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Optimization and Simulation of Hydro-Turbine Nozzle in Based on Ansys Analysis

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Abstract *This paper presents Optimization and Simulation of hydro-turbine nozzle in based on ansys analysis. Based on three-dimensional numerical flow analysis, the flow characteristics through the water turbine with nozzle are predicted. The Pressure and Velocity distribution of hydro-turbine nozzle is different points were calculated and analyzed for a Structural analysis and CFD analysis. The simulation results show that using nozzle can increase the pressure drop across the turbine and extract more power from available water energy. These results provide a fundamental understanding of the composite water turbine, and this design and analysis method is used in the design process.*

Keywords*- Hydro classification, Impulse Turbine, Nozzle, composite material, Computational Fluid Dynamics (CFD), Static Structural analysis***.**

I. INTRODUCTION

Hydro power plant- Hydro power plant is a system of mechanism which will initially store water to generate the potential head, then this potential head is converted to kinetic head (through nozzle), this kinetic head is used to create mechanical power by hydro turbines. Hydro turbine is connected to the generators for conversion of mechanical power to electrical energy.

II. TYPES OF HYDRO TURBINE

2.1 Impulse turbine- Impulse turbines are more widely used for micro-hydro applications as compared to reaction turbines because they have several advantages such as simple design (no pressure seals around the shaft and better access to working parts - easier to fabricate and maintain), greater tolerance towards sand and other particles in the water, and better part-flow efficiencies. The impulse turbines are not suitable for low head sites as they have lower specific speeds and to couple it to a standard alternator, the speed would have to be increased to a great extent. The multi-jet Pelton, cross flow and Turgo turbines are suitable for medium heads.

2.1.1 Pelton wheel turbine- The Pelton wheel is a water impulse turbine. It was invented by Lester Allan Pelton in the 1870s. The Pelton wheel extracts energy from the impulse of moving water, as opposed to its weight like traditional overshot water wheel. Although many variations of impulse turbines existed prior to Pelton's design, they were less efficient than Pelton's design; the water leaving these wheels typically still had high speed, and carried away much of the energy. Pelton's paddle geometry was designed so that when the rim runs at ½ the speed of the water jet, the water leaves the wheel with very little speed, extracting almost all of its energy, and allowing for a very efficient turbine.

2.2 Reaction turbine

2.2.1 Francis turbine- The Francis turbine is a type of water turbine that was developed by James B. Francis in Lowell, Massachusetts. It is an inward-flow reaction turbine that combines radial and axial flow concepts.

Francis turbines are the most common water turbine in use today. They operate in a water head from 10 to 650 meters (33 to 2,133 feet) and are primarily used for electrical power production. The turbine powered generator power output generally ranges from 10 to 750 megawatts, though mini-hydro installations may be lower. Penstock (input pipes) diameters are between 1 and 10 meters (3 and 33 feet). The speed range of the turbine is from 83 to 1000 rpm. Wicket gates around the outside of the turbine's rotating runner adjust the water flow rate through the turbine for different water flow rates and power production rates. Francis turbines are almost always mounted with the shaft vertical to keep water away from the attached generator and to facilitate installation and maintenance access to it and the turbine.

2.2.2 Kaplan turbine-The Kaplan turbine is a propeller-type water turbine which has adjustable blades. It was developed in 1913 by the Austrian professor Viktor Kaplan, who combined automatically adjusted propeller blades with automatically adjusted wicket gates to achieve efficiency over a wide range of flow and water level.

III. COMPONENTS

3.1 Penstock- Penstocks for hydroelectric installations are normally equipped with a gate system and a surge tank. Flow is regulated by turbine operation and is nil when turbines are not in service. They need to be maintained by hot water wash, manual cleaning, antifouling coatings, and desiccation. The term is also used in irrigation dams to refer to the channels leading to and from high-pressure sluice gates. Penstocks are also used in mine tailings dam construction. The penstock is usually situated fairly close to the center of the tailings dam and built up using penstock rings. These control the water level, letting the slimes settle out of the water. This water is then piped under the tailings dam back to the plant via a penstock pipeline.

3.2 Nozzle- A nozzle is a device designed to control the direction or characteristics of a fluid flow (especially to increase velocity) as it exits (or enters) an enclosed chamber or pipe. A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them. Nozzle with flow regulating device.

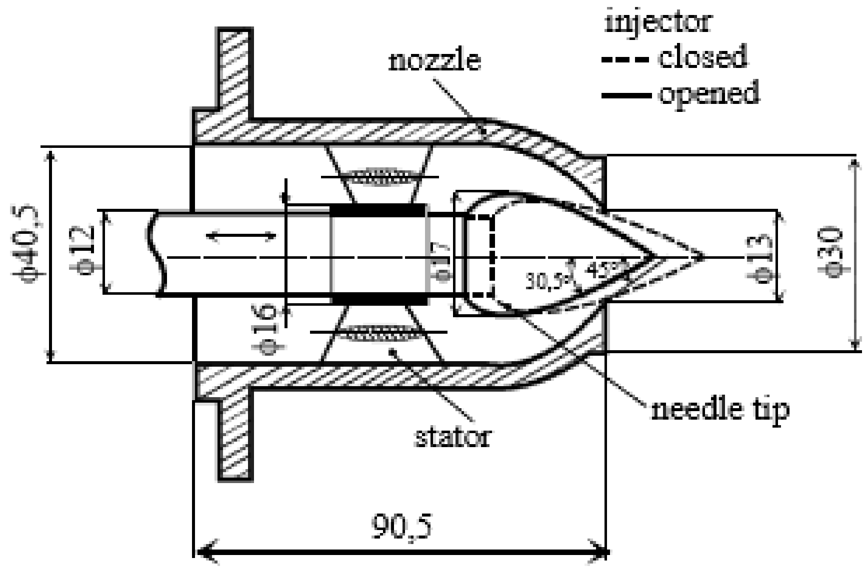

Figure 3.1 Nozzle and spear

In the nozzle passage, represented in axial section in fig. by the outline of a nozzle and a spear head, the surface are shaped so as to reduce the annular area steadily toward the exit, where they are usually conical. The cone of the spear tip is drawn straight to a point at the apex, or it may be extended to a point farther out by a curved profile. In some designs there is a marked difference between the angles of the nozzle and spear cones and in other little or none. Short “onion-shaped” spears are to be found, where the half-angle α of the nozzle may be as large as 60^0 and β of the spear 45^0 , but usually the spear is elongated, with α from 30^0 to 45^0 and β from 20^0 to 30^0

3.4 Water turbine- A water turbine is a rotary engine that takes energy from moving water. Water turbines were developed in the 19th century and were widely used for industrial power prior to electrical grids. Now they are mostly used for electric power generation.

3.5 MIV (main inlet valve)- Main inlet valve or shortly we say miv is the spherical valve which installed before water enter into spiral of the hydro turbine. Water from the dam go to the penstock and before water enter the turbine, MIV is a component in between stop the water for small maintenance purpose in the turbine hall.

3.6 Runner- Rotor having a series of vanes mounted on it is known as runner.

3.7 Deflector- The purpose a deflector is to change or (defect) the direction of the stream flow either to narrow or deepen the base flow channel or to create sinuosity in the channel.

IV. LITERATURE REVIEW

Kai Shimokawa et al [1] The Darrieus-type hydro-turbine utilized of extra-low head hydro-power. In this type of hydro turbine cross flow and it is high torque and efficiency. When a narrow intake at the upstream of the runner, called as “inlet nozzle”. More simplified runner casing, composed of only the inlet nozzle and the small upper-casing. **John S. ANAGNOSTOPOULOS et al [2]** The Laboratory pelton impulse turbine is applied to study the jet runner interaction in various operation condition and then to perform numerical design optimization of bucket shape. The algorithm is based on the Lagrangian approach and the unsteady free surface flow. A new small Pelton turbine (150 kW) is designed, manufactured and tested in the Laboratory, and its performance and efficiency verify the model predictions. **Ji-feng WANG, et al [3]** A design of composite water turbine using Computational Fluid Dynamics (CFD). Based on three-Dimensional analysis and the simulation results show that using nozzle and diffuser can increase the pressure drop across the turbine and extract more power from available water energy. Its performance and efficiency verify the model predictions. **Abid A. Khan et al [4]** Small-scale hydro power systems utilize kinetic energy of the flow. Flow can be accelerated through convergent nozzles for run-of-river turbines in open flow channels. The analytical and computational work presented here converts kinetic energy of water flow to electric power. **F. Montomoli et al [5]** Thermal gradients are reduced by using high conductivity materials and, as a consequence, the nozzles life is appreciably increased. Numerically it is shown that using inserts of nickel-aluminide alloys in nozzles may reduce the thermal gradients from 3 to 4 times if compared to nowadays design. **B. Yu et al [6]** Experimental studies were carried out on water spraying nozzles taper inlet and different ratio of length/diameter at different injection pressures and back pressures. The relationship between the discharge coefficient and the Reynolds number (Re) can describe as Cd = Re/(1465.8 l/d + 1.008 Re). The critical cavitations number increases as the back pressure increases, and the formula for calculating the critical cavitations number. **ZhikeLan et al[7]** An experimental study on the spray characteristics, including mass flow rate, spray flux distribution, spray cone angle and drop size spectrum, was conducted. A testing loop with nine swirling nozzles was established for the study. The work is expected to be helpful for the optimization design of spraying systems. **J.L.Xie et al [8]** The spray characteristics and heat transfer performance of pressure swirl nozzles were experimentally investigated in an open loop system. The spray cone produced by the pressure swirl nozzles changes from hollow cone to full cone as the axial distance increases. Nozzle-to-surface distance was developed to fit the present experimental data with an average error of 14%. **T.R. Bajracharya et al [9]** Erosion was also observed in nozzle of the Pelton turbines due to sand particles and such problem was observed in 22 MW Chilime Hydropower Plant in Nepal. A wear rate of 3.4 mm/year was estimated for the needle and the bucket after a systematic analysis. **Bryan R. Cobb et al [10]** The Turgo turbine is similar to the Pelton wheel, often used in pico-hydro systems. The Turgo can handle significantly higher water flow rates. Turgo operating performances are limited; despite the differences, discussion thereof in design manuals is generally lumped in with the discussion of Pelton wheels. The results stress the importance of proper system design and installation, and increase the knowledge base regarding Turgo turbine performance that can lead to better practical implementation in pico-hydro systems. **Ahmed M.A. Haidar et al Deepak Divashkar Prasad et al [11]** A cross-flow turbine as Direct Drive Turbine (DDT) for wave power generation. The highest turbine output power of 14 W was recorded at a turbine speed of 30 rpm at the wave period of 3 s, giving a turbine efficiency of 55%. **Konstantin Pougatch, et al [12]** The inlet gas-liquid mixture non-uniform on the performance of the TEB-type effervescent nozzle. The comprehensive mathematical model includes the liquid continuous flow through the variable cross-section nozzle, atomization, and spray dispersion. It is not enough for the flow with moderate to strong degree of vertical non-uniformity. **Abhijit Date et al [13]** The split reaction water turbine is defined and an equation for the optimum diameter is derived. Design and building procedures for a split reaction turbine are described. The relationship between k-factor and relative velocity for a split reaction turbine model is discussed with reference to experimental data. **SirichaiDangeam[14]** The design of the single phase induction generator for hydro turbine that driven by waterfall power. and the water flow is nozzle. The buckets drive the rotor shaft of the single phase induction generator and generated 220 V a.c. voltage for distributing electric load. **Abhijit Date et al [15]** Theoretical analysis of a simple reaction turbine is presented including consideration of the fluid frictional losses for a practical situation and that can operate under very low hydro-static head with high energy conversion efficiency. This type of turbine exhibits prominent self-pumping ability at high rotational speeds. The split pipe design of the reaction turbine tested is easy to manufacture and it has been shown to have overall energy conversion efficiency of approximately 50% even under low heads. **R.K.Saket [16]** the design aspects and probabilistic approach for the generation reliability evaluation of an alternative resource: municipal waste water (MWW) based micro-hydro power plant (MHPP). Generation reliability evaluation of the developed MHPP using the Gaussian distribution approach, safety factor concept, peak load consideration and Simpson 1/3rd rule has been presented in this paper. **G.A. Aggidis [17]** Empirical formulae to estimate the cost of electro-mechanical equipment and the costs of different types of turbines. The derived results were compared to the results obtained from using other methodologies and were found to provide more realistic cost estimates. **S. Gowing [18]** the mixture passes through the pressure gradient of the convergent nozzle, and energy is imparted to the water from the air in a complex fashion. The measured efficiencies are lower than or comparable to predicted values.

V. SIMULATION OF HYDRO-TURBINE NOZZLE IN BASED ON ANSYS ANALYSIS

5.1 3D MODELIND OF NOZZLE

To identify the optimal design with confidence Preparation of nozzle in to base point is the modeling. Modeling is doing in solid work as per standard of dimension of nozzle. Modeling of nozzle is generated in solid work and that is exported in ansys workbench in geometry section show in figure 5.1.

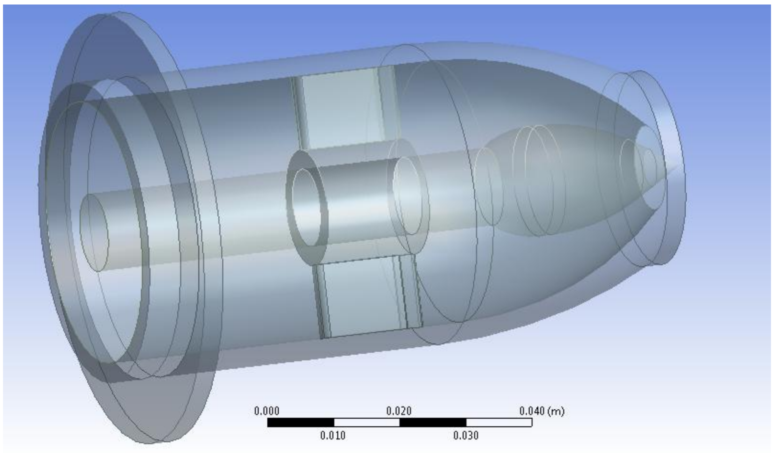

Figure 5.1 Hydro-turbine Nozzle

5.2 MATERIAL SELECTION

Selection of material of nozzle is also the main property function in the efficiency of the nozzle design. There are many material available in market which can be use to select the material, but in the observation of deferent material we select the gray cast iron as a nozzle material. Gray cast iron has some benefits which cause we selected.

- Low material density
- Excellent Stiffness
- Higher graphitization level
- Elevated temperature performance
- Good translation of fiber property
- Control matrix flow in process
- Electro-chemical oxidation effect

Material property given below:

Gray Cast Iron

Density	7200 kg m^-3
Coefficient of Thermal Expansion	1.1e-005 C^-1
Specific Heat	447 J kg^-1 C^-1
Thermal Conductivity	52 W m^-1 C^-1
Resistivity	9.6e-008 ohm m
Compressive Ultimate Strength Pa	8.2e+008
Compressive Yield Strength Pa	0
Tensile Yield Strength Pa	0
Tensile Ultimate Strength Pa	2.4e+008
Reference Temperature C	22

Table 5.2 Gray Cast Iron constants

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.1e+011	0.28	8.3333e+010	4.2969e+010

Table 5.3 Isotropic Elasticity

5.3 MESH AND GEOMETRY REPORT OF STANDARD NOZZLE

Model is preparing in catia after that this model import in geometry model in ansys work bench after that model transmitted into the mesh model. In mesh model, transition of mesh using the finite element modeling process and meshing detail given below of meshing geometry and property in table 5.5 and 5.6. The meshing of model is shown in figure 5.2.

Geometry report of Standard nozzle

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	D:\deepak\new_files\dp0\Geom\DM\Geom.agdb
Type	Design Modeler
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	6.65e-002 m
Length Y	9.5e-002 m
Length Z	6.65e-002 m
Properties	
Volume	5.6738e-005 m^3
Mass	0.41604 kg
Scale Factor Value	1.
Statistics	
Bodies	3
Active Bodies	2
Nodes	69084
Elements	39076
Mesh Metric	None

Table 5.4 Geometry Report

Mesh report of standard nozzle
Model (D3) > Mesh

Object Name	*Mesh*
State	Solved
Defaults	

Physics Preference	Mechanical
Relevance	0
Sizing	
Minimum Edge Length	1.6089e-004 m
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Statistics	
Nodes	69084
Elements	39076
Mesh Metric	None

Table 5.5 Mesh Information

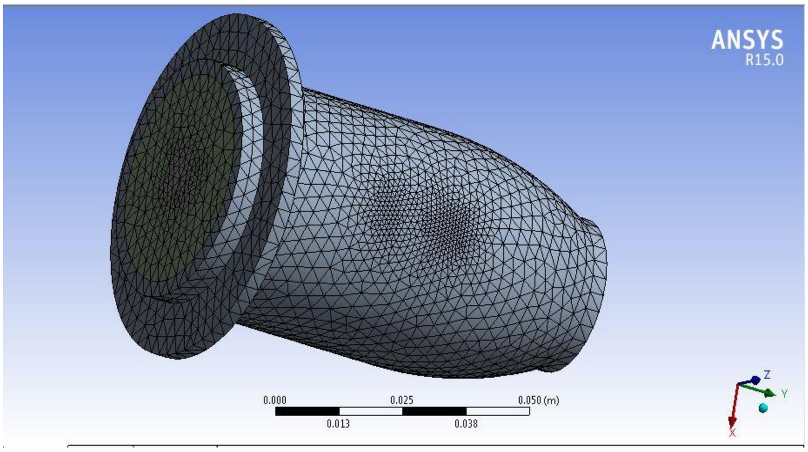

Figure 5.2 Meshing of Nozzle Model

5.4 DESIGNING AND ANALYSIS OF STANDARD NOZZLE

Modeling meshing and boundary condition describe in ansys. After that the reference value computed from inlet and air is reference zone for solution setup of program. All solution in the study was computed using the Reynolds Averaged Navier-Strokes solution scheme. Numerical analysis was done using the pressure-based solver by applying the transport equation at the node of the grid elements. The Langtry-Menter four-equation SST Transition model was used for all computations. Solution method is compiling in pressure-velocity coupling and solution initialized computed on blade surface, running calculation give Result show below.

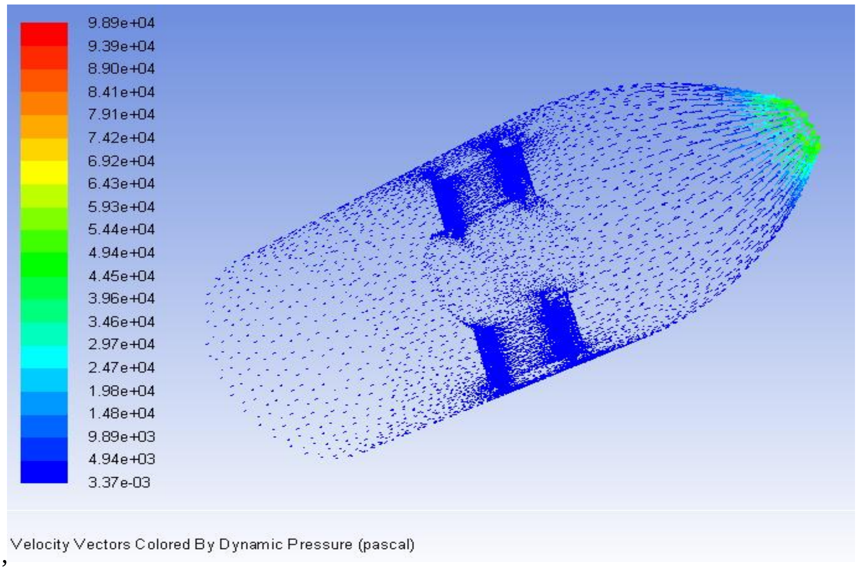

Figure 5.3 Dynamic Pressure of water flow through nozzle

The dynamic Pressure also show reverse force that is nozzle internal stress acting out side. This dynamic Pressure imported to the static structure workbench for mechanical analysis of nozzle. The Pressure importing reflected from the nozzle which is generated by the water flow in nozzle that is show in figure 5.3.

CFD Load Transfer Summary for Static Structural Analysis

All values correspond to the CFD results before the application of any Scale or Offset operations set in Mechanical.

CFD Computed Forces from CFD Results File
X-component = 8.1057e-003 N
Y-component = 95.579 N
Z-component = 3.746e-003 N

Mechanical Mapped Forces for Mechanical Surface File
X-component = 0.37358 N
Y-component = 108.69 N
Z-component = -0.26083 N
100% of Mechanical nodes were mapped to the CFD surface.

Stress, Strain and Total Deformation of hydro-turbine nozzle as shown in figure below:

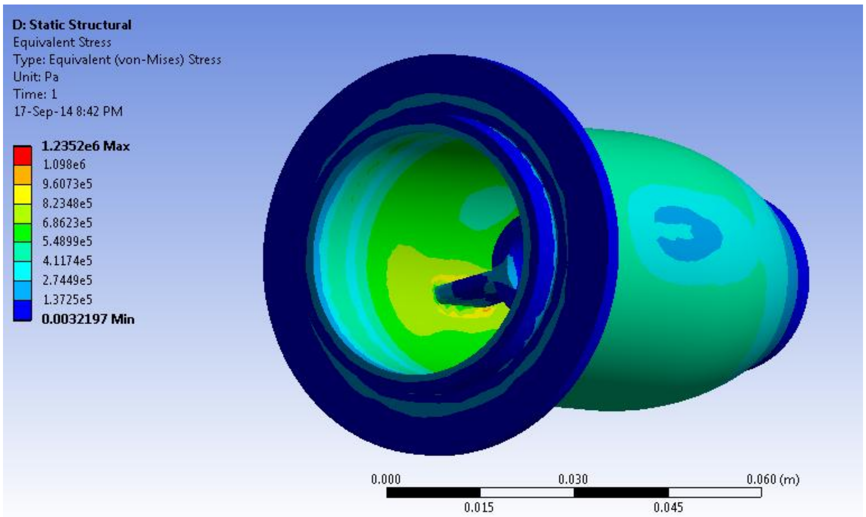

Figure 5.4 Stress Distribution Analysis

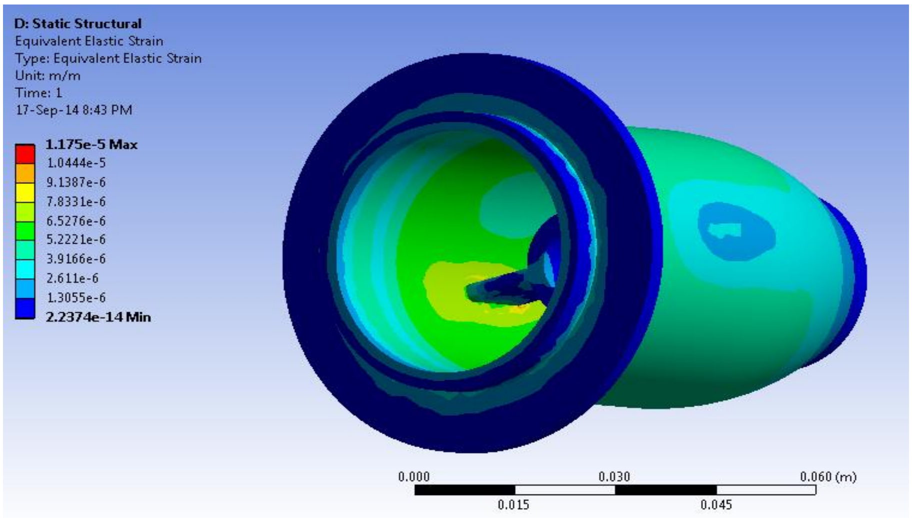

Figure 5.5 Strain Distribution Analysis

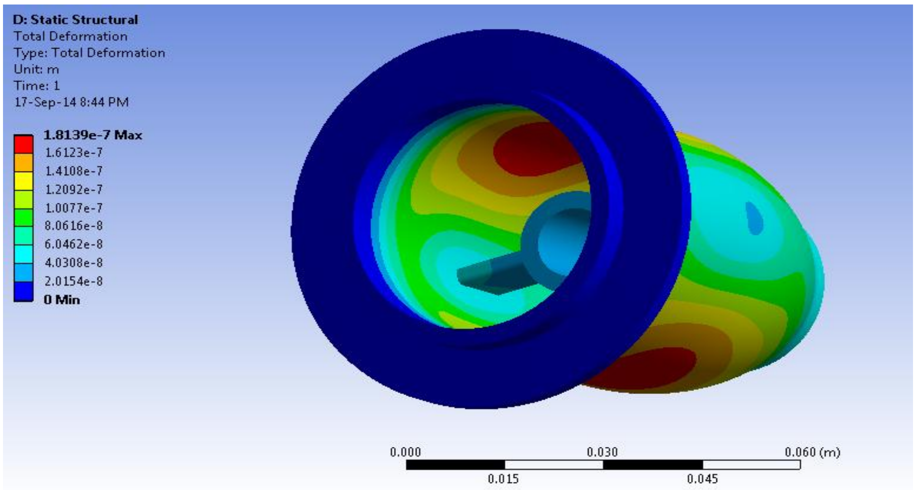

Figure 5.6 Total deformation Analysis

The stress, strain and total deformation are concentrate values of nozzle shown in table 5.6.

Results			
Type	Total Deformation	Equivalent (Von-Mises) Stress	Equivalent Elastic Strain
Maximum	1.8139e-007 m	1.2352e+006 Pa	1.175e-005 m/m

Table 5.6 Result of Nozzle

VI. CONCLUSION

Introduction of hydro-power and study of pelton turbine and nozzle. Hydro-turbine nozzle material is used in gray cast iron. The Structural analysis and CFD analysis of Hydro-turbine nozzle is used ansys software. Simulation for Hydro-turbines nozzle in based on ansys analysis is more accurate results.

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