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Design of polimer concrete main spindle housing for cnc lathe

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Abstract: Advanced composite materials have been widely used to improve various properties such as impact resistance, strength, durability and vibration damping. Polymer concrete is one of the new materials, which has been developed for potential application in the machine tool industry. This paper describes modeling and structural analysis of main spindle housing structure made by different materials. The casting metal structure of the origin structure is substituted by the structure made with polymer concrete. This work is a contribution to the practicability of the use of polymer concrete in machine tool design.

Keywords: Main spindle housing, Polymer concrete, Machine tool structure, Modeling

1. INTRODUCTION

International competition in machine tool manufacture demands flexibility, high quality, reaction to the market demands and low costs. Therefore the processes and machines are designed with modular structure. A main spindle box could be such a module of machine tool. The most important factor affecting machining accuracy is an accuracy of the machine tool itself resulting from low stiffness and damping ratio of machine tool structure. In this paper the feasibility of applying new material is studied in order to improve static and dynamic performances of the structure to desire level. The new design of a main spindle box structure is made of polymer concrete instead of cast iron structure [1, 2, 3].

Polymer concrete consists of a mineral filler and a polymer binder. When sand is used as filler, the composite is referred to as a polymer concrete. Generally, any dry, non-absorbent, solid material can be used as filler [1, 2, 3]. The sand and the fillers are cheap and natural materials available for easy use. The overall process of production of polymer concrete is performed on room temperature and recycling of the materials is much easier than cast iron. Also, the control of the properties of polymer concrete may be much easier and less costly in comparison with cast iron. As a results of the above and some other advantages (flexibility of the design, short development time, simple and less costly production process) the overall competitive advantages of the company may significantly improve [1].

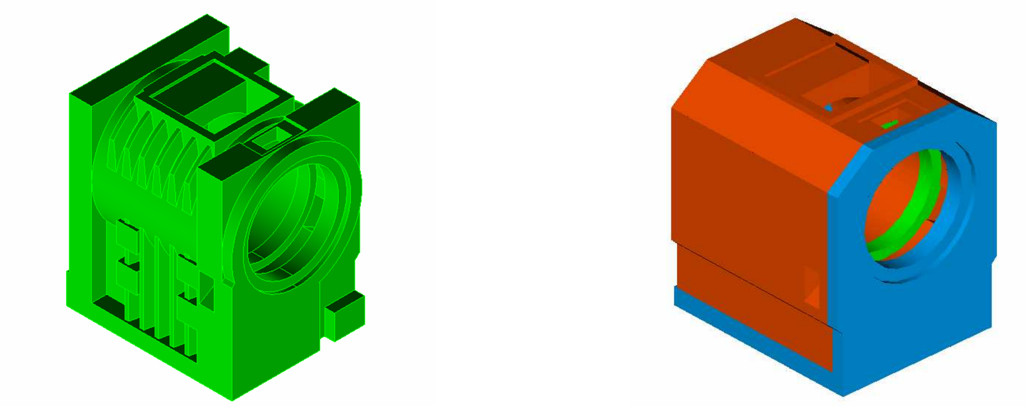
Comparison of different constructive materials is shown on table 1. It can be seen that the major advantage of polymer concrete in comparison with cast iron is a much better damping ratio, which may lead to improve dynamic performances of the machine. The other characteristics of polymer concrete are substantially worse in comparison with the cast iron, which requires appropriate redesigning of the structure to be able to achieve desirable performances. As a results of the implementation of polymer concrete in the structure design many of the advantage may occur [1, 2, 3].

Table 1.
General Characteristics of Constructive Materials

Characteristics	Unit	Steel	Cast Iron	Granite	Cement Concrete	Polymer Concrete
Compression Strength	MPa	250-1200	600-1000	70-300	40-100	140-170
Flexural Strength	MPa	400-1600	150-400	up to 35	up to 3	25-40
Young's modulus	GPa	210	80-120	35- 85	20-40	30-40
Heat transfer coefficient	W/mK	45-50	45-50	2.4	2.0	1.3-2.0
Coef. of linear expansion	10^{-6}/K	12	10	6.5- 8.5	10-14	12-20
Density	kg/m^3	7850	7150	3000	1900-2800	2100-2400
Damping ratio	-	0.002	0.003	0.015	0.015	0.02-0.03

2. REDESIGN OF SPINDLE BOX WITH POLYMER CONCRETE

The aim of this investigation is the possibilities of use of polymer concrete in building machine tools structures. For that purpose, the NC lathe Mazak QT 10 headstock's housing is completely redesigned and polymer concrete constructive material has been chosen and applied. The available references [1, 2, 3] have shown same examples of use of polymer concrete in substitution of cast iron in the design of machine tool beds. We have decided to investigate the possibilities of the use of polymer concrete in main spindle housing design due to the more demanding requirements connected with the dissipation of temperature, damping and high accuracy of the structure. To be able to redesign the original housing for the purpose of material substitution, we have performed static, dynamic and thermal analysis of the structure. The differences in the material properties (table 1) have initiated an iterative process of redesign with the aim to achieve properties of the original design. Both models, of original and redesigned housing are shown on figure 1.



a. Original b. Redesigned

Figure 1. Models of main spindle housing

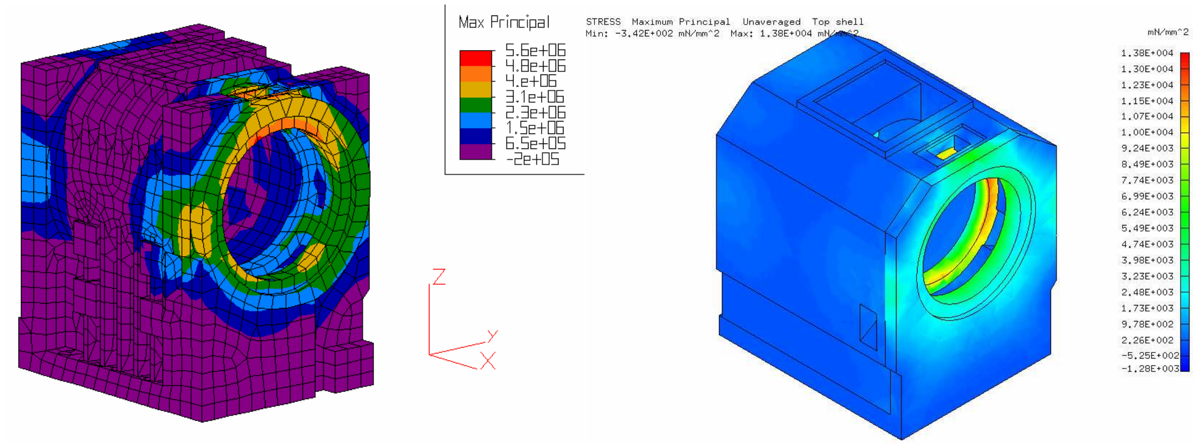
3. THEORETICAL AND EXPERIMENTAL STUDY OF NEW DESIGN

We have performed wide numerical and experimental investigations of static, dynamic and thermal behaviour of original and redesigned housing, part of which are presented in this article.

3.1. Statical Modelling and Analysis

Modelling and processing of housing were performed with the use of ALGOR and I-DEAS commercial packages [1]. Figure 2 shows maximal principal stresses of both models.

Comparative analyses of the statical characteristics (displacements, Von Mises, Maximal Principal Stress, Mass and Young's module) of both housings (original and redesigned) are shown on figure 3. Despite worsening of Von Mises and maximal Principal Stress the new design satisfied the limits. We have reduction of mass of redesigned housing for approximately 50% in comparison with the original design which strongly recommend the use of polymer concrete [1].



a. Original b. Redesigned

Figure 2: Maximal Principal Stress of Models

3.2 Dynamical Modelling and Analysis

We have used the same models, developed with ALGOR and I-DEAS, for dynamic analysis of both housings [1]. The comparative analysis of Eugene frequencies of both models is shown in figure 4. As we can see the Eugene frequencies of polymer concrete design are twice higher then those of cast iron design which represents certain improvement of the design. Figure 5 shown comparative analysis of the experimental data of the damping ratio of both designs. The results show superior performances of polymer concrete housing in comparison with cast iron structure [1].

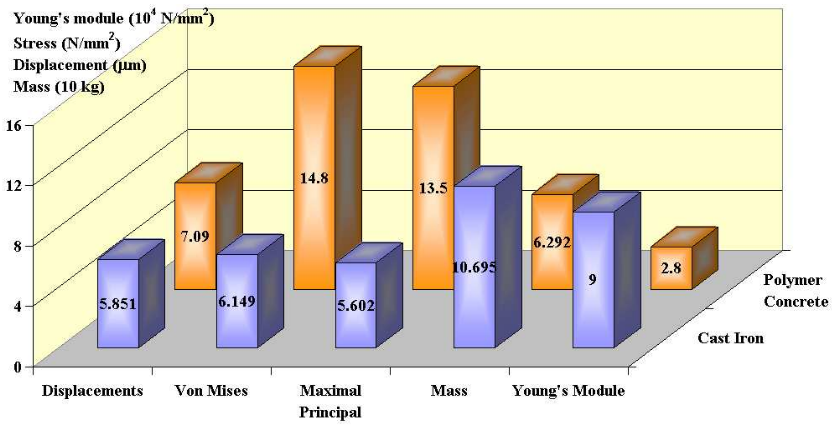


Figure 3. Comparative Analysis of Statical Characteristics

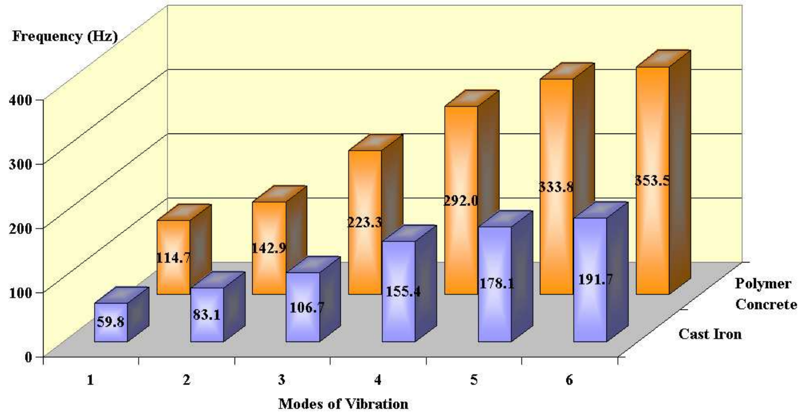


Figure 4. Comparative Analysis of Dynamical Characteristics

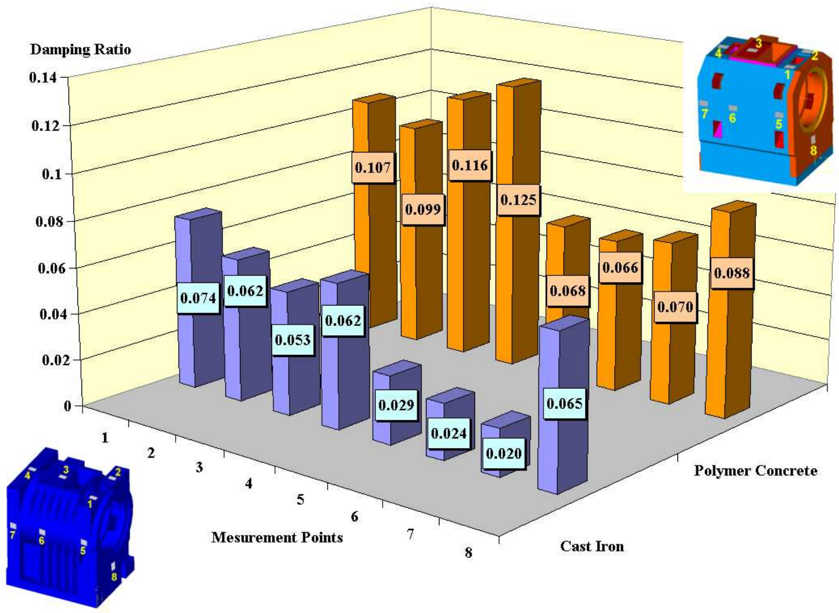


Figure 5. Comparative Analysis of Experimental Damping Ratio

4. CONCLUSION

The substitution of cast iron with polymer concrete in machine tool main spindle housing has been investigated. Without considerable reduction in static performances a significant improvement in damping and Eugene frequencies has been achieved. The superiority of polymer concrete has been demonstrated in the 50% reduction of the weight. Also, the new product development time and the manufacturing cost have been dramatically reduced due to the simplification of the production process.

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