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Optimization of the Supporting Structure of the Machine Tool

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Abstract: The aim of this thesis is to identify the characteristics of the existing welding column of horizontal boring machine TOS Varnsdorf a.s. MAXIMA and his subsequent replacement with a casting column regard to the static rigidity, dynamic parameters and mass due to the economics production. To achieve the optimal solution this work used a method of parametric optimization and topology optimization method, which both are applied to the finite element method.

Keywords: Topology Optimization; Parametric Optimization; Support Structure; Machine-Tool; FEM.

1 Introduction

Static stiffness and dynamic behavior (natural frequencies, mode shapes and damping of oscillations of the individual mode shapes) has significant influence on the precision parameters and machine productivity. For medium size horizontal boring machine are these parameters influenced primary by the body of the column [1]. One of the possibilities to influence the productivity of the machine is to increase the feed rate of the axes, which eventually resulted in an increase in claims on the rigidity of the machine and its dynamic behavior. Static rigidity of the machine is generally increased by the additional ribs, but this is related to the mass increase and affection of the dynamic properties. These properties are directly related to selecting and tuning powerful drives, in contrast, this leads to a reduction in productivity [2].

2 Optimization

2.1 Parametric Optimization

Parametric optimization of the column was done for 4 construction parameters:

- A: Thickness of the outer wall.
- B: Thickness of the inner ribs.
- C: Number of the floors.
- D: Size of the chosen entities which reduce mass.

The main difficulty of this method was to create a parametric CAD model which must be correct for any of the combination of the construction parameters.

For comparing results of the parametric optimization we choose displacement of reference point on front of the ram, total displacement dU is calculated via Eq. 1.

$$dU = \sqrt{dX^2 + dY^2 + dZ^2} \tag{1}$$

As we can see in Tab. 1, the greatest influence on displacement of reference point considering mass difference dm = 2000 kg has construction parameter A – thickness of the outer wall. On the other hand the smallest influence has construction parameter C – number of the floors. Influence of construction parameters B and D is comparable.

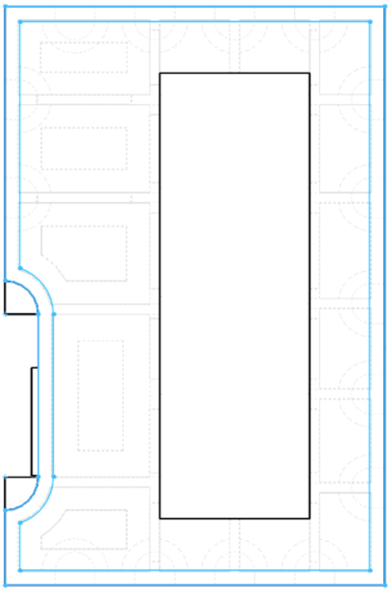

Fig. 1: Construction parameter A – thickness of the outer wall.

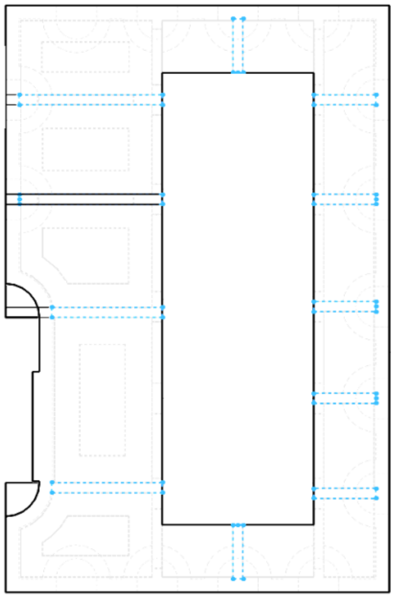

Fig. 2: Construction parameter B – thickness of the inner ribs.

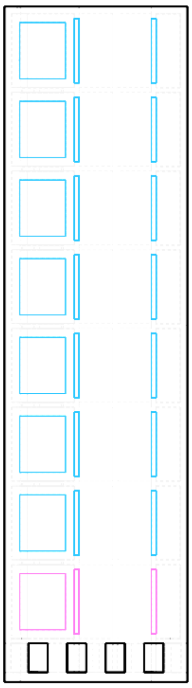

Fig. 3: Construction parameter C – number of the floors.

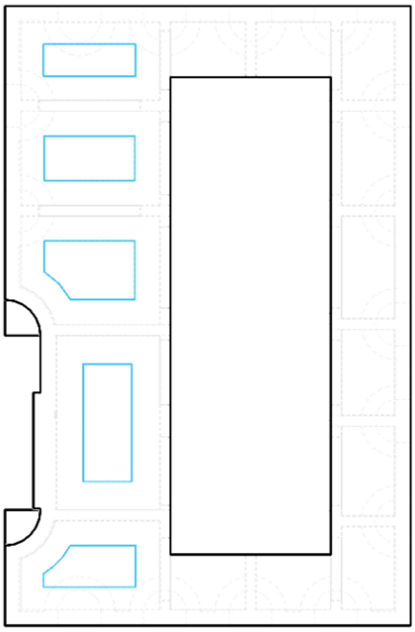

Fig. 4: Construction parameter D – size of the chosen entities which reduce mass.

Tab. 1: Reference point displacement difference for mass difference dm = 2000 kg after linearization.

Displacement difference	A	B	C	D
dX [μm]	7.80	2.06	3.73	1.59
dY [μm]	19.92	15.05	11.52	14.78
dZ [μm]	13.91	9.77	6.92	9.38
dU [μm]	25.52	18.06	13.94	17.58

2.2 Topology Optimization

The basis of the method of topological optimization is finding a minimum strain energy. Assume the strain energy density in the form Eq. 2 and the Hooks law Eq. 3.

$$\lambda = \frac{1}{2}\sigma_{ij}.\varepsilon_{ij} \tag{2}$$

$$\varepsilon_{ij} = C_{ijkl} \cdot \sigma_{kl} \tag{3}$$

Substituting Hooks law Eq. 3 in form of the strain energy Eq. 2 gives us Eq. 4.

$$\varepsilon_{ij} = C_{ijkl}\sigma_{ij}\sigma_{kl} \tag{4}$$

$$\left\{\hat{C}, \hat{\sigma}\right\} = \arg \min_{C \in C} \min_{\sigma \in \sigma} \frac{1}{2}\left(\int_{\Omega} C_{ijkl}\sigma_{ij}\sigma_{kl} d\Omega\right) \tag{5}$$

One of the goals of this thesis is to try to apply a topology optimization method on the body of the column. It is highly difficult to set the right options for the optimization, and the results is hard to interpret. But it may give us some hints, which can be used in design.

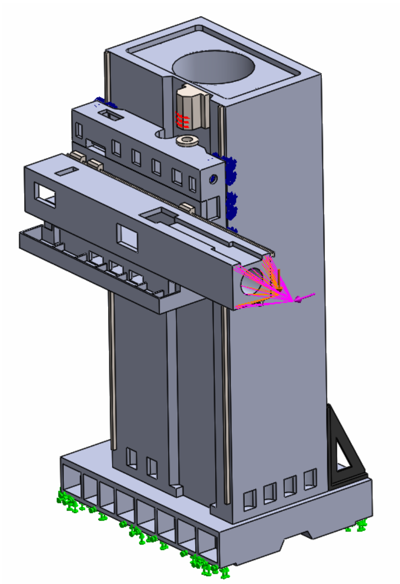

Fig. 5: FEM model of the machine TOS Varnsdorf MAXIMA with the existing welding column.

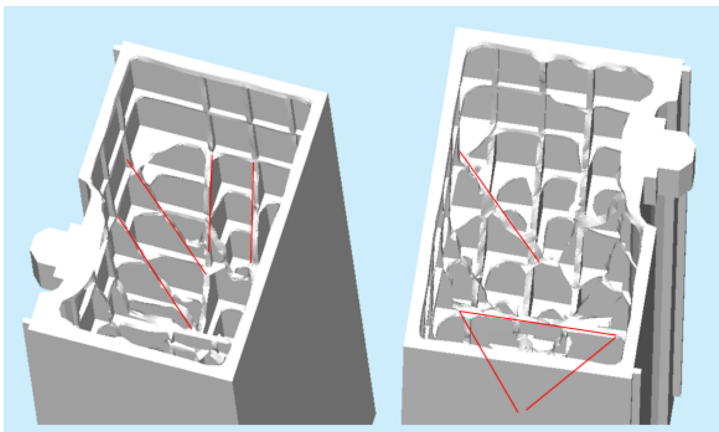

Fig. 6: Results of topology optimization on the body of the casting column with 30 % volume reduce from the full-ribbed design.

From visualization of results of topology optimization several conclusion can be deduced.

- Remove of material has started from the top of the column and continues vertically. On the outer walls remains rib reinforcement.
- At first sight it is obvious that there is a material removal on all the floors in the areas between the ribs.
- Reinforcement transversely appears approximately in the mid height of the column.

3 Conclusion

In the context of this thesis was created simplified mathematical model of bed type horizontal boring machine TOS Varnsdorf MAXIMA with existing welding column. This model was used to identify static stiffness and modal parameters of current design. The goal of this work was to design such a casting column which its properties as close as possible to the current column.

Result of this work are 3 designs of the column which is optimized by conclusion of the parametric and topology optimization. The main difficulty of parametric optimization method was to create a parametric CAD model which must be correct for any of the combination of the construction parameters. Topology optimization method on the body of the column provides results, which is highly difficult to interpret. It turned out that the main difficulty in the designing the bodies of machine frame are limitation in manufacturing and assembling.

Acknowledgement

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