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# MODELLING OF LARGE-SIZE MILLING CUTTER

**Kosmol Jan**

**Joszko Mariusz**

**Department of Machine Technology of the Silesian University of Technology**
**Gliwice**
**Poland**

## ABSTRACT

*The paper presents results of simulation and experimental investigation of dynamic vibration eliminator, built-in a large- size milling cutter. The aim of such simulation research was to find parameters (stiffness and damping coefficient) of eliminators, applied for machining of double crankshafts used in shipping engines. The Finite Element Method was used for simulation. Experimental investigation were performed on a special milling machine tool FS 550CNC produced by "Rafamet" (Poland).*

**Keywords:** MES simulation, vibration, damping, milling

## 1. INTRODUCTION

Elimination of vibration during machining belongs to operation which influences on the better quality of machining surfaces. Especially it is important while milling, because of discontinuous machining and dynamic changes of cutting forces. In special cases like crankshaft elements machining for shipping engines the overall dimensions of cutting tools are very large, for example over 5 meters (diameter of a milling cutter used in FS 550CNC is about 5,5 meters). For that reason we say that such cutting tool is not very resistance to vibration and a vibration damper should be used. One of very simple (in the point of view of design) vibration damper is a dynamic eliminator, idea of which is shown at Fig. 1. To the vibrating element (for example milling cutter) is added a special mass $m_d$ connected to the vibrating element m through spring elements $c_d$ and damping elements $k_d$. If such mathematical condition is fulfilled :

$$\frac{c}{m} = \frac{c_d}{m_d}$$

what means that natural frequency $f_{rez}$ of mass m and of mass $m_d$ is the same, the component of vibration $f_{rez}$ may be suppressed (compare Fig. 1b and Fig. 1d), and two new components of vibration $f_1$ and $f_2$ will appear. The coefficient of vibration suppression ($A_d/A_{rez}$) depends on the coefficient $k_d$ of damper. The two new components of vibration are much smaller than component $f_{rez}$.

Such idea of dynamic eliminator was applied to the large-size milling cutter for double crankshaft machining. Fig. 2 shows a general view of large-size milling tool used at special machine tool for crankshafts milling FS 550CNC produced by a polish manufacture F.O. "Rafamet" SA. Because the milling tool is situated horizontally (the axis is vertical) we have got a flexibly plate sensitive to vibration, forces by dynamically changes of milling force. Because the milling tool has 144 cutting edges placed along circumstances and the rotational speed of milling tool is about 4 – 10 rev/min, the forced vibration frequency may very from 10 Hz to 24 Hz. The question is the natural (free) frequency of the cutting tool (milling cutter) and relation between free vibration frequency and forced vibration frequency in the point of view of possibly resonance.

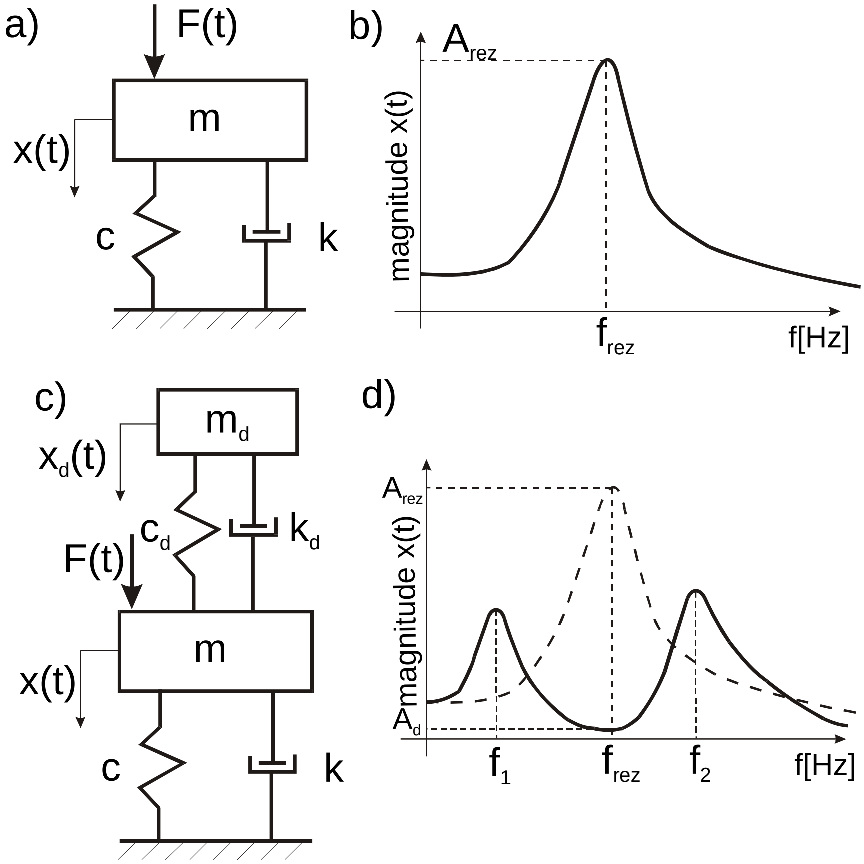



*Figure 1. Idea of dynamic damper: a) model of milling tool, b) spectrum of milling tool, c) model of dynamic damper, d) spectrum of milling tool equipped with dynamic damper.*
*m-mass of vibrating element, c,k – natural stiffness and coefficient of damping of vibrating element, F(t) – force, $m_d$-mass of dynamic damper, $c_d$,$k_d$- stiffness and coefficient of damping of dynamic damper, $f_{rez}$-resonance frequency*

## 2. MODELING AND SIMULATION OF MILLING CUTTER VIBRATION

We have applied the Finite Element Method for modeling the large-size milling cutter shown at Fig. 2. The model consist of eight holes, where dynamic eliminators will be added. Because of large-size of the cutting tool (diameter about 5,5 meters), we have simplified and omitted some details of the tool like small holes, chamfering and rounding about small dimensions.

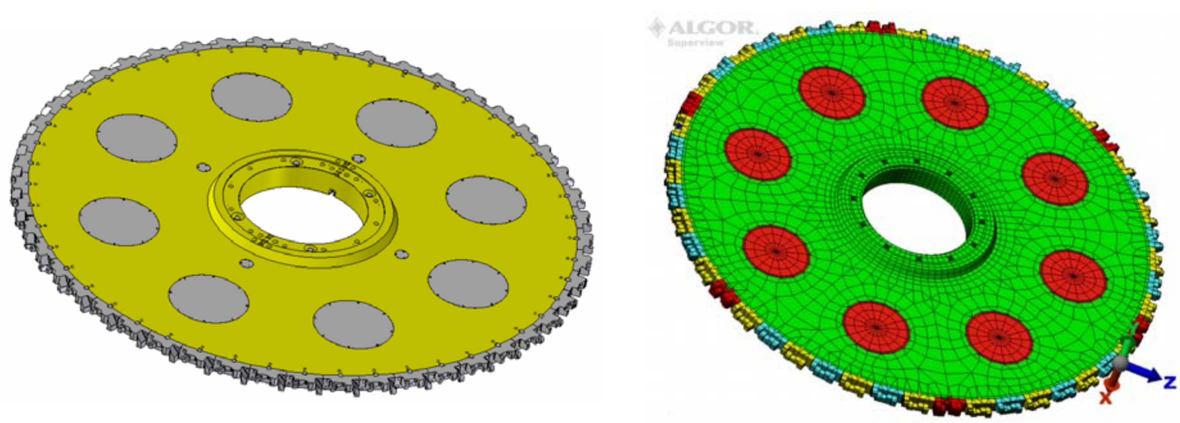



*Figure 2. General view of large-size milling cutter and its FEM model*

The main goal of simulation was to identify the first natural (free) frequency of the milling cutter, because possibly dynamic eliminators should be tuned to this frequency (in many cases the first natural frequency is the lowest and is most dangerous in the point of view of resonance).
Our FEM model built in ALGOR v.16 consist of over 15500 bricks elements and over 23700 nodes. It is shown at Fig. 2.
In the next step of analysis we have modeled an vibration damper. The form and mass of the damper was determined by the designer of the cutting tool. We tried to determine the stiffness of special elastic damping elements made of eladur [3] in the point of view of resonance criteria. It means that first natural (free) frequency of the damper should be the same as of milling cutter. The FEM model of the vibration damper and its application to the milling tool is shown at Fig. 3. The eladur elements chosen from a catalogue [3] may have different damping properties. It means that we may very the damping coefficient of vibration. For that reason doing FEM simulation we were able to find the best value of damping coefficient changing the eladur elements adequately.

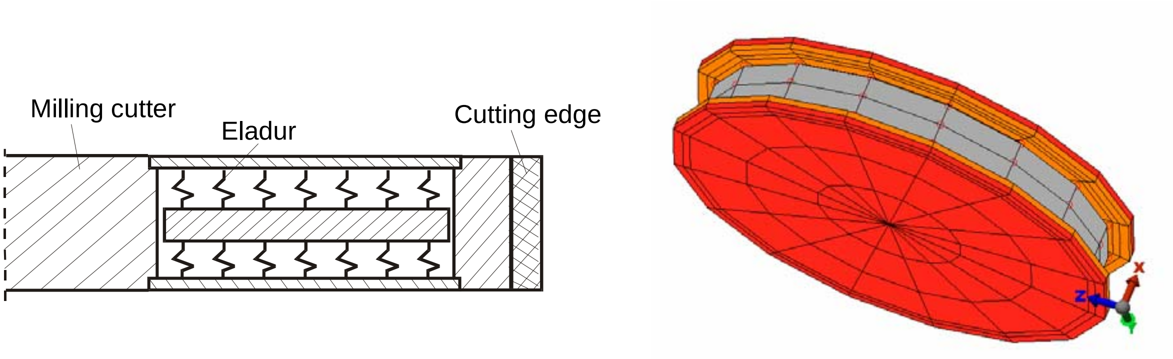



*Figure 3. Conception of dynamic eliminator and its FEM model*

## 3. RESULTS OF SIMULATION

Obtained spectrum analysis of milling tool model enabled to get the first natural frequency. The form of vibration (for first free frequency) and the response function for impulse constraint force is shown at Fig.4. The value of first free vibration of the milling tool model is about 30 Hz.
Eight dynamic eliminators were applied to the large-size milling cutter. Each of them have the natural frequency 30 Hz and the coefficient of damping was chosen during simulation research. We have forced an impulse constraint force which simulated cutting force while milling process and have observed vibration of milling tool in several points. Changing the coefficient of damping we tried to find the best solution in the point of view of minimization of vibration in selected points of cutting tool. Fig. 5 shows a frequency spectrum of the milling tool model with vibration eliminators for different coefficients of damping.

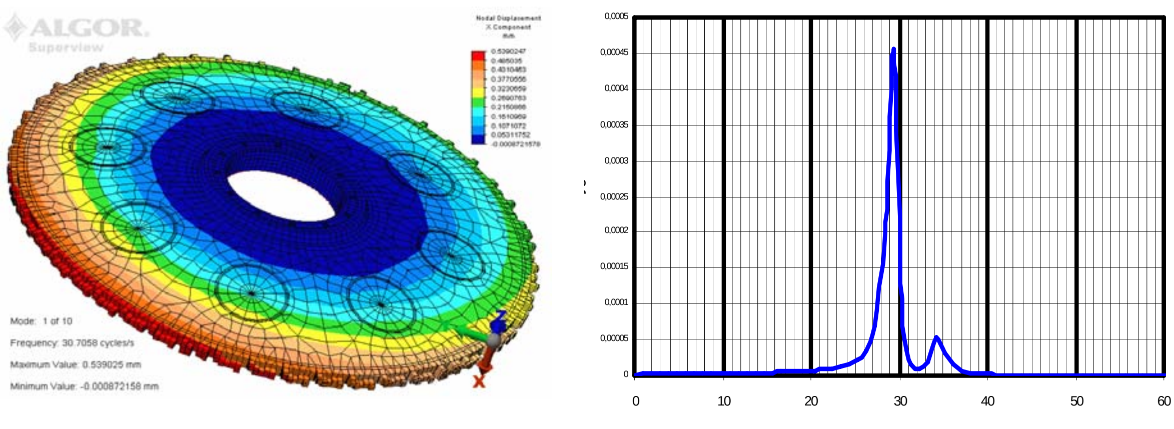
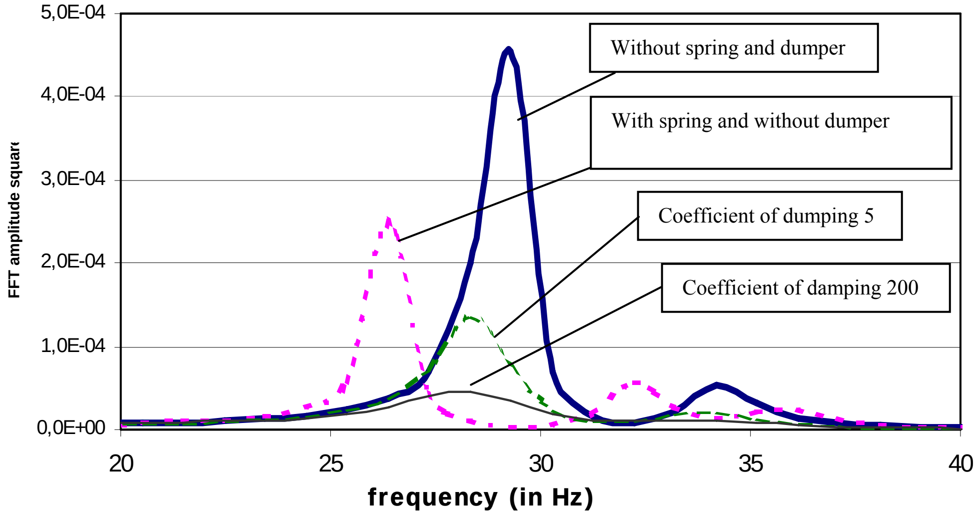



*Figure 4. The form of free vibration of large-size milling cutter and its spectrum of response function*



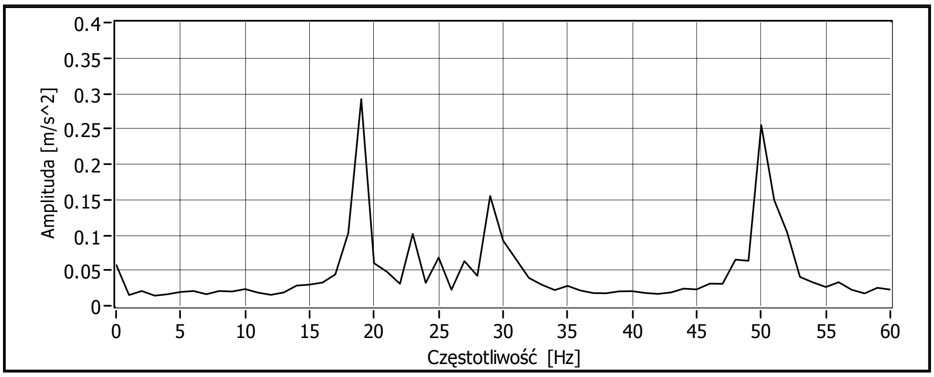



*Figure 5. Frequency spectrum of milling cutter with vibration eliminators for different value of dumping coefficient and frequency spectrum obtained from experimental investigation*

The results of such analysis confirms that conception of dynamic eliminator may be effective if the stiffness and damping coefficient of eliminator are tuned to the dynamic properties of milling cutter and to the frequency of cutting force.

## 4. CONCLUSIONS

Summarizing simulation results it should be said that best effects of vibration elimination may be obtained using spring elements which frequency are fit to frequency of free vibration of milling tool. These kind of solution leads to reduction of multiplication factor of amplitude of cutting tool Better effect can be obtained, if damping set will be used. Damping coefficient has its optimum value in the range between 0,1 and 0,3 value of critical damping, that mean about 200(N*s)/mm. In real conditions the damping value is limited to the construction capabilities of damping elements.

## 5. REFERENCES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[2] Technical documentation of special machine tool FS 550CNC (in polish)
[3] Catalogue of spring elements of ELADUR firm. http://www.veith- kg.de/deutschland/downloads/ Veith_Eladurkatalog05.pdf