Modeling laser head housing and engineering by analyzing walls rigidity in CAE-systems

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Abstract. The paper considers a possible way to expand the technological capabilities of numerically controlled machines by upgrading and integrating a fiber laser system into their composition. An important task is to facilitate the details of laser head housing while maintaining their stiffness parameters. To achieve the aim of the research, the laser head body was completely redesigned, some structural elements were combined, and all the walls of the body became lighter and more functional. The new design will be much more convenient to use while maintaining the same rigidity. The new laser head housing will make it possible to expand the range of work for numerically controlled machines, which in turn will lead to a reduction in the production time of not only one product, but also the final product as a whole. This approach will reduce the cost of maintaining and maintaining a large number of equipment, since the integration of laser equipment into numerically controlled machines will reduce the number of equipment in the workshops. In addition, marking and manufacturing parts on the same machine will not only significantly automate the processes of further Assembly of the final product by applying QR codes, but also will increase the accuracy of marking and engraving on the product due to a one-step process.

1. Introduction

The main goal of the work is to carry out an engineering analysis of the laser head body parts in the Solid Works and Patran Nastran CAE systems after forming their topology.

The combination of laser technologies and machining technologies will complement the traditional processes of milling materials with marking, engraving, microstructuring [1] and other laser processes of materials surface treatment. The use of a concentrated flux of laser radiation energy as a working tool will not only reduce the costs associated with the wear of a mechanical contact tool but also switch to fundamentally new microprocessing ranges for various products.

At the same processing center, along with traditional methods of processing workpieces from various materials by cutting, it will be possible to use such types of laser processing as marking, creating a gradient surface structure using laser radiation, creating various complex contour regular microtopology of the surface, surface finishing, 3D engraving reliefs, processing of ceramic surfaces [2], [3], macro- and microstructuring of the surface layer, cutting carbon fiber alloys, local surface oxidation (decoration), local thermal hardening, perforation, welding sheet material [4], ensuring information storage on the work surfaces by applying micro-sized bar and QR codes used in information technology, digital production [5], [6], [7], [8], [9], [10], metallization, etc. A laser head...
can be used to apply local physical effects [11], which greatly facilitates the removal of material from a workpiece with a tool equipped with cutting ceramics [12], [13], [14].

To realize the possibility of using the laser system on a CNC machine, it is necessary to partially or completely modernize the laser head housing and adapt it for manual installation in a machine spindle by an operator or an adjuster [15], [16].

Laser head housing should be redesigned so that it can be easily disconnected from a collimator after works completion. Previously, the laser head could not be used for manual installation in the machine spindle due to its design and overall dimensions. To ensure this, it is necessary to make laser head housing not only more compact, but also lighter due to a change in the topology of the majority of housing parts.

2. Materials and methods

When changing the topology of body parts (Figure 1), much attention was paid to an upper wall, since all the elements including a tool cone were attached to it. The wall should hold the entire mass of the structure at one central point, which in turn implies a large number of stiffeners to reduce its deformation. After the formation of the upper wall topology its weight decreased by 59%. The initial weight was 640 grams, and after optimization it became equal to 260 grams. Stiffeners in the upper wall made it possible to preserve strength characteristics as much as possible. The result of changing the design of all walls of the laser head was a decrease in the total weight of housing and a decrease in the number of parts.

![Figure 1. Laser head housing: original housing (a), modified housing (b)](image)

The topology of the rear wall has changed dramatically, making it possible to combine several elements into one. Thus, the radiators from the general design switched to the wall and became a single element with it (Figure 2), and due to an additional pocket it was possible to reduce the element weight by 16%. It is also worth noting that the presence of cooling fins reduces the total weight of the part by 24%.
Figure 2. Two types of rear wall of laser head housing after design change

The combination of several elements into one resulted not only in a decrease in their total number, but also in a more rigid construction of the back wall.

Figure 3. Engineering analysis of rear wall of laser head housing: initial design (a), modified design (b)

Analysis of the back wall showed that its strength characteristics did not change both in assembly and separately. The rear wall in the assembly held a collimator and a lower wall. The lower wall of the body lost a significant amount of material, the total volume of which amounted to 48.5%. This
structural element required a lot of attention when optimizing its topology, since it was a carrier for the entire optical circuit. It was necessary to arrange stiffeners in such a way that on the one hand they were interconnected, and on the other hand, they included elements of the optical scheme, creating a single frame. This approach made it possible to avoid deformations not only of the lower wall, but also of the entire laser head.

![Figure 4](image1.png)  
Figure 4. Engineering analysis of lower wall of laser head housing: initial design (a), modified design (b)

Optimization of the collimator topology was a rather difficult task, since this element of the housing initially performed not only the function of fixing the optical fiber inside the laser head body, but also the function of fixing the entire laser head. In the future, it is necessary to conduct a set of tests on the modified design of the laser head housing in CAE-systems for climatic and vibration effects.

To ensure the efficiency of the laser system and create greater clutch stiffness of the collimator and laser head, a quick-mount system of a “Bayonet” type was developed. A similar principle is used in professional photographic equipment to adjoin a photo lens to the camera. Such a system will make it possible to ensure quick coupling and opening of the collimator with the laser head and to maintain alignment of the laser optical circuit without a back-up tool. Also in the place of the collimator and the LG housing fixation there are two groups with electrical contact pads, which allows removing connectors and plugs from its general design. The proposed system includes a mechanical safety button, which will prevent an arbitrary separation of the collimator and the laser head without fully pressing it. The collimator was completely redesigned in such a way as to retain the function of fixing the optical fiber inside the collimator. At the same time, the function of fixing it on the body was disabled, since a new laser head housing was designed for its installation into a spindle of a CNC machine. Changing the design of the collimator resulted in a decrease in its weight by 46%. Figure 5 shows an example of (a) the initial variant of fastening the collimator to the rear wall in comparison with (b) the modified version.
3. Results and Discussion
The results of engineering analysis showed that the new design of the laser head housing retains rigidity close to the original version, but the new housing is much lighter and this increases the usability of the laser system.

A laser head housing installation in a CNC machine and its removal by a machine operator will be more convenient and faster due to new changes in the topology of the body walls as well as the design of the collimator and the method of its attachment to the LG body.

The original design of the laser head housing did not allow it to be manually installed in the spindle of the processing center, i.e. to use it as part of this machine due to the lack of the necessary mounting, as well as due to the presence of a rigid and permanent connection of the collimator with the laser head housing.

4. Conclusion
Thus, a method for introducing a laser system into an existing processing center is proposed, by modernizing the design of the laser head housing by introducing a tool cone into its structure, due to which the laser head is installed in the machine spindle [15], as well as changing the design of the lower, rear and upper walls of the laser head housing and mounting the collimator in order to facilitate the installation of the laser head in the machine spindle.

By introducing a laser system into an existing machining center, the range of work will also grow, which will allow the formation of one-stage automatic processes combining two types of processing (mechanical and laser), thereby expanding the functionality of the CNC machine. At the same time, the implementation of laser processing system will enable to carry out laser processing of individual sections of surfaces with sizes up to 30-50 microns on CNC machines of normal accuracy. Such a high resolution will enable to apply informational data in the form of QR codes on products with extremely high density, which in turn will ensure placing more information about the product on a small area.
Along with this, its implementation will reduce the amount of equipment in production, which will result in lower costs for electricity and maintenance. Consequently, time and financial costs for manufacturing products as well as the final cost will be reduced. This approach will allow marketers to attract the attention of not only domestic but also foreign customers. The experience in introducing laser equipment will become interesting for many industries in the modern market.

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