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RESEARCH OF SUPPORTING STRUCTURE OF VERTICAL LATHE USING FINITE ELEMENT ANALYSES

Krzysztof Lehrich
Department of Machine Technology
Silesian University of Technology
Gliwice
Poland
e-mail: krzysztof.lehrich@polsl.pl

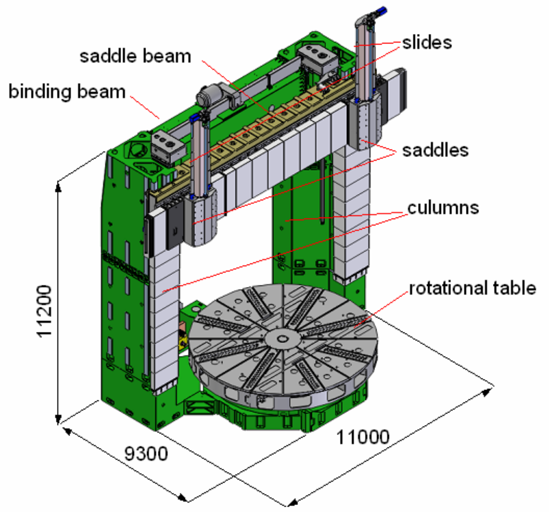
ABSTRACT
This paper presents the results of simulation research of vertical lathe KDC 700/800. The simulations were done with using finite elements method in cooperation with producer of this machine tool, Rafamet S.A factory.
In this paper the selected range of simulation research concerning on estimation of shape stiffness influence of supporting structure selected subassemblies on static stiffness of whole design was presented. On the basis of producer's design documentation the model of supporting structure, it means: columns, crossrail with carriages and tie beam was worked out. To the simulation a few characteristic positions of carriages and slides were selected. In point of tool clamping the forces affected in three direction were applied. In simulation research the ideal stiffness of selected subassemblies in succession were assumed. On the basis of simulation results the estimation of subassemblies influence on static stiffness of whole machine tool design was done.
Keywords: analysis and modelling, machine tools, static stiffness

1. INTRODUCTION
One of the identification methods of law elements in machine tool structure, on the design stage, are simulation research with using finite elements method. This type of research has particular meaning in case of large-size heavy machine tools. The heavy machine tools belong to this group of machine tools for which the prototype and research of prototype weren't done. It comes from piece production, most often especially against order of customer. Therefore the simulation research have in this case especially meaning. Moreover the simulation research allow on preliminary identification of using properties of machine tool like: stiffness, mode shapes and natural frequencies and thermal displacements.
The results presented in this paper are effect of cooperation with producer of heavy machine tool, Rafamet S.A factory. This factory specializes in production of heavy machine tools like vertical lathe, planer mills, special machine tools for railway industry and shipbuilding industry.

2. RESEARCH OBJECT
The main use of vertical lathe KDC 700/800 is machining of reactor vessels. It's worth pay attention to overall dimension of this machine tool presented in the figure 1. From modeling point of view so large overall dimension connecting with thickly ribbing inside of frames cause big difficulties. Small thickness of ribs (30 to 40 mm) and large overall dimensions (even to tens meters) cause, that number of finite elements in models are meaningful. Therefore demanded solution capacity is bigger, especially when besides static stiffness of frames we would like take into account nonlinear effects connected with contact stiffness.

Presented in this paper the simulation results concern the static analysis of supporting structure. It contains: columns, tie beam , crossrail and carriages with slides. The main aim of simulation research were analysis of static stiffness of supporting structure and estimation of stiffness influence of selected frames on stiffness of whole structure. In presented research only shape stiffness of frames was took into consideration. The same the nonlinear effects on the contact slideways and guides were omitted.

a) b)



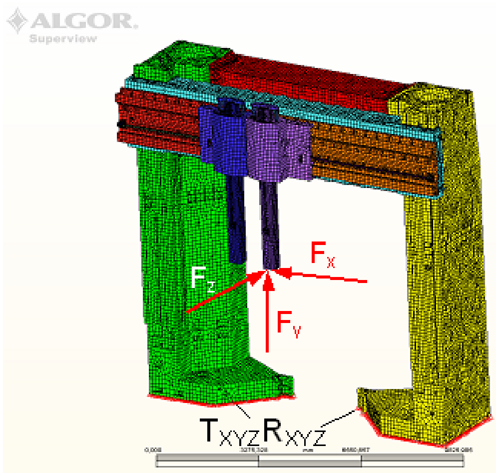


Figure 1. Model CAD of vertical lathe KDC 700/800 (a), discrete model of vertical lathe with one of selected positions of carriages and slides (b)

The estimation of stiffness of supporting structure was made on the basis of displacements of slide end under the influence of forces located in point of cutting tool clamping.

$$j = \frac{\Delta P}{\Delta f} \tag{1}$$

where:

j – static stiffness, N/μm
P – loading force, N
f – displacement on the loading force direction, μm

The estimation of flexibility influence of particular frames on flexibility of whole structure achieved similarly. During the research assumed, that residual frames are ideal rigid. For selected positions of carriages and slides the research was done. The discrete model of supporting structure in one of selected position of carriages and slides was presented in the figure 2.

3. RESULTS OF SIMULATION RESEARCH

On the basis of analysis of obtained results we should say, that static stiffness of supporting structure in the direction X (feed direction) with hide slides and carriages in middle position on crossrail is the same for both carriages and equals 101 N/μm. While for side-extreme carriages position the stiffness is about twice bigger and equals 227 N/μm. When we assumed “ideal” rigidity of carriage and slide, that stiffness for selected positions are meaningfully different. Similar situation concern an “ideal” rigidity of crossrail, carriages and slides.

For Y direction we observe repeated increase of static stiffness but differences dependence of carriage position are not already meaningful. Increase in this cause the rigidity of carriage and slide already haven’t the same great meaning for stiffness of whole structure. The stiffness of whole structure arise from columns rigidity is four times bigger in Y direction in comparison with stiffness on X direction.

For Z direction visible is insignificantly lesser static stiffness in comparison with values obtained in X direction, for material properties answered real properties. The “ideal” rigid carriage and slide increases twice stiffness of whole structure, similarly like on X direction. In Z direction visible is also about twice bigger stiffness of structure for carriage in side-extreme position on crossrail.

Increase of slide line feed to extreme position causes about four times decrease of static stiffness of whole structure in X direction. The influence of slides line feeds on stiffness in Y direction isn't so meaningful. While in Z direction visible is about twice decrease of stiffness. The value of static stiffness of whole structure in Z direction is very similar to value in X direction for real material properties. The influence of carriage position on stiffness of whole supporting structure is visible too. The supporting structure are characterized by bigger static stiffness when both carriage are situated in the middle position. The biggest influence of this position visible is in static stiffness results in X and Z direction and a little smaller in Y direction.
In the figure 3 the distribution of stress and displacements in supporting structure under gravity load were presented. The values of stress in design is negligibly small, what is characteristic for majority of heavy machine tools. Resultant displacements of slide end equal about 1 mm and slide line feed and carriage position on crossrail have little influence on this value.

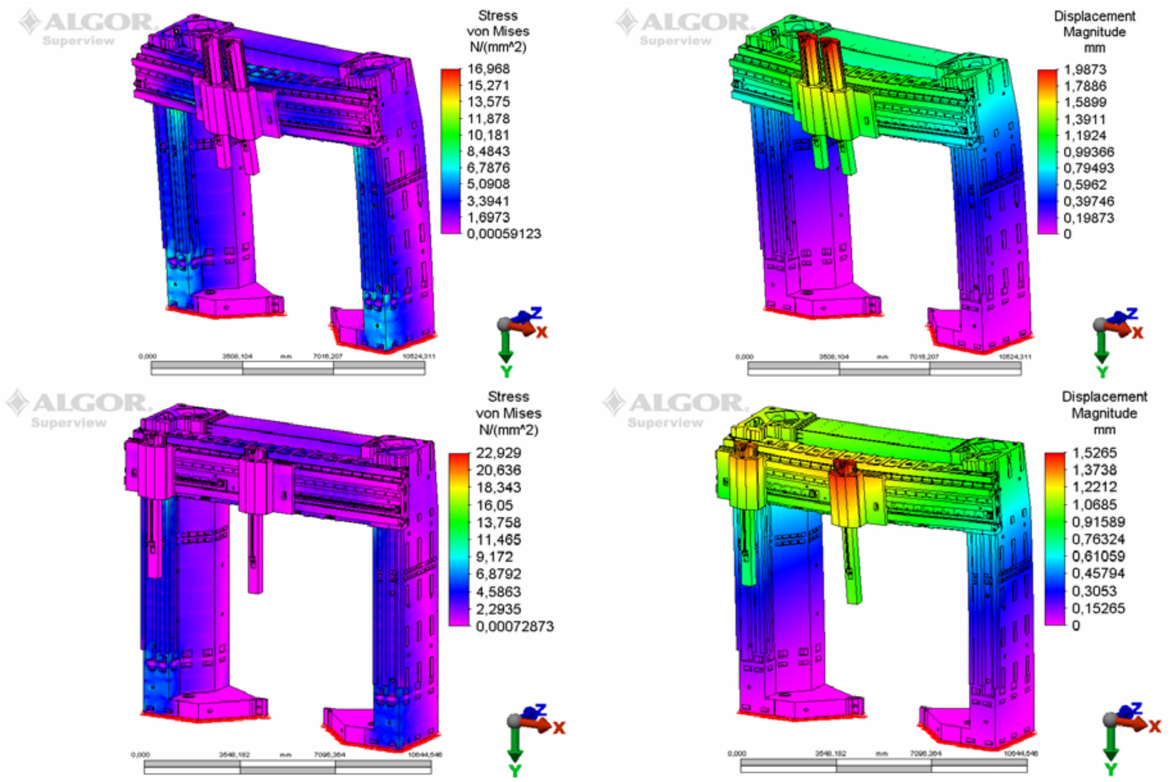


Figure 3. Stress and displacements distribution in supporting structure of vertical lathe for selected position of carriages and slides in results of gravity load

The exemplary results of research of supporting structure behavior in loading by force equals 30 kN in three selected direction were presented in the figure 4. In assumption to stiffness analysis disregarded the influence of gravity load. Therefore the results in the figure 4 and in the figure 3 should not be directly compared.

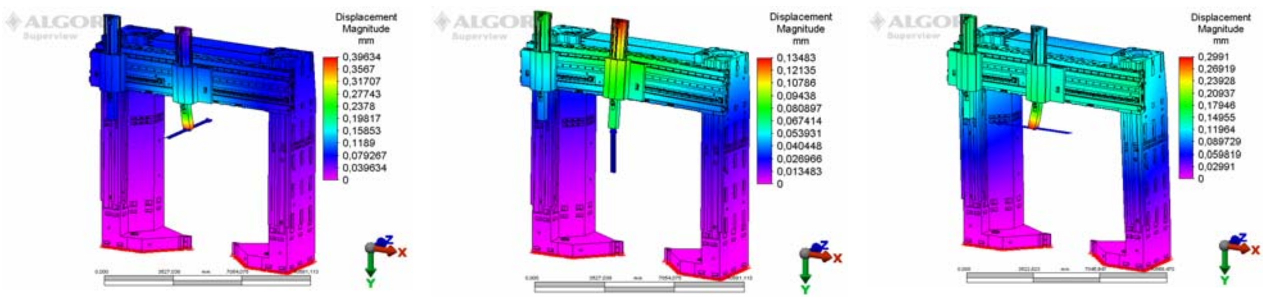
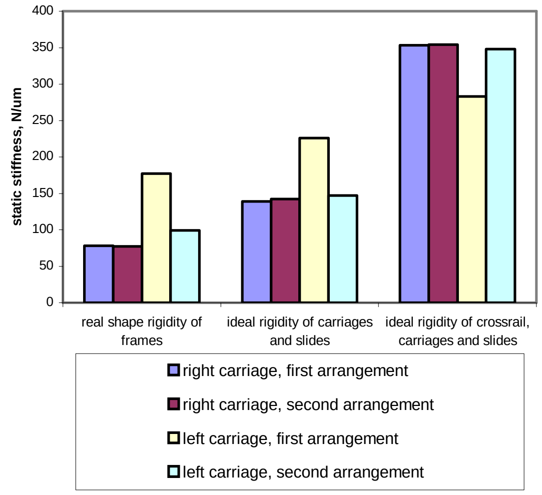


Figure 4. Displacements of supporting structure in results of loaded force about value 30 kN in three selected directions

In the aim of better showing the simulation results of influence of slide line feed value on stiffness of whole structure in the figure 5, the results of static stiffness analysis for Z direction were compiled. The results concern two position of carriages: first- both carriages in the middle position and second cause- one carriage in the middle position and the second in side-extreme position.

a)



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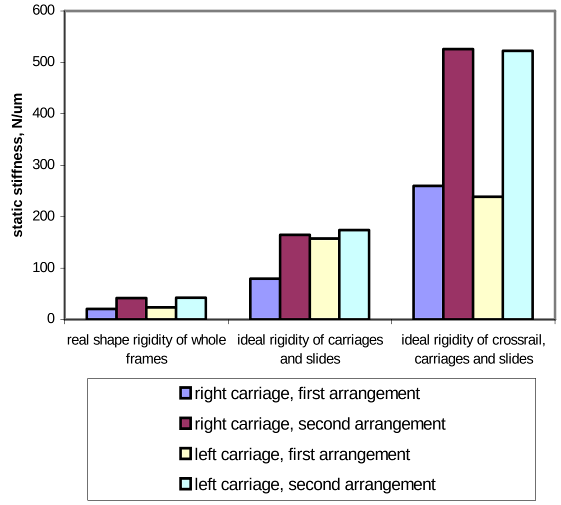

Figure 5. The setting-up of static stiffness results of supporting structure in Z direction. Selected position of carriages and slides: a) slide hidden in the extreme positions, b) slide moved to forward to opposite extreme position

In summary to worked research it should be found, that the greatest meaning for stiffness of whole structure have shape stiffness of slides and value of line feed. The position of carriages on crossrail has meaning too.

The stiffness of supporting structure will has influence on machining accuracy and from this point of view, allowable values of cutting forces. Therefore in searching the improvement of supporting structure stiffness in first order should be consider the change of slides design.

4. REFERENCES

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