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RESEARCH ON THE APPLICATION OF FAST PROTOTYPING (NON–CONVENTIONAL FDM TECHNOLOGY) FOR THE MANUFACTURE OF SOME PARTS IN THE FIELD OF AGRICULTURAL MECHANICS

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Abstract: This paper presents the process by which, with the help of 3D printing technology, the prototype of the microbial bioinoculants dispenser was made with Markforged Onyx One 3D printer using Fused Filament Fabrication (FFF), which uses a continuous filament of thermoplastic material fed through a heated printer extruder head and deposited to form layers. The material used is Onyx Carbon Fibre Filament, which is a universal, time–resistant, non–toxic and non–combustible thermoplastic material. The prototype of the part was used as a conceptual model for visualization, dimensional analysis and for performing functional tests. The microbial bioinoculants dispenser is part of a combined equipment for biological soil treatment, which can apply microbial bioinoculants (liquid formulations) on the furrow or bury in the soil to a depth of 5... 10 cm microbial bioinoculants (granular formulations) in tomato vegetable crops.
Keywords: 3D printer, Fused Filament Fabrication, Thermoplastic polymer

1. INTRODUCTION

In the CAD design process with the help of specialized 3D design programs of a new product in the field of agricultural mechanization, especially in the design phase, it is very difficult to detect mistakes, using only the 3D image on the desktop.

Having the real model of the future part, the designer can detect and remove certain defects or possible shortcomings.

The actual prototype of the part, which is used to visualize, design and develop the manufacturing process before mass production, allows design engineers to perform modifications and functional tests.

Initially, rapid prototyping was used to create scale parts and models for the automotive industry, and today it has been taken over by a wide range of applications, in several industries, such as medical and aerospace, but also in the industry for machines intended for agriculture mechanization.

For example, the rapid prototyping of the piston of an injection device used for crop fertilization equipment was made using a BCN3D SIGMA R19 Printer (FFF) [6].

Within the complex project "Integrated management system of agroecosystem resistance to pests for promoting sustainable agriculture under climate change conditions", component project 2 "Technology for biological soil treatment with microbial bioinoculants" INMA Bucharest developed an experimental model of combined technical equipment, which can apply microbial bioinoculants (liquid formulations) on the furrow or can bury in the soil to a depth of 5... 10 cm microbial bioinoculants (granular formulations) [4].

Figure 1. Box with grooved roll type dispenser

For the gravitational distribution of fungal type bioinoculants (granular formulations), the experimental model consists of a prismatic box (Figure 1) with inclination angles of the walls to its bottom greater than the friction angle between the material to be applied and the box wall to ensure its uniform gliding.

The box is provided at the bottom with some grooved roll type dispensers, which perform the distribution of fungal bioinoculants (granular formulations), a process that consists in dosing and evacuating them through the guiding tubes in furrows (ditches) with determined depth created by sliding ploughs.

Before the constructive finalization of the experimental model of combined technical equipment used for the application of microbial bioinoculants (granular formulations), given that the grooved roll type dispenser

consists entirely of plastic components, its rapid prototyping was made using a material that ensures a special surface finishing, rigidity and temperature tolerance.

2. MATERIALS AND METHODS

To verify and develop the new design idea of the grooved roll type dispenser, the rapid prototyping technology was applied by using the Markforged Onyx One 3D printer (Figure 2). The Onyx One printer makes 3D carbon fibre parts with good dimensional stability and a smooth surface, which do not require post–processing and can be used immediately after being removed from the printer bed [7].

Figure 2. Markforged Onyx One 3D printer

The main characteristics of the printer are:

— Layer thickness (Z–axis) – 100–microns;
— Maximum dimensions (X×Y×Z) – 320 x 132 x 154 mm;
— Overall dimensions – 57.5 × 32.2 × 36.6 cm.

The technology of Markforged Onyx One 3D printer, patented [3], is Fused filament fabrication, Figure 3, which consists in depositing, on the printing tray, several successive layers of Onyx plastic (specially developed by Markforged, based on nylon) reinforced with carbon flakes with a resolution of 100 μ on the Z axis, until the completion of the part.

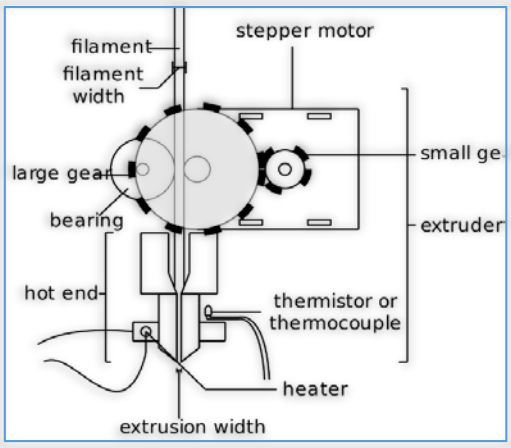

Figure 3. Technology used by Markforged Onyx One 3D printer [9]

Mechanical properties of the Onyx:

- Young's modulus [GPa]: 1.4
- Yield stress [MPa]: 36
- Ultimate stress [MPa]: 30
- Flexural Strength [MPa]: 81
- Flexural Modulus [GPa]: 2.9
- Density [g/cm^3]: 1.2

Through a series of experimental tests, the mechanical properties of the material reported by the manufacturer were verified and presented in the paper [1].

3. RESULTS

The stages of rapid prototyping of the dispenser were:

— **generation of CAD files** – was made in the SolidWorks CAD assisted design program [10], version 2018, produced by SOLIDWORKS®.

The geometry generation of the components of the grooved roll type dispenser was performed according to the methodology presented in the works [2], [5].

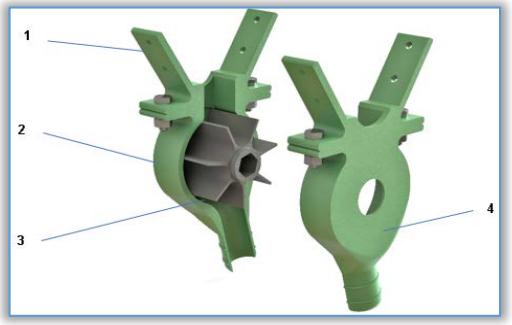

Figure 4. 3D CAD geometric model of the grooved roll type dispenser; 1–support, 2–left housing, 3– grooved roll, 4–right housing

Figure 4 shows the 3D CAD geometric model of the grooved roll type dispenser that was made using SolidWorks 2018 software.

— **conversion of component files to STL format** – Standard Triangulation Language format – Stereolithography is a standardized format that approximates the three–dimensional surface of any object through a set of plane triangles, the information corresponding to each triangle consisting of the coordinates of the three vertices and the direction of the outer normal.

The degree of approximation of the geometry depended on the density of the triangular lattice, the accuracy increasing with the number of triangles. In SolidWorks 2018 the export of geometry in STL format was done very simply by using the "Save as" option and specifying the export options, through the Export Options window, figure 5, by following the steps below:

≡ Binary or ASCII file type selection;
≡ selection of the unit of measurement, from the Unit list;
≡ specifying the resolution; there are predefined resolutions (Coarse, Fine), for the Custom variant, the Deviation and Angle parameters can be specified;
≡ enabling or not the option Show STL info before file saving, which displays the number of triangles generated, the file size and type, the path and the name of the STL file;

≡ the Preview option, which generates a preview of the triangular facets.

For the components pos.1, pos. 2, pos. 3 and pos. 4 in figure 5, which represent the grooved roll type dispenser, the value 0.03536 mm was imposed for the Deviation parameter, respectively 4 degrees for the Angle parameter, which generated the following:

— **decomposing the object into layers** – was done in a specialized program Cloud Eiger Software [8] offered by the supplier of Markforged Onyx One 3D printer.

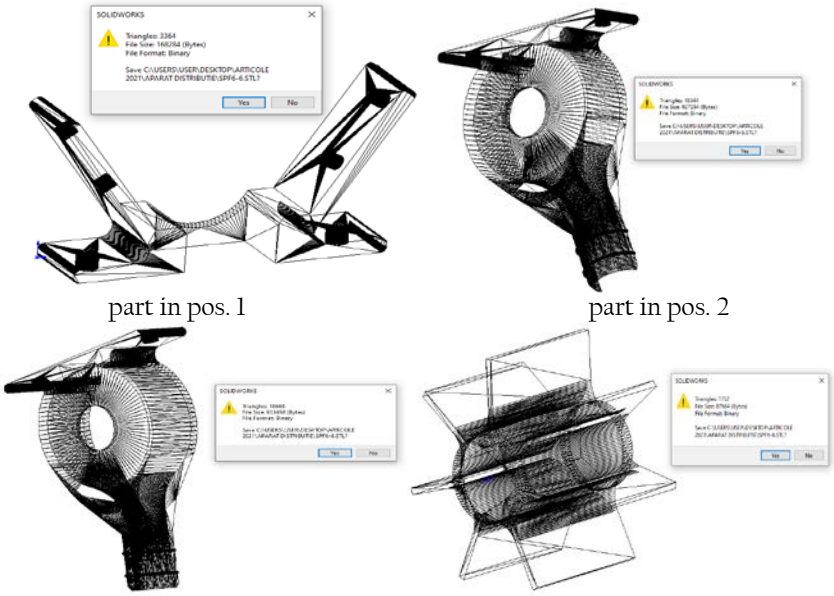

Figure 5. Saving the geometry of the dispenser's components in STL format

Each STL file representing the components of the dispenser was decomposed into a number of layers, the thickness of which varied according to the settings made; also, the program additionally generated a structure to support the material during the printing of the 3D object. The arrangement of the dispenser's components on the printer tray, Figure 6, were calculated automatically by the application to ensure minimum material consumption and printing time.

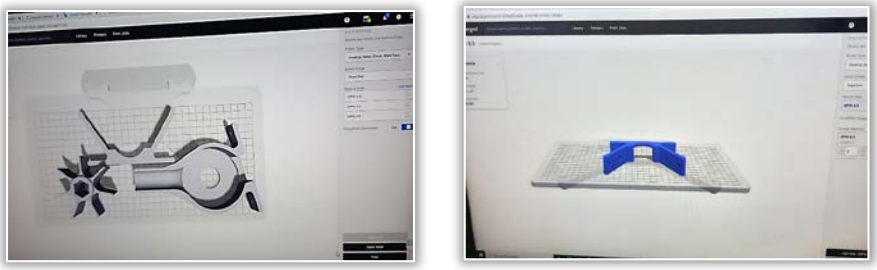

Figure 6. Dispenser's components on the printer tray

— **layer–by–layer 3D object printing** – was made using the Onyx Carbon Fibre Filament material.

Figure 7 shows the different steps of 3D printing of the dispenser's components.

— **cleaning and finalizing the components of the dispenser** – consisted of removing them from the printer and removing the support material.

Finally, the components of the grooved roll type dispenser were assembled. Figure 8 shows the components of the dispenser in the final version.

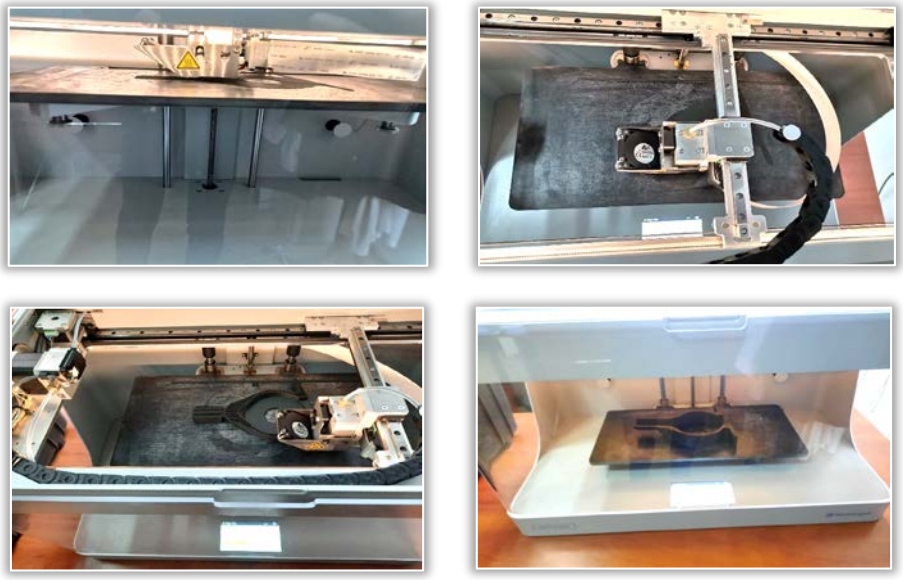

Figure 7. Different steps of 3D printing of the dispenser's components

Figure 8. Dispenser and its components in the final version

4. CONCLUSIONS

— The grooved roll type dispenser, which consists entirely of plastic components, can be considered validated as the fineness of the details and the faithful reproduction of the CAD geometry were observed when the execution was assessed;

— FFF (Fused Filament Fabrication) rapid prototyping technology, due to its simplicity and ability to produce parts with high geometric complexity, has been increasingly used in the industry for machines intended for agriculture mechanization.

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