Modeling and Simulation of a Positioning-Fastening-Adjusting Device for Laser μ-Machining CNC System

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Abstract: - The paper presents steps followed in order to develop- desing, model, and simulate- a device for positioning, fastening and adjusting a Trumph TruPulse 62 lasers head onto the vertical slide of an Isel-automation Euromod-P CNC machine. So, a high-precision, versatile micromachining procedures device will be manufactured, meaning it will enable drilling, cutting and welding on both flat and comlpex surfaces. Specific engineering and desinging software were used (Dassault Systems SolidWorks and Autodesk Invetor) and some economic aspects were treated.

Key-Words: - laser, design, model, simulate , positioning, fastening, adjusting

1 Introduction

The growing demand for new inovative products leads to the development of new and advanced technologies better suited to cover the various type of products that need to be manufactured.

Classic mechanical machining is slowly beeing replaced by the laser machining because of its advantages like: better precision - due to the fact that there is no wear of the laser beam while machining, reduced chance of wraping the material - as laser systems have a small heat-affected zone; capacity of machining materials that, otheway, are difficult or imposible to be classically machined [2]. However laser machining does have its disadvantages for instance it requires high energy consumtion.

The word LASER comes from Light Amplification by Stimulated Emission of Radiation. The laser is an optical device that generates a coherent beam of light by stimulated emission and manipulates it by lenses. In laser technology coherent beam of light involves a light source that produces light in-step waves of identical frequency and phase.[1]

The component 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.

Based on all the above, the laser system studied by this application is a solid-state laser. A schematic representation of the working pinciple of the solid-state laser is represented in figure 1, while the principle of laser machinig can be seen in figure 2.

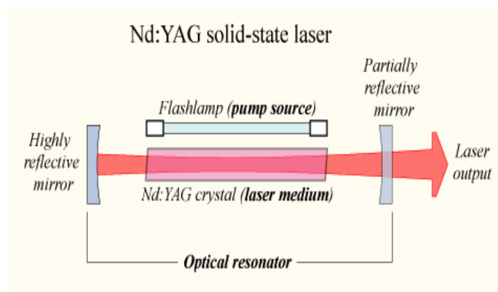


Fig. 1 Schematic representation of the working principle of the solid-state laser [19]

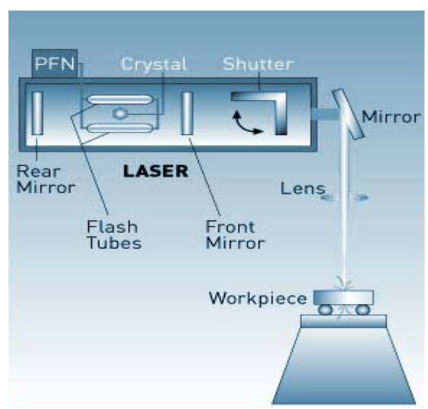


Fig. 2 The principle of laser machining [18]

There are many kinds of laser machining procedures, some of them being: welding, cutting, drilling, engraving, marking, indending, selective sintering.

So, a schematic representation of laser drilling principle is presented in figure 3 and a image from the drilling process is presented in figure 4.

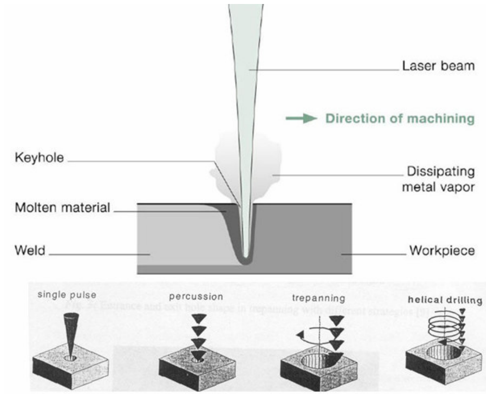


Fig.3 Schematic representation of drilling [10]

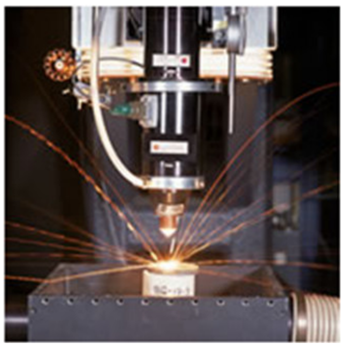


Fig.4 Drilling process image[17]

2 Objective and requirements

The device, whose development is presented by this paper , will be implemented in a micromachining CNC system, that involves laser and CNC machining and mainly is made up of two equipments: Trumph TruPulse 62 and Isel-automation Euromod-P.

The device is one of the key components of the resulting system and one of the essential link-up elements for joining the two equipments into one, thus resulting a complexe and complete system..

So, an image of the first equipment, *TruPulse 62* is presented in figure 4.

Fig.5 TruPulse 62 equipment [4]

Fig.6 Euromod-P CNC Isel-autoamtion machine [5]

TruPulse 62 equipment uses Nd-YAG solid-state gain medium.It is a pulsed lasers with short, powerful pulses of high pulse power, used for welding, cutting and drilling.

The second equipment used is *Euromod P* - see figure 6,, a CNC machining system for drilling, threading, milling (fig.6):

Designing a single system from two basic equipments involves issues like safety, assembly structure, stiffness. Meanwhile, by system's arhitecture (structure, component elements, etc.) the problem of replacing the CNC machine's main spindle by the laser equipment's head has to be solved. That is why, the need to develop a positioning-fastening-adjusting device of the laser head is so obvious

The stiffness of the final system is very important, as it enables the required positioning tolerance of 0.015 mm to be achieved..

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.

3 Modeling and Simulation

The positioning-fastening-adjusting device must make the „physical link" (joint) between two of the essential components of the basic equipments, specifically, the vertical slide of the CNC machine tool (Z axis) and the active element of the laser equipment.

So, the main spindle system, that was initially fastned on the CNC machine vertical slide, has to be replaced by the laser head, thus resulting the possibility of laser μ-machining.

The device's concept involves the ability to make two rotational movements around axses that are included into two reciprocal perpendicular planes – see figure 7.

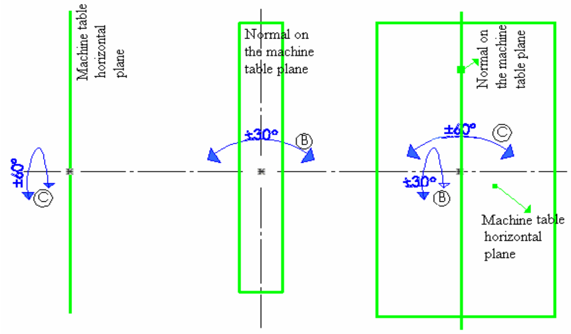


Fig.7 Device's conceptual idea scheme

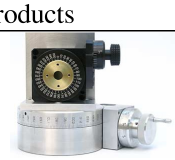
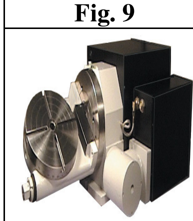
The device has the functions of:

- ensure positioning so as to have perpendicularity of the laser beam on the surface of the horizontal slide (table) of CNC machine tool;
- adjusting and locking in the right position of the laser head, on the two rotational axes, so that machining of both flat and complex surfaces to be possible..

Establishing of a new product target specifications represents an important step of its development. Based on them and, as it is the case, starting from the conceptual idea, further design of the product (device) was made.

Target values of product specifications were set according to the specifications of existing products on the market - see. Table 1 and table 2. For the studied device, the specifications were set so that to ensure tehnical and functional parameters, compared to the ones of similar products. Thus, knowing as starting point the functions that the device must fulfill, the ideal values for its specifications were established – see table 3.

Tab. 1 Existing products on the market

Products	Product Description
 **Fig.8**	VEMEX A4800 Tilt and pan for an intermediate payload using two rotary tables connected with adapter bracket [www.velmex.com]
 **Fig. 9**	Newmark Mount GM-12E -2 movements:base rotation, Inclination; [www.newmarksystems.com[
 **Fig.10**	Troyke L-6.5 Combines 2 rotary tables fist for Inclination the second for rotation [www.troyke.com]

Tab.2 Specifications of existing products

Nr. Crt.	Name	U. M	Products		
			VEMEX A4800	Newmark GM-12E	Troyke L-6.5
1	Accuracy	°	0,01	0,01	0,01
2	Repetability	sec	±100	±20	±50
3	Drive	Man /elec	Manual	Elec	Elec
4	Range	°	360x36 0	360x1 20	360x3 60
5	Mount		Bolt	Bolt	Bolt
6	Locking		Mecani că	Electr ică	Pneu matic
7	Table dimensions	mm	200x15 0	100x2 00	260x1 65
8	Display		drum	digital	digital
9	Height	mm	303	425	352
10	Weight	kg	3,5	20	152
11	Load	kg	14	35	45
12	Price	eur o	360	720	1200

Tab.3 Ideal values for the specifications

Nr. crt	Name	U.M.	Lim. Val.	Ideal Val.
1	Accuracy	°	0,02	0,005
2	Repetability	sec	±100	±0,10
3	Drive	Man /elec	Manual	Elec
4	Range	°	120x60	360x36 0
5	Mount		bolt	bolt
6	Locking		Mecanic	Electro-Mag
7	Table dimensions	mm	100x10 0	165x15 0
8	Display		drum	digital
9	Height	mm	200	150
10	Weight	kg	7	5
11	Load	kg	25	30
12	Price	euro	700	500

Considering the target specifications required by the resulting CNC system and analyzing the products on the market it was found that the device aimed to create the joint between the two mentioned equipments (TruPules and Isel-autoamtion) can not be purchased so, it has to be developped, meaning designed, manufactured, saled, serviced.

The conceptual idea can be physically implemented through different technical solutions, all performing the functions for which the device is aimed. So, two solution, presented above, were considered for product developement.

Considering the characteristics of the laser head and of the CNC machine vertical slide, the device was designed so that it could be easily assembled, used and maintained, in both of the considered variants .

The two technical solutions were modeled using Dassault Systems SolidWorks and Autodesk Inventor softwares.

The first variant (A) is presented in figure 11 and in figure 12 (as exploded view).

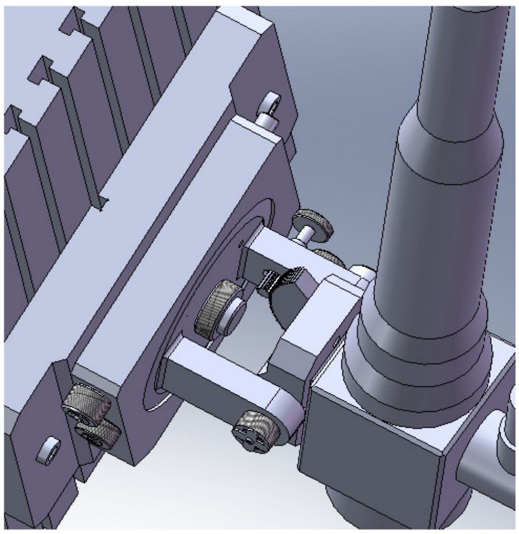


Fig.11 Device drawing, variant A

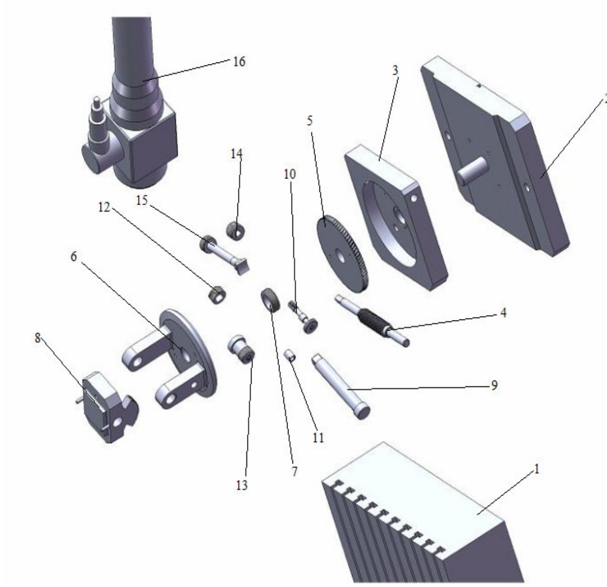


Fig.12 Exploded view for variant A

In order to to achieve the positioning-fastening-adjusting of the device needed for the machining process the first worm 4-worm wheel 5 subassembly is moved by the rosset 14 obtaining the desired position for the rotary table 6. With the locking system 15 the rotation position is established. Then using the shaft gear 10, the sector gear plate 8 is moved and so the inclination position is obtained. With the locking system 13 the machining position is complete.

The second variant (B) can be seen in figure 13, while its explode view is shown in figure 14

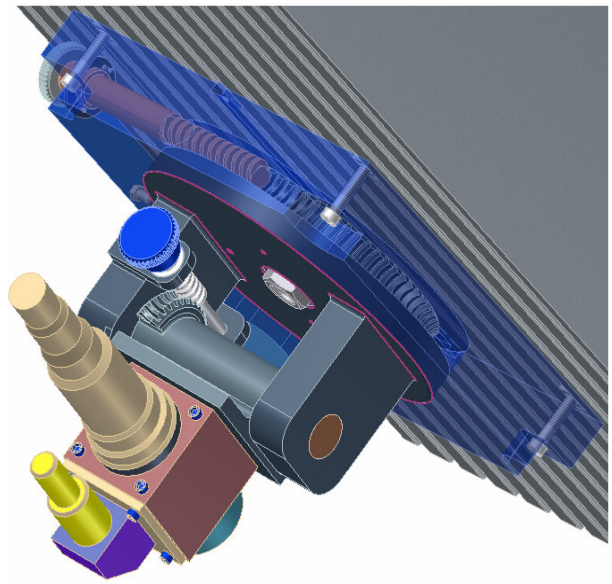


Fig.13 Device drawing, variant B

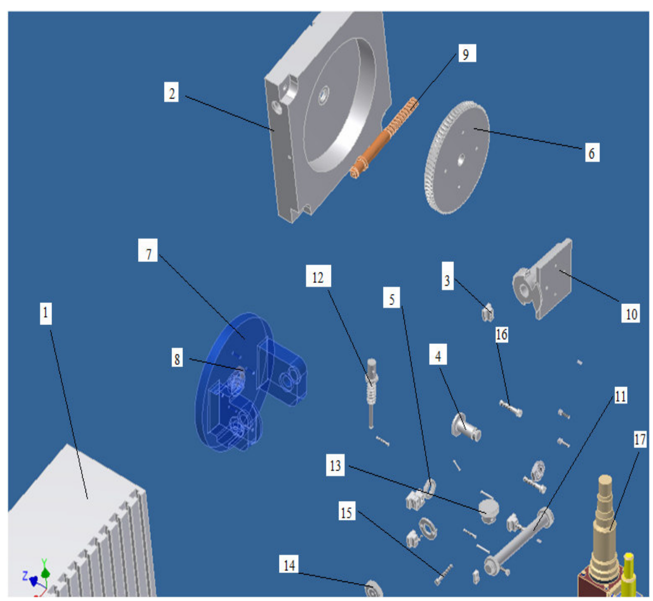


Fig.14 Exploded view for variant B

In order to to achieve the positioning-fastening-adjusting of the device needed for the machining process the first worm 9-worm wheel 6 subassembly is moved by the rosset 14 obtaining the desired position for the rotary table 7. With the locking bolt 15 the rotation position is established. Then using the second worm 12-worm wheel 10 the inclination position is obtained. With the loking bolt 16 the machining position is complete.

After the device was modeled simulations were made for the entire assembly and for the component parts. So, it was possible to check whether the required target specifications were met and to correct posibble design errors. Three types of simulations were performed, as follows.

♦. *Kinematic simulation* of the entire assembly, to study if the movements are accurate, continuous and smooth. At the same time the simulation revelead if the device „respects" its working range. Figure 15 and figure 16 present some images from the kinematic simulation.

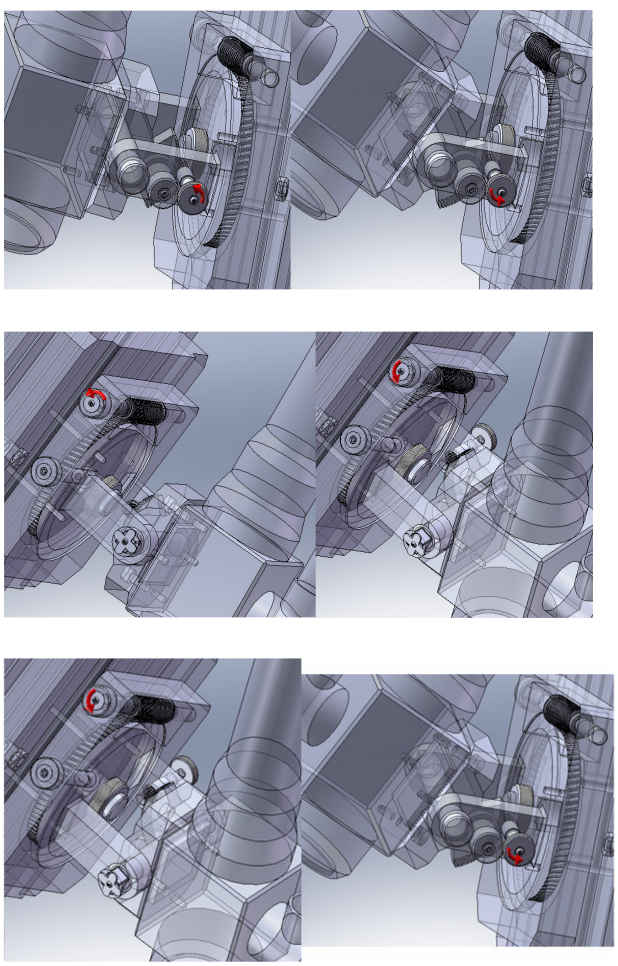


Fig. 15 Images from the kinematic simulation for variant A

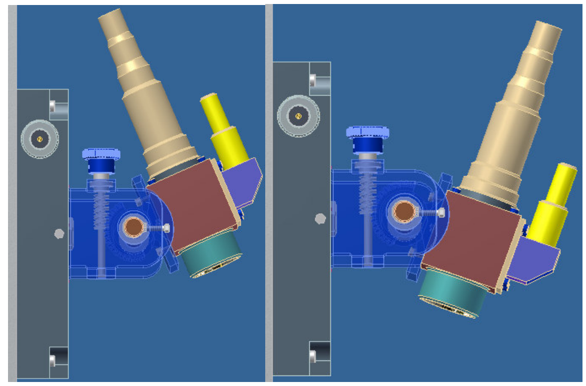


Fig.16 Images from the kinematic simulation for variant B

♦ *Strength and torsion simulation*

One of the components that is most subjected to mechanical stess is the rotary table. In figure 17 and figure 18, the generation of finite element mesh and the resuts of the simulation are presented.

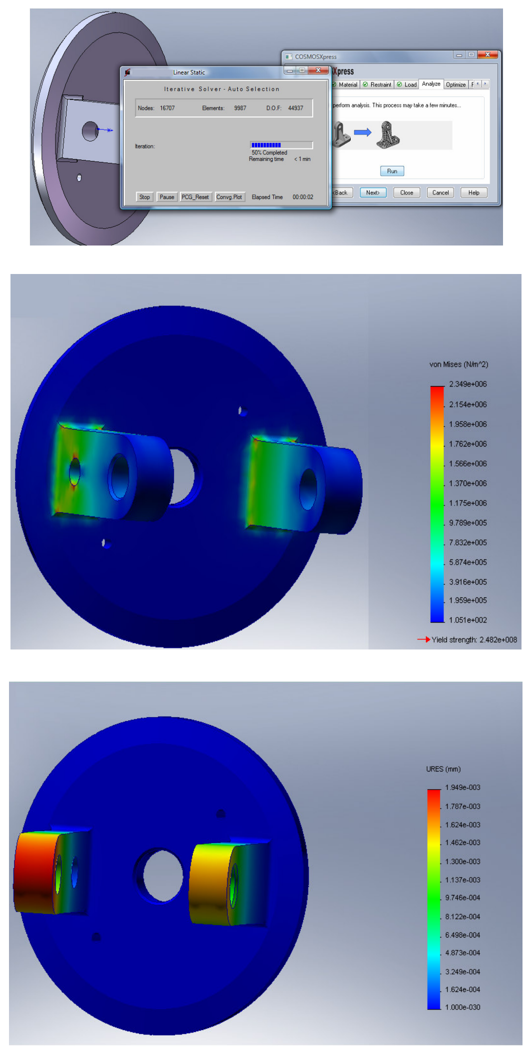


Fig. 17 Simulation for variant A

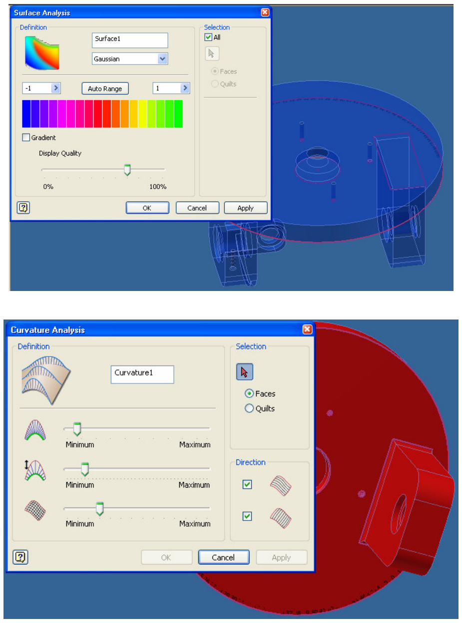


Fig. 18 Simulation for variant B

♦ *Interference detection*

In order to ensure that the assembly is propely designed, simulations were made to see if the component element do interfere with each other.

One of the simulations is presented in figure 19:

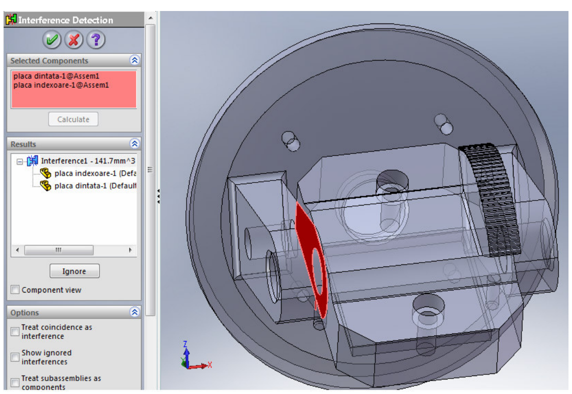


Fig. 19 Interference detection

4 Conclusion

Having done the comparative analysis it was possible to conclude that a device to perform the required functions couldn't be purchased and it was absolutely necessary to design one.

Analyzing both technical proposed solutions – variant A and variant B, some facts can be stated.

So, the first solution has the advantage of a simple contruction, but the one who best suits the required functions is the second solution.

This one (variant B) provides better accuracy for the inclination movement in the normal plane due to worm-worm wheel gear used for generating it. Also it reduces the positioning errors beacuse it requires only one fastening with the base plate.The moment needed to move the device is smaller due to the use of planar ball bearings.

Using computer aidded design – modeling and simulation, possible errors of technical conception were detected and corrected, therefore improving the overall deign of the device.

Further reseearch development should consider the use of angular motors to be added for positioning and locking. The motors could be controlled from a command panel of the final CNC system.

The positioning display system could be upgraded to a digital one.

References

[1]ww.inflpr.ro
[2]www.lasermicromachining.com
[3]www.newmarksystems.com
[4]www.trumpf-laser.com
[5]www.isel-germany.de
[6]www.lasersystems.ro
[7]www.precisionmicro.com
[8]www.operatorserv.ro
[9]www.efunda.com
[10]www.mrl.columbia.edu
[11]www.nnoble.com
[12]www.sandurо.ro
[13]www.rotarytables.com
[14]www.troyke.com
[15]www.velmex.com
[16]www.oxfordlasers.com
[17] www.aapg.org
[18]www.ebteccorp.com
[19]www.lancs.ac.uk
all of the web-sites were accessed on January, February, 2010

[20] Dahotre, Narendra B., Harimkar, Sandip *Laser Fabrication and Machining of Materials* 2008, ISBN: 978-0-387-72343-3

[21] František Racek, Teodor Baláž, Martin Macko Martin Ćervenka. *Measuring and modeling of initiation mechanisms of small arms*, Proceedings of the 9th WSEAS ACS '09, ISSN: 1790-5109, Genova, Italy, october, 2009

[22] Iliescu M, Nuţu E, Comănescu B, *Applied Finite Element Method Simulation in 3D Printing*, NAUN International Journal of Mathematics and Computers in Simulation, Issue 4, vol. 2, 2008, pag. 305-312, ISSN 1998-0159