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DINAMICS CHARACTERISTICS OF METAL CUTTING PROCESS

Prof. dr Bogdan NEDIĆ, Mašinski fakultet, Kragujevac
Nataša VESIĆ, Zastava automobili, Kragujevac
Milan ĆETKOVIĆ, Zastava kamioni, Kragujevac

Abstract

In this paper is presented analysis of the characteristics of metal cutting process based on oscillatory motion of machining system elements. Cutting process is determined by dynamic character of chips forming process and oscillations of tool - work piece - accessories - machine system elements. In this paper is presented part of large research which had the purpose to

- *study dynamic phenomena during cutting process*
- *form mathematic models of dinamics bearing of machining system elements*
- *find adequate sensors and parameters for describing the dynamic character of cutting process and*
- *form monitoring system*

***Key works**: dinamics, metal cutting, monitoring*

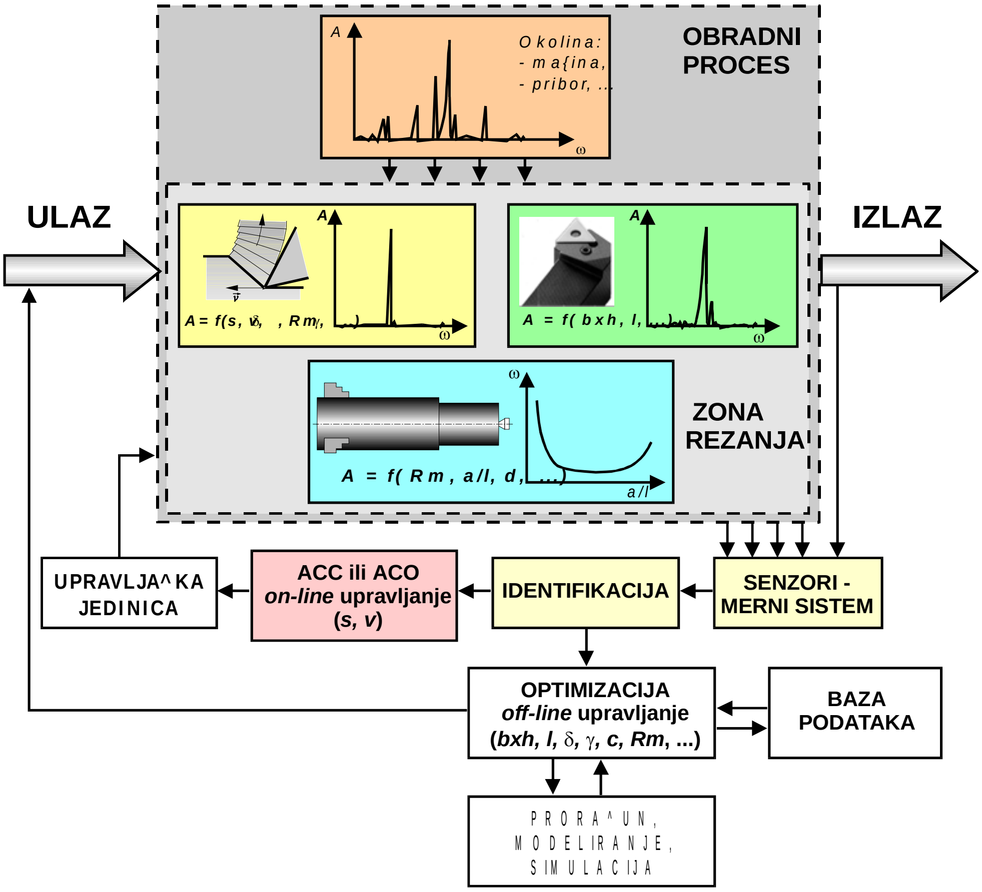
1. INTRODUCTION

Proper functioning of monitoring system is necessary for development of automatic machining systems, intelligent systems for supervision, control and management. It requires adequate analysis of failures and well chosen sensors, not only wear sensors, but also sensors for estimating functionality of working process: quality, accuracy, wear, reliability etc.

Development of adaptivelly management machining systems is tightly connected with the development of sensors and measuring devices. Discontinuity - direct (off-line, quality of working surface, wear, accuracy etc.) and continual - indirect (on-line, indirect measuring of wear through wear resistance, vibration, noise, accuracy, temperature etc.) systems for measuring output parameters of cutting process are simultaneously developed.

Reason for development of monitoring and on-line systems for management cutting process is because the automatic systems, numeric devices, have to react quickly and effectively, and adjust to any new situation caused by unexpected effects: sedimentation, unexpected flow of sawdust, tool damages, change of rigidity of tool - work piece - accessories - machine system etc. Influence of wear on behavior of machining system elements is usually known, but intensity of tool wear is not.

Off-line system for managing and optimisation has the purpose to determine all initial machining parameters and laws of their change. On this level, before and during machining, analyses, modeling and predicting the behavior of machining system elements are conducted. Proper dimensions and characteristics of tool, way of holding work piece, and other parameters are chosen.



Picture1: *Model of menaging cutting process based on dynamic characteristics of machining process elements*

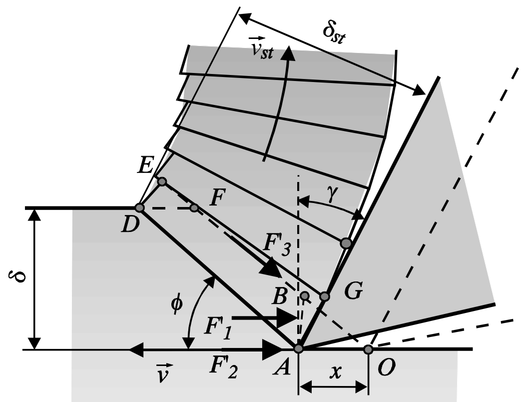
To form monitoring system and system for managing cutting process it's necessary to

- describe mathematically and verify experimentally:
    - dynamic character of chips forming process,
    - oscillatory behavior of tool,
    - oscillatory behavior of work piece,
    - sensors of cutting process
- develop adequate monitoring and managing systems.

2. DYNAMIC CHARACTER OF CHIPS FORMING PROCESS

Cutting process is highly dynamic. Oscillations formed during the process are unplanned, unwanted, and they can cause inaccuracy, shortening of tools duration and damages of machine elements. Basic problem with studyng cutting process is the problem of describing dynamic character of chips forming process. Cutting process can be described as series of processes conducted one after another: elastic deformation, plastic deformation, destruction of material and additional deformation - twisting and chips removing.

Starting from elementary of chips phenome–non, photographs and existing models of chips forming, cutting process can be observed as compression of material under cutting wedge, shear of material in cutting plane and shear in sliding plane. These processes are determined by variable pressure and shear tensions depending on way x of cutting wedge (picture 2).



Picture 2: *Elementary of chips segments forming*

Based on this picture, with the proper analyses of forces we can find the term for the way $x = x_{max}$ when shear begins:

$$x_{max} = \frac{\delta \cos\gamma}{tg\phi \left[1 + \frac{R_m}{\tau_s} \cdot tg\phi \, \frac{\cos\gamma \cos\phi}{\cos(\phi - \gamma)} \right]}$$

If the speed of cutting wedge is known we can find the period T_0 and frequency f_{st} of chips segments forming:

$$T_0 = \frac{60}{1000} \frac{x_{max}}{v} \quad ;$$

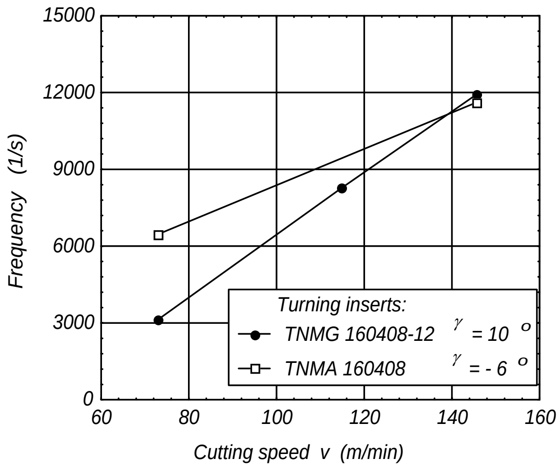
$$f_{st} = \frac{1}{T_0} = \frac{1000}{60} \frac{v}{x_{max}} =$$

$$= \frac{1000}{60} \frac{v}{\delta \cos\gamma} tg\phi \cdot \left[1 + \frac{R_m}{\tau_s} \cdot tg\phi \, \frac{\cos\gamma \cos\phi}{\cos(\phi - \gamma)} \right]$$

Experimental research of influence of working regime and tool geometry on value of chips compression factor, shear angle and frequency of chips forming show great match between estimated model and experimental data. The relation is:

$$f_{st} = f(R_m, \ \tau_s, \ \delta, \ v, \ \phi, \ \gamma).$$

The mathematical model was verified by measuring of chips and chips inserts length, calculating chips compression factor, shear angle and frequency of chips inserts forming.

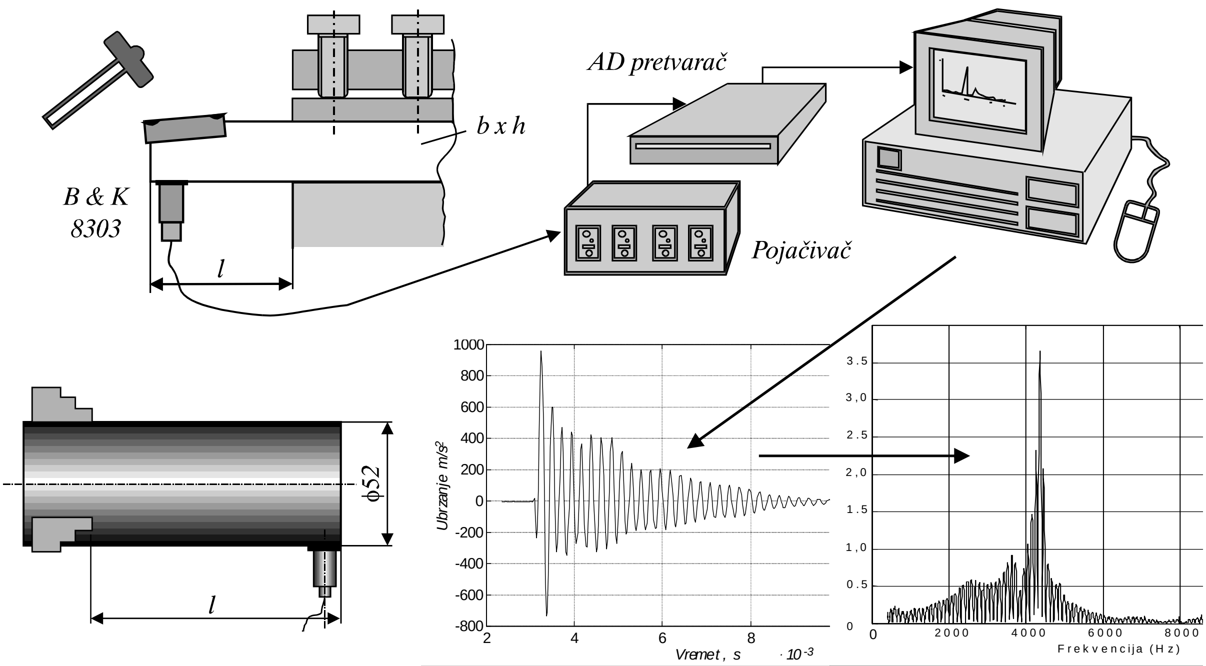


Picture 3: *Change of chips forming frequency depending on cutting speed*

3. DYNAMIC BEHAVIOR OF TOOL AND WORK PIECE

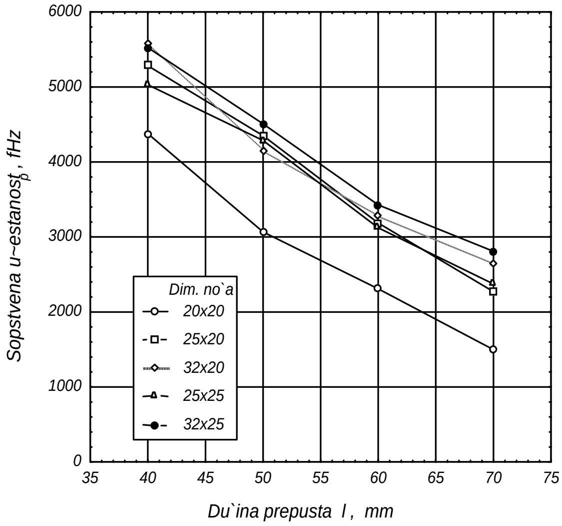
Knowing the parameters of oscillatory motion of tool and work piece enables us to predict it's behavior during cutting process. With purpose to describe their dynamic behavior tool and work piece can be approximated with systems with one degree of freedom. This way parameters of free damped oscillation can be mathematically modeled and experimentally determined.

Placing acceleration sensor directly under tool peak and in the proper places of work piece and leading them out of position of equilibrium, picture 4., during experimental research signals of damped oscillations were received.

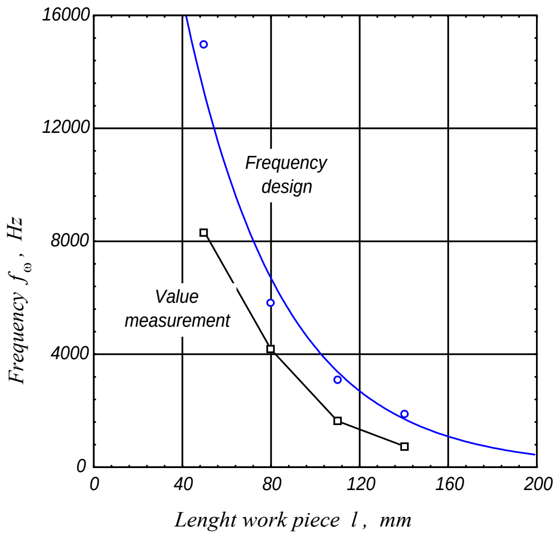


Picture 4: *Measuring of parameters of free damped oscillations*

Analysis signals and using proper computer programs, knowing circle frequency *p*, nondimensional damping coefficient δ and damping factor b were determined at 5 cutters with most frequently used dimensions of cross sections of holders: 20x20, 25x20, 32x20, 25x25, 32x25, and bracket lengths 40, 50, 60, and 70 mm.



Picture 5: *Change of tool peak oscillatons in cutting speed direction*



Picture 6: *Circle frequency of free oscilations of the workpiece in panel shape*

Terms for reduced mass and circular frequency of free damped oscillations depending on place of mass reduction were formed. These terms include specially introduced coefficients of mass reduction depending on the position (a/l_p).

Starting from these deductions it is possible to model oscillations of the work piece and the tool. It is particularly important for objects of greater length and smaller diameter with intensive axial rigidity change, and the tools with great bracket (l_a). It means that frequency of free damped oscillations can be written as

$$f_p = f(l_p, l_a, d, bxh, a/l_p, R_{mp}, \dots).$$

On pictures 5. and 6. are presented some of the results of measurig circle frequencies of damped oscillatios of tool and workpiece.

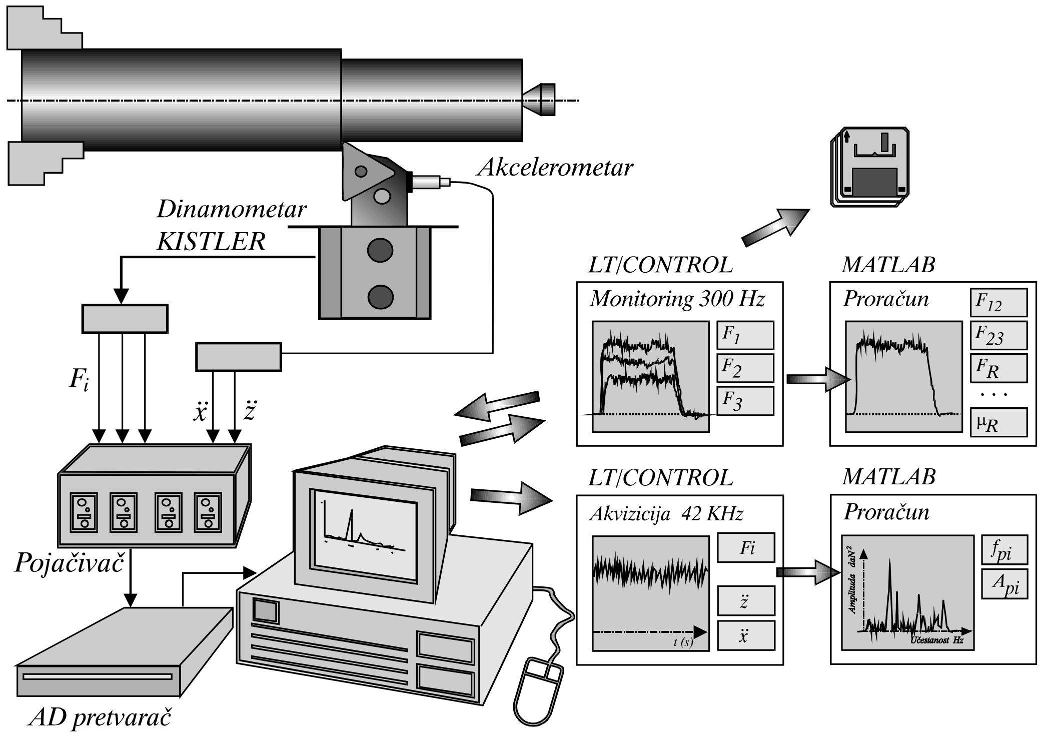
4. DETERMINATION OF SENSORS AND PARAMETERS OF DYNAMIC CHARACTER OF CUTTING PROCESS

Cutting resistances, as it was determined analysis great number of papers, are reliable and mostly used parameter for process identification during machining. That the reason why great deal of conducted investigations refers to analysis of machining process through dynamic characteristics of cutting resistance signal.

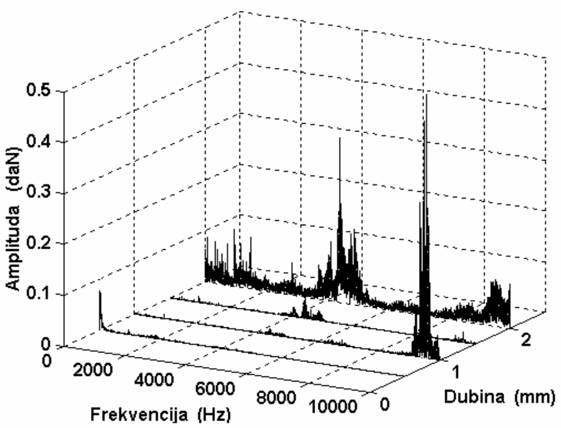
Based on larges experimental research, "static" and dynamic part of signal were analysis depending on machining regime and tool geometry. During these investigations equipment contains of piezo dynamometer for cutting resistance measuring, acceleration sensor, proper computer equipment and software. (picture 7).

Using amplitude-frequence analysis of cutting resistance signal and tool peak acceleration existance of characteristical frequence of oscillations of tool and work piece and the frequence of chips segments forming. It enabled analysis of cutting process based on dynamic characteristics of cutting parameters after knowing the origin of oscillations, the reasons of forming the oscillations of machining process elements.

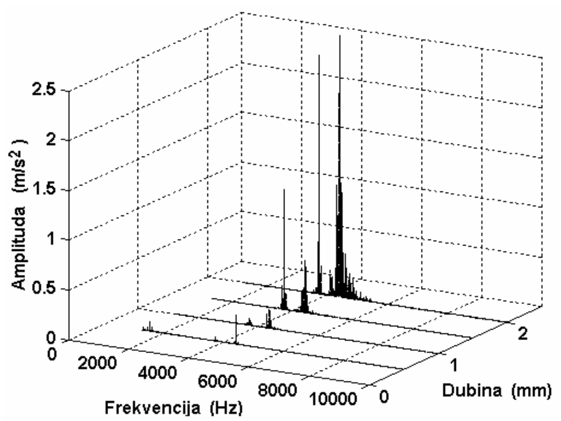
During the analysis influence of oscillation of other machining process elements (machine parts etc.), oscillations of work piece due to excentricity, and air gaps in holding elements cannot be ignored. That's the reason why research of dynamic character of cutting process included research in lower frequence regions of oscillations, the frequence of signal aquisition was great deal lower. It was also shown that analysis the cutting resistance signal in this case, changes during cutting process which resulted due to tool wear could be identified.



Picture 7: *System for identification of parameters of dinamics character of cutting process*



Picture 8: *Change of amplitude frequent spectrum of main cutting resistance signal*



Picture 9: *Change of amplitude frequent spectrum of tool peak acceleration in cutting speed direction signal*

On pictures 8. i 9. are presented some of the results of measuring signals of amplitude frequent analysis of cutting resistence and tool peak acceleration in cutting speed direction signal..

Management based on amplitude-frequence characteristics and analyses doesn't enable on-line system for monitoring on this level of computer technics, but in recent future terms for that will certainly be created.

5. CONCLUSION

Cutting zone is characterised by dinamics behavior of tool that can be described with the term for characterictic frequency depending on tool dimensions (bxh, l), dinamics behavior of work piece that can be described with changable rigidity and own frequency depending on work piece dimensions, machining point a/l and characteristics of the material. It is also characterised by dynamic character of chips segments forming process depending on characteristics of work piece material, tool geometry and machining regime.

Cutting zone is effected by the surrounding also characterised with dynamic character, machining system elements, machine elements, accessories etc. have specific rigidity and can be described by characteristic oscillatory frequences.

Managing this system, machining process, from aspect of dinamics characteristics, suppose estimation, modeling and experimental research. Magnetudes have to be determined and mathematical models estimated for these research.

Next level considers development of moduls for identification of changes and cutting process management and determination of origin of these changes manifested at measured magnitudes. If cutting process is continual, without side effects like unwanted vibrations, noise, tool damages etc., we could say that cutting process is running in anticipated course, and that process can be managed continually, on-line by determined criteria ACC, or optimising ACO

However, if it is not possible to achieve wanted effects, identification of existed effects must be done and origin determined. It's neccessary to stop cutting process and correct input parameters: change the tools, increase rigidity of work piece, change machining technology etc. In that case it is needed to conduct some calculations, modeling and simulation of cutting process from dynamic aspect using data base. Calculation and modeling can be done starting from derived terms. In that case development of cutting process simulation modulus in conditions of dynamic forced oscillations and change rigidity of the workpiece. It considers development of new CAD/CAM softwares. That's the way of getting references for defining technological methods that would ensure wanted effects.

6. LITERATURE

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