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DELTA 3D PRINTER

Abstract: *3D printing is a very used process in industry, the generic name being "rapid prototyping". The essential advantage of a 3D printer is that it allows the designers to produce a prototype in a very short time, which is tested and quickly remodeled, considerably reducing the required time to get from the prototype phase to the final product. At the same time, through this technique we can achieve components with very precise forms, complex pieces that, through classical methods, could have been accomplished only in a large amount of time. In this paper, there are presented the stages of a 3D model execution, also the physical achievement after of a Delta 3D printer after the model.*

Key words*: engineering, art, sculpture, metal, Autodesk Inventor*

1. INTRODUCTION

As a definition, rapid prototyping represents the process that creates the physical prototype from a virtual 3D CAD model, in a short period of time [1]. With the advent of visualizing systems of the physical objects (3D CAD modeling) and its translation in a virtual enterprise, the necessity to analyze these virtual prototypes appeared [2]. As a working technique, 3D printing is associated with a suite of technological processes, to which for the quick materialization of the functional prototype involved in the product's development process, we add or we extract material. The key idea of this new quick prototyping technology is based on the 3D decomposition on thin section layers and stacking them "layer by layer" [3].

2. PAPER PURPOSE

The Delta printer is based on the functional principle of a Delta robot, which is a parallel robot with 3 interconnected arms to a fixed to a motherboard, fig. 1, [4], [5].

Fig. 1 Delta Robot [4]; Delta 3D printer [5]

Technological development has permitted the apparition of 2D and 3D graphical representation systems of the information into a virtual environment, through which modeling using software applications dedicated to designing and manufacturing impose that they can be described in a series of modeling operation sequences. Graphical modeling of the printer's components had been accomplished using the graphical application Autodesk Inventor- design solution integrated in Autodesk Inventor Series, dedicated to applications from the mechanical and electrical-mechanical engineering field [6].

3. 3D EXTRUSION MACHINE CS3dx

Some of the components presented in the paper have been physically made with the help of a 3D printer which works in Cartesian coordinates system, 3D, CD3dx type. The 3D Printer CS3dx is a "reprap" (rapid prototyping) printing machine, meaning that the printer can auto replicate itself and create pieces to replace or improve its functionality. The printer works in the Cartesian coordinate system and it contains three guides corresponding to each of the Cartesian plan's axes. The axes are divided into three different modules which work independently from one another. In figure 2, there is presented the 3D model of the extrusion head system, pointing out its main elements, guides, steppers, and the trapezoidal screw that effectuates the movement on Z.

Fig. 2 3D model of the Cartesian system [7]

On the guide corresponding to axis X (on which are specified the movements on coordinate X), there are assembled two stepper motors which work in parallel, defining the translational movement through the timing belts. The guide corresponding to axis Y contains the drive system, a stepper, the transmission system, a timing belt and steering axes. The movement on axis Z is provided by a stepper which operates a trapezoidal screw through a reducer with a V-belt T2.5, with a transmission ratio of *i=0.5*. The heating platform is also located on this axis and it's made of two MK1 boards which ensure keeping the optimal temperature of the printing piece, figure 3.

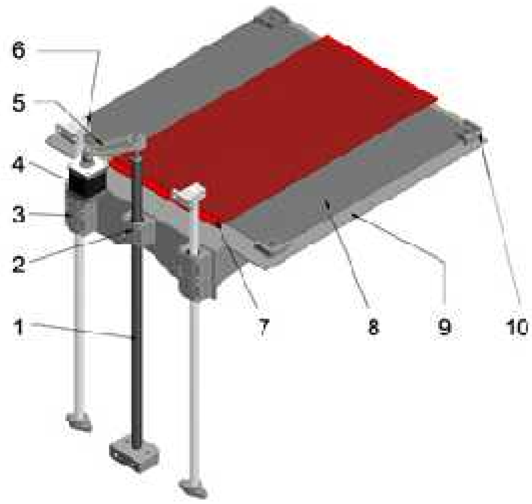


Fig. 3 Cartesian printer sketch [7]:
1 - trapezoidal screw; 2 - trapezoidal nut thread;
3 - rectified axis; 4 - Nema17 engine; 5 - T2.5 belt;
6 - axis support; 7 - heating plate; 8 - safety glass;
9 - support plate; 10 - spacer support

The extruding subassembly, figure 4, is the most important part of the 3D printer and it includes the training system of the wire and the extruder.

The raw material supplying the installation is a wire made of polymer, PLA, ABS, Nylon, polyamide, etc.

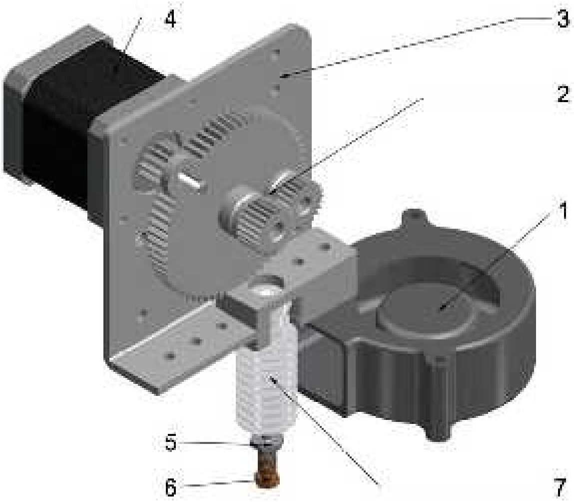


Fig. 4 Extruder subassembly [7]:
1 - fan; 2 - training system; 3 - support; 4 - Nema17 engine;
5 - thermal barrier; 6 - extrusion nozzle; 7 - radiator

Training the wire towards the extrusion head is made with the help of two aluminum rolls, which have a V-shaped notch, in order to imprint a constant movement to the wire, without any slip.

The training rollers are operated by two timing gear, which rotate at the same time, the rotation being given by the engine-gear mechanism with a gear ratio of i=0.35, figure 5.

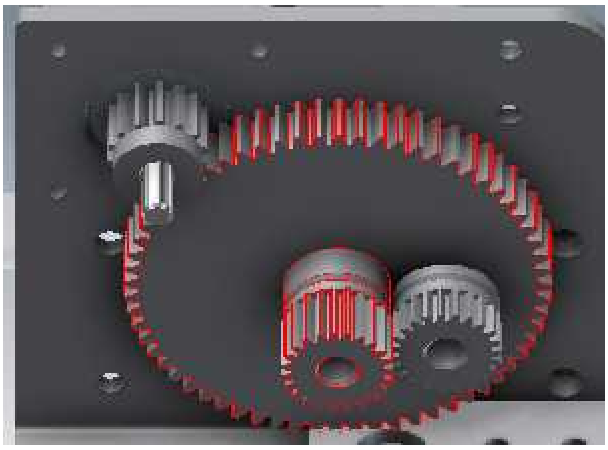


Fig. 5 Filament training system

After completing the 3D design of the components, based on the technical documentation extracted from Autodesk Inventor, we had passed on the physical realization of the assembly of components and physical parts, resulting the XS3dX, figure 6.

a. ***b.***

Fig. 6. 3D Cartesian coordinates printer, CS3dX; virtual model (a); physical model (b) [7].

4. DELTA 3D PRINTER

Compared to the Cartesian coordinates printer, the Delta printer has a bigger flexibility used to get the nozzle in the working position, as well as a series of other advantages, such as: higher working space, higher speed and temperature conditions, the possibility of using other types of printing material compared to the existing ones, futuristic design, usage of high quality pieces, higher stability.

4.1 Graphical Model vs. Physical Model

To achieve the graphic model of a Delta 3D printer was used Autodesk Inventor Professional software package.

We started from an existing model, with overall dimensions: height - 390 mm; core diameter - 233 mm; useful area dimensions: printing table diameter - 170 mm; printed height - 286 mm, fig.7.

Initially was achieved the motherboard's 2D model design, using *Sketch*  command, and by using *Extrude*  command, was achieved the solid yielding, figure 8.

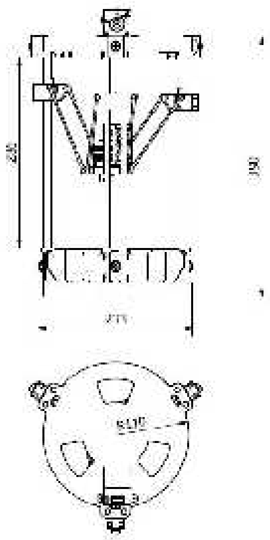


Fig. 7 2D model of the Delta 3D printer

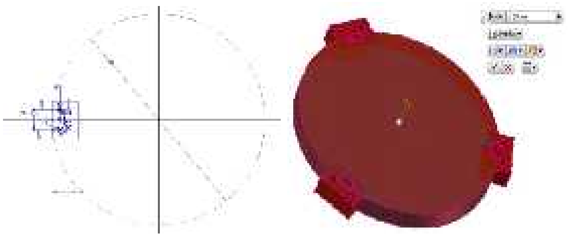
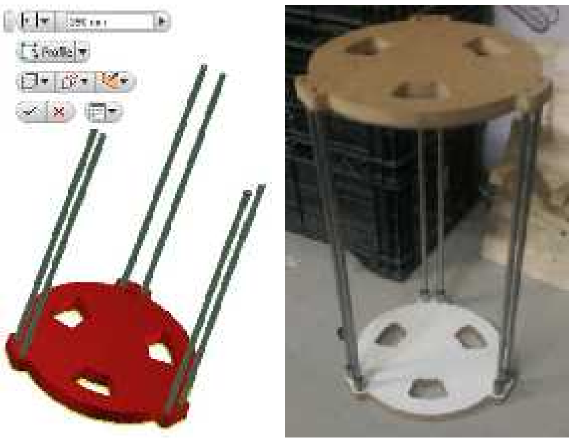


Fig. 8 Lower plate, 2D and 3D

The guide rods were made with the *Project Geometry* command. After the graphical modeling of the upper and lower plates was achieved the physical model, the two plates are made of MDF 20 mm thick, and processed on a Numerical Command Machine, fig. 9. The 8 mm diameter guiding rods were ordered online.



a. ***b.***

Fig. 9 Upper and lower plate assembly and guides; virtual model (a); physical model (b)

To build the physical model were also ordered linear bearings, fig. 10, that also required the design of a system for fixing them, fig. 11. The physical model of this system was performed using the CS3dX 3D printer in Cartesian coordinates.

Fig. 10 Axial bearing

There were physically made three such systems.

a. ***b.***

Fig. 11 Bearing fixing system: virtual model (a); physical model (b).

The holder of the cooling device was designed and physically built using the CS3dX 3D printer, fig. 12. The link between the guiding devices, fig. 13, was achieved through six rods with cylindrical joints, fig. 14, purchased separately. The component that ensures the cooling circuit has been graphically shaped using Autodesk Inventor, then and then physically realized in the mechanical processing hall of the University. Ingenious is the way the nozzle is made- from a M6 screw conical turned and central drilled using a special drill, Ø 0.4 mm diameter, fig. 15.

a. ***b.***

Fig. 12 Holder: virtual model (a); physical model (b)

Fig. 13 Guidance-support-cooler system assembly

Fig. 14 Guiding rod- virtual model

Fig. 15 Extruder- physical model

For fixing the stepper on the lower plate, it is necessary to, first of all, design a gripping device, subsequently made, also by the Cartesian coordinates 3D printer, fig. 16. Overall the three steppers and its electrical connections, the drive pulley of the belt is made from aluminum and it has been specially ordered in accordance with the dimensional format of the transmission belt, fig. 17 and fig. 18.

Fig. 16 Stepper-virtual model **Fig. 17** Pulley-virtual model

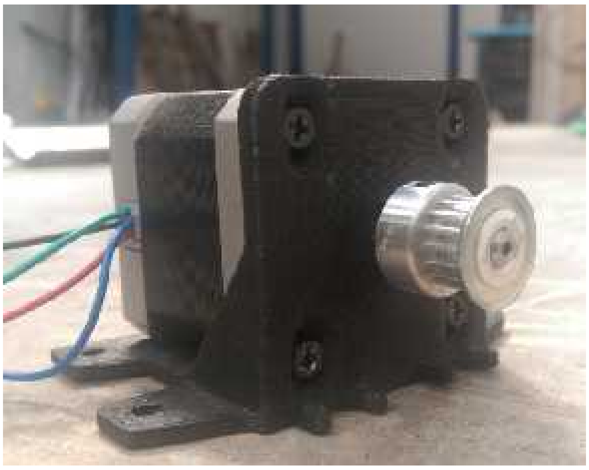


Fig. 18 Stepper-gripping device-pulley assembly

As a whole, the steppers are fixed on the lower plate through the gripping devices, fig. 19.

Fig. 19 Lower plate- stepper assembly – physical model

To limit the stepper's stroke it is necessary to install a stopper, also physically realized using the CS3dX 3D printer (fig. 20, fig. 21), and located in the belt's guiding device.

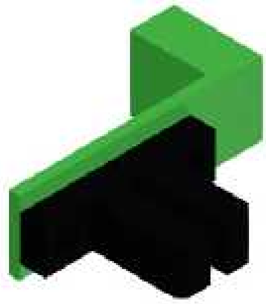
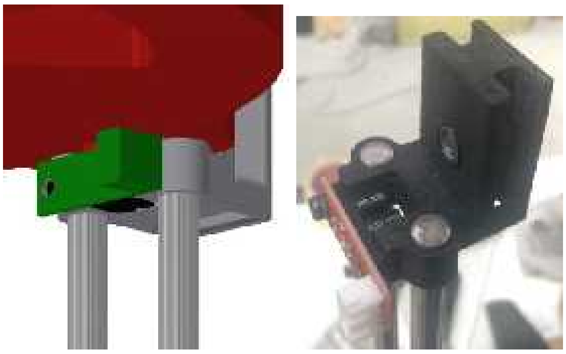


Fig. 20 Training belt device **Fig. 21** Stopper



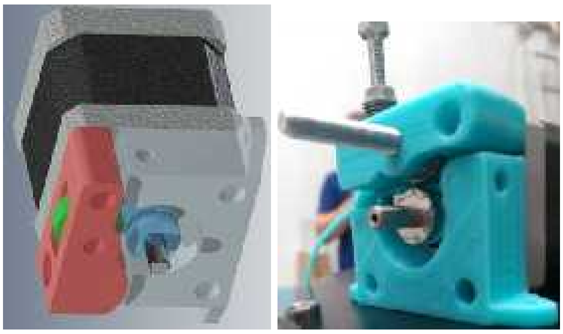
a. ***b.***

Fig. 22 Stopper-training belt device assembly: virtual model (a); physical model (b).

The assembly containing the stepper and printing filament drive device was graphically modeled and afterwards physically developed.

The top of the device has a rotary motion around a bolt that is attached to the stepper's housing. At the same time, at the top there also is a clamping screw, which presses a particular bearing on the stepper's pulley, thus guiding the filament, fig. 23.

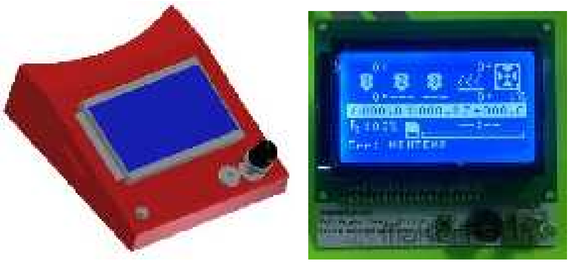
The Delta 3D printer can be controlled using a computer, but at the same time, the screen can be used as a control unit because it has a Micro SD card slot.



a. *b.*

Fig. 23 Stepper-training thread device assembly virtual model (a); physical model (b)

The graphical model has been achieved in CAD format, using the physical model ordered via internet, and was later placed as a whole, fig. 24.



a. *b.*

Fig. 24 LCD screen - virtual model (a); physical model (b)

To fixing the printing table, fig. 25, a device was designed, to catch the guide rods and that it is pressed against the stepper, fig. 26.

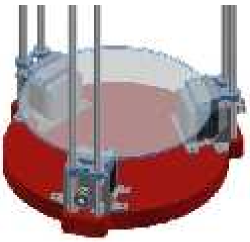


Fig. 25 Printing table

Fig. 26 Table support element

In its ensemble, so that the Delta 3D printer can achieve physical products, there must be observed the following aspects: after making the 3D model of the object to be printed in a graphical design environment-CAD, the drawing is exported with the .STL format, afterwards with using the *Cura* software package, the .STL format file can be opened. This program sets the parameters for printing and it generates a code – *Gcode*- which can be accessed through *Repetitierhot* software that will literally control your printer.

Upon reaching the printing temperature (controlled via a resistor), the printer will engage the extruder engine and it will train the thread through the nozzle. The movement on the XYZ axis will be achieved by combining the three stepper's movement.

The printing is being accomplished by a special software algorithm, according to *Gcode.*

In figures 27 and 28 it is presented the virtual model of the Delta 3D printer, also its physical model.

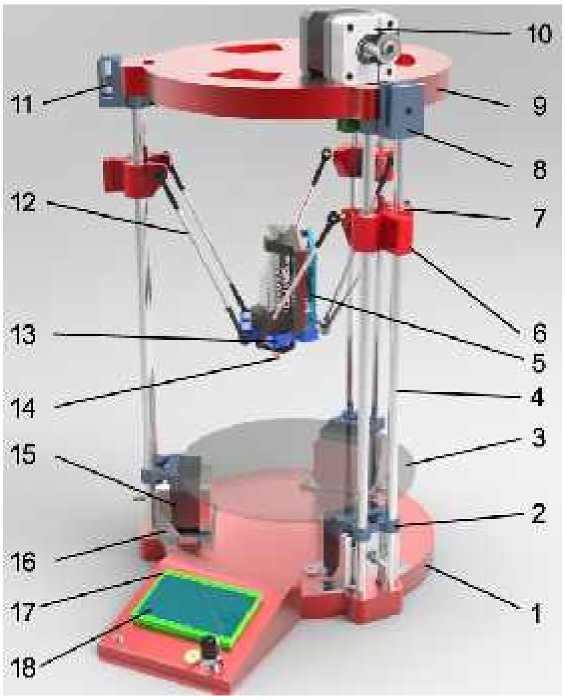


Fig. 27 Delta 3D printer- virtual model
1 - lower plate; 2 - printing table support; 3 - printing table; 4 - guide rods; 5 - fixing stepper devices; 6 - bearing guiding device; 7 - bearings; 8 - guide support strap; 9 - upper plate; 10 - extruder motor; 11 - bearing; 12 - cylindrical joint; 13 - fan and support assembly; 14 - nozzle; 15 - stepper motors; 16 - fixing device stepper motor; 17 - screen controller LCD display case; 18 - screen controller LCD display

Fig. 28 Delta 3D printer – physical model

The components of the Delta 3D printer (see fig. 27.) are: 1 - lower plate; 2 - printing table support; 3 - printing table; 4 - guide rods; 5 - fixing stepper devices; 6 - bearing guiding device; 7 - bearings; 8 - guide support strap; 9 - upper plate; 10 - extruder motor; 11 - bearing; 12 - cylindrical joint; 13 - fan and support assembly; 14 - nozzle; 15 - stepper motors; 16 - fixing device stepper motor; 17 - screen controller LCD display case; 18 - screen controller LCD display.

5. CONCLUSIONS

In this paper, we aimed to make a 3D printer, both virtually and physically. Using 3D projection in the graphic environment Autodesk Inventor, we have succeeded in constructing a 3D extruding installation with which new prototypes and products from different fields will be able to develop in the future.

The physical realization of the printer was made taking into consideration the technical work capacity, the printing speed, the thread's heating temperature and using quality materials, in order to increase the installation's lifetime.

The conducted tests have shown that using a metal extruder is superior to using one made of teflon, taking into consideration both the mechanical resistance and the higher printing temperatures which can be achieved.

Thereby, a printing is considered optimal as long as the technical characteristics of the most important components are respected, namely: printing nozzle with a 0.35 mm diameter; plastic thread with a 1.75 mm diameter; metallic extruder with a cooling fan; heating plate; high speed printing, up to 60 mm/s.

6. ACKNOWLEDGEMENTS

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