# INNOVATIVE METHODS OF MANUFACTURING HYDROELECTRIC TURBINE BLADES FROM POLYMER COMPOSITE MATERIALS

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*SUMMARY: Hydrodynamic energy systems produce renewable electricity by harnessing the kinetic energy of a body of water, energy resulting from their movement. Among the objectives of this scientific research are the realization of a preliminary model of a hydroelectric turbine as well as the realization and testing of cellular biomimetic structures that will be used, after optimization, in the manufacture of the turbine blade, increasing efficiency and reducing it`s weight.*

*KEY WORDS: turbine, energy, water, composite materials, additive manufacturing*

## 1. Introduction

The planet is becoming increasingly polluted and new sources of cleaner energy are being sought. To minimise pollution, the most sought-after methods are in nature, using water, wind and sun. Looking at the three broad categories, two of them are limited: the sun can be used when it is in the sky and the wind can be used at a certain speed, with the possibility of it being non-existent for some time. In contrast, (flowing) water has no limitations, at best it can increase its flow at times when rainfall has taken its place, resulting in much better efficiency.

The hydrographic area is very large and worth exploiting, so the research direction of this work is to develop a small hydroelectric turbine that could be placed in river and stream beds. In order to develop something different from what is available on the market, the research focuses on optimising the structure of the turbine blade, i.e. avoiding its total filling with biomimetic-inspired sandwich cell structures.

## 2. Current status

Renewable energy is one of the biggest challenges facing the planet, which is why engineers around the world are studying new technologies to replace polluting energy production.

In this project, an easy solution has been developed to provide reliable, predictable energy at low cost. This technology is a hydroelectric turbine made of polymer and composite material for direct use in rivers, irrigation canals or tailraces that channel water from existing dams. It is made up of several sub-components, as shown in Figure 2.1.

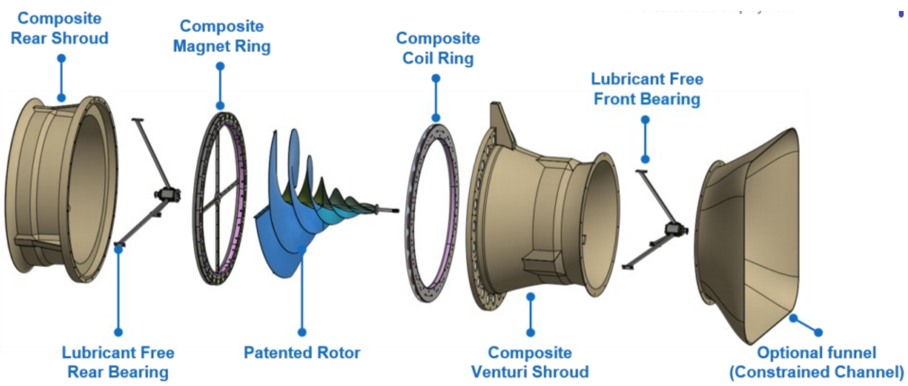


Fig. 2.1. General components of a hydroelectric turbine [7]

The most important component is, of course, the rotor and in figure 2.2 shows the 3D model made in CATIA software.

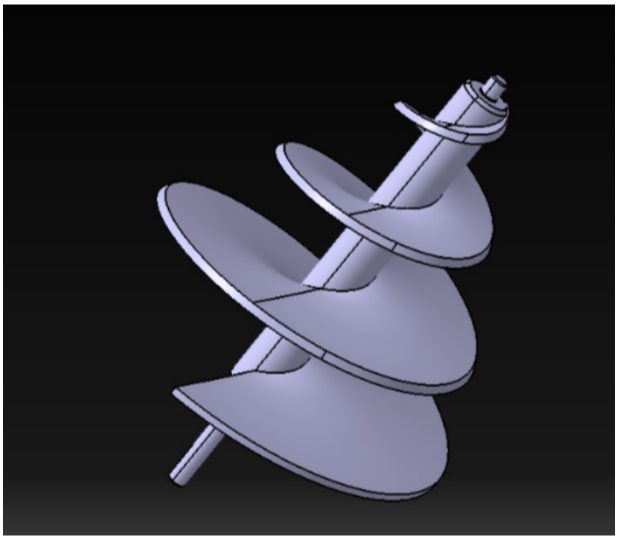

Fig. 2.2. Hydroelectric turbine rotor

Most hydroelectric turbines include propeller or fan blades arranged radially around the central axis and activate another mechanism to generate electricity inside the turbine when it is rotated by water, which is channelled down the turbine. These turbines work best in high head water systems, where the water falls a considerable distance along with the intake velocity and water pressure to produce a greater amount of power. In figure 2.3 shows the preliminary hydroelectric turbine using the rotor from figure 2.2.

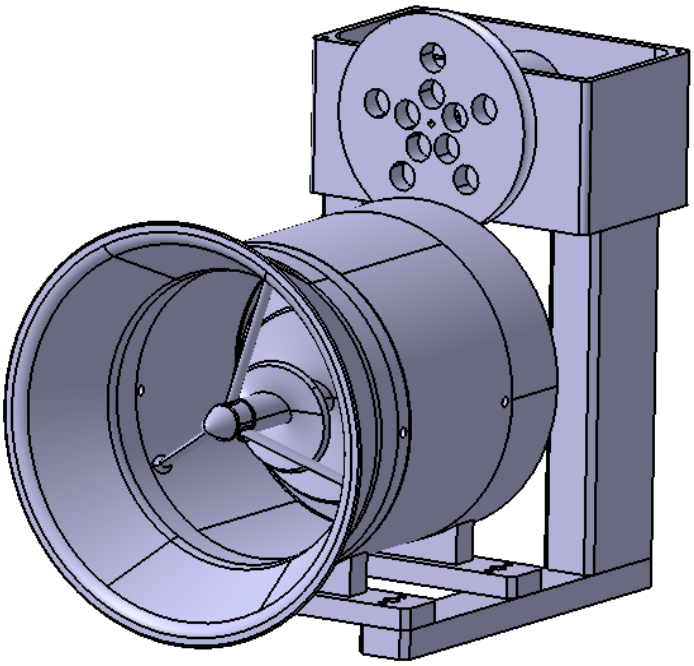

Fig. 2.3. Preliminary hydroelectric turbine

## 3. Manufacturing equipment

The MARKFORGED X7 printer works on the principle of FDM (Fused Deposition Modeling) 3D printing, the construction of the mark is achieved by layer upon layer of extruded material. The roll of thermoplastic filament is loaded into the printer and once the extrusion nozzle reaches the set temperature, the filament melts and the construction of the first layer of the landmark begins on the machine table through the printer's extrusion head. The extrusion head is attached to a system of three axes that move in the x, y and z directions, allowing movement to build the next layers [1].

The plastics used by this printer are: Onyx, Onyx FR, Onyx ESD and Nylon White, all of which can also have glass fibre, carbon fibre and Kevlar fibre reinforcements [2].

Fig. 3.1. Printer 3D MARKFORGED X7 [3]

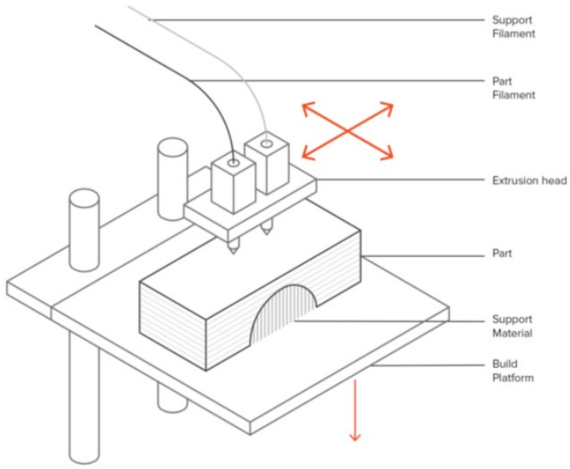


Fig. 3.2. Principle of operation FDM [8]

## 4. Used materials

Onyx is an ideal material for one-of-a-kind parts, based on a very tough nylon that provides parts with equal or greater stiffness than any pure thermoplastic material available for professional 3D printers. This material can be used in its pure state or can be additionally reinforced with different types of fibre: continuous carbon, Kevlar or glass fibre [4, 5]. The properties of the Onyx material can be seen in Table 4.1. Onyx has a degree of thermal deformation at a temperature of 145°C.

Table 4.1. Material properties [6]

| **Properties** | **Onyx** |
|---|---|
| Density[g/cm$^3$] | 1,2 |
| Viscosity [cPs] | - |
| Flexural strength [MPa] | 81 |
| Tensile modulus [MPa] | 1400 |
| Flexural modulus [MPa] | 2900 |
| Ultimate tensile strength [MPa] | 36 |
| Impact strength [J/m] | 330 |

## 5. Prototyping

The 3D concept of the prototype was created using Catia V5 design software and the elements that make up the prototype are highlighted in figure 5.1.

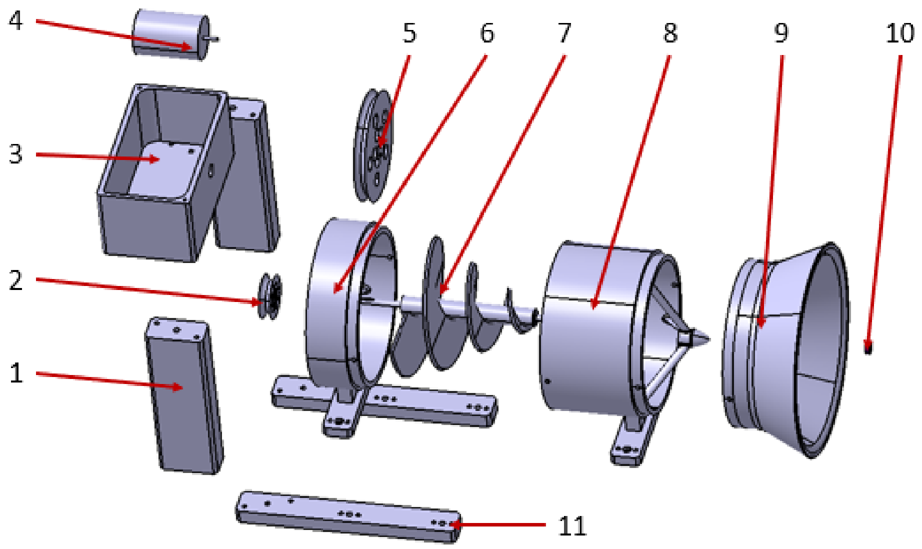


Fig. 5.1. Component elements

The detail of the component parts is as listed:

1 - housing support leg;
2 - small wheel;
3 - dynamic housing;
4 - dynam;
5 - large wheel;
6 - lower casing;
7 - rotor;
8 - upper casing;
9 - funnel housing;
10 - bearing;
11 - support sole.

As previously mentioned, the manufacturing of the components will be done using 3D printing and their assembly will be modular but also with standard connecting elements such as screws, pins and 2 special bearings chosen for use in water.

## 6. Testing

Given the recommendations and the suitable qualities of the chosen material, it was possible to carry out controlled tests on it. By controlled tests we mean testing specimens to different stresses: tensile stress and bending stress. In figure 6.1 shows a picture of the specimen during the bending test on the INSTRON DX equipment.

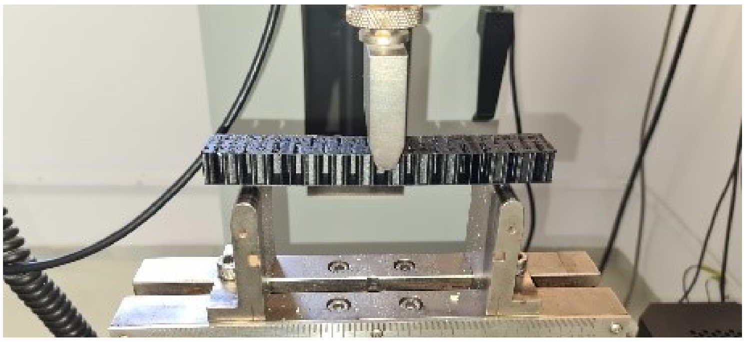

Fig. 6.1. Bending test

Different types of cellular structures were tried for the inner shape of the specimens, for some of them the 3D model was interfered with because it was concluded that their initial design was not adequate, e.g. in the case of bone-type structures, their connecting bridge was the first to fail, requiring thickening.

The first steps in the integration of the sandwich structures investigated in this work were taken and they were introduced in the NACA XXXX series airfoils. The first integrated structures were bone and snowflake structures, which can be found in figure 6.2 and 6.3.

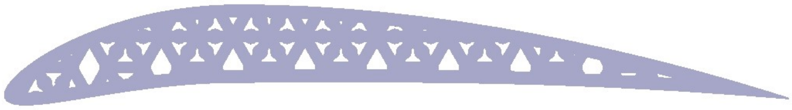

Fig. 6.2. Integration of snowflake cells into the structure

Fig. 6.3. Integration of bone cells into the structure

The airfoils were additively manufactured using MARGKFORCED technology and tested for 3-point bending. These tests are necessary at this early stage of integration in order to bring optimizations to the sandwich structures, resulting in the best mechanical performance relative to the limitations of additive manufacturing technology.

The test results show a bending strength for the snowflake structure of up to 3000 N and for the bone structure 500 N.

## 7. Conclusions

The initial steps were to design and develop a hydroelectric turbine capable of providing the user with a free source of electricity, provided by nature when the user is in remote areas without other public sources.

Of course, this concept was developed following needs, such as:

- the need to communicate with the outside world (charging a mobile phone);
- the need for light (the ability to turn on a light bulb);
- the need for warmth (the ability to heat an element to light a fire).

These are small but necessary needs if the user is isolated, hiking or simply running out of electricity, but is nevertheless near running water.

The development of the turbine's design, material and size also remains an open topic, as research can develop an improved version that can be cheaper, lighter, smaller in size and produce more electricity.

This new concept can be seen as a plus and a great benefit to adventure enthusiasts and to people who cannot afford the benefits of a popular medium that offers an advantage such as electricity.

## 8. Development directions

Biomimetic cells can be used as sandwich structures in the composition of reinforced polymer composite parts such as turbine blades or other components of the structure.

In addition to the high strength offered by these structures, the aim is to reduce the mass of the whole assembly by implementing them in the other components supporting the electrical part and the tubing.

Coating of certain surfaces can be done in such a way that the water flow is smooth and uniform, but at the same time provides additional protection of the material.

At the same time, the aim is to simulate with the help of dedicated test software different types of stresses on the turbine auger in order to develop an ergonomic design that meets the requirements for which it was developed.

After assembling the prototype, it is intended to test it on a water pump where the flow rate is determined in order to calculate all the forces occurring during use, but also in mountainous areas, on a spring where the water flow rate is fluctuating in order to observe its behaviour.

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