Dorian Nedelcu, Raoul Avasiloaie, Dănuţ Florea, Aleksandar Rajic

Applications of the Rapid Prototyping Technology to Manufacture the Pelton Runners

The paper presents an application of the Rapid Prototyping technology using Objet Desktop 3D Printer to manufacture two Pelton runners that are destined for experimental measurements on a Pelton microturbine. The runners are different by bucket's number and the bucket's geometry of the second runner is similar with those of the first runner, but scaled in all directions with the bucket's numbers ratio.

Keywords: *Rapid Prototyping, Pelton, runner*

1. Introduction

Rapid Prototyping is a process which assures the product's design from an original idea to the industrial manufacturing. Rapid Prototyping is a technology used to generate physical objects directly from files generated in a Computer Aided Design software. There are several options for generating 3D objects, together with the fact that the geometry is created by the deposition of successive layers, so the addition of material, in contrast to conventional techniques such as milling or turning, whereby the objects are generated by removing material. Some Rapid Prototyping applications in medical, mobile robots, cultural heritage, sheet metal parts and examination of gear wheels fields are presented in [1], [2], [3]. The Rapid Prototyping technology steps are [4]:
- creating a model with the object geometry into a CAD software;
- export the CAD model into STL format;
- import the STL file into the printer 's software, slicing the STL file into thin cross-sectional layers and generate the object layer by layer;
- cleaning and finishing the model and - if a base or support structure was built - removing the support structure; because the model is built up in layers, there may be areas that could float away or have overhanging features, which could distort the resulting model; a base and support structures have to be added, which must be easily removed after the building step.

2. The description of the 3D Printer

Objet 3D Printer Multifunctional Desktop 30 (http://objet.com), figure 1, can be used for multiple applications based on different types of materials: Vero and Durus and different colours: blue, black, white and gray. Surface quality and smoothness details are due to the Objet technology. Maximum print size is defined by the parallelepiped 294 mm x 192.7 mm x 148.6 mm, with a resolution of 600 dpi in the X, Y axis respectively 900 dpi in Z axis. The layer thickness on Z-axis direction is 28 microns. Accuracy can vary depending on the geometry, orientation and size of the object, up to 0.1 - 0.2 mm. The models do not require further finishing, but can still be processed by drilling, soldering, metal coating, painting. The wall thickness is 0.6 mm and minimum diameter of the holes is 1 mm. The printer has the ability to generate functional models overall (crank mechanism, threaded parts, gears, etc.). Weight of 93 kg and dimensions of 82.5 cm x 62 cm x 59 cm of the printer allow its placement in an office without the need for special conditions. Normal operating conditions are: 18-25°C, relative humidity 30-70%, not toxic printing process. 3D printer is controlled by dedicated Objet Studio software, which allows automatic orientation / optimized piece / pieces per tray, divided into layers in real time, simulating the printing process and provides information on material consumption and generation time, pre-release process printing. 3D geometry. The input files can be of STL or SLC type, which can be generated from any CAD program. The range of material model (material used to print the full part of a model) available include: DurusWhite, VeroBlue, VeroBlack, VeroGray with the following mechanical properties: tensile strength 49.8 MPa, flexural strength 74.6 MPa, modulus 2495 MPa, elongation breaking 20%. As support material (material used to print a model empty space) is used FullCure a non-toxic gel-type photopolymer, that can be easily removed by Objet Waterjet System, figure 2, the equipment being included in the printer configuration. Waterjet use pressure water jet to remove material support. The printer is powered by four cartridges with capacity of 1 kg, of which 2 are for the material model and 2 for material support. The printer control interface displays the type and weight of materials available in cartridges.
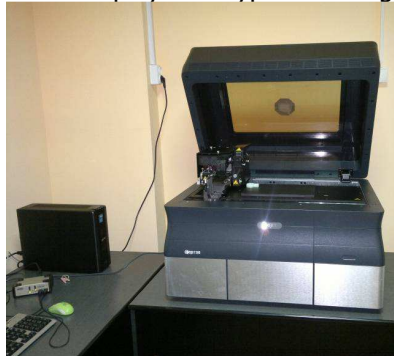
**Figure 1.** Objet 3D Printer Desktop 30

Figure 2. Objet Waterjet System

3. The CAD model of the Pelton runners

The CAD model of the Pelton runners was created using the SolidWorks software. The geometry of the Pelton runner V1, with 21 buckets, is presented in figure 3. The geometry of the Pelton runner V2, with 19 buckets, is presented in figure 4. The buckets of the Pelton runner V2 are scaled with the 21/19 ratio on the X, Y and Z directions, maintaining the same characteristic diameter of 148 mm. The maximal dimensions for the V1 runner are 182.75 mm x 182.68 mm x 41.01 mm and for the V2 runner are 186.5 x 186.5 x 45.3 mm.
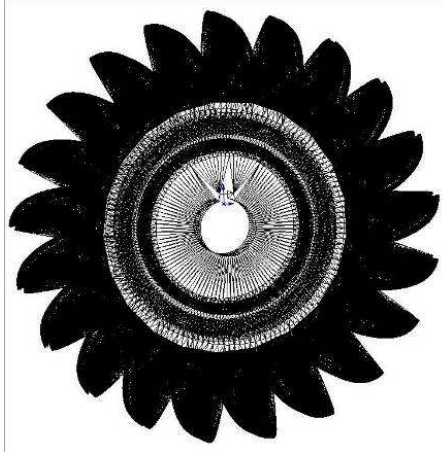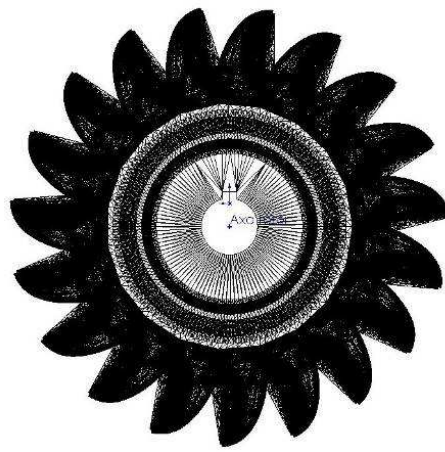

Figure 3. The CAD model of the runner V1
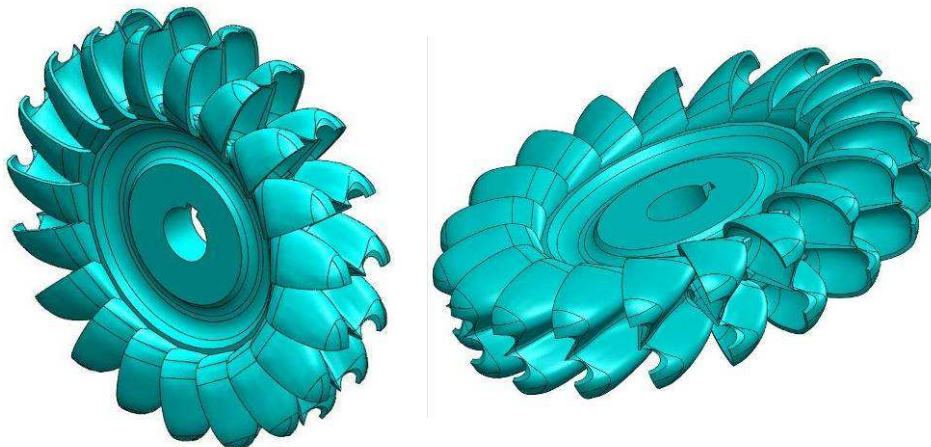
Figure 4. The CAD model of the runner V2

The CAD geometry of the runners was exported on an STL file, resulting in 1455222 triangles for the V1 runner, figure 5, and 1285098 triangles for the V2 runner, figure 6.

Figure 5. The STL format
of the V1 runner (1455222 triangles)

Figure 6. The STL format
of the V2 runner (1285098 triangles)

4. The printing process

Models that are saved in a CAD program as STL files may be inserted into the Objet Studio tray. Figure 7 and figure 8 show the STL files loaded in Objet Studio software. The orientation of models on the build tray affects how quickly and efficiently they will be produced by the 3D printer, where and how much support material is used, and whether or not model parts will have a gloss finish. To minimize printing time [5]:

- the longest dimension of a model must be placed along the X-axis;
- the smallest dimension of a model must be placed along the Z-axis;
- the tallest model must be placed on the left of the tray.

When a tray is ready to be printed, it is sent to Job Manager, where it is placed in the print queue. When the job reaches the head of the queue, Job Manager preprocesses the tray file to create slices, and feeds them to the 3D printer. Table 1 show the printing parameters for the two runners.

Table 1. The printing parameters of the two runner

Parameter	UM	Runner V1	Runner V2
Material	-	VeroWhite	VeroBlue
Model Material	g	766	839
Suport Material	g	639	726
Printing Time	h/min	17 h 01 min	17 h 20 min
Layer Thickness (Z-axis)	μm	28	28
Layer's number	-	1464	1671

194
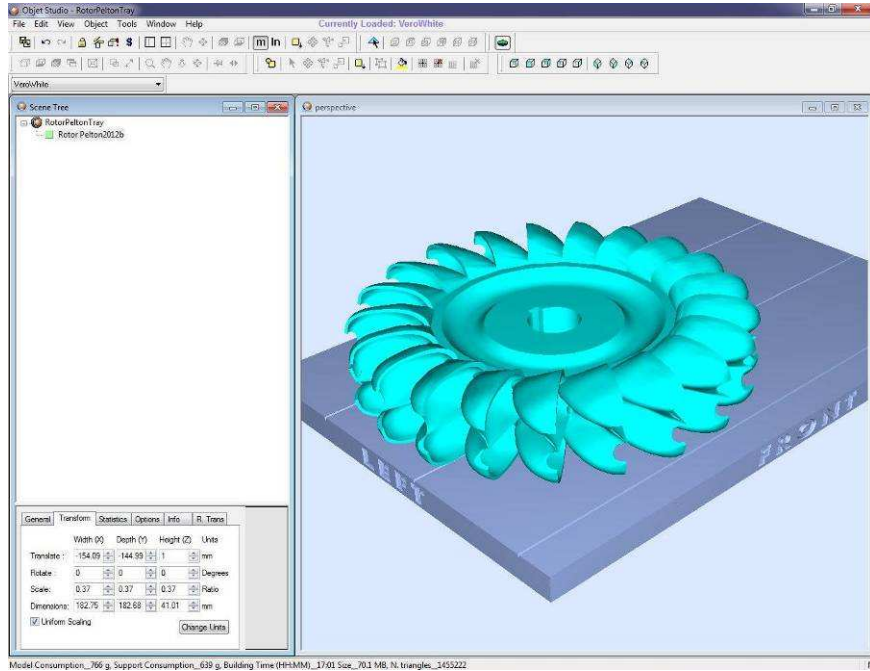
Figure 7. The STL file of the V1 runner loaded in Objet Studio software and placed on printer tray
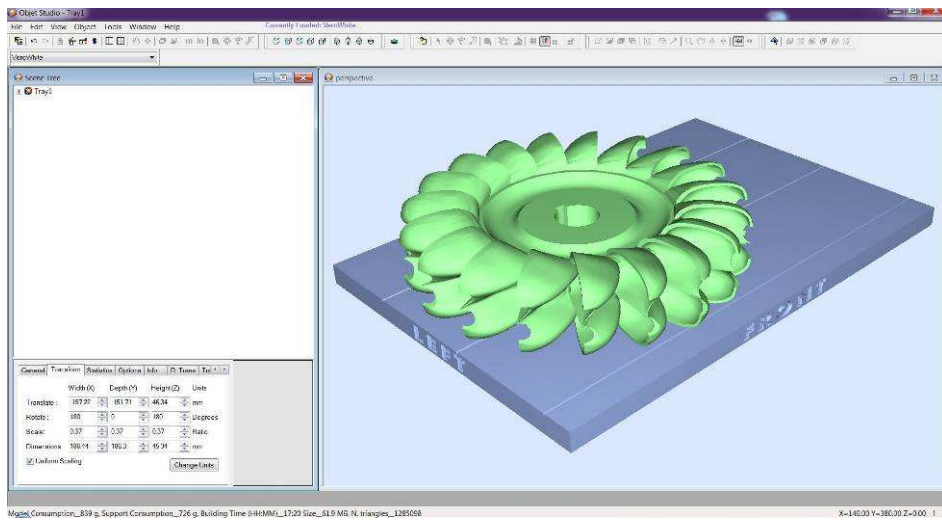
Figure 8. The STL file of the V2 runner loaded in Objet Studio software and placed on printer tray

Objet Studio software offers the following additional features [5]:

- **dividing objects** – to produce objects larger than the build tray by dividing the model into separate parts; with this feature, it is possible to print only a specific section of a model;

- **choosing the support strength** – when producing models, support material fills some hollow and empty sections; Objet Studio allows to adjust the strength of the structure formed with the support material; this adjustment is useful when producing either large/massive models or small/delicate models;

- **smartcast - filling models with support material** - many objects placed on the build tray from STL files are "solid"; this means that, when printed, the model will be completely filled with model material; often, especially with large objects, this is unnecessary; instead, the model can be filled with support material, which is less costly. It is also advisable to fill models with support material when preparing them for investment casting, since this material burns off more quickly during the process of making the cast. Objet Studio enables to print objects on the build tray with an outer shell of model material and a centre filled with support material. This feature of Objet Studio is called "Smartcast/Hollow." It is possible to set the thickness of the shell between 0.015 and 3.825 millimetres.

Figure 9 shows the different stages in the printing of the V1 runner. Figure 10 shows the different stages in the printing of the V2 runner. Figure 11 shows the removal of the support material with Objet Waterjet System for the V1 runner. Figure 12 shows the final shape of the two Pelton runners.
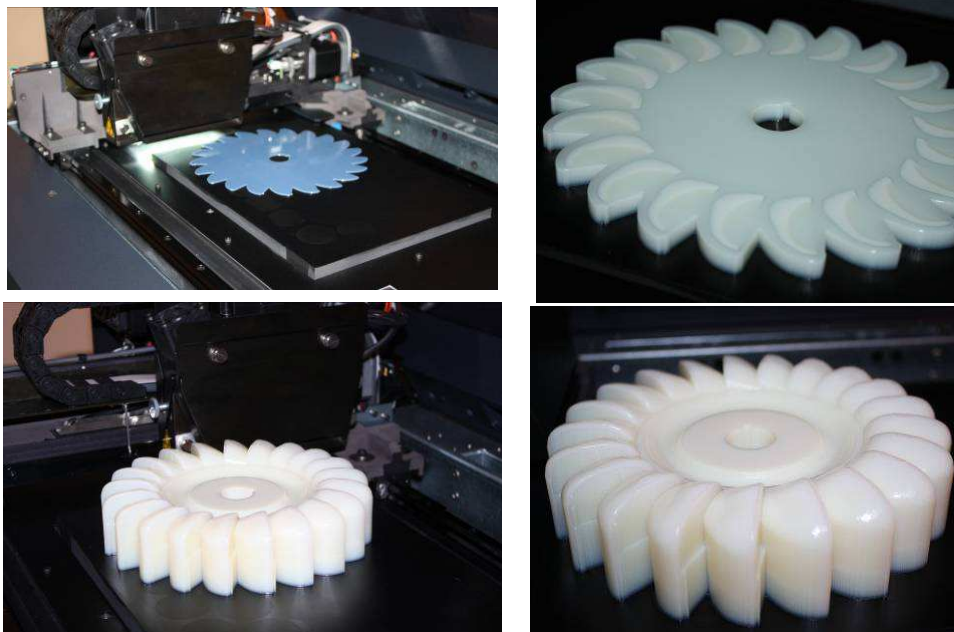
Figure 9. The different stages of the runner V1 printing
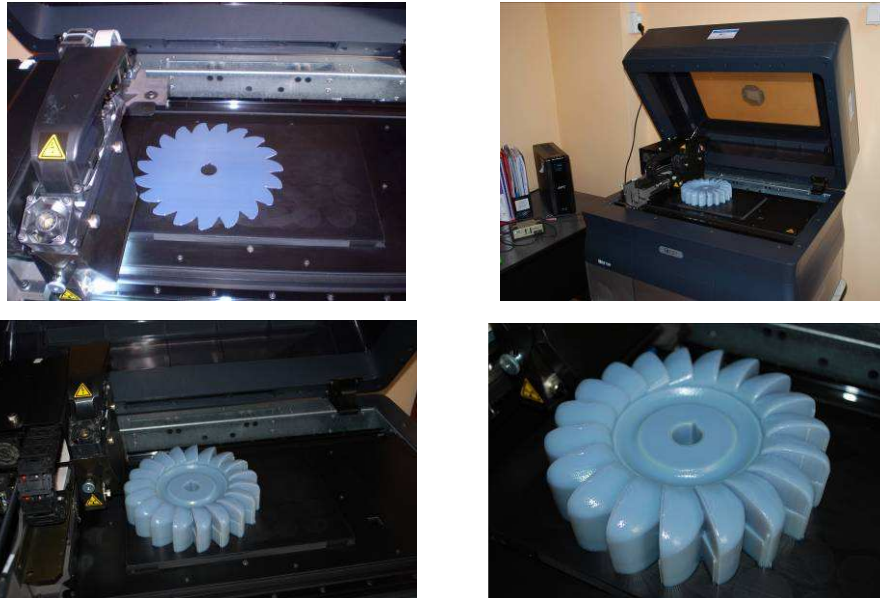
Figure 10. The different stages of the runner V2 printing

Figure 11. The support material removal with Objet Waterjet System

Figure 12. The final shape of the two Pelton runners
(The runner V1 with 19 bucket and the runner V2 with 21 bucket)

5. Conclusion

The Rapid Prototyping Technology can be used to create complex objects, like Pelton runners and to use these objects on the experimental stand to measure hydrodynamic characteristics. The following advantages are important: surface quality, smoothness details, great level of accuracy and reduced manufacturing time.

Acknowledgements

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Addresses:

- Prof. Ph.D. Dorian Nedelcu, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, Romania, d.nedelcu@uem.ro
- PhD stud. Eng. Raoul Avasiloaie, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, Romania, raulynoxx@yahoo.com
- PhD stud. Eng. Dănuţ Florea, "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, Romania, danut.florea@petrom.com
- PhD student Lecturer Aleksandar Rajic, Technical College of Applied Sciences in Zrenjanin, Djordja Stratimirovica 23, 23000 Zrenjanin, Republic of Serbia, aleksandarrajic@yahoo.com