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3D printing of hydrodynamic coupling for school education

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3D printing of hydrodynamic coupling for school education

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Abstract. The application of 3D printing technologies in the industry is growing as new possibilities for their application are discovered, which take advantage of their functionalities. Also, today more and more 3D technology is used for educational purposes. Incorporating of 3D printing in the form of production of three dimensional shapes into the teaching process improved the understanding of geometry.
Hydrodynamic couplings works on the hydrodynamic principle, which takes place based of the indirect principle of operation. The pump wheel transfers the introduced mechanical energy into the kinetic energy through the fluid flow. The fluid of higher energy flows centrically from the pump wheel to the turbine wheel, where re-conversion to mechanical energy takes place. In this paper, the description and principles of operation of hydrodynamic couplings are presented, as well as their basic characteristics and advantages. Also, the calculation of one hydrodynamic coupling and its 3D model that would be used in the education system are given.

1. Introduction

3D printing technology in developed countries has already entered the field of education, in primary and secondary school, as well as at the university, and has become a powerful tool for "intelligent manufacturing". The application of 3D printing at universities enables the acquisition of knowledge through the creation of 3D models during the creation of project tasks. Integration of 3D printing skills development into curricula is done through inclusion in existing courses. 3D printing is very important for learning at the university level. The application of 3D printing in education has several goals: training students and teachers about 3D printing, supporting new technologies in teaching, creating models that contribute to better learning, skill development and increased engagement of students and teachers in the subject. At technical faculties, almost all areas of engineering can be understood better through 3D printed models. Also, 3D printers in Universities have greater applicability and possibility for use in engineering and applied science [1]. Students can print models to simplify and understand complex theories and learn about new technology, while teachers can create models to teach subjects that are difficult to explain in 2D. Also, the equipment used for 3D printing within the teaching purposes is relatively cheap [2].

3D printing is the process of making 3D solid objects from a digital file by building up layer by layer of material. This type of manufacturing process has a many of advantages over traditional manufacturing: 3D printed designs do not become more expensive due to complexity, it is very cheap to customize the design, and shapes that are impossible to produce through manufacturing techniques can be printed [3]. Also, 3D printers are more environmentally sustainable than other manufacturing techniques because they use fewer raw materials, create fewer by-products, and represent a less energy-intensive process [4, 5].

The 3D printing process begins with loading the 3D printer with the appropriate material for printing, making sure that the material is selected to meet the needs of the printed object [2, 3].

2. Hydrodynamic coupling

There are two types of hydraulic power transmission, namely hydrostatic (displacement) and hydrodynamic (turbo transmissions). The advantage of hydraulic power transmission compared to others is found in small dimensions and low specific weight in relation to power, as well as in a small moment of inertia of moving parts. For example, a comparison of aircraft hydraulic transmissions with electric transmissions with an analogous purpose shows that the volume of the hydraulic motor and pump is about 12 % of the volume and the weight is 10 to 20% of the weight of the electric motor and generator.

Fluid couplings are designed in two types: constant-fill couplings and variable-speed (fill-controlled) couplings. Constant-fill couplings (figure 1) are mainly used for start-up (to limit torque) and to cushion the torsional vibration of the drive chain when variable-speed couplings are used to control or regulate the speed of the driven machine over a wide range below the drive speed [6].

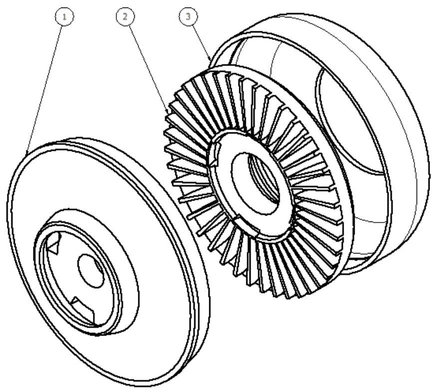

Figure 1. Hydrodynamic coupling assembly elements: 1 – pump wheel, 2 – turbine wheel, 3 – housing.

Hydrodynamic couplings work on the hydrodynamic principle. In drives where there are hydrodynamic couplings, there is no mechanical contact between the driving and driven machines, and the power is transmitted using fluids. Due to the mechanical separation between the driving and the driven machine, the hydrodynamic coupling enables the achievement of two separate acceleration values: a high acceleration value for the driving machine and, at the same time, a low acceleration value for the driven machine. Hydrodynamic couplings are often used to drive large inertial machines in combination with cage motors. They allow the engine to accelerate without load, and consequently, with increased oil filling, enable a soft/slightly quasi-stationary start of the machine [6].

The advantages of application of hydrodynamic couplings are:

- No load on the engine at start,
- Smooth start-up of driven machine,
- Avoid of shocks and overload protection,
- Dampens torsional vibration in the drive chain,
- Protects system components, thereby increasing service life,
- Power transmission is performed without wear; maintenance is easier,
- There is a possibility of load sharing in multi-motor drives [7].

3. Calculation of hydrodynamic coupling

The calculation of the geometric parameters of the working spaces of the hydrodynamic coupling is based on a one-dimensional flow model and the similarity theory. This method implies the averaging of current parameters by flow sections, taking as reference the values of these quantities in the meridian surface.

Its main task is to provide the possibility of designing a hydrodynamic coupling that meets the requirements of the design task, i.e. a coupling with pre-defined working characteristics. The project task defined the initial data used to calculate the geometrical parameters of the working areas of the coupling. These parameters are:

P_e - the power transmitted by the driving machine to the coupling input shaft [kW],
n_e - number of revolutions of the drive shaft [min^{-1}],
η - the desired degree of utility in the nominal mode of operation [/],
ρ - density of the working fluid [kg/m^3],
p - working pressure of the coupling [Pa].

The process of calculation is given in figure 2 and the calculation was done in the MathCAD software.

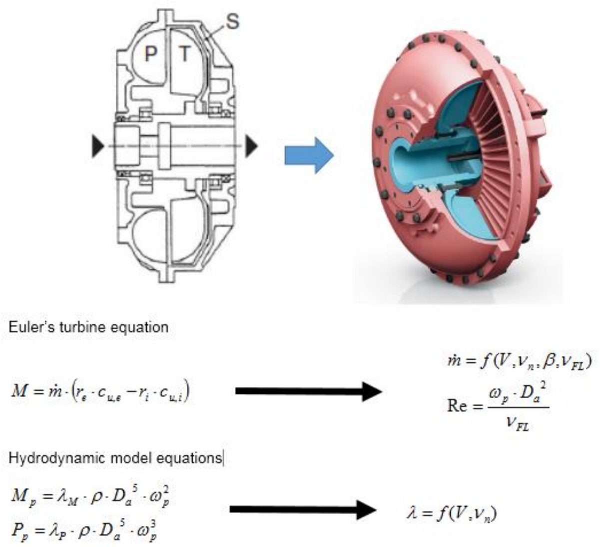

Figure 2. Calculation based on hydrodynamic principles, *adapted from* [8].

The calculation, 3D model and 3D printing were done at the Faculty of Engineering within the course Fluid Power Transmission. Initial and the calculated data are given in table 1. The data was adjusted to create 3D model.

Table 1. Input and calculated data.

Input data	
P_e (kW)	11
n_{emax} (min^{-1})	2770
ρ(kg/m^3)	860
Δt (K)	50
p (Pa)	$3.2 \cdot 10^5$
η (/)	0.97
Calculated data	
D_o (mm)	40
D_a (mm)	200

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Q (m^3/s)	0.023
Y (J/kg)	588.6
z_p (/)	38
z_t (/)	40

After the calculation, the 3D model of the hydrodynamic coupling was created in the Autodesk Inventor software package, and after that, 3D print is accessed (figure 3). 3D printer supports .STL files which are obtained in any 3D modelling program.

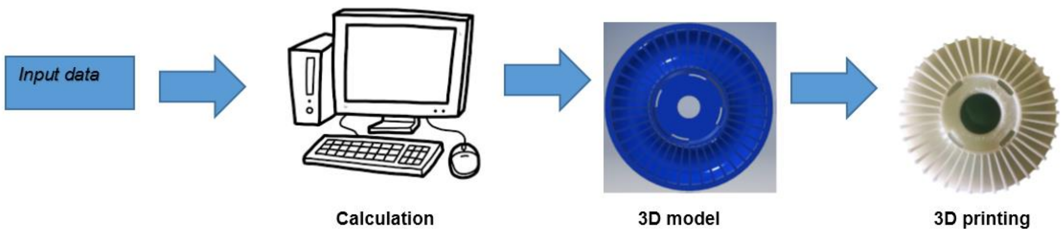
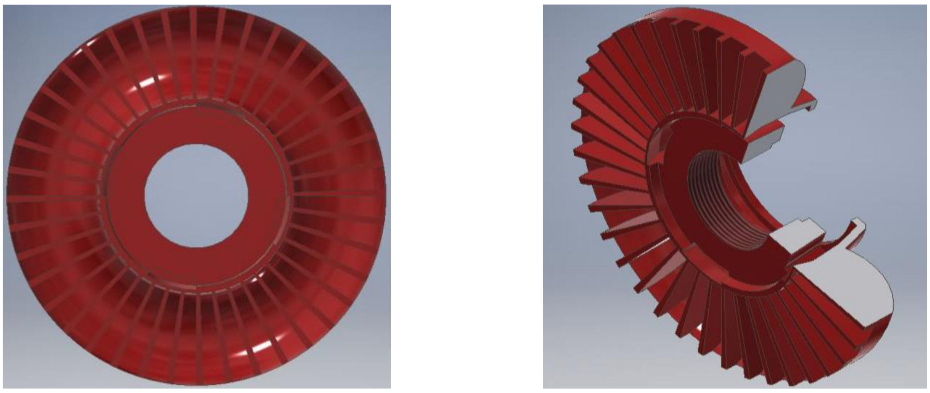
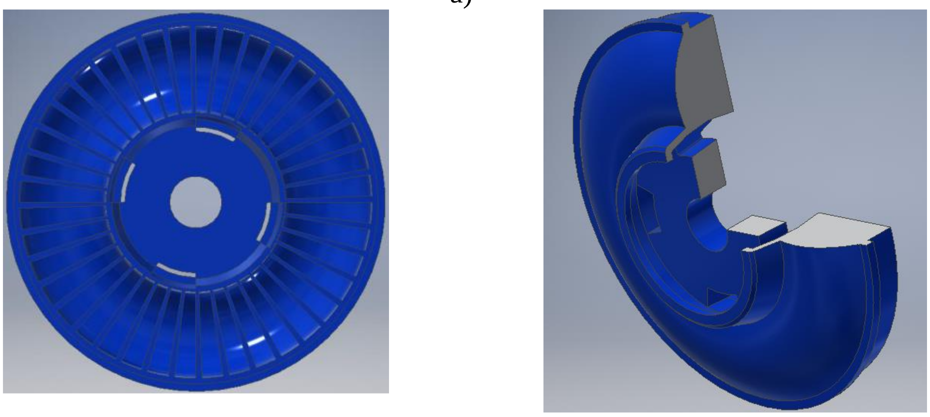


Figure 3. The process of creating a 3D model.

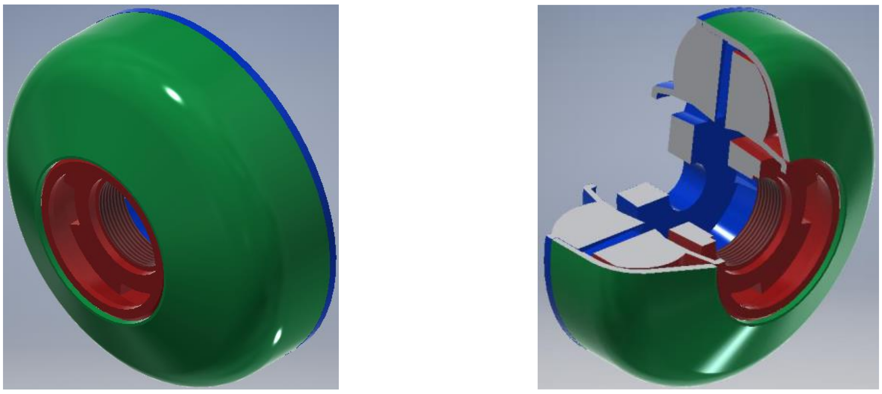
Figure 4 shows 3D model of pump and turbine wheels, housing and also assembly of hydrodynamic couplings, and figure 5 shows 3D printed models of the same elements. Before printing, it is necessary to set a number of parameters such as: plastic melting temperature, substrate temperature, printing speed, speed of movement of the printer head when passing from one place to another, percentage of filling of objects, support material etc.



a)



b)



c)

Figure 4. 3D model of hydrodynamic coupling a) pump wheel, b) turbine wheel and c) assembly.

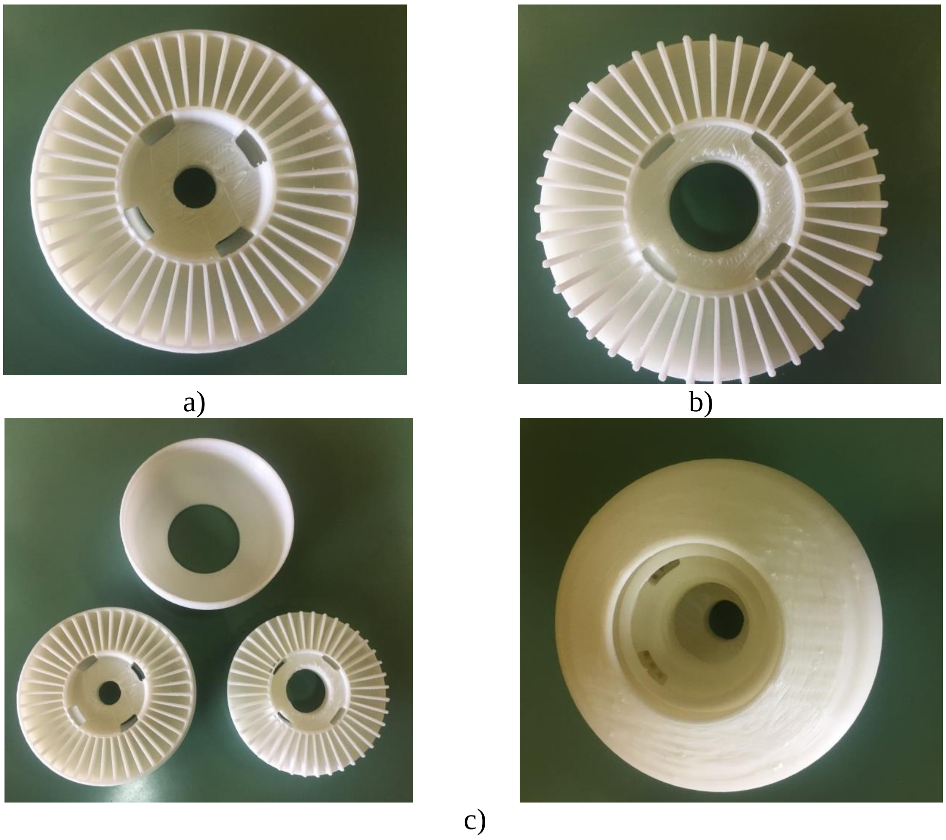


Figure 5. 3D printing of hydrodynamic coupling a) pump wheel, b) turbine wheel and c) assembly.

4. Conclusion
Today, sustainable development is most often associated with raising awareness of the preservation of the environmental and the preservation of natural resources. 3D printing is often considered additive manufacturing (AM). It represents a manufacturing process of object through layer by layer with the selective fusion, sintering or polymerization of materials. The additive manufacturing process begins by taking a 3D computer generated file and slicing it into thin slices (typically ranging from 0.01mm to 0.25mm per slice depending on the technology used).

Today, 3D printers are used for various applications, from the auto industry, the food industry, the construction industry, for educational purposes etc. In education, 3D printing technologies facilitate learning, skills development, and increased engagement of student and teacher in the subject. Furthermore, 3D printing encourages greater creativity and collaboration in solving problems.

Hydrodynamic couplings are often used to drive large inertial machines in combination with cage motors. They allow the engine to accelerate without load, and consequently, with increased oil filling, enable a soft / slightly quasi-stationary start of the machine. As the hydrodynamic coupling enables quick acceleration of the motor and a short duration of high-value starting current, it results in an economical design.

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