Lab Based Project (MIN-300)

Design and Rapid Prototyping of Francis Turbine

Supervisor: Dr. B.K. Gandhi

Students involved:

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3. Hitender Pal Singh - 15119019

CANDIDATE'S DECLARATION

I hereby declare that work carried out on this report entitled, "Design and Rapid Prototyping of Turbine", is presented for the subject MIN-300 Lab based project submitted to the Department of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee (India), is an authentic record of our own work carried out under supervision of Dr. B.K. Gandhi, Professor, MIED, IIT Roorkee.

I have not submitted this record embodied in this project report for the award of any other degree or diploma in any other Institute.

Date: 20th April, 2018

Group : G-07 (Govind, Hardik, Hitender)

CERTIFICATE

This is to certify that above statement made by candidate is correct to the best of my knowledge and belief.

Dr. B.K. Gandhi
Professor, MIED IIT Roorkee

Introduction

Flexible electricity demand and low profit margin have pushed hydro turbines to their extreme operating limits. The turbines are often operated at unfavourable load, which has raised significant concerns for the hydropower industry and has challenged the existing design criteria. In fact, the main requirement for modern turbines is high efficiency over the whole operating range. However, this is difficult to obtain. Francis 99 is one such turbine. Research has been going in our campus under the guidance of Dr. B.K. Gandhi to redesign the blade of Francis 99 turbine in order to obtain a certain velocity profile which mimics the original velocity in Working Turbines at a higher input velocity as well as to analyse the whirling motion of water in draft tube.

Motivation

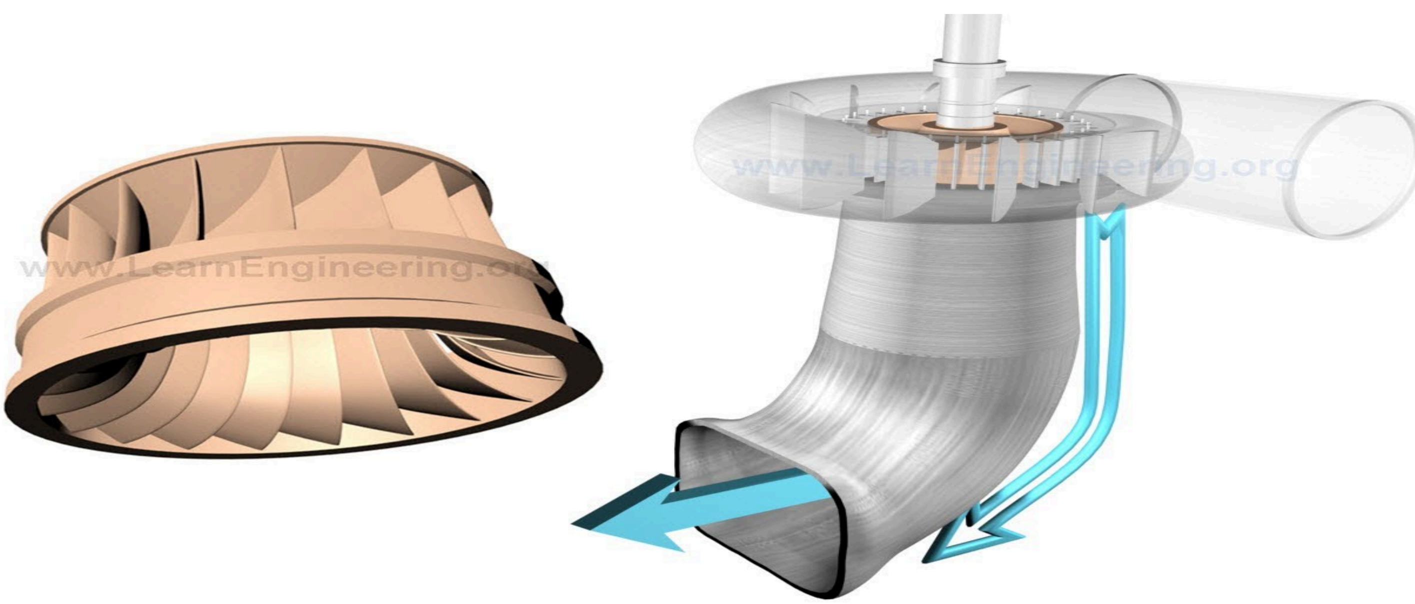
The thought process that we put before picking up the project was that it should have realistic targets that can be achieved in one semester. Also, we were expecting that the work should have both theoretical as well as practical component (some aspect of it should involve either testing/manufacturing a component). Ideally a project like this will improve our basic understanding of the concept, improve the specific knowledge of the topic that we are working on, give us a taste of research, as well as expose us to some practical work which intern would improve our understanding of the equipment, and train us in operating some machine. Apart of this, the group members who had to work together had a common interest and skill in basic Design and Prototyping.

Our Advisor was extremely helpful and supportive. He gave us the project for designing a CAD Model and prototyping it using a 3D Printer (available in Tinkering Lab) for Francis 99 turbine.

Problem Definition:

"**To Model and Fabricate a modified Francis Turbine Model using Additive Manufacturing Technology (Rapid Prototyping) which can be used for small scale testing and validation.** "

Explanation: The Blade of the turbine has been designed by the Research group in order to keep the outflow velocity profile same as that of the original Working Turbines. In order to mimic that on a smaller scale, certain design changes were required. The total number of blades were reduced to 13 and the area between two consecutive increased. Blade angles were adjusted and dynamic and kinematic similarity was established. Based on the coordinates thus generated we were supposed to present a complete CAD Model of the Turbine Blades, Hub and Shroud Assembly. After the completion of the modeling the files were to be put for 3D printing. Parallel to the process we were supposed to completely understand the mechanism of 3D Printing and get a deep insight into how to operate the machines. After the appropriate prototype is made, analysis of whirling motion of water in draft tube (i.e. when water comes out from the runner at high velocity) will be carried out on a small scale model of Francis Turbine in order to validate the results.

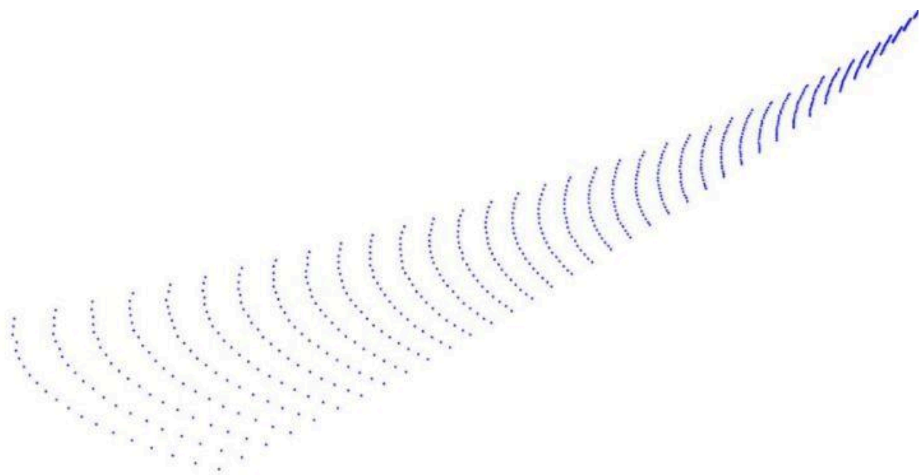


<u>Francis Turbine</u>

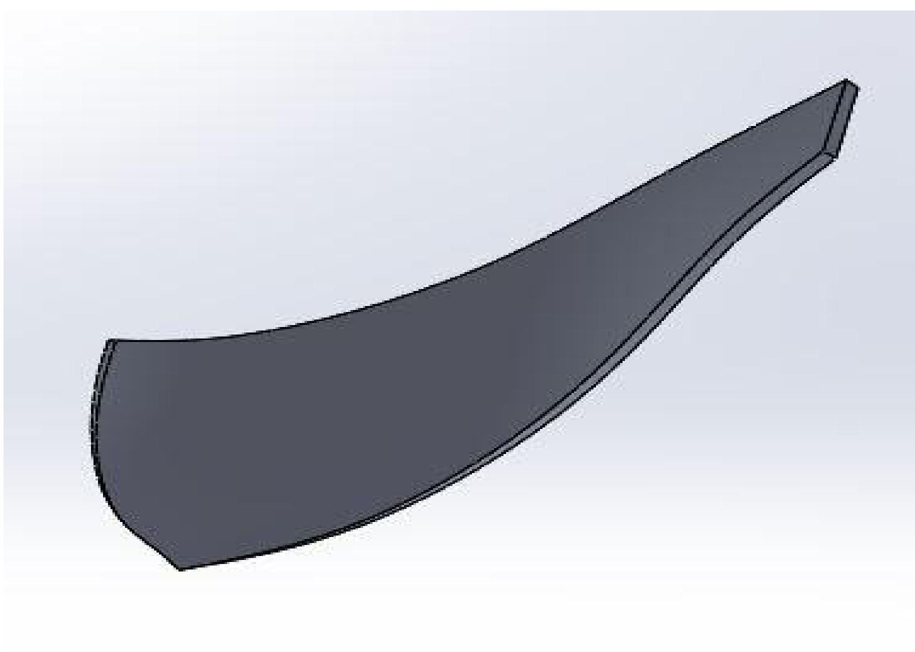
Methodology

A. CAD Modelling :

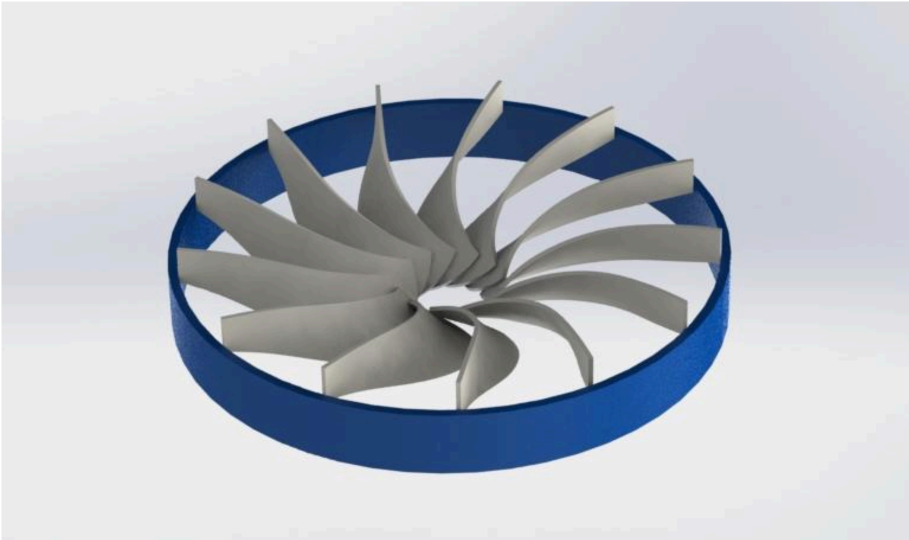
1. The first step was to import the Coordinates of Blade profile generated in MATLAB into SolidWorks.



2. Surfacing of the coordinates was done and thickness was added in order to get the final profile of the Blade.

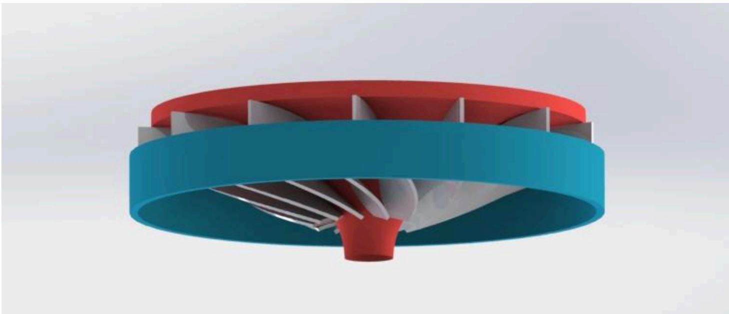


3. Rotation about the central axis was done with specific dimensions in order to get the desired number of Blades(i.e. 13) in a given Diameter.



4. The HUB was made which runs touching the lining of the blades. The profile of Hub is quite complex and is made in such a way to fit to the side profile of the Blade.

5. Shroud is added in the similar way as Hub, and hence the final Assembly of the Francis Turbine is completed.



B. 3D Printing:

1. First step for prototyping was to read and understand the variety of Rapid Prototyping Processes available in the industry.

2. Based on the strength requirement of the Turbine Blade we selected a specific printing technology. (Stereolithography) The parameters that went behind identifying this machine were the material strength and the availability in Institute so that we could materialize the prototype.
   (Initially we finalized Stereolithography but later we had to switch to Fused Deposition Modelling because of unavailability of material in prior one)

3. After the finalization of machine we went on to understand the way it works and how it is operated.

About 3D Printing

This technology has gained significant academic as well as industry interest due to its ability to create complex geometries with customizable material properties. 3D printing or additive manufacturing is a process of making three-dimensional solid objects from a digital file. There are major 7 techniques which come under the umbrella of Additive Manufacturing namely.

- Extrusion (FDM)
- Direct Energy Deposition
- Selective Laser Sintering
- Solidification of powder (binder jetting)
- Photo Polymerization (SLA)
- Polyjet processes
- Sheet Lamination

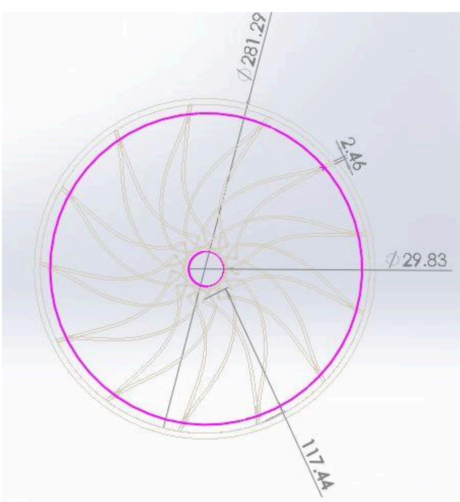
We initially finalised the use of SLA should be done, but due to resource constraints in the lab we switched to the manufacturing using FDM. The machine being used for the same is Ultimaker 2+ . Some of the specifications for the same has been attached henceforth.

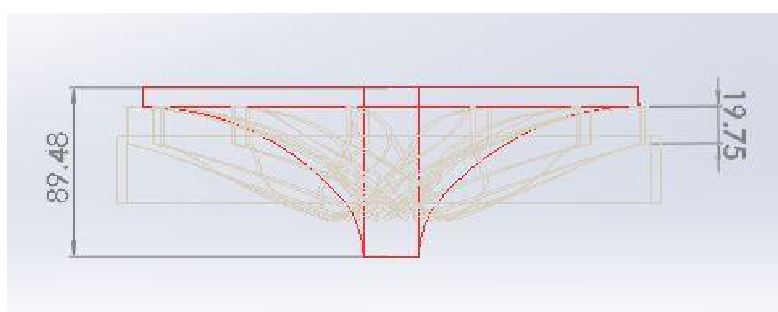
ULTIMAKER 2+

Build volume	Materials	Layer resolution	Speed
Ultimaker 2+ 223 x 223 x 205 mm	Filament system: Open filament system	From: 600 micron	Build speed: Up to 24 mm³/s
Ultimaker 2 Extended+ 223 x 223 x 305 mm	Optimized for: PLA, ABS, CPE, CPE+, PC, Nylon, TPU 95A	Up to: 20 micron	Travel speed: Up to 300 mm/s

After the basic understanding of the machine and its working, we went on to learn the software which is compatible with Ultimaker (CURA). The need for this software is that it is used for the scaling, orienting and slicing purpose of the part that we are planning to print.

Specification of the part to be printed





Material Specifications sheet: Acrylonitrile Butadiene Styrene (ABS)

Sr. No.	**Property**	**Value**
1	Density	1.04g/cc
2	Tensile Strength	42.5-44.8MPa
3	Flexural Yield Strength	60.6-73.1MPa
4	Rockwell Hardness	103-112
5	Elongation at break	23-25%

Validation Calculation:

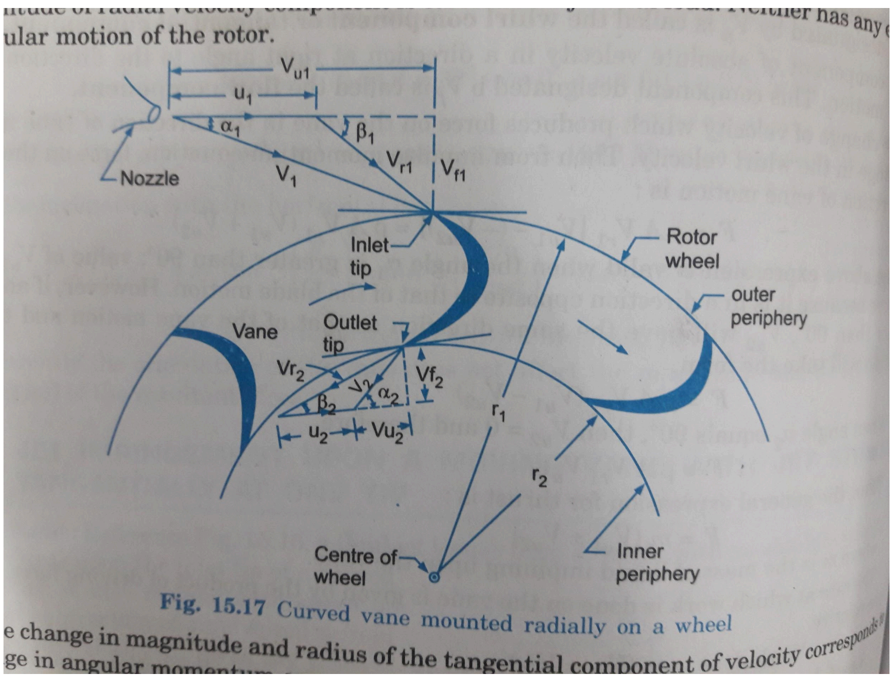


Fig. 15.17 Curved vane mounted radially on a wheel

Formula for Torque = **pQ(V_{u1}r1-V_{u2}r2)** [p= density; Q = Flow Rate; Vu = inflow velocity; r1 = outer radius]

*After the calculations we came to the conclusion that ABS won't be the right material for manufacturing the Turbine and Hub for experimental purpose.

Results:

CAD model of Runner (Blade + Hub + Shroud) has been completed. After analyzing the constraints in the machine available to us, we realized that we won't be able to print the parts upto the exact scale which is required. (The Build surface area of the machine was slightly less than what was required from the parts). For printing the part to the full scale of experiment, we initially thought of cutting the model into 4 parts, alternatively we thinking of making a locking mechanism. But what we realized was that if the parts are not made in a single go then additional turbine balancing needs to be done, which is quite a difficult task for such small weight objects. Then we finally decided to make a small scale prototype (smaller than the experimental dimension) for better visualization of the components.

Shroud + hub+blade failed Assembly HUB Blade on Machine

Dimensions of the Blade: Failed Blade Assembly

Thickness = 2mm ; Length = 15cm