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PRELIMINARY APPROACH TO OPTIMIZATION OF MACHINE TOOLS FRAMES

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ABSTRACT
This paper presents the preliminary results of geometry optimization of experimental design of column frame of milling machine center. The aim of optimization were frame mass reduction with maintaining of unchanged value of design static stiffness. The results of static stiffness analyses of whole design of milling machine center with optimized frame were compared with results of research of design proposed by designer with non optimized column frame. The simulation was done with using the Ansys system.
Keywords: analysis and modelling, machine tools, optimization

1. INTRODUCTION
The competition in every production areas forces on producers the necessity of searching cost reduction. Constantly evolutional the computer engineering CAD and computational numerical methods such as Finite Elements Method allow on shortening the time of production preparation process and defining the using properties of design already on the stage of design. It concerning also to design process of machine tools. Evolving from many years cooperation with one of the biggest in Europe producers of heavy machine tools, Rafamet S.A company and appearance of optimization modules in commercial computational systems encouraged us to take the subject matter connected with optimization of heavy machine tools frames designs. In this paper we would like to present outline of proposed methodology and first tests of optimization using Design Xplorer module of Ansys.

2. FRAMES OF HEAVY MACHINE TOOLS
Designs of heavy machine tools and designing process of them belong to very special. Mainly it is effect of large overall dimensions, even to tens meters (lathe TV 240 CNC – length equal 41 m, width 5,2 m and height equal 4,2 m) and very large masses of machine tools and workpieces (lathe TV 240 CNC – mass equal 205 tons and maximal mass of workpiece equal 120 tons). The second factor is piece production and the same area deficiency for prototype building, tests and correction of unsuitable design solutions on the basis of them. Additionally difficulties are short times for realization of order and high cost of machine tool. From economical point of view, in case of important design error the two last factors very often could decide about financial standing on the

market. Therefore happen, that new designs are created on the bases of old, verified solutions. Not always these designs are optimal.
Frames design of machine tools mainly depends on designer experiences. In case of heavy machine tools the main criterion decided about frames geometry is stiffness criterion. The machine tool stiffness influences directly on accuracy of machining. During the design analysis of frames the particular attention should pay heed to:

- large overall dimensions even to tens meters with simultaneously accuracy of machining on a few micrometers level,
- large throat distance with simultaneously relatively small stiffness of frames, which role are fixing of tools,
- large forces of inertia connected with large masses of moving sub-assemblies and workpieces especially in case of HSM machine tools,
- configuration of slideways.

For optimization are both economic factors and using properties of machine tool contained accuracy first of all.

3. METHODOLOGY OF OPTIMIZATION PROCESS OF MACHINE TOOLS FRAMES

Proposed methodology of shapes optimization with using genetic algorithms and Ansys system was worked out on example of milling centers column. Geometrical shape of milling center proposed by designer showed in the Figure 1. The aim of analysis was determination of frame shape characterized by smaller mass and flexibility not bigger than flexibility of original frame.

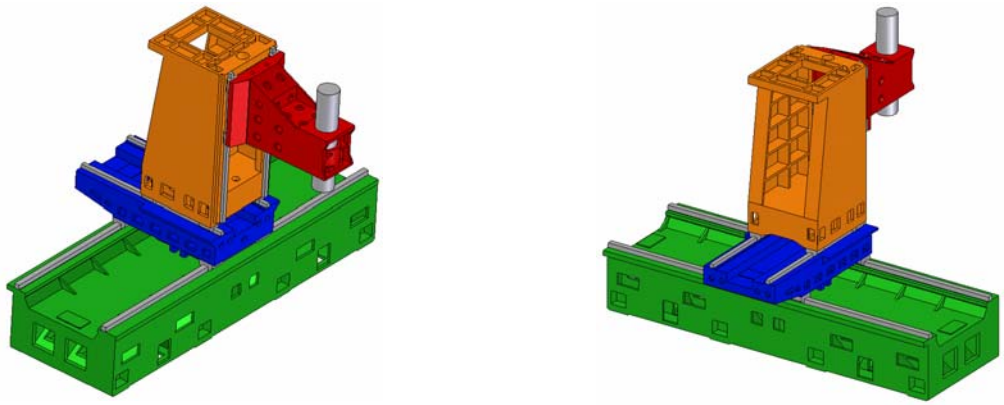

Figure 1. Design shape of milling machine center proposed by designer – Model 0 [2]

For that purpose the following method of procedure was proposed:

1. Assumption the first geometrical shapes of frames as simple bodies about shapes closed exemplary to cubicoids (Figure 2). The overall dimensions come from general conception of machine tool. It takes into consideration the chain of frames from apply a force point to support places of analyzed frame.
2. The assumption of boundary conditions. Selected degrees of freedom should be taken in places of guides location or in places of machine tool clamping to the foundation.
3. The assumption of loading. The forces and the moments affected the frame should be taken into consideration. Each load independently and combination of loads should be taken into account. Exemplary results of that approach were presented in the Figures 3 and 4.
4. The solution of problem with using Ansys system.
5. The analysis of obtained results. The results of FEA analysis is geometrical shape of frame obtained by elimination of “useless” portion of material. The obtained shapes of frame depend on kind of loading and supporting (Figures 3 and 4).
6. Execution of 3D geometrical model of new frame on the basis of results of optimization process.
7. The analysis of frame producibility.
8. Parametrical optimization of new geometrical shape of frame with using the genetic algorithms.

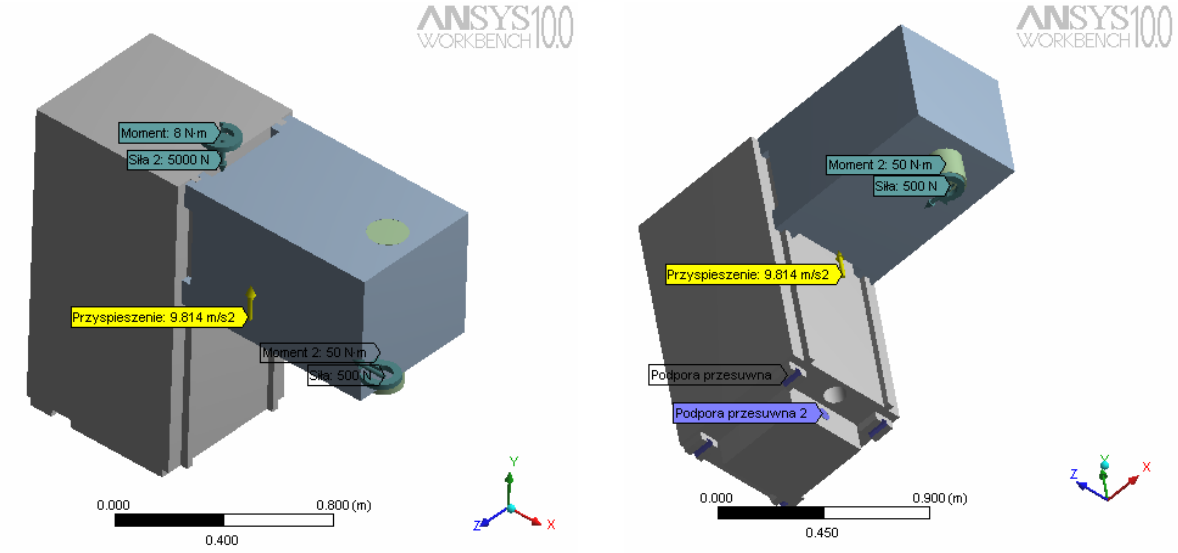

Figure 2. The input geometrical shape of frame model and one of assumed kinds of loading and supporting

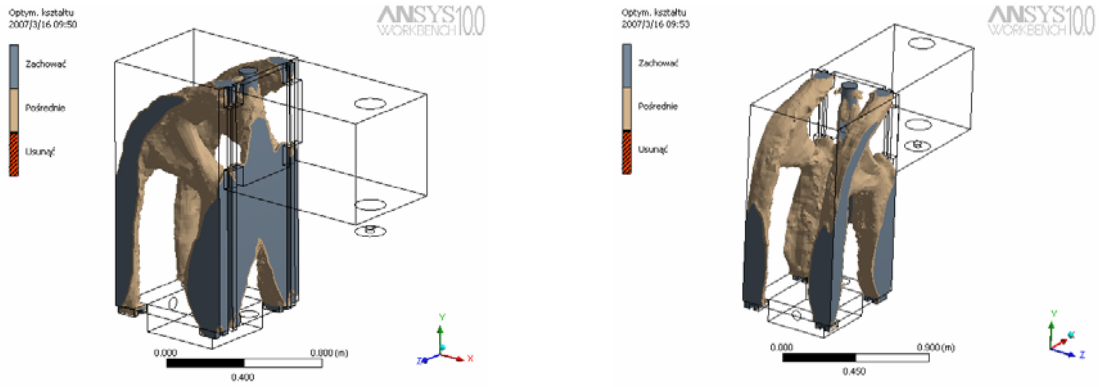

Figure 3. The geometrical shape of frame after optimization process, complete loading

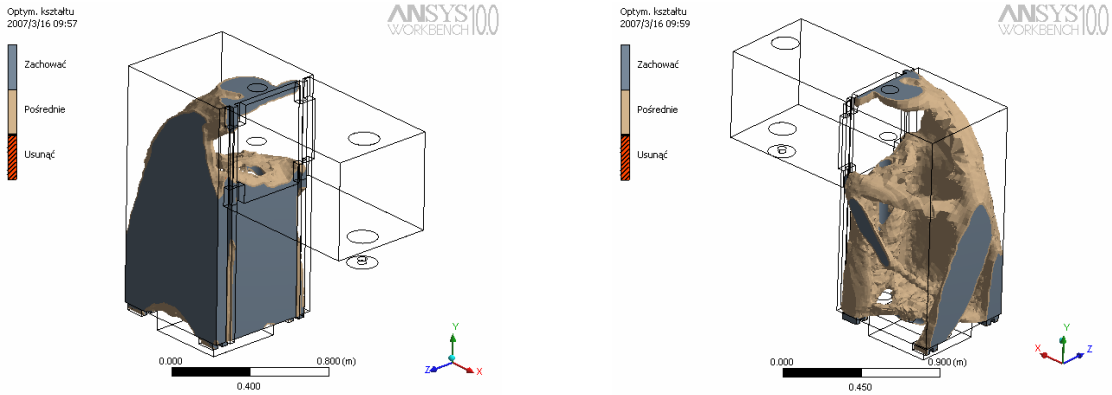

Figure 4. The geometrical shape of frame after optimization process, loading only from resultant cutting force

9. The static stiffness analysis of whole design of machine tool and comparison obtained results with results of analysis of design proposed by designer.
10. The analysis of dynamic properties of new design enclosed the mode shapes and natural frequencies.
11. Comparison of masses of frame after optimization and frame proposed by designer.

12. Repetition of optimization process for next frame in chain.

In the figures 5 and 6 the milling center with new column models after shape optimization were showed. The comparison of column masses and results of static stiffness analyses of whole milling centers were presented in the table 1.

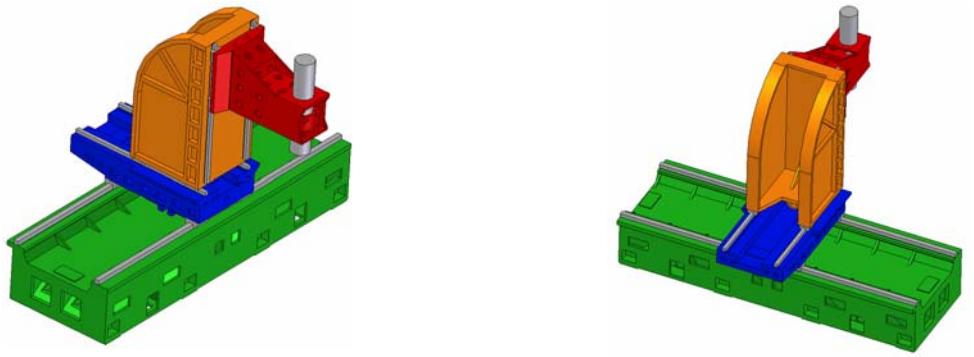

Figure 5. The geometrical shape of column frame after optimization process - Model 1

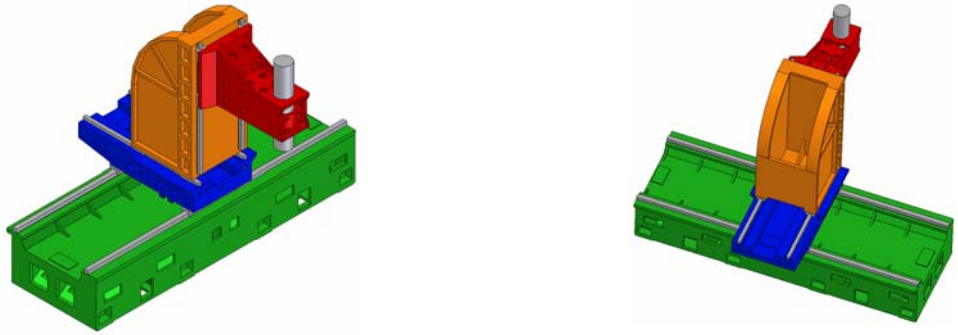

Figure 6. The geometrical shape of column frame after optimization process - Model 2

Table 1. The comparison of frame masses and static stiffness results of whole milling machine centers before and after optimization

model	mass, kg	mass decrement, %	static stiffness N/μm			increase of static stiffness, %		
			X direction	Y direction	Z direction	X direction	Y direction	Z direction
Model 0	879,43	---	127,1	79,2	34,1	---	---	---
Model 1	758,48	**15,9**	142,9	91,7	34,2	**11,1**	**13,6**	**0,4**
Model 2	807,45	**8,9**	143,0	91,9	38,7	**11,2**	**13,9**	**12,0**

4. SUMMARY

Proposed methodology of machine tool frames optimization will verified in design process of heavy machine tools frames, where certainly a lot of new aspects connected with this process will appear. The experiences obtained to this time showed, that the most of all time-consuming is parametrical optimization process. Available commercial software owns meaningful limitations in this regard. Therefore the studies on own application based on genetic algorithms and allowed on most effective optimization process are making now [1].

5. REFERENCES

[1] Wilk P., Kosmol J.: First attempt to optimization of column of milling machine using genetic algorithm and finite element method. Scientific work of Department of Machine Technology Nr 2/2006, Gliwice 2006, (in polish).

[2] Design documentation of vertical milling machine center, Machine Tool Research and Design Centre, Warszawa 2006, (not published), (in polish).