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MECHANICAL ANALYSIS OF AN AUXILIARY TABLE WITH COMPOSITE STRUCTURE

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Abstract: This paper gives a brief summary on the application on of finite element methods during the design of a component. The solutions of mechanical and thermal problems are demonstrated on the given component. Among the several numerical methods the paper focuses on the FEM. During the article we present the problems, then define mechanical simulations for the possible solution that was designed and the evaluation of the results.

Keywords: *FEM, mechanical, thermal, numerical*

1. INTRODUCTION

When designing machines, all factors related to the accuracy and in-service parameters of the machine must be taken into account. These factors include deformations and vibrations caused by certain thermodynamic and mechanical phenomena. The effect of these should be taken into account already in the planning phase, since in this case it is the most economical to detect errors. Since the device is not physically available in the design phase, these phenomena can be modeled using simulation software [1].

The part to be examined is an auxiliary table with a composite structure, the task of which is to guide two laser devices facing each other with the best possible accuracy. The two laser devices are located on a carriage, which guidance is provided with linear guideways. Such guideways can be purchased as commercial parts for the industry in several different accuracy classes, however, ensuring accuracy depends not only on the properties of these components, but also on the base on which they are mounted. The mechanical properties of this component should be investigated, which will be done by finite element analysis [2], [3].

The laser devices or its guides are generally mounted on optical tables, however, the flatness of optical tables based on catalog data does not meet the accuracy required for roller guideways (0.015 mm) [4], [5]. Therefore, an auxiliary table should be designed that has adequate mechanical accuracy, good rigidity and good thermal properties. In accordance with these requirements, we consider the structure to be optimally designed. Various solutions were developed during the design process, in which the ribbed aluminum version *(Figure 1)* was discarded due to poor thermal properties, and the steel version was not considered a suitable choice due to its significant weight. As a final solution, a composite design was chosen, which is illustrated in *Figure 2*, in which an aluminum-granite-aluminum bonded structure was used. When designing the composite table, we aimed to create a structure with as low weight as possible and which can perform its functions with maximum static and dynamic rigidity and minimum thermal deformation, taking into account ergonomic principles.

Figure 1. *Ribbed structure with aluminium material*

Figure 2. *Table with composite structure equipped with guideways*

The choice of aluminium material is due to the fact that by using a suitable alloy, it will have mechanical properties similar to mild steel materials but have significantly lower weight. The chosen alloy is EN-AW-2014-T6, which is also defined for the simulations. Aluminium alloy EN-AW-7075-T6 has similar properties. Granite was chosen because of its low coefficient of thermal expansion and good vibration damping ability.

2. DEFINING DIMENSION USING SIMULATION

As a starting size, the dimensions of the parts were defined, except for the dimensions of the inner granite core. The enclosing dimensions of the aluminum-based bottom and top sheets are taken into account in the simulation tests with values of 552.5 × 2090 × 20 mm.

Due to the right setting, the table is designed with a three-point support system, that allows the right height and leveling to be adjusted perfectly, having a layout which is shown in *Figure 3*. During the optimization of the static stiffness of the structure, these support points will not be changed. Their positions will be adjusted to the appropriate places during the optimization for minimum deflection, caused by the self-weight.

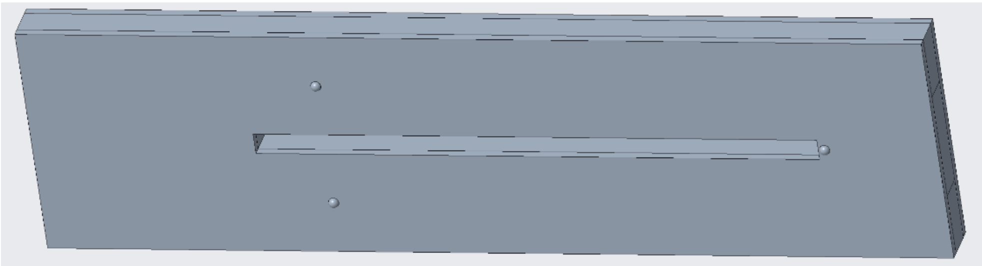

Figure 3. *The points of the three-point support system*

In order to obtain adequate results in the analyzes, the material properties of each material used must be defined in the software. After entering this data, in the 3D model, the individual parts must be provided with a finite element mesh, and the gluing have to be set on each contact surface, since the assembled table will also be assembled by gluing, these are shown in *Figure 4*.

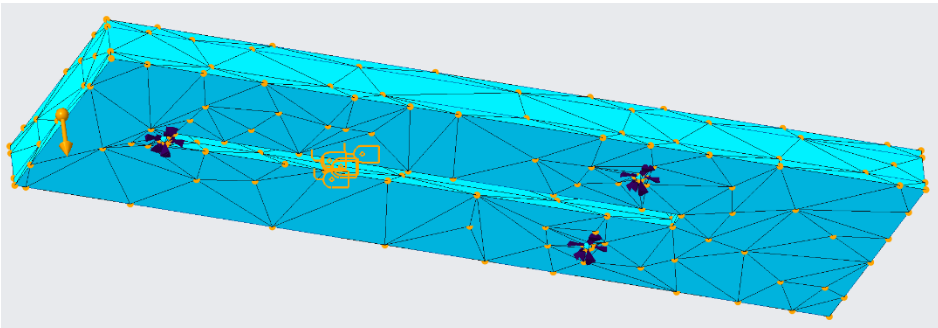

Figure 4. *The meshed model with contact definitions*

Since the size of the aluminum slabs was fixed at 20 mm, we only changed the geometry of the granite in the middle during the optimization. In doing so, the thickness of the granite block was one variable and the other was the width of the opening in the granite. Because it is necessary to design the opening on the table, its dimensions will be determined by the aluminum plates, but the dimensions of the filler granite will be different, this is also true for the width of the table. The remaining voids will be filled with polyurethane foam.

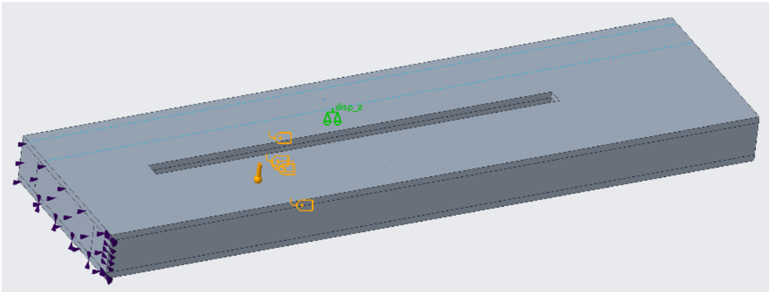

Figure 5. *The highlighted point (marked with green)*

The opening was examined with several different sizes, the results of these are illustrated in *Figure 6*, in which we examined the displacement of a highlighted point, which is shown in *Figure 5*.

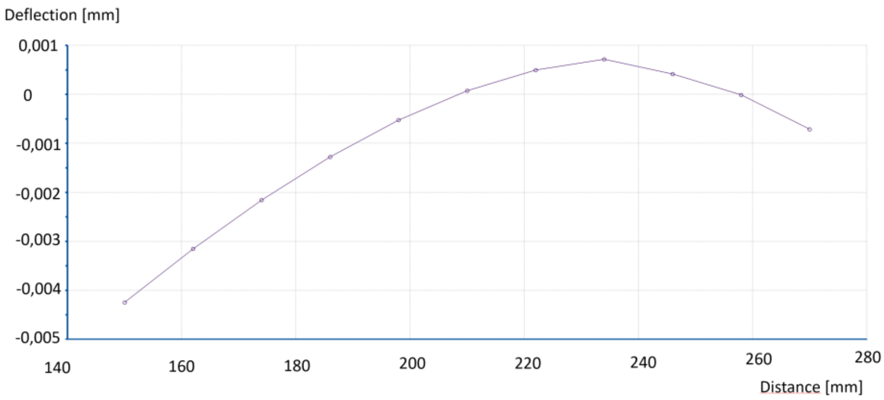

Figure 6

The effect of the opening size on the displacement of the highlighted point

From the simulations it can be concluded that the point displacement is the smallest in the case of opening size around 235 mm, so during further design, we will modify the given elements by keeping this opening close to this value.

3. Defining the dimensions of the three-point supports

To further increase the static stiffness and decrease the deflection of the composite table, the three-point support must be investigated. By choosing its dimensions properly, it is possible to minimize the deflection of the longitudinally asymmetrical table due to its own weight. For this purpose, various optimization algorithms can be used in engineering design systems to define the variables that we want to bring to an optimal value, and the system determines the value of these variables after the necessary calculations.

Table 1

The definition of the variables during the optimization process

Variable	**Current**	**Minimum**	**Initial**		**Maximum**	**Units**
d12:Granit	237	200	210		270	mm
d20:Also	1744	1500	1950		2070	mm
d6:Felso	1617	1500	1950		2070	mm

During the optimization, we wanted to get the longitudinal position of the support points and, depending on them, the thickness of the granite core. To determine the optimal values, the maximum values of the table and the preferred point(s) must be defined *(Table 1)*, as a function of which the software determines the geometrical dimensions where the support points and the thickness of the granite give the smallest possible displacement.

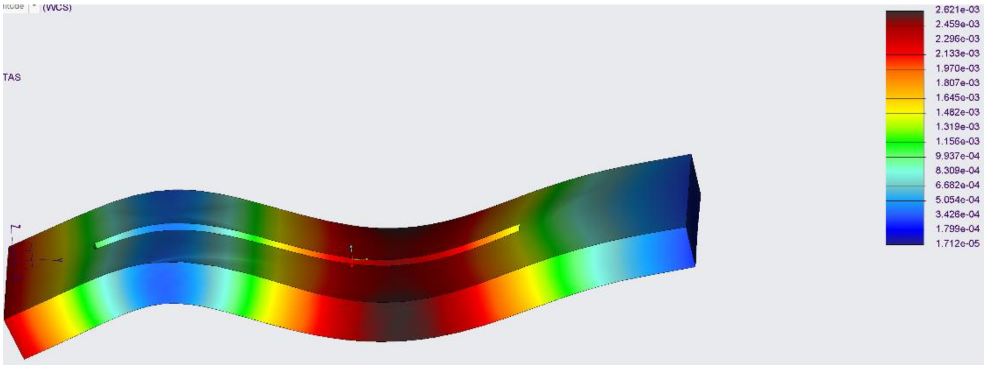

Figure 7. *The result of the optimization*

The obtained results and their mechanical simulation are shown in *Figure 7*. It can be read from the scale that the maximum displacement during the static test is 2.6 μm, which is considered an acceptable value, so the values of the calculated points and the thickness of the granite core are recorded for the further design process.

4. DYNAMICAL ANALYSIS OF THE OPTIMIZED PART

In addition to the static stiffness, the smallest eigenfrequency value of the modified and already statically optimized composite structure have to be determined. Our goal is that the lowest eigenfrequency of the structure exceeds the frequency range that can typically be transferred from the environment to the equipment and cause adverse resonant effects. This range is typically the frequency range of 1 to 150 Hz.

We therefore considered it reasonable to design the structure so that its minimum eigenfrequency falls upwards from the referenced frequency range.

Table 2

The result of the dynamic simulation

Mode	Frequency (Hz)
1	154.23
2	187.48
3	323.11
4	332.05

Based on the data obtained as the result of the calculation *(Table 2)*, we can state that the smallest natural frequency of the examined structure is outside the frequency range mentioned. The oscillation image for the lowest eigenfrequency is shown in *Figure 8*. It can be seen from the figure that the first oscillation image *(Figure 8)* typically corresponds to a torsional oscillation around the longitudinal axis.

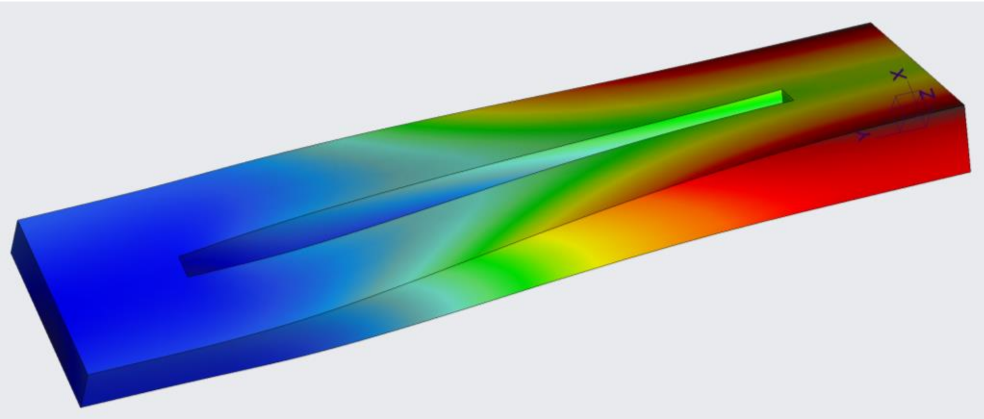

Figure 8. *Oscillation of the first eigenvalue*

5. Summary

In the present article, we have shown how to use numerical methods in the design of an auxiliary table, what we have mainly done with the finite element method. In an example, we demonstrated the necessity and effectiveness of each mechanical test. It has been described how finite element software, which is part of every major engineering design system today, can greatly contribute to the successful completion of engineering work.

Acknowledgement

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