MICROHYDROPOWER WITH PERMANENT MAGNET GENERATOR AND IMMERSED RUNNER

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Abstract. The paper presents a new solution of a microhydropower equipped with a permanent magnet generator and an immersed runner. The configuration is similar with a bulb turbine, with a conical wicked gate, an axial runner and a suction tube. These parts with complex geometry will be manufactured through rapid prototyping technology, using the Objet 30 Desktop Multifunctional 3D printer included in the endowment of the Center for Numerical Simulation and Prototyping from the "Eftimie Murgu" University of Resita. The generator is equipped with permanent neodymium magnets that are included in a stator. Both are placed on the runner periphery. All of these components will be included in a duct and immersed in water. The main purposes of this solution are to obtain a compact configuration and to avoid the gear connection between the turbine and the generator.

1. Introduction

This paper aims to present:

- the constructive solution of the microturbine;
- the numerical simulation of flow through the microturbine;
- the hydrodinamic design of the three axial runners based on the numeric simulation results;
- the Rapid Prototyping of the three axial runners and of the wicked gate;
- the experimental results on the magnetic runner.

2. The constructive solution of the microturbine

The constructive solution of the microturbine is presented in Figure 1 and it is similar with a bulb turbine, with a conical wicked gate, an axial runner and a suction tube. The turbine can be entered through the upstream housing. The stator has 2 blades and the wicked gates has 14 blades on conical placement. The new concept of the microturbine is the magnetic runner, which is placed on the axial runner periphery through 4 bolts, Figure 2. The magnetic runner consist of one disc with 24 cuts and 24 neodymim magnets with 5x10x10 dimensions, which are grouped into 2 pairs of poles. The neodymim magnets advantages are safe operation and excellent magnetic characteristics relative to smaller dimensions. Since the stator will come into contact with water, it will be sealed with resin. The two stator ends are closed with 2 caps and its interior is flooded throughout with resin, which will provide sealing against water. The turbine can be exited through the suction tube and downstream housing.

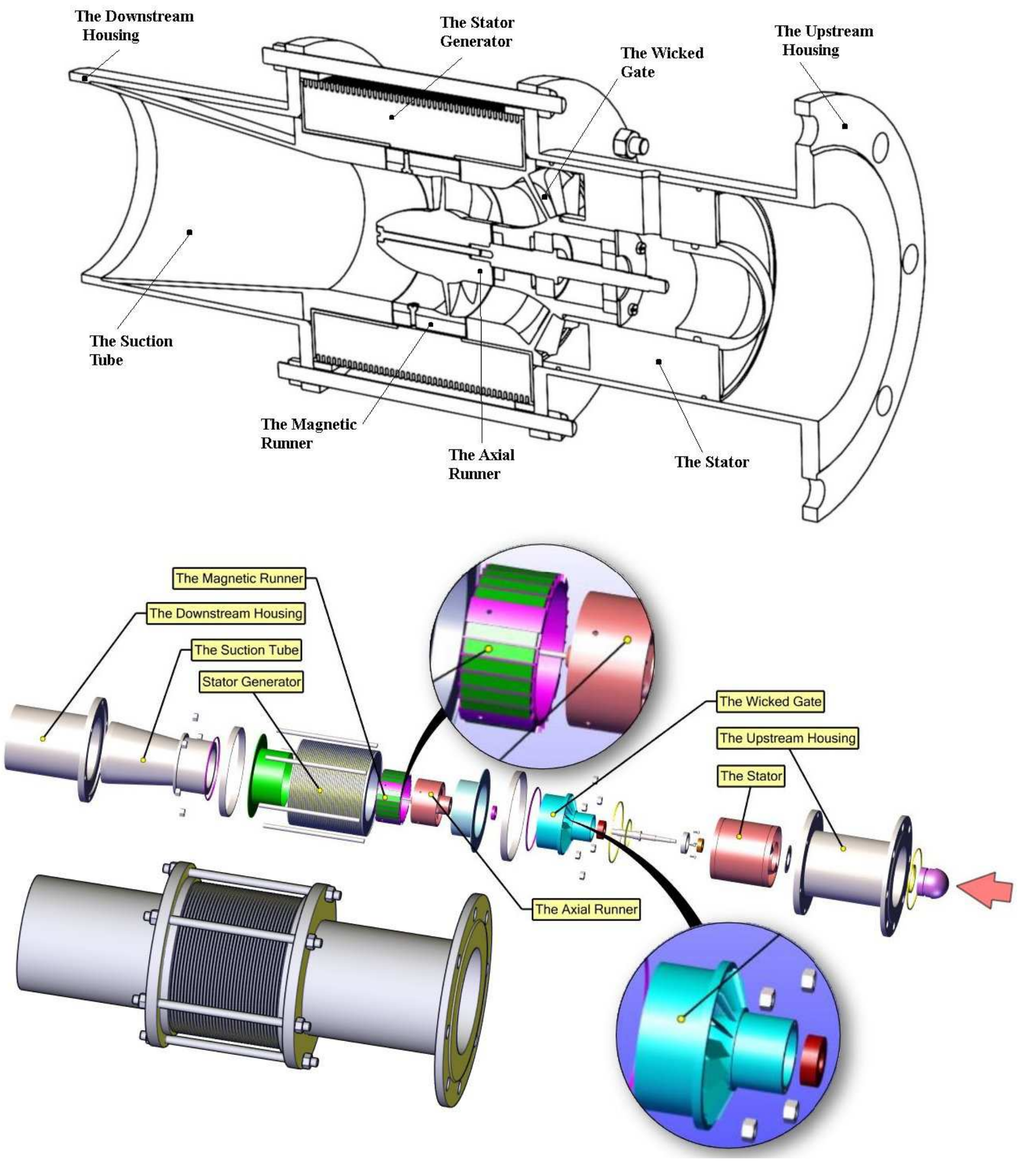


Fig. 1 The constructive solution of the microturbine (section and exploded views)

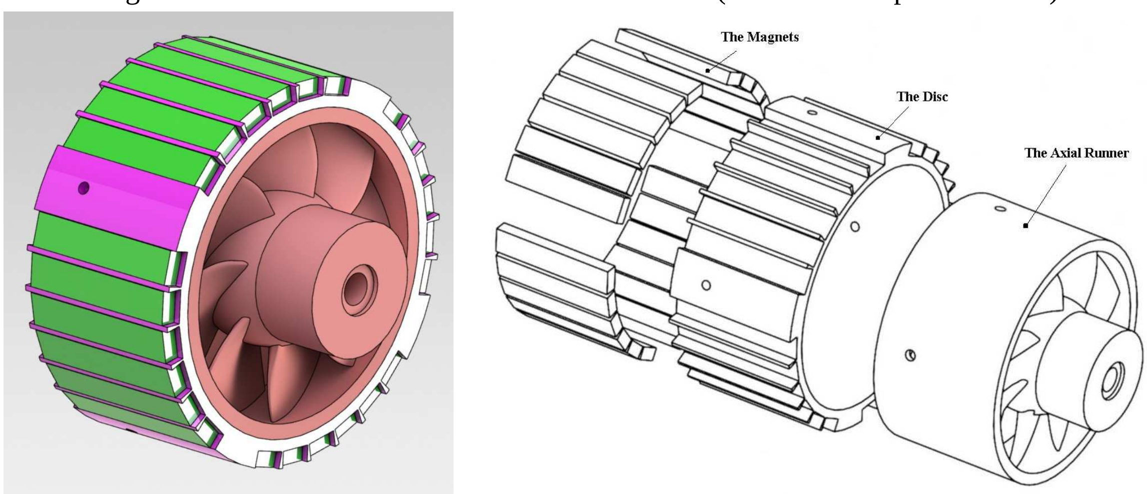


Fig. 2 The Axial and the Magnetic Runner

3. The numerical simulation of flow through the microturbine

The simulation of flow through the microturbine aimed to determine the variation of the meridian velocity in the absence of the runner blades. The simulation was performed using the Flow Simulation module, included in the SolidWorks software, for three operating points that will provide design data for the blade runners' hydrodynamic design: runner R4 → Q = 0.0109 m^3/s, runner R6 → Q = 0.0106 m^3/s and runner R8 → Q = 0.0094 m^3/s. Figure 3 shows the microturbine geometry that was used in the flow simulation. The imposed boundary conditions were the discharge value Q at the microturbine entrance and the atmospheric pressure at the exit.

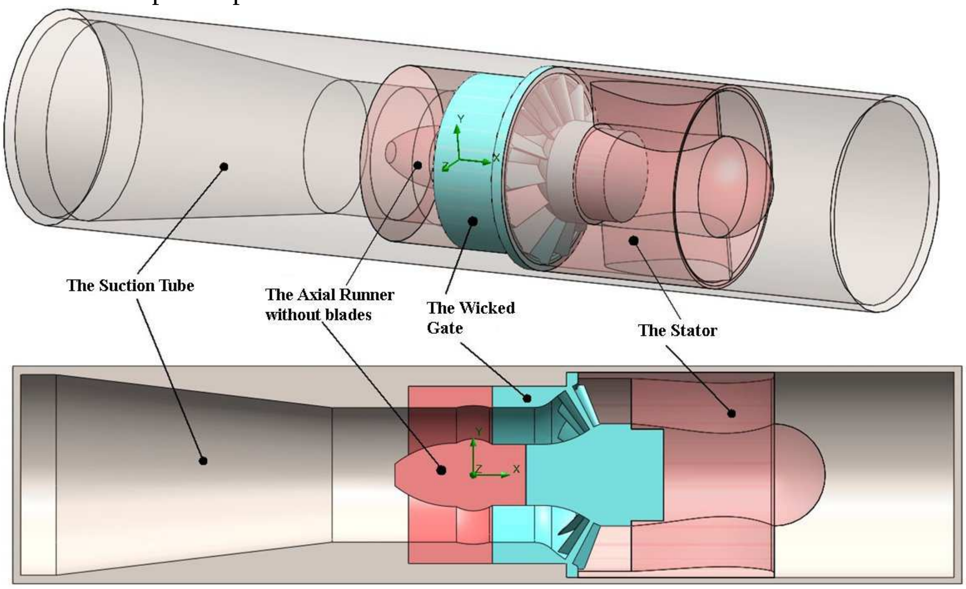


Fig. 3 The microturbine geometry used in the simulation

Figure 4 shows the 3D streamlines through the microturbine and it is visible that the streamlines are horizontal and parallel with the axial direction of the flow, after which the streamlines are deviated by the wicked gate into a rotational movement. Figure 5 shows the meridian velocity distribution for the R6 runner.

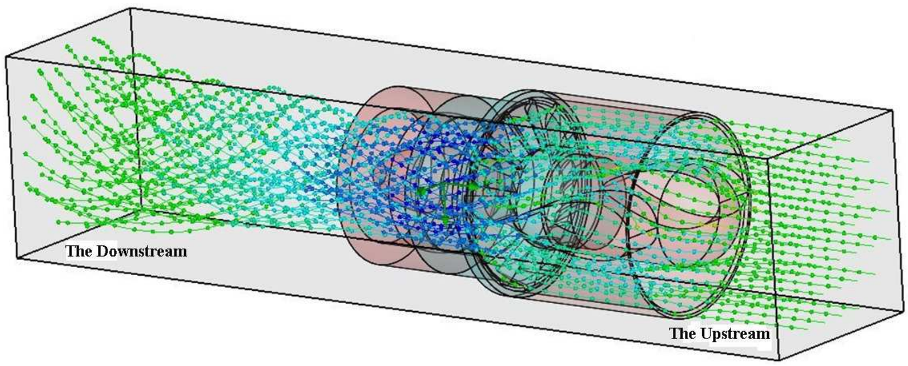


Fig. 4 The 3D streamlines through the microturbine

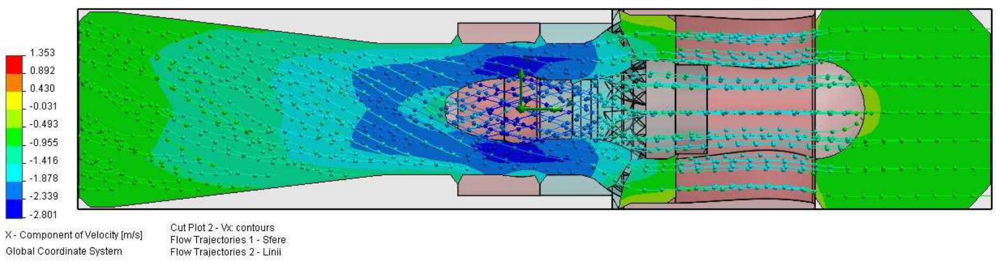


Fig. 5 The meridian velocity distribution for the R6 runner

Figure 6 shows the points from the runner area where meridian velocity values were taken from the flow simulation. The Figures 7 ÷ 9 show the velocities distribution V, V_x, V_y, V_z as a function of radius for the R4, R6 and R8 runners, where the radius direction is identical with Y and the X direction is identical with the flow direction.

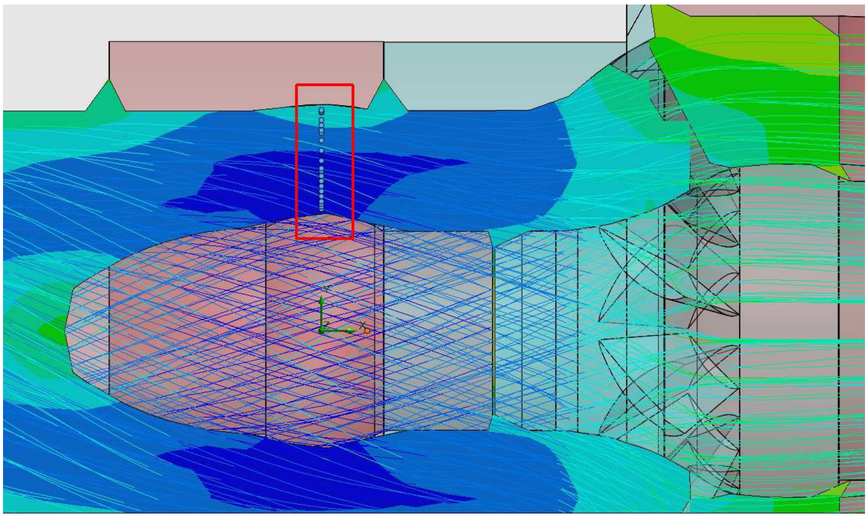


Fig. 6 The points where the meridian velocity values were taken from flow simulation

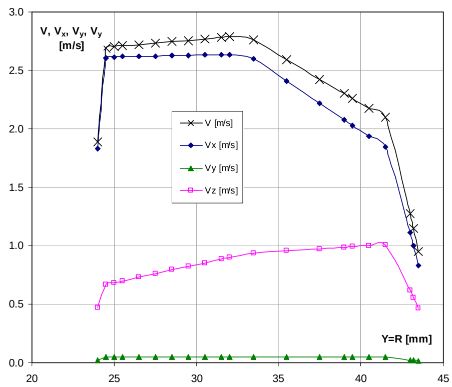


Fig. 7 The velocities distribution for the R4 runner

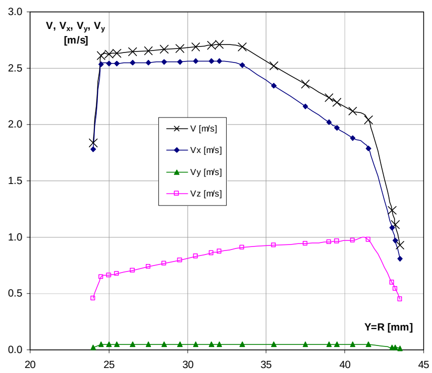


Fig. 8 The velocities distribution for the R6 runner

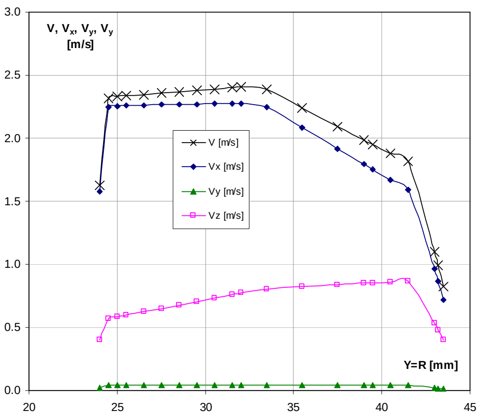


Fig. 9 The velocities distribution for the R8 runner

The values of the meridian velocity V_x are close to the values of the main velocity V, so the others components of the velocity V_y and V_z have smaller values. The meridian velocity values V_x were used as input data for the R4, R6 and R8 blade runners' hydrodynamic design. The difference between runners is the blade number.

4. The hydrodinamic design of the three axial runners: R4, R6, R8

The hydrodinamic design of the three axial runners was processed by the software presented in [2], based on prof. O. Popa's algorithm [3], which was extended by Prof. V. Câmpian [1]:

- specify the input data;
- the calculus of the main runner parameters;
- the calculus of the asymptotic elements (angular and kinematic):
- the calculus of the Fourier coefficients of the profiles;
- the calculus of the profiles, distribution of tangential velocity and the pressure coefficients;
- the calculus of the rotation axis position of the profiles;
- the calculus of the spatial coordinates of the profiles and the exportation of the results to Microsoft Excel and SolidWorks.

Figures 10, 11 and 12 show the 3D runner geometry, the blade intersection with radial and horizontal planes, for the R4, R6 and R8 runners.

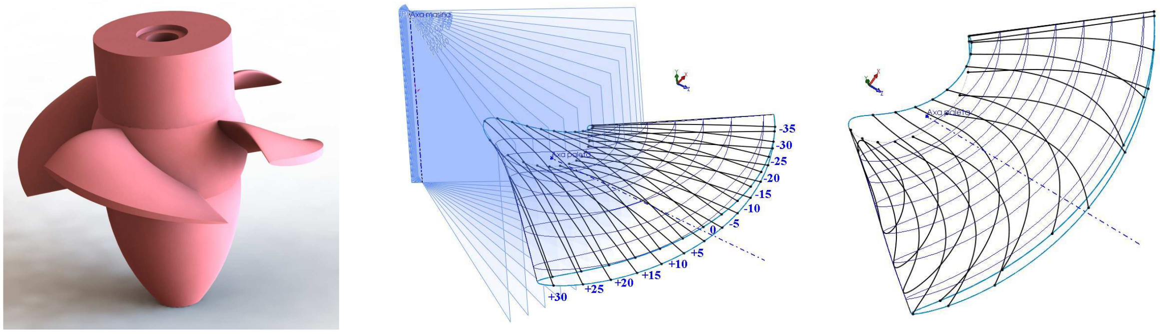


Fig. 10 The geometry of the R4 runner

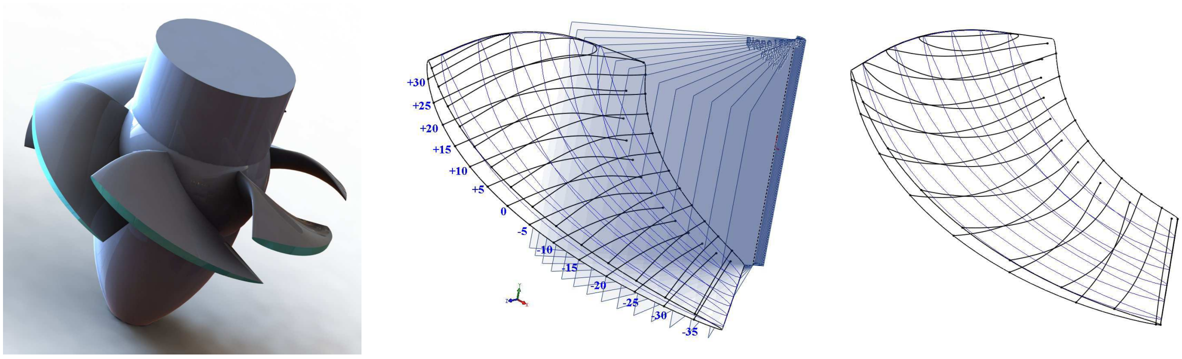


Fig. 11 The geometry of the R6 runner

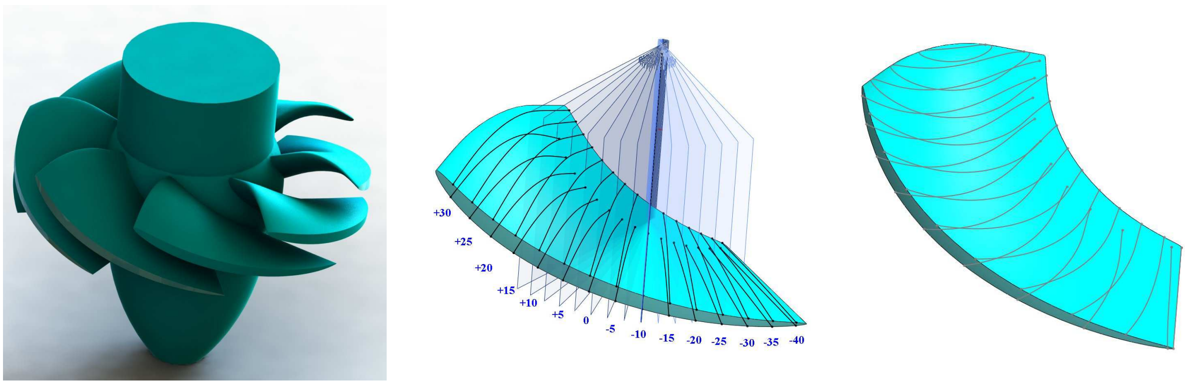


Fig. 12 The geometry of the R8 runner

5. The Rapid Prototyping of the three axial runners and of the wicked gate

The three runners: R4, R6, R8 and the Wicked Gate were manufactured by Rapid Prototyping technology on the Objet 30 Desktop printer included in the endowment of the Center for Numerical Simulation and Rapid Prototyping, "Eftimie Murgu" University of Resita. From SolidWorks, the 3D geometry was exported in STL format and imported into the Objet Studio software, an application that manages the entire process of the 3D printing. Table 1 shows the printing parameters.

Table 1 The printing parameters

The part	Material	Number of Layers	Number of Triangles	Dimensions [mm]	Model Material	Support Material	The Printing Time
The R8 Runner	Vero Black	2696	299104	Φ 96 x 55	413 g	281 g	17 h 00 min
The R4 & R6 Runners	Durus White	3055	3938054	Φ 96 x 55	762 g	473 g	19 h 15 min
The Wicked Gate	Vero Black	3991	227212	Φ 132 x 111	786 g	628 g	29 h 08 min

Figures 13, 14 and 15 show, for the R8 runner, the STL geometry, the placement of the runner on the print tray of the Objet Studio software and the final geometry. Figure 16 shows the final geometry of the R4 and R6 runners.

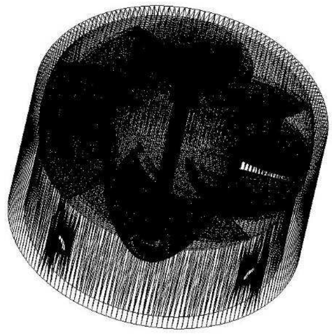


Fig. 13 The STL geometry of the R8 runner

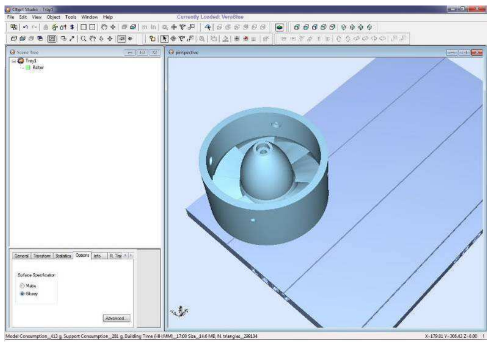


Fig. 14 The placement of the R8 runner on the print tray

Fig. 15 The final geometry of the R8 runner

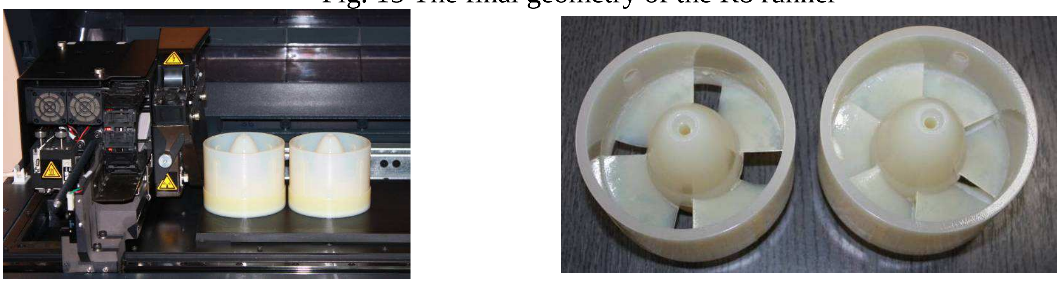


Fig. 16 The final geometry of the R4 and R6 runners

Figures 17, 18 and 19 show, for the Wicked Gate, the STL geometry, the placement on the print tray of the Objet Studio software and the final geometry.

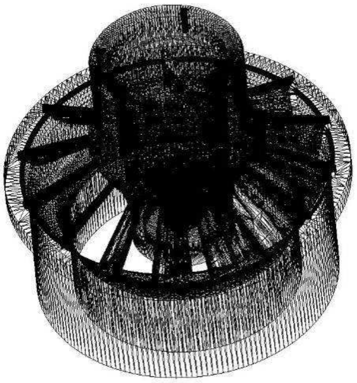


Fig. 17 The STL geometry of the Wicked Gate

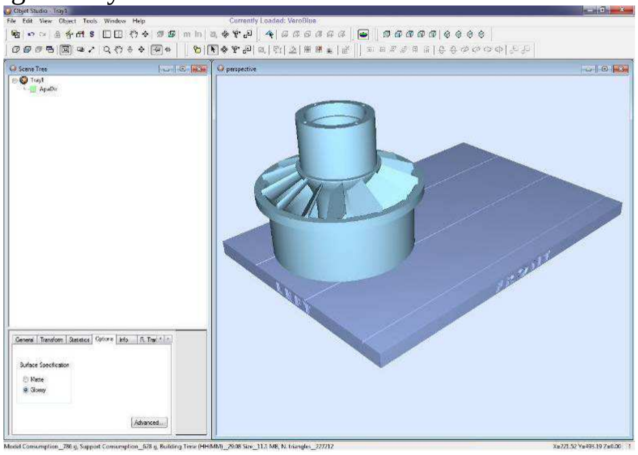


Fig. 18 The placement of the Wicked Gate on the print tray

Fig. 19 The final geometry of the Wicked Gate

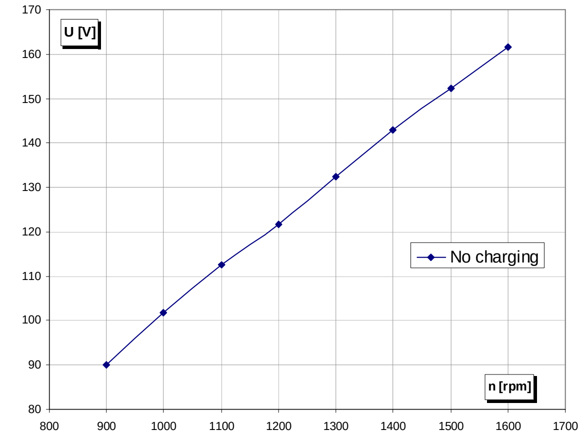
6. The experimental results on the magnetic runner

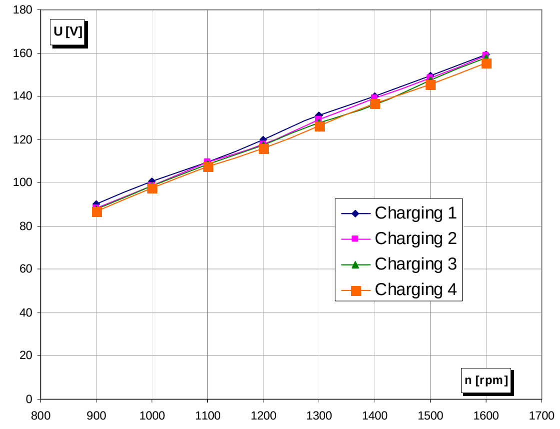
The original runner of the generator was turning at the inner diameter of the magnetic runner, in order to be fixed on the axial runner periphery, Figure 20. Preliminary tests performed on the generator that was equipped with a magnetic runner were conducted to measure the electrical parameters of the magnetic runner. For this purpose, the generator was placed in a stand via a belt driven by a DC motor of 450 W and 1680 rpm, and coupled with a battery terminal with bulbs of 60 W, Figure 21.

Fig. 20 The Axial and the Magnetic Runner

Fig. 21 The stand

The results are presented in Figure 22 on the following variations: the voltage as a function of number of revolutions U=f(n) with no generator charge, the voltage as a function of number of revolutions U=f(n) with four charges and the power as a function of number of revolutions P=f(n) with four charges.





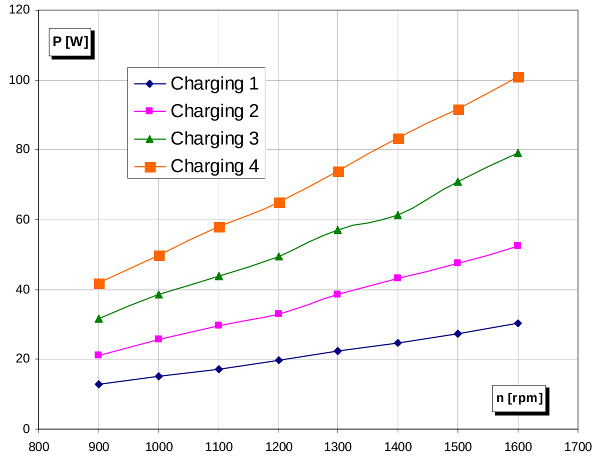


Fig. 22 The electrical parameters of the magnetic runner

7. Conclusions

The paper presents a new concept of axial microturbines equipped with a magnetic generator, where the magnetic runner is fixed on the axial runner periphery. The final constructive solution of the microturbine and of the three types of axial runners with different blade numbers was designed. The hydrodynamic parts with complex geometry (the axial runners and the wicked gate) were manufactured by Rapid Prototyping technology. The electrical parameter results of the magnetic runner are presented. The numerical results on the experimental stand for the whole microturbine will be available after the final execution of all of the components.

References

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[2] Nedelcu, D., *Modelarea matematică a fenomenelor hidrodinamice cu aplicaţie la proiectarea asistată de calculator a turbinelor şi turbinelor-pompe axiale şi radial-axiale*, Teză de doctorat, Universitatea “Politehnica“ din Timişoara, 1996.

[3] Popa, O., *The Determination of a General Relation between the Aerodynamic Properties of a Single Airfoil and those of the same Airfoil Arranged in an Arbitrary Cascade*, Proc. of the Fourth Conference on Fluid Machinery, Budapest, 1972.