FAKULTA STROJNÍ
ZÁPADOČESKÉ
UNIVERZITY
V PLZNI

DYNAMIC PROPERTIES OF RAM

Modal test result & Correlating simulation

SVOČ – FST 2019

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ABSTRACT

This work deals with dynamic properties of a ram of gantry machine tool from firm TYC Strojírny s.r.o. Respectively by casting of the ram determining its own nature frequencies and its own waveforms. The work contains experimental measurement and its results, and transferring this data to the NX12 and modal analysis simulation in NX12. Correlation of measured and calculated modal analysis results.

KEYWORDS

The ram, test modal analysis, nature frequencies, waveforms, correlation

INTRODUCTION

The aim of this work is to obtain the necessary data set of properties of casting of the ram for future use in a complex model of the whole gantry machine tool. It is therefore a research in the field of experimental measurement in combination with the modal properties calculations in the NX environment.

I have been given a unique opportunity to measure nature frequencies and waveforms of each main part of portal machine tool called FPPC 500, which will be the subject of my final research. The assembly of the machine tool has already started. Even so, I managed to measure nature frequencies and waveforms on casting of the ram, casting of the saddle, casting of the longitudinal traverse, casting of the cross rail and casting of the columns. The ram was chosen as a representative part, as it contributes most to the overall stiffness both static and dynamic with the greatest assumption. Measurements were made with borrowed apparatus from RTI.

It is possible to obtain data from individual parts of the stand-alone and then in combination with others. Processing large amounts of data in multiple programs complicates their clarity. The measurement of each part of the machine is complicated and in real world it is almost impossible to measure it, so that the time when creating a new machine is effectively used. Therefore, it is moving from experimental measurements to calculations. For the processing and presentation of differences between measurements and calculations, it is ideally possible to work with both types of results in one environment (program). In this case, the NX12 program was used.

The result is a correlation of experimental measurement results and modal analysis. Determine the actual waveforms that are actually reflected on casting of ram and determine the natural frequencies.

The ram

Since this post is not intended only for specifically targeted people, a picture has been created. The Figure1 shows the location of the ram on the gantry machine tool. It is the part of the machine that is terminated by the spindle, where the milling head (not at Fig.1) is usually located. The ram moves up and down, it is being held in the saddle that moves from left to right. The saddle is positioned on a cross rail that moves forward to backward along the longitudinal travers, which lies on the columns.

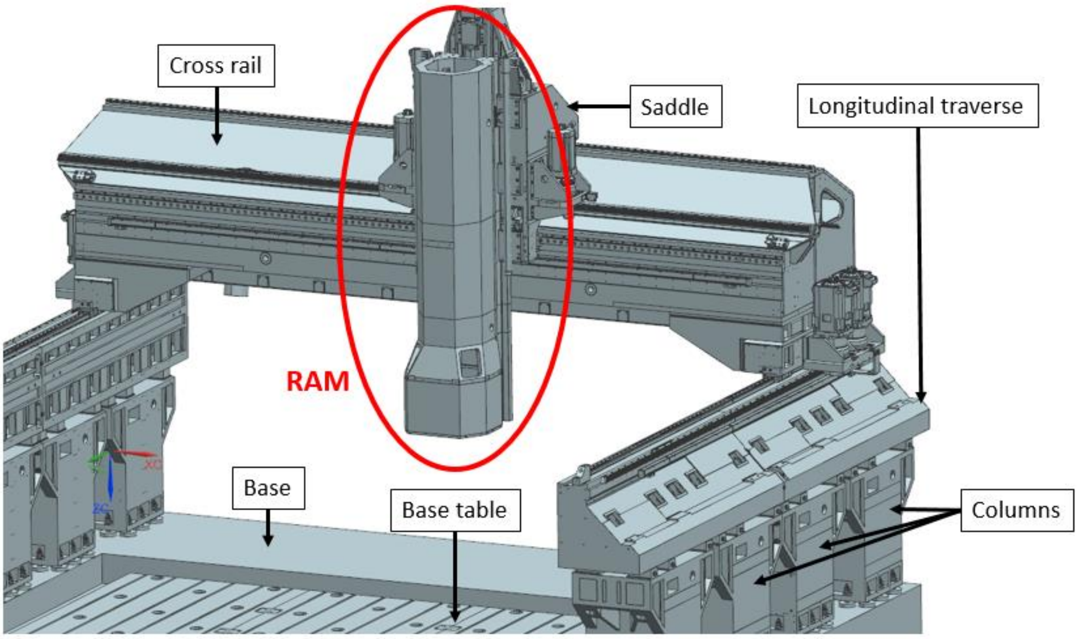


Fig. 11 – The ram positioned at top gantry machine tool

MODAL TEST

Measurement

The measurement was carried out on the halls of TYC Strojírny s.r.o in Mýto. The slide was hung on the crane with ropes and rods (see Fig. 2). So that the suspension resembles the free suspension as much as possible. In the Figure 2, you may notice pieces of paper adhesive tape with numbers. This is the preparation for subsequent measurement. These places were hit by modal sledge hammer. In the Figure 2 at the point where is the asterisk triaxial accelerometer was placed. This arrangement uses the principle of superposition. It doesn't matter if the sensors are at all marked spots and hits one point or the sensor is at one point and hits all the marked spots. Results should be the same from both possibilities.

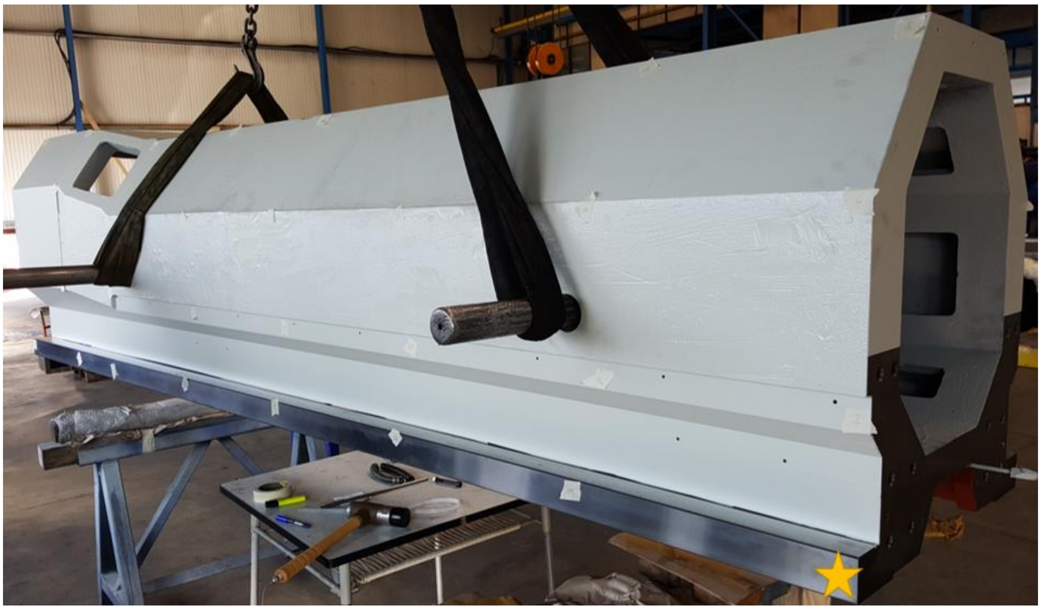


Fig. 12 - The ram hung on ropes (prepared for measurement)

Equipment

Modal sledge hammer (Fig. 4) and triaxial accelerometer (Fig. 3) were used, both were plugged in generator module (Fig 5). Ports one, two, three for axis X, Y, Z and port four modal sledge hammer. The generator module can be used as a "stand alone analyser", but in this case it was connected to a PC. In the PC, the data was collected using PULSE 19. In the PULSE19 there was wireframe created. The wireframe was filled with data for individual points during measurement.

Fig. 14 - Modal sledge hammer: Type 8206-003

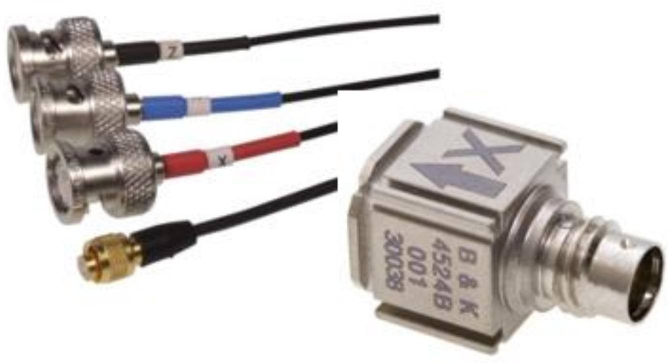


Fig. 13 - Triaxial accelerometer: Type 4524-B

Fig. 15 - Generator module: Type 3160 + battery

Measured data

The processing of the measured data was realized in the program PULSE19. It was necessary to go through the measured data and organize it for further work. The modified data for export was saved to the universal .unv format. These data were subsequently displayed in NX12. Comparison of the display of results in PULSE 19 and NX12 can be seen at Fig. 6 and Fig. 7.

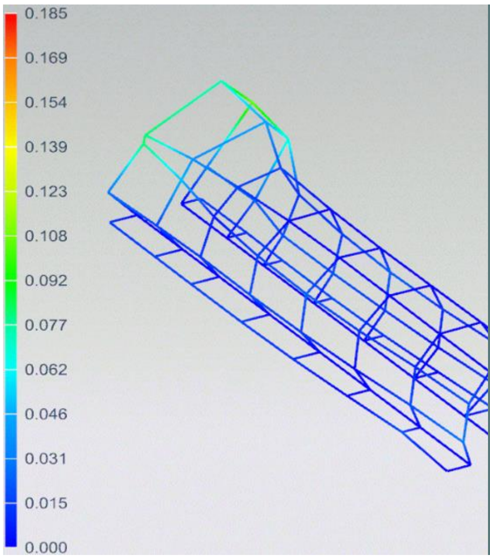


Fig. 17 - Results displayed in NX12

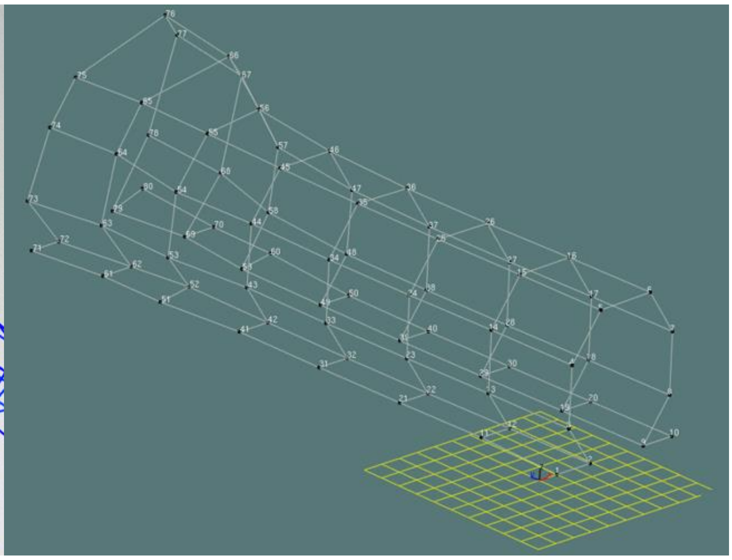


Fig. 16 - Result displayed in PULSE19

CORRELATING SIMULATION

It is necessary to perform a modal analysis in the NX12 environment before the data comparison is started. Only in the result environment of this analysis the program allows to insert data for correlation.

Alignment

Both programs work in otherwise shifted coordinate networks. The NX12 allows you to move a wireframe to an existing 3D model. Selecting three points in the wireframe and 3D model rotates the model to the required position.

Subsequently, it is selected with which tolerance the points overlap each other. The resulting laying of the 3D model and my wireframe can be seen at Fig. 8.

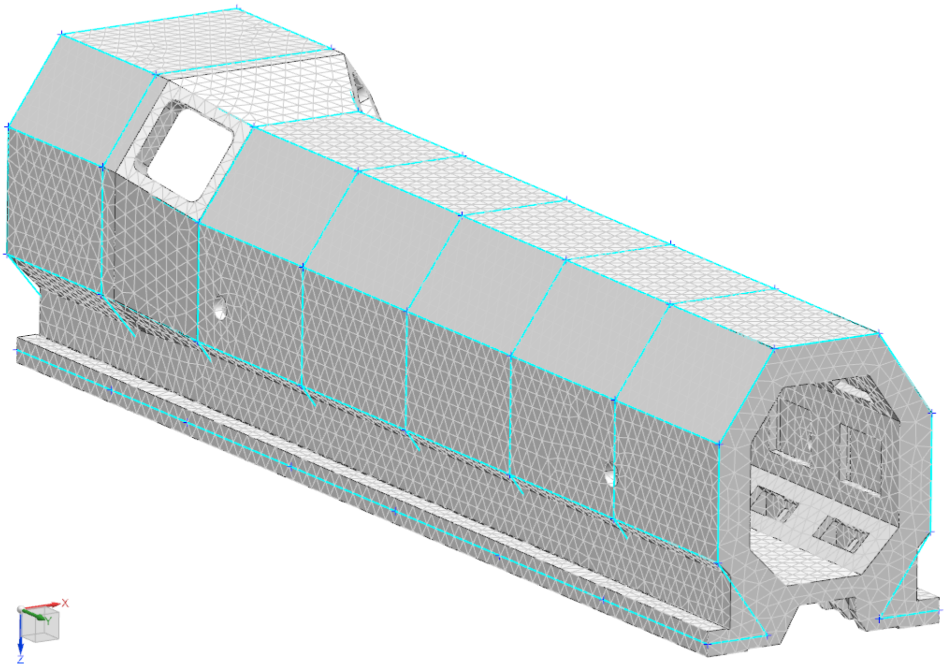
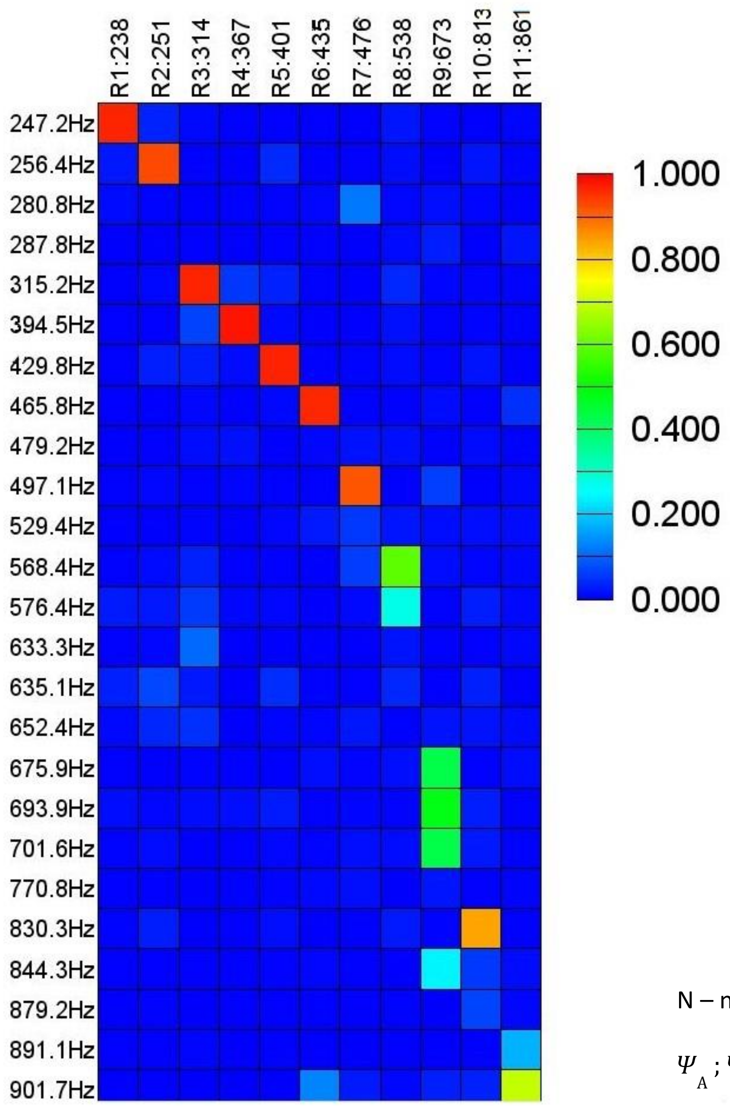


Fig. 18 - Final alignment of wireframe (Blue) at 3D model

MAC – Modal Assurance Criterion

The Modal Assurance Criterion (MAC) is a parameter indicating the degree of consistency between a mode shape from test and another one from simulation. In my case between mode shape from measuring and modal analysis simulation in NX. This parameter is a scalar value between 0 and 1. A MAC value near 1 indicates a high degree of correlation or consistency between two mode shapes. In the Figure 9. the vertical axis is the values of the natural frequencies from the modal analysis simulation in NX, and the horizontal axis is the values of the measured natural frequencies. The equation (1) shows background of creation MAC matrix. A and X are two mode shapes that you want to compare. [1]



N – number of common simulation and test mode shape components

Ψ_A ; Ψ_X – mode shapes

Fig. 19 - MAC matrix

$$MAC(A,X) = \frac{\left|\sum_{j=1}^{N} \Psi_{Xj} \Psi_{Aj}^{*}\right|^2}{\sum_{j=1}^{N} \Psi_{Xj} \Psi_{Xj}^{*} \sum_{j=1}^{N} \Psi_{Aj} \Psi_{Aj}^{*}} \qquad (1)$$

Boundary condition of modal analysis simulation

Thanks to MAC, I was able to find the boundary conditions that are most close to the experimental measurements. Repeating the previous steps to do the MAC matrix did not have the most matching fields. The most convincing result was a model without boundary conditions. For which the MAC matrix (Fig. 9) is displayed.

Pairing based on MAC

For a visual comparison of waveforms from measurement and from simulation is necessary to make mode pairing (Fig. 10). And its again based on MAC. Reference Modes are frequencies from measurement and work modes are frequencies from simulation. You could notice that paired frequencies aren't the closest values. But they are still close ones if you check percent deviation (Tab. 1).

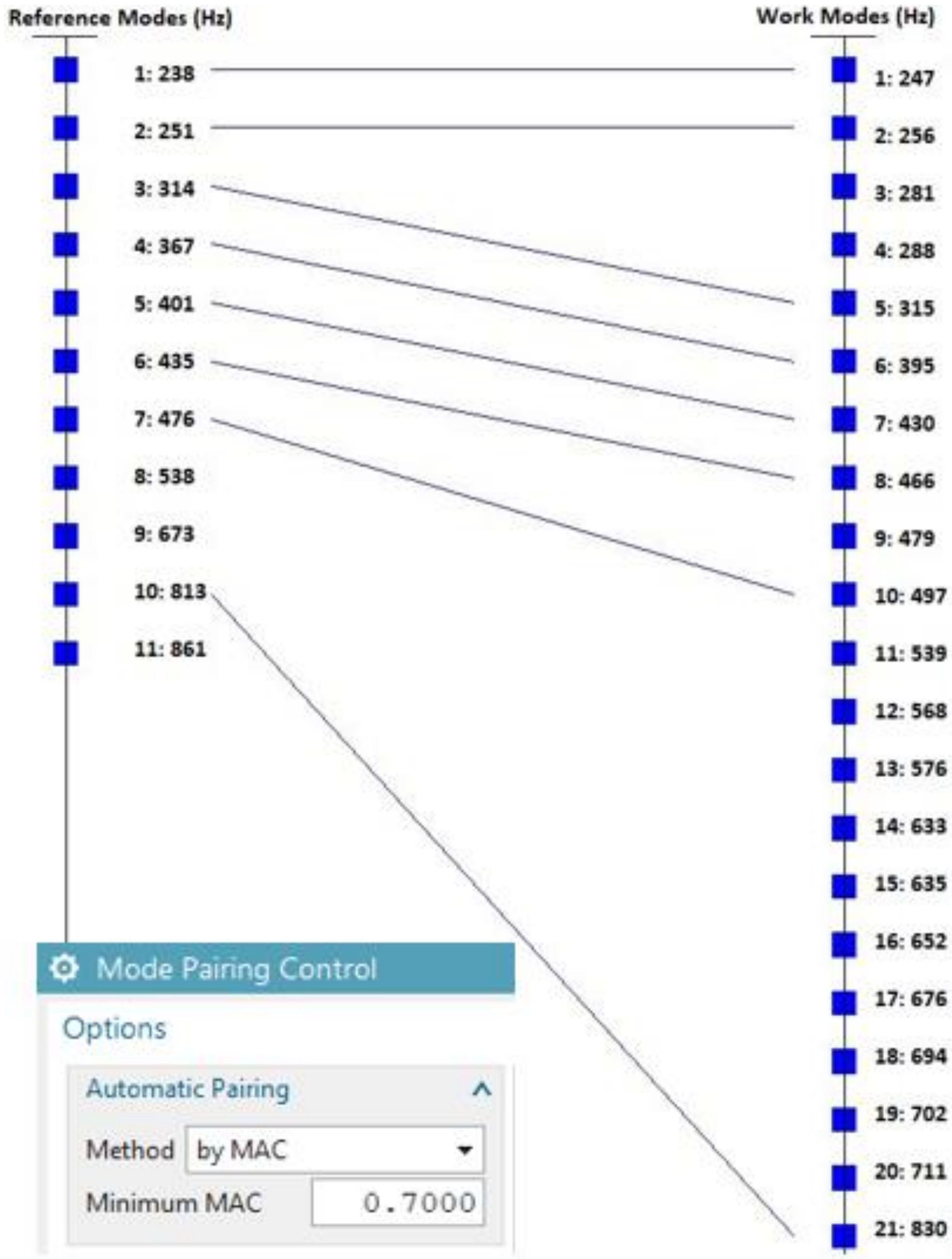


Fig. 20 - Mode pairing based on MAC – connected frequencies

Pair	Reference Modes (Hz)	Work Modes (Hz)	Percent deviation %
1.	238	247	3,78
2.	251	256	1,99
3.	314	315	0,03
4.	367	395	7,63
5.	401	430	7,23
6.	435	466	7,12
7.	476	497	4,41
8.	813	830	2,09

Tab. 1 - Paired frequencies and theirs deviation

CONCLUSION AND RECOMMENDATIONS

The result of this work are visual comparison of individual measured and calculated wavefroms. These images will be presented during the SVOČ, since it is a graphical rendering of the deformations over time, they cannot be briefly transferred to motionless forms.

The comparison of measured and calculated values of nature frequencies and waveforms by correlation was performed. The results are very satisfactory and this will be a good basis for further work.

The next step is to measure the nature frequencies and waveforms on combinations of the individual parts of the stand as the machine progressively folds. Some of these measurements have already taken place and it is now necessary to process the results and prepare the basis for measuring the entire top gantry machine tool FPPC 500.

ACKNOWLEDGMENTS

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REFERENCES

[1] Post at https://mechanicalengineeringblog.tumblr.com/post "Correlating Simulation & Modal Test Results with Simcenter 3D; Nov 8th, 2017 (#engineering, #simcenter, #siemensplm)