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DYNAMIC ISSUES AND PROCEDURE TO OBTAIN USEFUL DOMAIN OF DYNAMOMETERS USED IN MACHINE TOOL RESEARCH ARIA

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Abstract: *Vibration analysis has long been used for the detection and identification of machine tool condition. The specific characteristics of the transfer function of the dynamometers used in machine tool research aria are detailed in the papers. Main focus is to identify a procedure to obtain eigenvalue frequencies for dynamometers used to improve cutting conditions process on the machine tool.*
Key words: *dynamometers, vibration, transfer function*

1. INTRODUCTION IN DYNAMIC ANALYSIS

Analysis of dynamic behaviour of machines and equipments it's an important method to redesign the product or the manufacturing process and to assure the proper quality, maintenance and service. When we study machines or only part of them, dynamic behaviour is analysed for the following situations:

- Constant operating speed (e.g. speed rate of a rotor);
- Variable speed into a limited operating domain;
- Imposed speed inside the operational domain (e.g. rotational frequency 1...1000 Hz);

In all of this cases mentioned, the behaviour of the system under the effect of external excitation is evaluated (fig. 1).

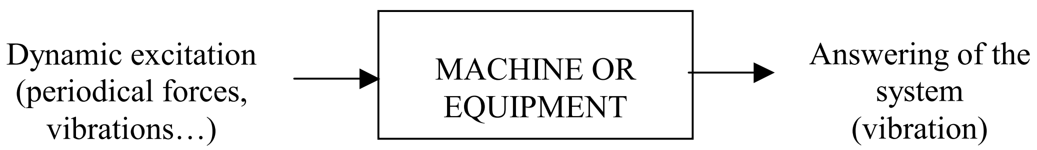


Fig. 1 Transfer function

The transfer function is evaluated like the ratio response of the system / dynamic excitation. To diagnose one machine or equipment the main characteristics offered by transfer function are:

- Dynamic rigidity or compliance;
- Resonance frequencies;
- Damping factor;
- Natural modes of vibration.

The most used methods to measure the transfer function are detailed in the figure 2.

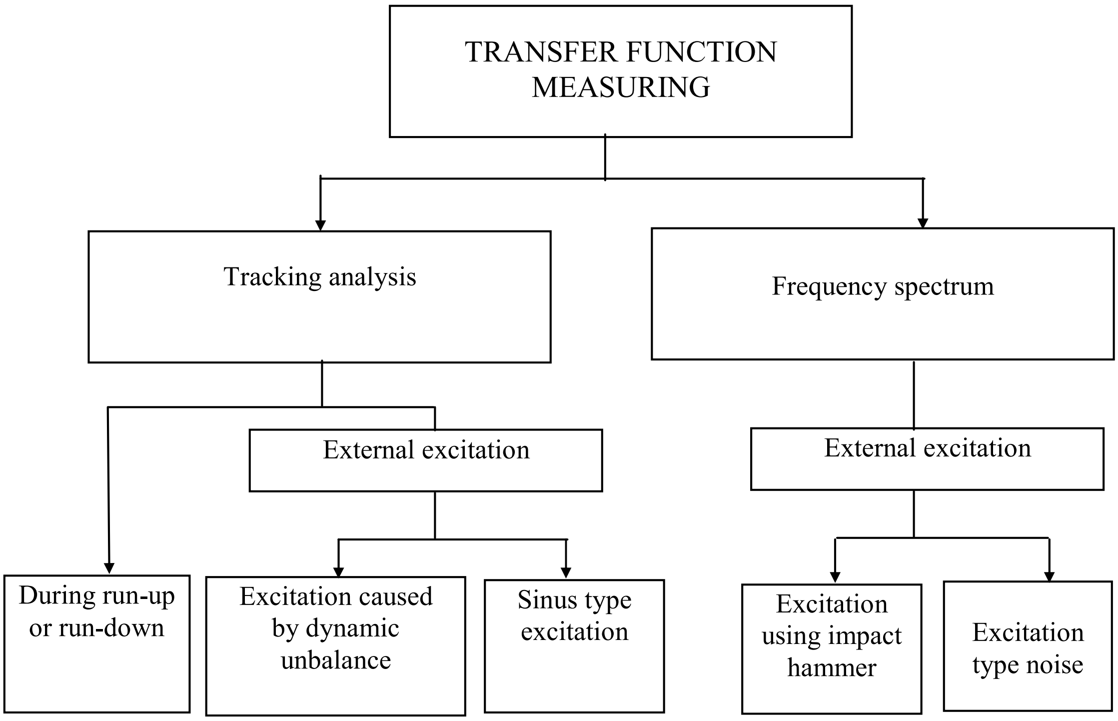


Fig. 2. Method to obtain the transfer function

Vibroport 41 (Schenck) is a portable apparatus and has the correspondence with European Standard EN 10204. It is an autonomous apparatus using two channels for the vibration signal acquisition.

2. MEASUREMENT OF THE FREQUENCY OF CHIP SEGMENTATION IN TURNING

The methodology is based on the acquisition of chip segmentation frequencies according to different cutting speeds and feed rates. The measurement of chip segmentation frequencies was realized by three methods:

1) Acquisition, at a high frequency, of cutting forces and Labview FFT signal processing;

2) Chip geometric measurement based on microscopic observations;

3) FFT spectrum acquired using Vibroport 41 (Schenck) simultaneously with the signal for cutting forces [1] in order to validate the segmentation frequency [2] (Fig.3).

During this work, two working parameters were considered: the cutting speed V_c = 60–120 m/min and the feed rate f = 0.2–0.47 mm/rev. The cutting depth was kept equal to a constant value: a_p = 1 mm.

In the following, it was proposed to study the frequency of the shearing plane formation. For that, firstly, measurements at high-frequency sampling, of cutting force signals were performed, secondly, geometrical measurements on the chip sawtooth were made, and, finally, the frequency related to facet appearing on the machined surface was calculated and compared with the frequency acquired with Vibroport 41.

The aim of this section is to propose a calculation procedure dealing with the saw-tooth frequency appearing during machining based on measurements on the chip section. Measurements are made using a microscope.

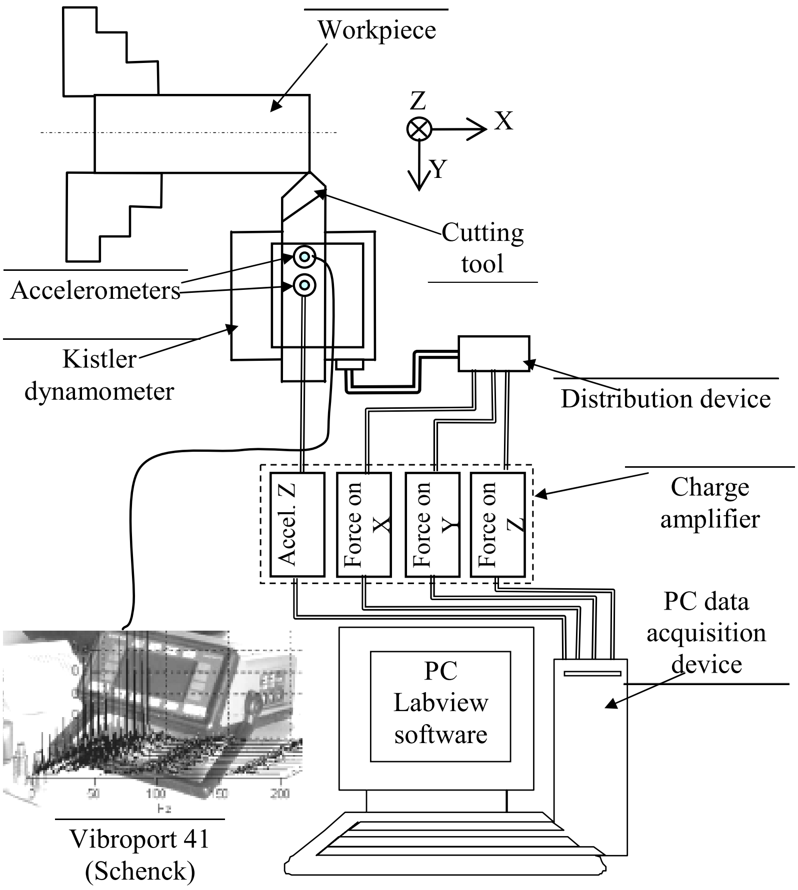


Fig. 3 Experimental acquisition chain in turning process

By considering the mean speed of chip evacuation on the tool rake face and the distance Δx_{chip} measured between two shearing planes the frequency can be established as:

$$F_{hzCG} = \frac{100 V_s}{6 \Delta x_{chip}} \tag{1}$$

where

F_{hzCG} = Frequency of the formation of shearing planes determined from chip geometry (Hz); V_s = chip slip speed on the tool rake face (m/min); Δx_{chip} = distance between two consecutive shearing planes measured in the direction of the tool rake face (mm).

By assuming that the mass of the metal deformed during machining is constant, it can be written the following equation:

$$\rho_1 V_c f\, a_p = \rho_2 V_s e_c\, l_c \tag{2}$$

where

ρ_1 and ρ_2 are metal densities before and after deformation respectively (kg/cm^3); V_c = cutting speed (m/min); V_s =chip slip speed on the tool rake face (m/min); f = feed rate (mm/rev); a_p = depth of cut (mm); e_c =mean of the chip thickness (mm); l_c = width of the chip (mm). If is neglected material compressibility, it is assumed that the ratio ρ_1/ρ_2 is equal to the unit. Consequently, the chip slip speed V_s on the tool rake face is given by the equation:

$$V_s = V_c \cdot \frac{f\, a_p}{e_c\, l_c}. \tag{3}$$

The obtained results were that feed rate variation, for a fixed cutting speed, doesn't have a great influence on the appearance frequency of the shearing bands. This influence is larger when the cutting speed increases (Fig.5). Frequency increases as the cutting speed increases; being a direct influence of the cutting speed on the chip evacuation speed -equation (2).

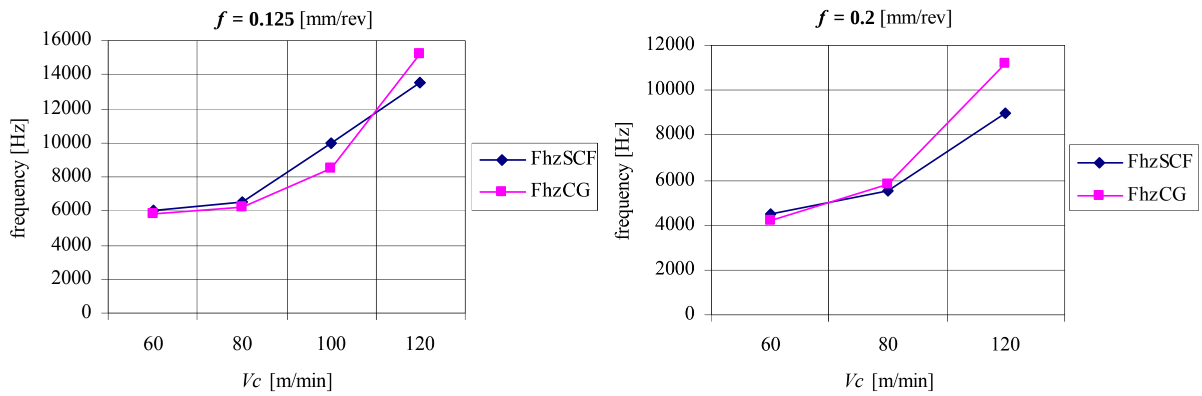


Fig. 5 *Frequency accompanying saw-tooth chip formation depending on cutting speed*

Principal eigen frequencies values obtained with Vibroport 41 using module *Transfer Function*, for the assembly tool – toolholder – Kistler dynamometer – support – transversal saddle are the followings: 150 Hz in Z direction, due to the assembly tool – toolholder, in the case using four screws to fix the tool; 850 Hz in Y direction, 1300 Hz in X direction and 2400 Hz in Z direction, due by the assembly transversal saddle and Kistler dynamometer; eigen frequency in Z direction had a strong influence on the dynamical behaviour of the machine tool assembly.

The figure 6 presents an example of FFT spectrum acquired during hard turning. This is a good example when was very easy to separate the chip segmentation frequency by the machine tool vibrations. Others two significant frequencies were 11950 Hz and 17925 Hz – the first two harmonics.

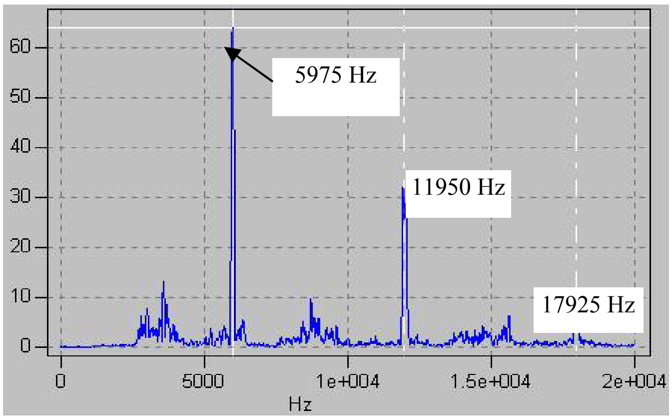


Fig. 6 *Test with Vibroport 41; V_c=80 m/min; f=0.125 mm/rev*

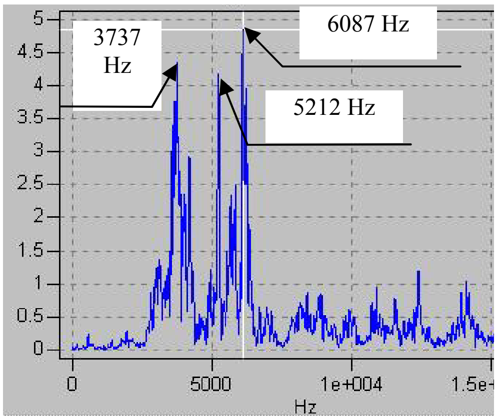


Fig. 7 *Acquisition using V_c=60 m/min and f=0.05 mm/rev*

The figure 7 presents one significant example when was difficult to separate the frequency of chip segmentation. The segmentation process had 6087 Hz and the significant vibration of machine tool had 5212 Hz. Was important also to know and avoid the frequency due to the instability signal. Useful domain considering the proper signal of transducers was 3 – 15600 Hz; these limits are made by piezoelectric accelerometers.

3. MEASUREMENT OF THE SPINDLE VIBRATION OF ONE HIGH SPEED MILLING MACHINE

In order to know the proper domain for High Speed Cutting for specific milling processes the authors propose to begin the research with the vibration of the spindle machine tool (Fig. 8) using *Tracking* analysis module of Vibroport 41 [3,4].

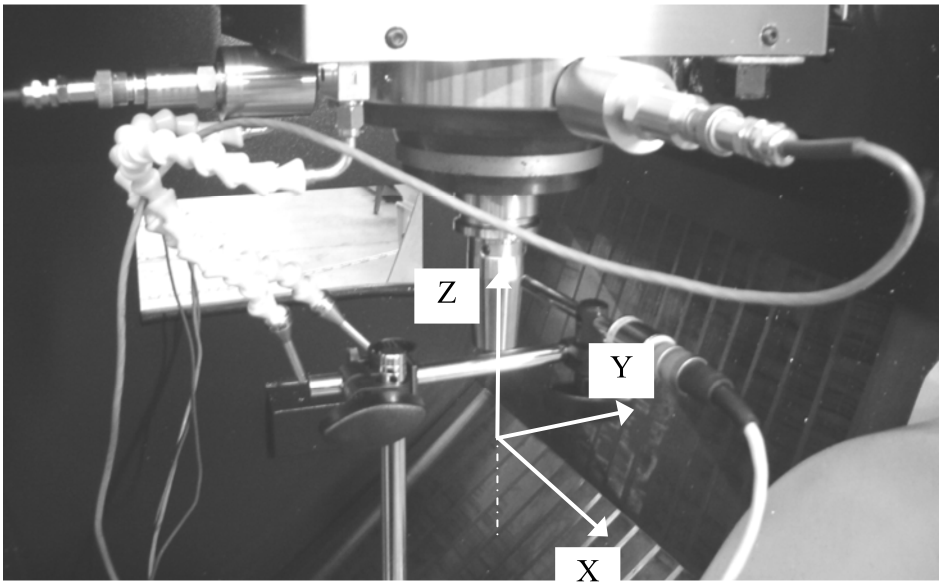
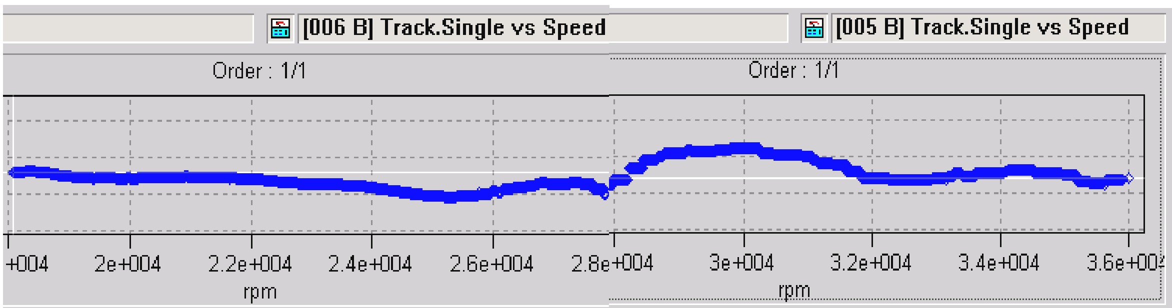
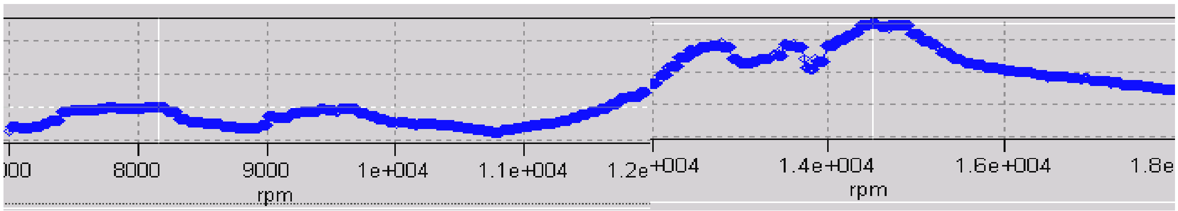


Fig. 8 *Accelerometers placement on the spindle of milling machine tool*

Eigen frequencies of the assembly spindle-bearings (no cutting process) were: 29130 rpm (first harmonic of 242.5 Hz), 14550 rpm (242.5 Hz) and 12.600 rpm (210 Hz). In the figure 9 is presented the tracking signal acquired using Vibroport 41.

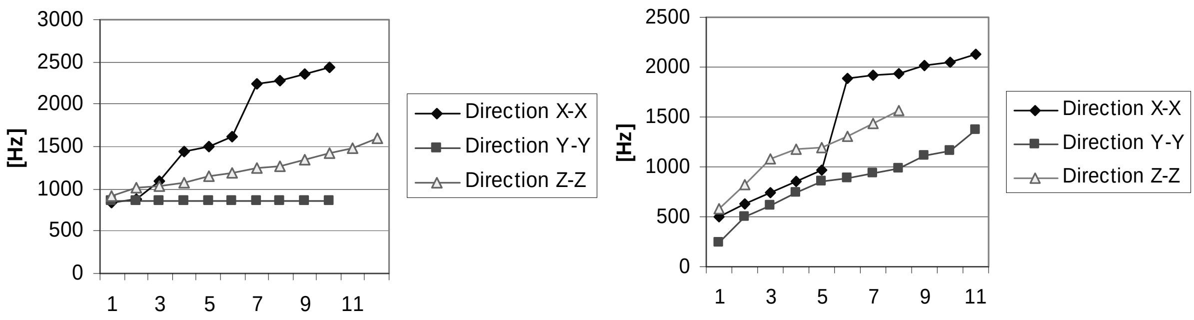


a).



b).

Fig. 9. *Tracking signal using speed domain* 36000-7000 rpm; *direction X-X*



a) Table without dynamometer *b) Table with dynamometer*

Fig. 10 *Influence of the dynamometer on the eigen frequencies of the table*

The figure 10 presents the first 10 eigen frequencies of the table of the milling machine tool (a) - without dynamometer and (b) with the quartz dynamometer mounted on the machine tool table.

4. CONCLUSION

Main objective in this research paper was to find the frequency for saw-tooth chip formation (found it on the FFT spectrum). Secondly was important to separate the dynamics of the cutting process by the dynamics of the machine tool. High Speed Machining and particularly turning and milling processes have an evolution concerning on the limits of the cutting parameters and it is necessary to have a good control for these processes. In this context, actual subject is important and it can help to elaborate a proper model for the cutting process, specifically in orthogonal hard turning, taking into account the separation of the frequencies having like cause machine tool and the frequencies having like cause the cutting process. This work was validated by the experimental results based on the measuring of the cutting forces using dynamometers simultaneously with a FFT signal obtained using Vibroport 41 apparatus and a piezoelectric accelerometer AS020.

Further step will be in the direction to correct the numerical model simulating the cutting process, in this particularly conditions, in order to have a prediction of the real cutting conditions and to improving the knowledge by one general approach. An actual tendency in dynamic of machine tool research aria has to use the sensors with six-axis force and torque measure the full six components of force and torque: vertical, lateral, and longitudinal forces as well as camber, steer, and torque movements.

5. REFERENCES

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