for CNC vertical machine centre.

4. DESCRIPTION OF MEASUREMENT

The measurement of vibrations of CNC machine centre - milling operation by shank cutter - was performed in order to investigate:

- vibrations of spindle and fixture for fixing the workpiece (frequency-amplitude characteristics),
- natural frequencies of spindle and fixture,
- vibrations for various conditions of machining (cutting speed, feed, revolutions, cutting depth, material of workpiece etc.)

The goal of our measuring was data evaluation of correlation between vibrations magnitude (cutting tool and workpiece system) and micro-geometry of machined surface.

The vibration scanners (accelerometers) were fixed on:

- spindle – radial (channel number 0) perpendicularly to feed,
- workpiece - perpendicularly to feed.

Before the measurement, the shock test of basic components of measured mechanical system (spindle – workpiece) was made. Its aim was to find natural frequency (frequency-amplitude response on the unit shock impulse). By means of mentioned test, we can estimate resonance zones, i.e. zones by which the oscillation raising (raising of vibrations amplitudes) is appeared. The measuring showed that the spindle natural frequency in radial direction is in vicinity of 72 Hz.

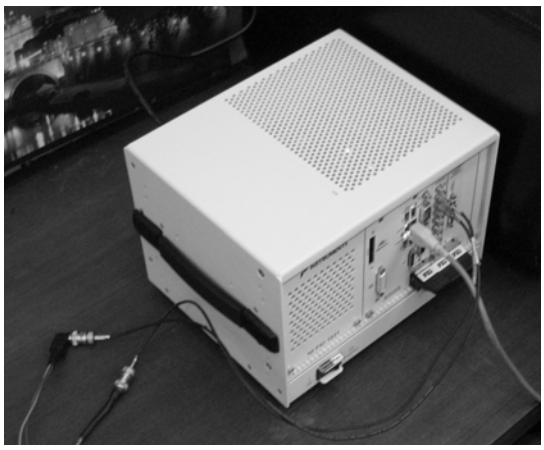

Fig. 3. The modul of PXI system.

The next measuring of vibrations was realized by system PXI (PCI eXtensions for Instrumentation - NI LabVIEW Order Analysis Toolkit, NI LabVIEW Sound and Vibration Toolkit). System is shown in Fig. 3. The vibration scanner MTN/1135C is accelerometer of small dimensions widely applied in industry, mainly for measuring of vibrations of action members with rotation motion.

5. RESULTS AND CONDITIONS OF MEASUREMENT

Cutting tool:

- 4-teeth cutter, material – Co coated tool, diameter d=16mm,
- 2-teeth cutter with replaceable cutting blades – diameter d=16mm,

Workpiece: BÖHLER M 201

M 201 – heat-treated steel, alloyed steel Cr-Mn-Mo with low content of sulphur

Usage:

- large and medium moulds and frames of moulds,
- processing of plastic materials,
- mould frames for pressured metal casting,
- parts of machines with higher strength and ductility.

The strength of material is 950 – 1100 MPa.

Cutting conditions:

- Number of cuttings: 5
- Feed: 280 mm/min
- Cutting depth: 0.2 mm
- Spindle speed: 1980, 2070, 2160, 2250, 2340 min^{-1}

Table 1

Spindle speed

Number of cutting	**1**	**2**	**3**	**4**	**5**
Spindle speed (min^{-1})	1980	2070	**2160**	2250	2340
Spindle speed (s^{-1})	33	34,5	**36**	37,5	39
Double of exciting speed from milling (Hz)	66	69	**72**	75	78

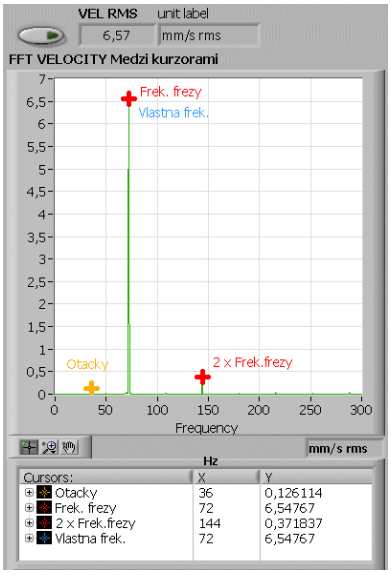

Fig. 4. FFT spectrum (spindle speed 2160 min^{-1}, 2-teeth cutter with replaceable cutting blades – diameter d = 16mm).

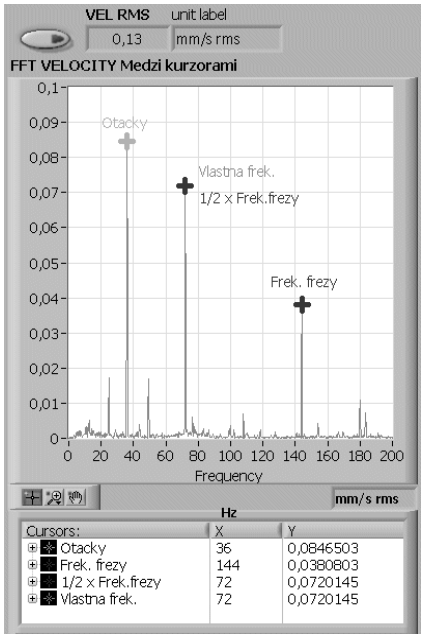

Fig. 5. FFT spectrum (spindle speed 2160 min^{-1}, 4-teeth cutter made of material – Co coated tool – diameter d = 16mm).

When spindle speed is 2160 min^{-1}, the double of exciting from cutter is the same as free frequency of spindle (72 Hz). Such settings of machining parameters cause the resonance of all system. The measured vibrations are high. The limit values for milling can be suggested:

Alarm 1 – warning = 1.4 mms^{-1},

Alarm 2 – danger = 2.3 mms^{-1}.

The amplitude velocity RMS is 6.5 mms^{-1} if milling conditions caused spindle resonance is 72Hz. The mentioned value is much higher in comparison with recommended value of steady machining conditions (influence on machining surface quality, tool service lifetime, spindle and fixture loading).

Fig. 4 illustrates FFT spectrum if spindle speed is 2160 min^{-1} and 2-teeth cutter with replaceable cutting blades – diameter d = 16 mm is used.

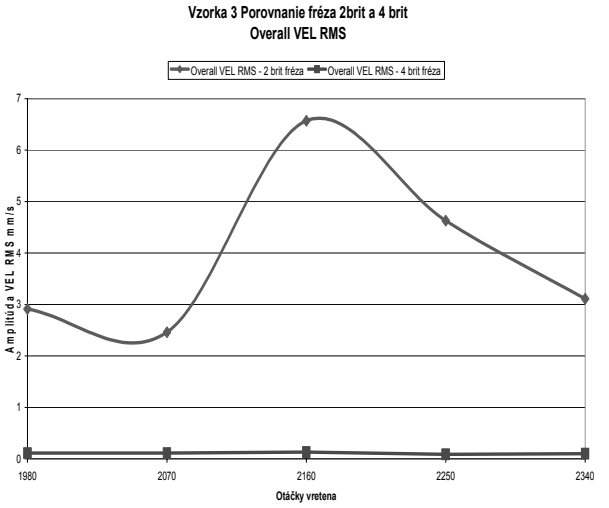

Fig. 6. 2-teeth cutter and 4-teeth cutter.

Fig. 5. illustrates FFT spectrum if spindle speed is 2160 min^{-1} and 4-teeth cutter made of material – Co coated tool – diameter d = 16 mm is used.

The FFT analysis of vibrations signal (sensor on spindle) was used to evaluate the reason of workpiece and spindle high-frequency vibrations growth. FFT spectrum Acceleration showed the low values of amplitudes. In range of 6 kHz the amplitudes are up to 0.01g Peak.

The following graph (Fig. 6) shows measuring of oscillation acceleration (acceleration, g detection Peak, total sum value of signal in high-frequency zone up to 15 kHz). The graph indicates the large difference of measured vibrations. The vibrations for 2-tooth cutter are 6-7 times higher and the spindle vibrations are 30-45 times higher. The green curve depicts 2-teeth cutter and red curve 2-teeth cutter.

6. RESULTS

FFT spectrum velocity shows amplitudes of frequency 66 Hz (revolutions of spindle – milling machine) and also multiplies of revolutions (69, 72, 75 and 78 Hz) caused by cutting edges of teeth. The amplitude values are low in low-frequency range up to 150Hz. The vibrations indicate good condition of spindle according to STN ISO 10 816–3.

The second step was the FFT analysis of 2-teeth cutter. The results of the analysis are in Fig. 4. FFT spectrum Acceleration shows high values of amplitudes. In range of 6.57 Hz the amplitudes are up to 0.45 g Peak. It means the 35 times higher values of vibrations as in the previous case.

FFT spectrum Velocity shows amplitudes with frequency 66 Hz (revolutions of spindle – milling machine) and also multiplies of revolutions (69, 72, 75, and 78 Hz) caused by cutting edges of teeth. The amplitude values are low in low-frequency range up to 72 Hz. The vibrations indicate good condition of spindle according to STN ISO 10 816–3.

The reason of high-frequency vibrations growth is the increase of dynamic excitation of fixture in range of natural frequency. Because of mentioned excitation cased by cutting process the resonance of fixture is appeared in

Table 2

Graphic show of roughness measuring of milled grooves of Material - M 201

Number of cutting	*Rz*	*Rq*	*Ra*
1.	4.84	1.15	0.94
2.	4.03	0.99	0.81
3.	4.84	1.13	0.93
4.	4.2	1.03	0.83
5.	4.37	1.1	0.93

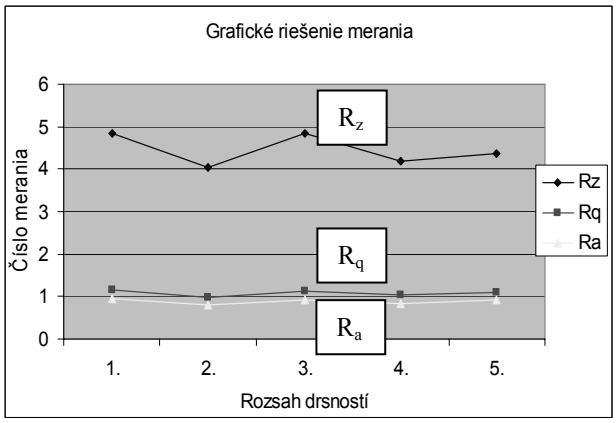

Fig. 7. Graphic show of surface profile measuring of single cuttings.

range of 1500−5000 Hz. The machining in such conditions causes the increasing of oscillation of workpiece – spindle system and results:

- degradation of micro-geometry of machined surface, change of surface quality,
- decreasing of cutting edges lifetime, blunting of tool,
- increasing of loading of fixture, spindle and linear slide etc.

Fig. 7 indicates results of measuring the cutting profile by measuring equipment Mitutoyo. In the upper part of figure, the measured cutting profile of 2-teeth cutter is situated: (R_a, R_z, R_q) (μm)).

7. DISCUSSION AND CONCLUSIONS

The scanning of active members of CNC machine allows setting of optimal working machine parameters. This fact brings higher quality of machined surfaces, increasing of tools lifetime and improving the economic characteristics of machining process. The artificial intelligence elements allow on-line managing and control of active members of CNC machine. This fact enables for example to watch dangerous spindle and workpiece frequencies in cutting process under maximum values of parameters such as operating speed, feed and chip thickness. The final effect of such diagnostic is lifetime extension of CNC machine and its working in optimal conditions.

ACKNOWLEDGEMENTS: This research was supported by Slovak grants AV 2/2022/08 and VEGA 1/0140/08.

REFERENCES

[1] Bernold, T. (1991). *Artificial Intelligence in Manufacturing*. Elsevier, Science Publishers B. V. Amsterdam, The Netherlands.

[2] Jaduš, J., Murčinko, J. (2008). *Implementácia prvkov umelej inteligencie v systéme global monitoring pri vybraných technologických procesoch. (Implementation of artificial intelligence components in global monitoring in chosen technological processes)*, Proceedings of Nové smery vo výrobných technológiách 2008, 9, medzinárodná vedecká konferencia, pp. 294−297. ISBN 978−80−553−0044−3, Prešov, 19−21.6.2008, FVT TU.

[3] Murčinko, J. (2008). *The Vibration Analysis of Machining Process of CNC Vertical Machine Centre VMC 650*, Proceedings of Transfer 2008, Využívanie nových poznatkov v strojárskej praxi, ISBN: 978−80−8075−357−3, Trenčín.

[4] Murčinková, Z. (2008). *The computational models for simulation of cavity microstructure*, Scientific Bulletin, Fascicle: Mechanics, Tribology, Machine Manufacturing Technology, Vol. 22, Serie C, pp. 305−310, ISSN 1224−3264.

[5] Murčinková, Z. (2004). *Softvérová lokalizácia maximálnych podpovrchových napätí pri bodovom kontakte 3D telies.* (Software localization of maximal sub-surface stress in point contact), Proceedings of Nové smery vo výrobných technológiách 2004, 7, medzinárodná vedecká konferencia, Prešov, 17−18.6.2004, Zborník referátov, Technická univerzita Košice, pp. 468−471, ISBN 80−8073−136−5, Košice.

[6] Mihalčová, J., Fábry, S. (2009), *Aplikovanie tribo a vibrodiagnostických metód pri posúdení stavu leteckého motora* (Application of tribo and vibrodiagnostic methods in examination of aeroplane engine), Technický týdeník, Tribotechnické informace, Vol. 57, No. 9, pp. 6−10, ISSN 0040−1064.

Authors:

PhD, Eng, Jaromír MURČINKO, Researcher, Faculty of Manufacturing Technologies in Prešov, Technical University Košice, Department of Manufacturing Technologies,
E-mail: jaromir.murcinko@tuke.sk
PhD, Eng, Zuzana MURČINKOVÁ, Lecturer, Faculty of Manufacturing Technologies in Prešov, Technical university Košice, Department of Technological Devices Design,
E-mail: zuzana.murcinkova@tuke.sk