DEVELOPING AND 3D PROTOTYPING OF A CUSTOMIZED DEVICE FOR CNC LASER MICRO-MACHINING

Mihaiela ILIESCU[1]

ABSTRACT: There was the need of developing a device for CNC laser micro-machining on both flat and spatial surfaces. That was determined by the requirement of using an existing laser head of a TRUMF TruPulse unit and an Isel automation Euromod CNC machine, so that complex surfaces to be generated by various laser micro-machining procedures. The paper presents aspects of developing (by modeling and simulation) and prototyping (by 3D Printing) of the customized device's most important components. Thus, it was possible to discover and correct any possible errors in design, right before production launch The obtained prototype was tested and good results were predicted.

KEY WORDS: customized device, 3D printing, prototype, *laser head,, CNC micro-machining*.

1 GENERAL ASPECTS

The strong need for high performance, innovative products determines the development of new and advanced machining and, specially, micro-machining technologies that, replace or supplement the conventional machining ones..

Some of the involved advantages should be mentioned as:

- *high precision* - because there is no wear of the laser beam while machining,
- *reduced chance of wrapping the material* – as the laser generates a small heat-affected zone;
- *ability of machining materials that are difficult* or, even, *impossible* to be conventional machined (www.lancs.ac.uk, 2011).

LASER it is the noun derived from Light Amplification by Stimulated Emission of Radiation. The laser is an optical device that generates a coherent beam of light by stimulated emission that is further directed by lenses. In laser technology coherent beam of light involves a light source that produces light in-step waves of identical frequency and phase (www.aapg.org, 2011)

The most important parts of a laser system are: the gain medium, the pump energy system and the optical resonator. Depending on the gain medium there are different types of lasers, like: gas lasers, solid-state lasers, liquid lasers, chemical lasers, semiconductor lasers, plasma lasers.

The laser system studied is a solid-state Nd:YAG one and a schematic representation of its working principle can be noticed in figure 1 (www.lancs.ac.uk, 2011)..

[1] POLITEHNICA University of Bucharest, Engineering and Management of the Technological Systems Faculty, Manufacturing Department,

E-mail: iomi@clicknet.ro , mihaela.iliescu@ltpc.pub.ro

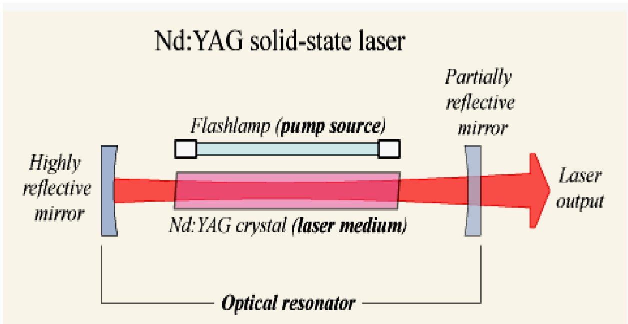

Figure 1 Schematic representation of the Nd:YAG solid-state laser principle (www.lancs.ac.uk)

Laser micro-machining processes are complex and involve good knowledge on the phenomena involved, like laser radiation – material interaction, laser pulse characteristics – as shape, duration, energy, etc. There are many types of laser micro-machining processes some being: drilling, welding, cutting, engraving, marking, etc. A schematic representation of laser micro-drilling and laser micro-welding is shown in figure 2 and, respectively, figure 3.

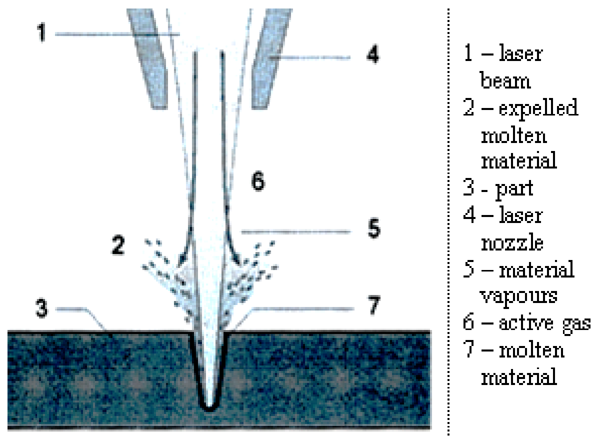

Figure 2 Laser micro-drilling scheme (www.trumpf-laser.com)

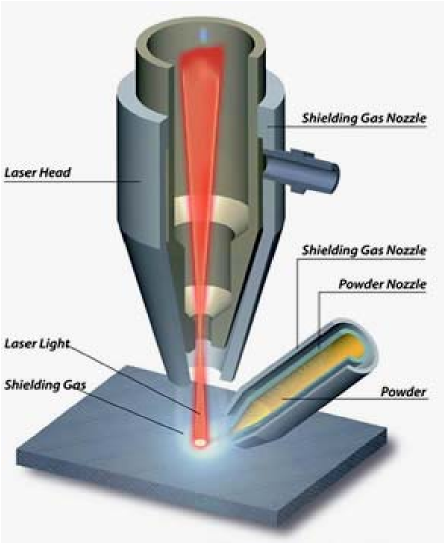

Figure 3 Laser micro-welding scheme (www. stellite.co.uk)

When the surfaces to be laser micro-machined are complex, spatial ones, there should be used, either a sophisticated and expensive laser CNC equipment or, if available, the laser head of an existing unit should be mounted on the vertical slide of an existing CNC machine. This last mentioned situation is the one that determined the customized device's development.

Thus, complex trajectories for the laser head would be easily and accurately generated.

2 REQUIREMENTS FOR THE CUSTOMIZED DEVICE

The customized device studied by this paper will be implemented in a CNC micro-machining system made of two major equipments that are – see figure 4:

- Trumph TruPulse 62 laser unit
- Isel-automation FlatCom machining unit

Joining the two below mentioned equipments involves issues like: safety, construction assembly, stiffness, accuracy. This "joint" would be possible by replacing the spindle of the CNC machine with the laser head. So, there is obvious the need for the customized device that should position, fasten and adjust the laser head on the vertical slide of the CNC machine.

The device's conception is so that it enables two rotational movements around the OX and OY axes (of the vertical plane, XOY) – as shown in figure 5.

Moments and forces specific to machining process are different once the main spindle (were cutting tool is clamped) is replaced by the laser device, so measures to maintain right stiffness should be taken.

The whole assembly should ensure a 0.015 mm positioning tolerance.

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True Pulse 62 laser unit (www.trumpf-laser.com)

FlatCom XL Isel-automation (www.isel.com)

Figure 4 Basic equipments to be "jointed" by the device

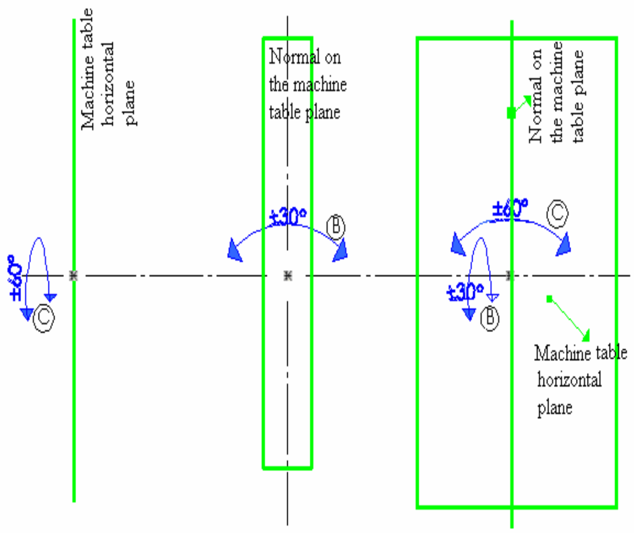


Figure 5 The device's concept scheme

3 MODELING AND SIMULATION

When designing the device, there had to be considered the "restrictions" determined by the existing equipments – meaning the vertical slide of the CNC machine characteristics and the unit laser head geometrical characteristics. So, device's design has to match the existing components (Iliescu M., et al., 2010)

Considering, the above mentioned aspects, device's components were designed in two variants:

- variant A – with worm – worm wheel gear for both, rotation of the plateau (around OX axis) and rotation of the laser head support (around OY axis) - see figure 6.

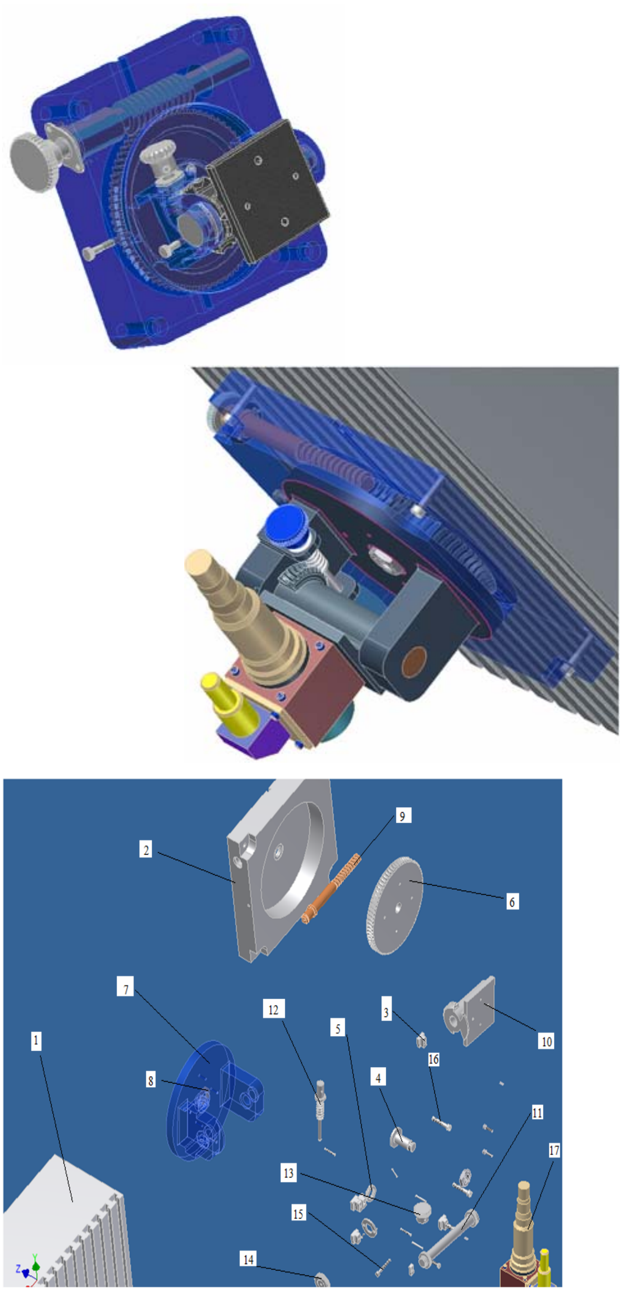


Figure 6 Modeling variant A

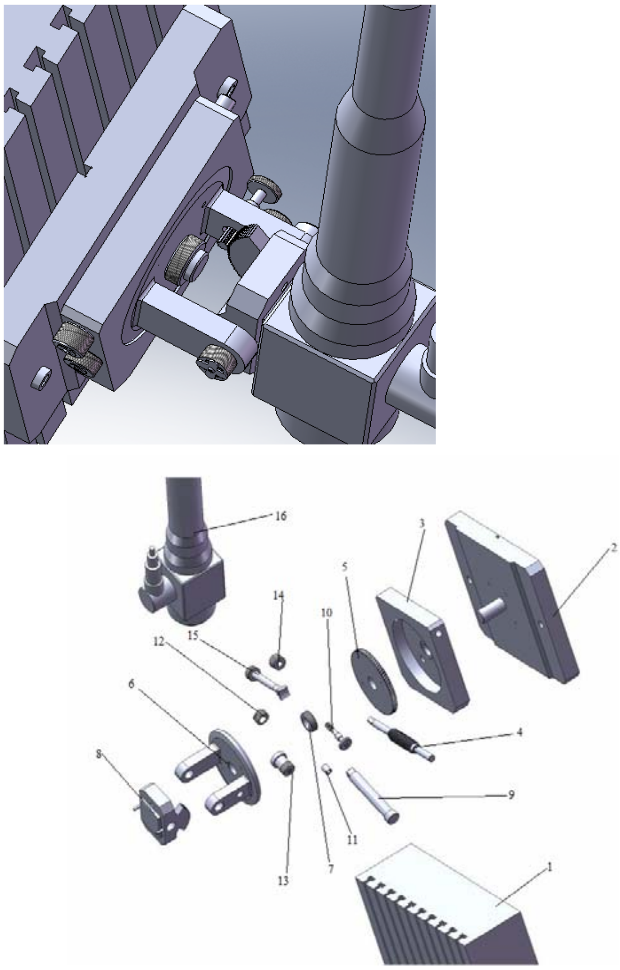


Figure 7 Modeling variant B

- variant B – with worm – worm wheel gear for rotation of the plateau (around OX axis) and shaft – sector plate gear for rotation of the laser head support (around OY axis)

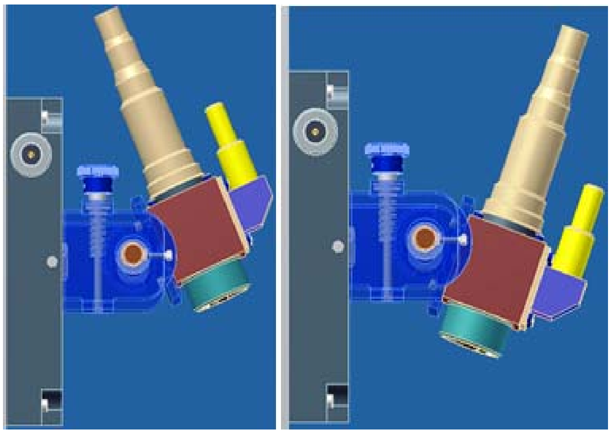
The design was conceived so that the device could be easily assembled, used and maintained. The two technical solutions were modeled using Autodesk Inventor and, respectively, Dassault Systems SolidWorks software.

Once the customized device modeled, three types of simulations were performed:

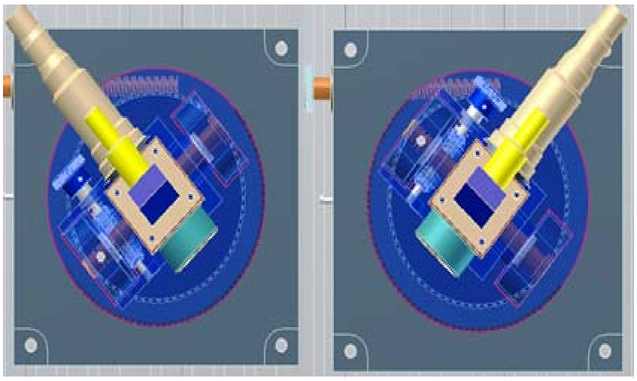
First was the *kinematics simulation* of the entire assemble to check if the movements are accurate, continuous and smooth. Also, there can be observed if the component elements are able to make movements within the limits needed – see figure 8.

The second simulation was the *strength and torsion simulation* – for the most loaded elements - see figure 9.

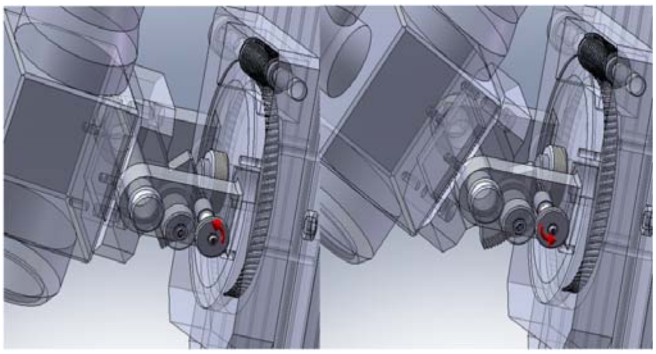
The third simulation was about *interference detection* - in order to ensure that the assembly is properly made and the components does not „bump" into each other. An image of it is shown in figure 10.



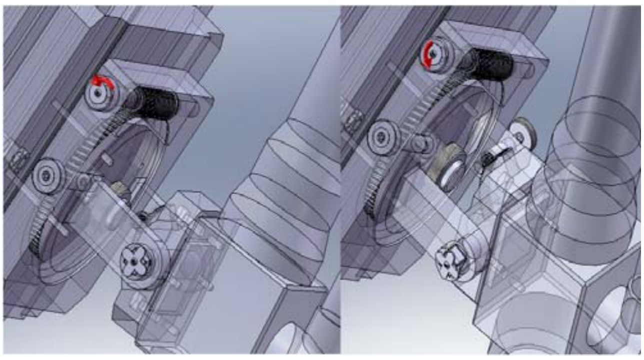
simulation of rotational movement around OX axis



simulation of rotational movement around OY axis
- variant A model -

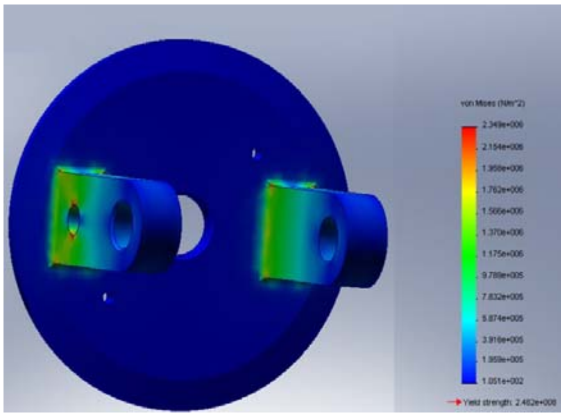


simulation of rotational movement around OX axis

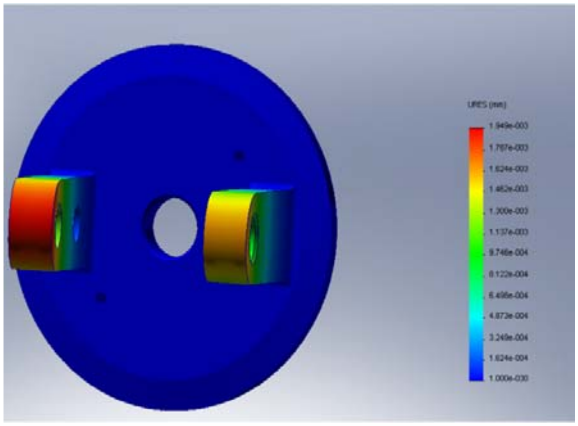


simulation of rotational movement around OY axis
- variant B model -

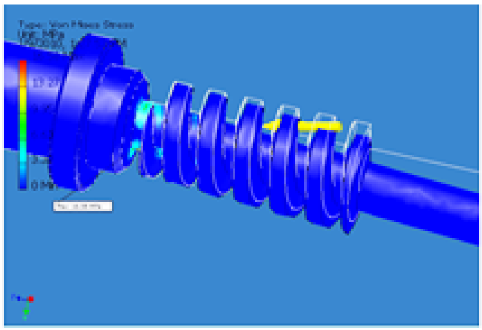
Figure 8. Simulation of rotational movements



von Mises stress



displacement distribution
- rotational plateau loading simulation -



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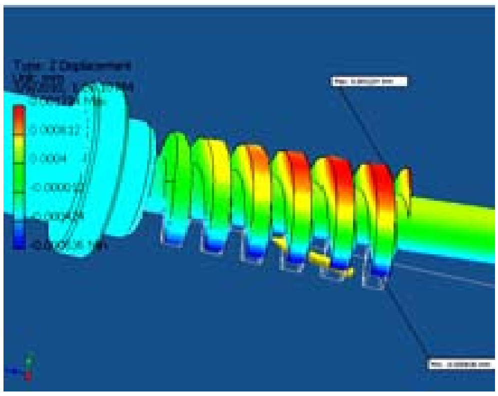
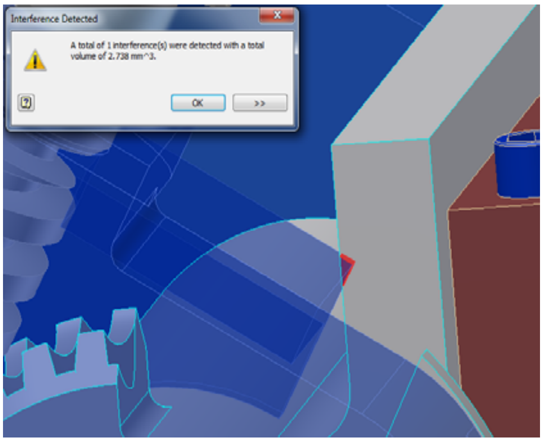
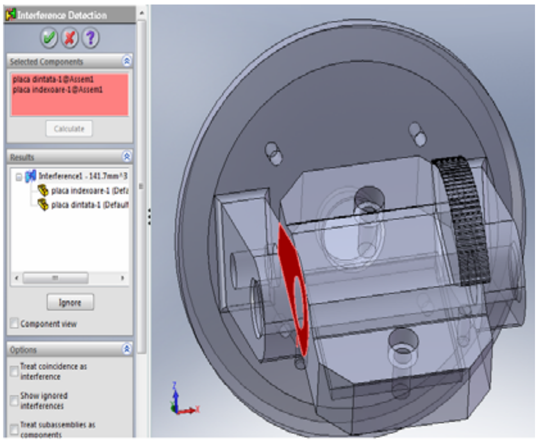


displacement distribution
- worm loading simulation -

Figure 9. Component elements loading simulation



- variant A model -



- variant B model -

Figure 10. Interference simulation

Further development of the device was that for variant A – because of higher accuracy in positioning and fastening the components.

4 3D PROTOTYPING

Prototypes are useful when developing a new product, as they can “predict” how it really would be and, meanwhile, can represent an important mean of improving product’s characteristics.

There are many techniques of prototyping, the one used for the studied device being Rapid Prototyping (RP), more specifically, Three Dimensional Printing (3DP).

In fact, Rapid Prototyping, represents the process of obtaining solids by successive deposition of material layers. The obtained parts are very complex and the time required for prototyping is relatively low (hours).

The process of 3D printing (patented by Z Corporation) involves shooting droplets of liquid (binder) to a solid compound (plaster or resins powder). By selectively binding of powder together a layer of the model corresponding to the cross-section of the part is formed.

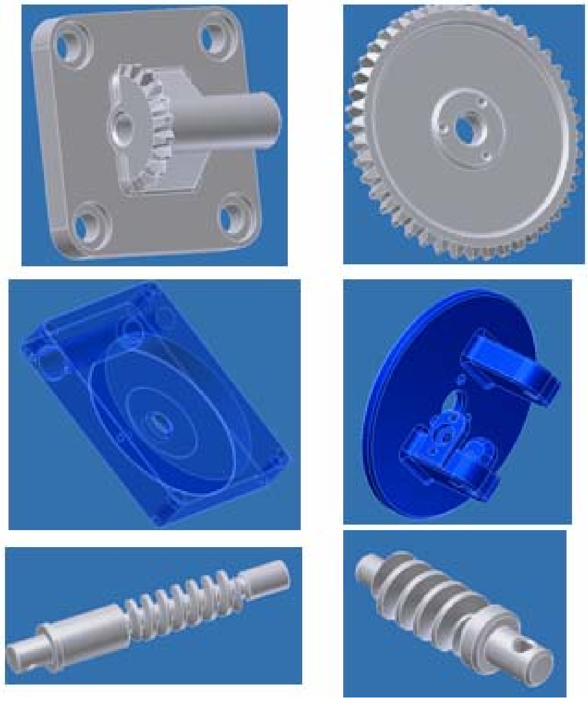


Figure 11. Component elements for prototyping

For the studied customized device, it has been decided to prototype the non-standardized components, that are shown in figure 11.

The printing machine is ZPrinter 310 Plus (www. zcorp.com, 2011). Its software does automatically determine the necessary mass of powder for prototyping, as well as the volume of binder and the time required for obtaining the prototype.

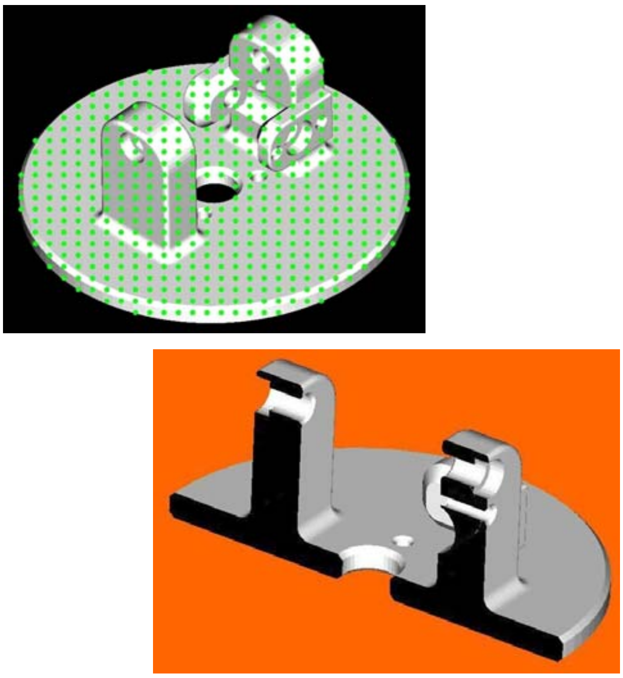


Figure 12 Software checking of element drawing (rotational plateau)

This software, also does enable to check the drawing of the element to be prototyped, just to discover any possible hidden errors. An example of this is evidenced by figure 12.

An image taken from ZPrinter machine's computer screen – at one random moment of the prototyping process - is shown in figure 13. The obtained prototyped components are evidenced by in figure 14.

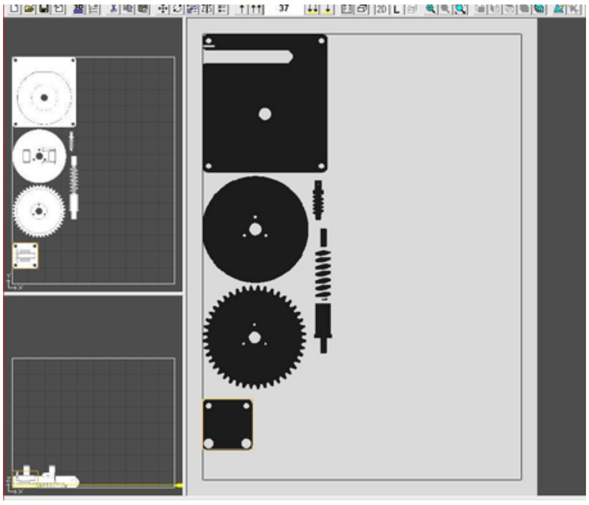


Figure 13. Computer screen image – at one random moment of the process

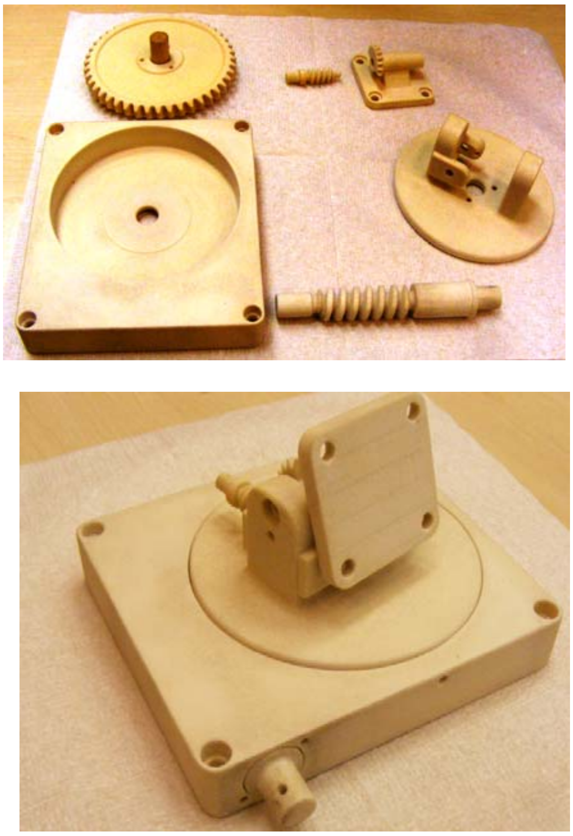


Figure 14. 3D prototyped device's component elements

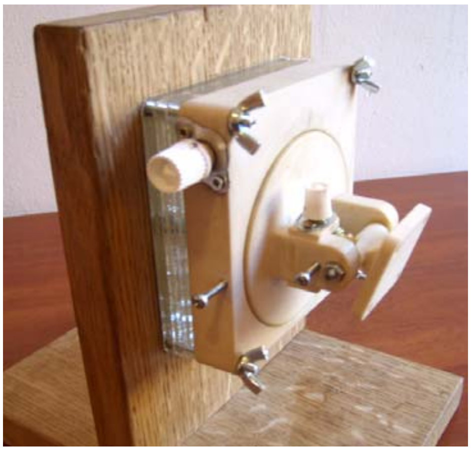


Figure 15. Prototyped customized device

Once all the component elements being ready, they were assembled and thus, the customized device prototype could finally be used for testing – see figure 15.

Any necessary changes should and can be done, before production launch.

5 CONCLUDING REMARKS

It was developed a customized device as solution to the need of performing some laser micro-machining procedures with two existing equipments – TruePulse 62 laser unit and FlatCom Isel automation CNC machine.

There were considered two variants, A and B, the first one more accurate, while the second one, simpler. Prototyping the main component elements of varinat A and, further, assembling them into the customized device, enabled tests of how it works and design changes, prior to production.

Further development and improvement of the device, by considering angular motors and digital displaying system, are worth to be considered.

6 REFERENCES

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