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CFD Analysis of a Nano Output Based Turbine for Holistic Communities

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Abstract:- In this paper CFD analysis of a Pyro hydro turbine is presented. The main objective of this research work is to diagnose the design of existing low head Pyro hydro turbine by theoretical calculations to enhancement the power output from 3W to 20W. In this project an existing 3W prototype Pyro turbine has been install which is widely used in developing countries as well as in remote areas. In this paper, a three dimensional pyro hydro turbine is modelled using CATIA V5 software and then analysis was done through Computational Fluid Dynamics using ANSYS Fluent. With this background, an attempt has been made to modify original blade material (SS340) with Stainless Steel SA516 Grade70, which withstands the turbulence. From this analysis Von-Mises stress and deformation values are obtained and the results are compared for two different materials.

Keywords:- *Pyro hydro turbine, CATIA, CFD, Stainless steel, von-mises stress.*

I. INTRODUCTION

Pyro hydro is a term used to generate electricity from water of under 1 kW. This type of turbines have to be useful in remote communities [1-2] that require only a very low amount of electricity – like to power one or two LED bulbs in homes. A turbine is a mechanical device that converts the hydraulic energy into mechanical energy. The simplest turbines have penstock; a runner assembly in which a shaft is connected with blades are attached. The pressure energy of fluid converted into kinetic energy and this energy acts on the blades, then the runner is rotate the shaft connected to generator and imparts electrical energy. Pyro hydro setups typically are run-of-stream, means a reservoir/dam is not required; only a small narrow river is common [3]. Through Penstock water from canal/river flow through the turbine before being exhausted back to the stream [4]. There are many areas where people having a source of water falling from some head but it is not used to convert electricity. For these rural communities, pyro hydro is the lowest-cost technology for producing electricity. Design analysis of Pyro turbine is done through CFD [5-9] using Ansys Fluent. Pyro hydro turbine is best suited for rural communities where grid is not available.

II. MATERIALS AND METHODS

The type of material used to design a turbine affects its efficiency. Best materials are hard and must be able to resist erosion and corrosion. This ensures that the pyro hydro turbines will work at their best efficiency for the expected life span. SS material is mainly used for turbine blade and mild steel is used for casings. The other materials like Aluminium, Cast Iron and Sheet steel are also used as turbine material. The materials considered in this work are SS 340 and SS SA516 Grade70 (Gr.70 stands for increasing tensile strength and thickness levels of 55, 60, 65 and 70). The mechanical properties are shown in below table.

Property	SS340	SS SA516Gr70
Yield strength of the material	241 MPa	260 MPa
Shear stress at Yield	120.5 MPa	130 MPa
Modulus of elasticity	$193x10^3$ MPa	$210x10^3$ MPa
Density	8.03 g/cm^3	8.03 g/cm^3
Poisson's ratio	0.3	0.3

Table 1. Mechanical properties of materials

III. THEORETICAL CALCULATIONS

A. Input Parameters

Discharge, $Q = 3 \times 10^7 \ \frac{mm^3}{sec}$

$Q = 0.03 \frac{m^3}{sec}$

$H = 4.86 \times 1.68$

$= 7.864m$

$\approx 8m.$

Side clearance angle , $\varphi = 15°$

Case-1:

Speed $N = 650rpm.$

Tangential velocity ,

$\mu = \frac{\pi \times D \times N}{60}$

$= \frac{\pi \times 0.05 \times 650}{60}.$

$= 1.701\, m/se\, c$

Fluid velocity,

$V_1 = C_v \sqrt{2gH}$

$= 0.975\sqrt{2 \times 9.81 \times 8}$

$= 12.215\, m/sec$

$V_{\,1} = V_{w_1}$

$V_{r_1} = V_{w_1} - \mu_1$

Where,

$\mu = \mu_1 = \mu_2\ m/sec$

V_{w_1} = Velocity of whirl at inlet.

V_{w_2} = Velocity of whirl at outlet.

$V_{r_1} = V_{w_1} - \mu_1$

$= 12.215 - 1.701$

$= 10.514 m/sec$

$V_{r_1} = V_{r_2}$

$V_{w_2} = V_{r_2} cos\varphi - \mu_2$

$= 10.514 cos15° - 1.701$

$= 8.454\, m/sec$

Work done,

$W\ = \rho\ Q\ (V_{w_1} - V_{w_2})\mu$

$= 1000 \times 0.03(12.215 - 8.454)1.70$

$= 191.923\ Nm/sec$

Power

$P\ = Work\ Done/60$

$P\ = \frac{191.923}{60}$

$P\ = 3.198W$

Case-2:

Speed, N=1200 rpm

P=20W

IV. DESIGN AND ANALYSIS

The pyro hydro turbine is modelled in CATIA V5 software is shown in below figure. Computer-aided three-dimensional interactive application (CATIA) software is easy way to draw the complex parts and converts into 3D solid parts. The below figure represents the existing model of Pyro hydro turbine.

Fig 1:- Constructional View of Pyro Hydro Turbine Station

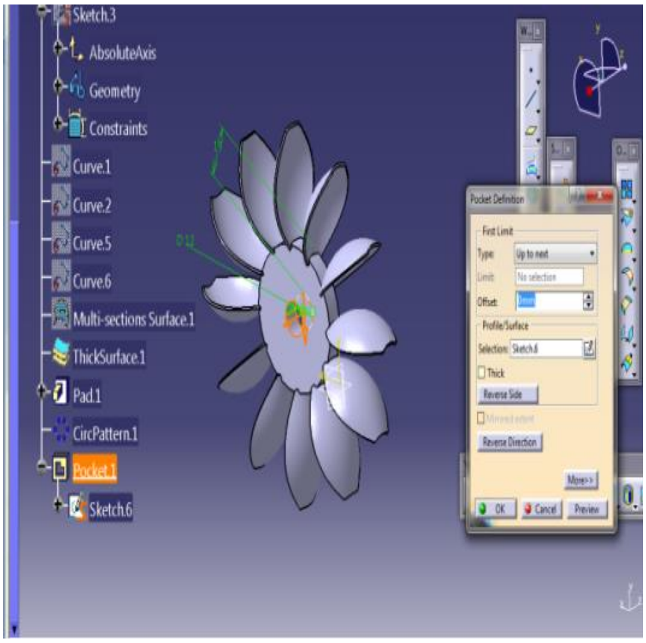


Fig 2:- Part of Pelton wheel

A. Static analysis

- Inlet Boundary conditions:
  Inlet velocity is taken as inlet boundary condition for the pyro hydro turbine.
- Outlet Boundary Condition:

Mass flow rate is taken as Outlet boundary condition

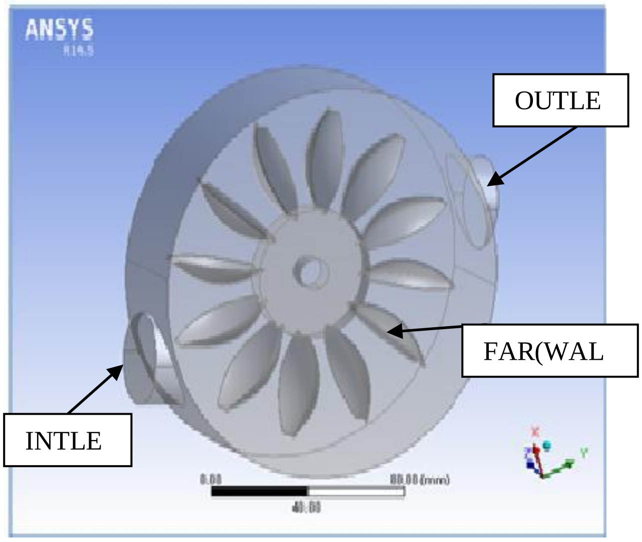


Fig 3. Boundary Conditions

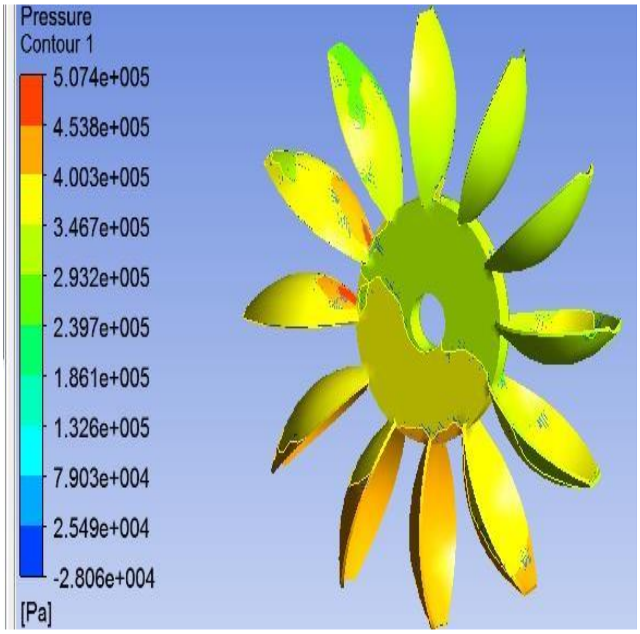


Fig 4:- Dynamic Pressure

From the above figure 4, it was observed that the dynamic pressure is distributed mainly all around the whole periphery of the turbine runner - blade contour and is maximum at the walls and increases rapidly

B. SS340:

Material	= Stainless Steel 340
Speed of turbine	= 1200rpm
Inlet flow velocity	= 15m/sec
Total pressure	= 1.28Mpa
Each blade	= 1.28/12
	= 0.1066Mpa

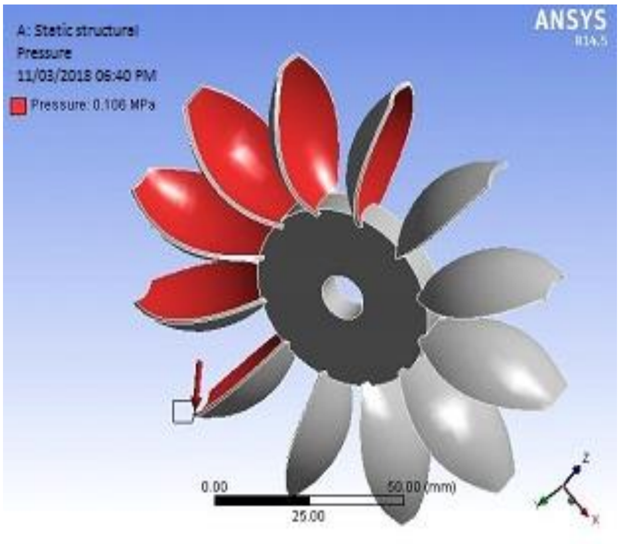


Fig 5:- Static pressure applied to original material

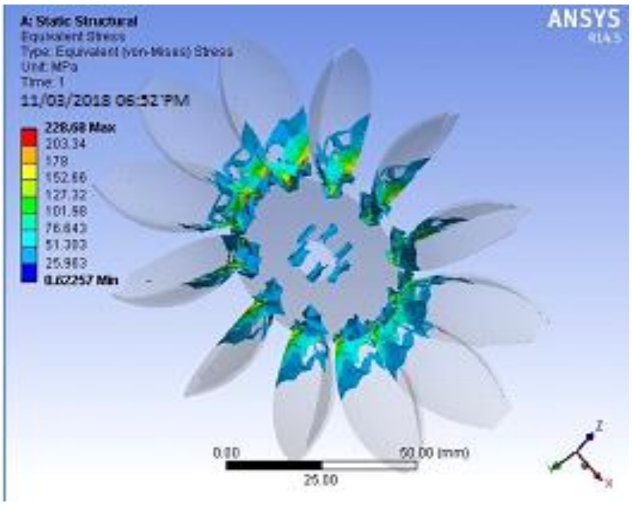


Fig 6:- Equivalent Von-Mises stress

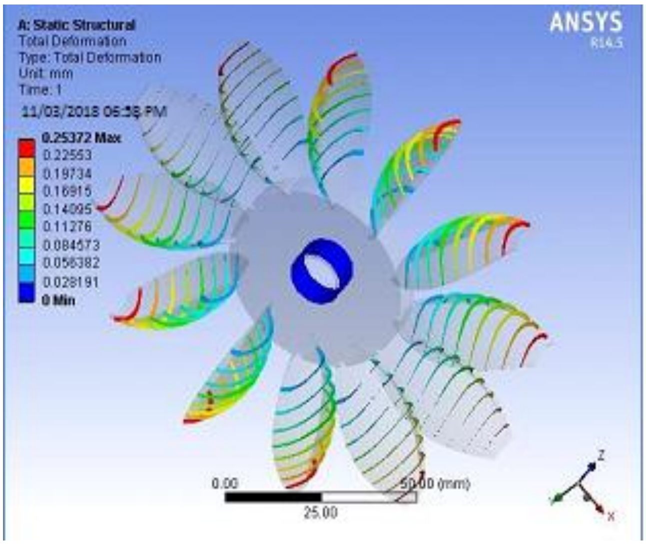


Fig 7:- Total deformation

C. SS SA516 Gr.70

Material	= Stainless Steel 340
Speed of turbine	= 1200rpm
Inlet flow velocity	= 15m/sec
Total pressure	= 1.28Mpa

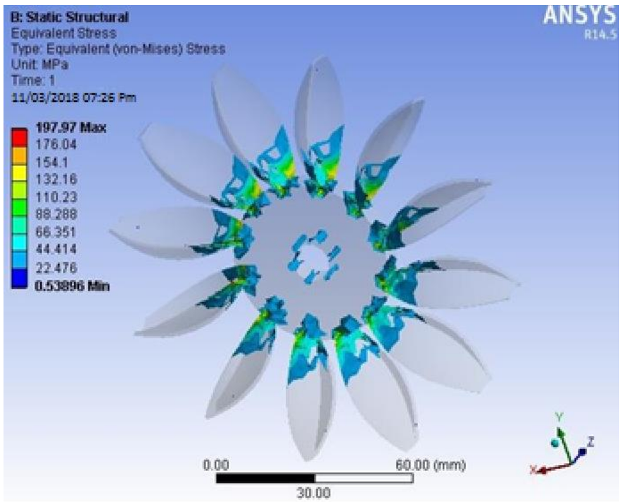


Fig 8:- Equivalent Von-Mises stress

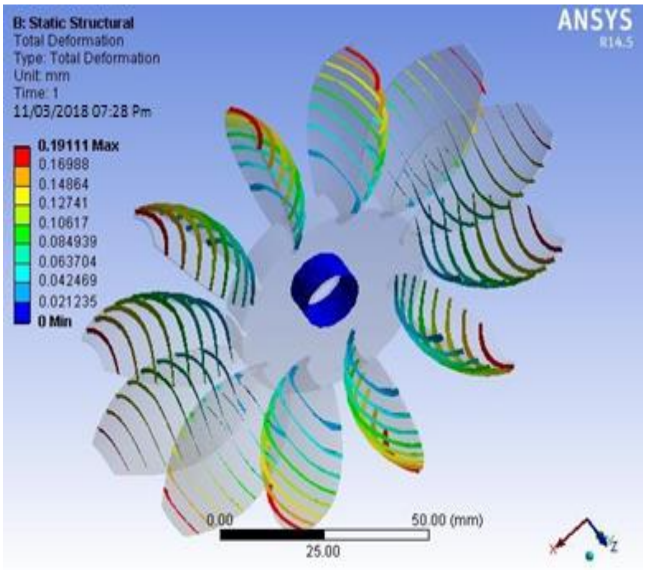
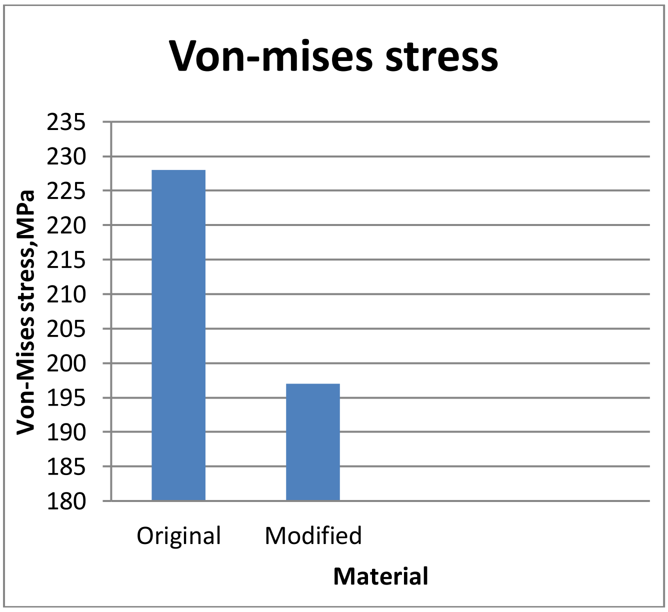


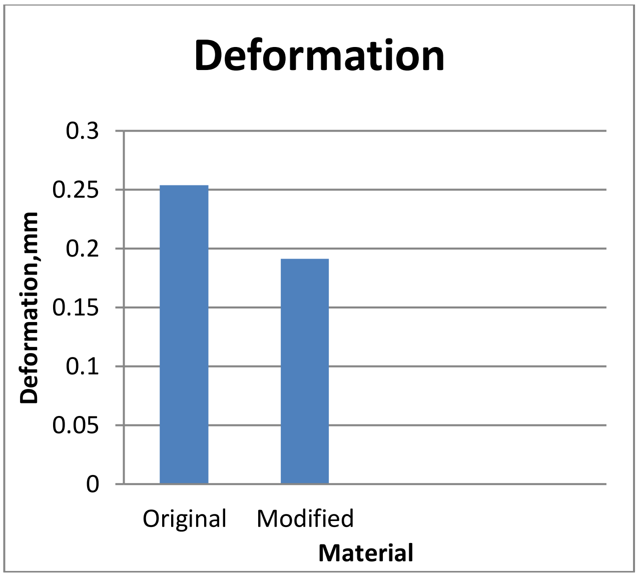
Fig 9:- Total deformation

V. RESULTS AND DISCUSSION

The following graph represents the comparison of deformation and Von-Mises stress for two different materials. From these results SS SA516 Grade70 material is best suited for our case i.e.0.1911mm deformation and 197.7Mpa stresses are developed and it is graphically represented in following graphs.



Graph 1. Material Vs Von-Mises stress



Graph 2. Material Vs Deformation

The following are the Static analysis results obtained from the Ansys software. Von-Mises stress and deformation values for different materials are represented in following table 2.

Material	Pressure, MPa	Equivalent stress, MPa	Deformation mm
SS 340	0.1066	228.68	0.25372
SA516 Grade70	0.1066	197.7	0.1911

Table 2. Static Analysis Results

VI. CONCLUSION

Pyro hydro turbine with 12 blades is designed in CATIA and static analysis is carried out by varying the load acting on the blades considering the factor of safety 2.0843 in ANSYS Fluent. Von-Mises Stress and deformation values for two different materials namely SS340 and SA516 Grade70 are obtained. By the number of iterations, comparing with the existing model the blades designed with Stainless Steel SA516 Grade70 material is best suited and the stresses produced are within the working stresses i.e. 0.1911mm deformation and 197.7Mpa stresses are produced. The material Stainless Steel SA516 Grade70 is best suited for pyro hydro turbine used at low head. From the graphs it is observed that, the material withstands huge turbulence and also gives low turbulence dissipation rate.

VII. ACKNOWLEDGMENT

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