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Static Structural Analysis of Spherical – S Turbine by using ANSYS Workbench

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ABSTRACT

The main objective of this work is to investigate and analyse the stress distribution of Spherical – S turbine. In this paper static analysis is done by using to different materials (Structural Steel, Stainless Steel and Aluminium Alloy). The parameter used for the analysis is forces acting on turbine blades and material properties of Spherical – S turbine. A general Spherical-S turbine configured to rotate transversely with in a cylindrical pipe under the power of fluid flowing either direction there through is operatively coupled with rotating machine or generator to produce electricity. Two vanes are placed to the shaft in the centre of spherical blades to control the flow. The blades of the spherical turbine are aerofoil in cross-section to optimise hydrodynamic flow to minimise cavitation and to maximise conversion from axial to rotating energy. Turbine fail mainly due to mechanical stresses and thermal stresses. The analysis predicts that due to forces whether the blades of the Spherical – S turbine may be damaged or broken during the operating conditions. The model of Spherical – S turbine is created using CREO2.0 software. CAD model is then imported into ANSYS software for geometry and meshing purpose. The FEA performed by using ANSYS 14.5(ANSYS WORK BENCH).

KEYWORDS: : *Spherical-S turbine, Static,Aluminium, Cavitation, Aerofoil, CATIA V5, ANSYS14.5.*

I. INTRODUCTION

TURBINE:

A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbo machine with at least one moving part called a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades so that they move and impart rotational energy to the rotor.

There are two main types of hydro turbines: impulse and reaction. The type of hydropower turbine selected for a project is based on the height of standing water referred to as "head" and the flow, or volume of water, at the site. Other deciding factors include how deep the turbine must be set, efficiency, and cost.

Impulse turbine:

The impulse turbine generally uses the velocity of the water to move the runner and discharges to atmospheric pressure. The water stream hits each bucket on the runner. There is no suction on the down side of the turbine, and the water flows out the bottom of the turbine housing after hitting the runner. An impulse turbine is generally suitable for high head, low flow applications. Impulse turbines change the direction of flow of a high velocity fluid or gas jet. The resulting impulse spins the turbine and leaves the fluid flow with diminished kinetic energy. There is no pressure change of the fluid or gas in the turbine blades (the moving blades), as in the case of a steam or gas turbine, all the pressure drop takes place in the stationary blades (the nozzles). Before reaching the turbine, the fluid's pressure head is changed to velocity head by accelerating the fluid with a nozzle. Pelton wheels and de Laval turbines use this process exclusively. Impulse turbines do not require a pressure casement around the rotor since the fluid jet is created by the nozzle prior to reaching the blades on the rotor. Newton's second law describes the transfer of energy for impulse turbines.

Reaction turbines

Reaction turbines develop torque by reacting to the gas or fluid's pressure or mass. The pressure of the gas or fluid changes as it passes through the turbine rotor blades. A pressure casement is needed to contain the working fluid as it acts on the turbine stage(s) or the turbine must be fully immersed in the fluid flow (such as with wind turbines). The casing contains and directs the working fluid and, for water turbines, maintains the suction imparted by the draft tube. Francis turbines and most steam turbines use this concept. For compressible working fluids, multiple turbine stages are usually used to harness the expanding gas efficiently. Newton's third law describes the transfer of energy for reaction turbines.

Pelton:

The Pelton wheel is an impulse type water 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 water's dead weight like the traditional overshot water wheel. Many variations of impulse turbines existed prior to Pelton's design, but they were less efficient than Pelton's design. Water leaving those wheels typically still had high speed, carrying away much of the dynamic energy brought to the wheels. Pelton's paddle geometry was designed so that when the rim ran at half the speed of the water jet, the water left the wheel with very little speed; thus his design extracted almost all of the water's impulse energy which allowed for a very efficient turbine.

Cross flow:

A cross-flow turbine is drum-shaped and uses an elongated, rectangularsection nozzle directed against curved vanes on a cylindrically shaped runner. It resembles a "squirrel cage" blower. The cross-flow turbine allows the water to flow through the blades twice. The first pass is when the water flows from the outside of the blades to the inside; the second pass is from the inside back out. A guide vane at the entrance to the turbine directs the flow to a limited portion of the runner. The cross-flow was developed to accommodate larger water flows and lower heads than the Pelton.

Francis:

The Francis turbine is a type of reaction turbine, a category of turbine in which the working fluid comes to the turbine under immense pressure and the energy is extracted by the turbine blades from the working fluid. A part of the energy is given up by the fluid because of pressure changes occurring in the blades of the turbine, quantified by the expression of Degree of reaction, while the remaining part of the energy is extracted by the volute casing of the turbine. At the exit, water acts on the spinning cup-shaped runner features, leaving at low velocity and low swirl with very little kinetic or potential energy left. The turbine's exit tube is shaped to help decelerate the water flow and recover the pressure.

Kaplan:

The Kaplan turbine is an outward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. Power is recovered from both the hydrostatic head and from the kinetic energy of the flowing water. The design combines features of radial and axial turbines.

The inlet is a scroll-shaped tube that wraps around the turbine's wicket gate. Water is directed tangentially through the wicket gate and spirals on to a propeller shaped runner, causing it to spin. The outlet is a specially shaped draft tube that helps decelerate the water and recover kinetic energy.

The turbine does not need to be at the lowest point of water flow as long as the draft tube remains full of water. A higher turbine location, however, increases the suction that is imparted on the turbine blades by the draft tube. The resulting pressure drop may lead to cavitation. Variable geometry of the wicket gate and turbine blades allow efficient operation for a range of flow conditions. Kaplan turbine efficiencies are typically over 90%, but may be lower in very low head applications.

Current areas of research include CFD driven efficiency improvements and new designs that raise survival rates of fish passing through. Because the propeller blades are rotated on high-pressure hydraulic oil bearings, a critical element of Kaplan design is to maintain a positive seal to prevent emission of oil into the waterway. Discharge of oil into rivers is not desirable because of the waste of resources and resulting ecological damage.

Steam turbine:

As its name suggests, a steam turbine is powered by the energy in hot, gaseous steam and works like a cross between a wind turbine and a water turbine. Like a wind turbine, it has spinning blades that turn when steam blows past them; like a water turbine, the blades fit snugly inside a sealed outer container so the steam is constrained and forced past them at speed. Steam turbines use high-pressure steam to turn electricity generators at incredibly high speeds, so they rotate much faster than either wind or water turbines. (A typical power plant steam turbine rotates at 1800– 3600 rpm—about 100–200 times faster than the blades spin on a typical wind turbine, which needs to use a gearbox to drive a generator quickly enough to make electricity.) Just like in a steam engine, the steam expands and cools as it flows past a steam turbine's blades, giving up as much as possible of the energy it originally contained. But, unlike in a steam engine, the flow of the steam turns the blades continually: there's no push-pull action or waiting for a piston to return to position in the cylinder because steam is pushing the blades around all the time. A steam turbine is also much more compact than a steam engine: spinning blades allow steam to expand and drive a machine in a much smaller space than a piston-cylinder-crank arrangement would need. That's one reason why steam turbines were quickly adopted for powering ships, where space was very limited.

Gas turbine:

A gas turbine, also called a combustion turbine, is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in between. The basic operation of the gas turbine is similar to that of the steam power plant except that air is used instead of water. Fresh atmospheric air flows through a compressor that brings it to higher pressure. Energy is then added by spraying fuel into the air and igniting it so the combustion generates a high-temperature flow. This high-temperature high pressure gas enters a turbine, where it expands down to the exhaust pressure, producing a shaft work output in the process. The turbine shaft work is used to drive the compressor and other devices such as an electric generator that may be coupled to the shaft. The energy that is not used for shaft work comes out in the exhaust gases, so these have either a high temperature or a high velocity. The purpose of the gas turbine determines the design so that the most desirable energy form is maximized. Gas turbines are used to power aircraft, trains, ships, electrical generators, and tanks.

Wind turbine:

A wind turbine is a device that converts kinetic energy from the wind into electrical power. The term appears to have migrated from parallel hydroelectric technology (rotary propeller). The technical description for this type of machine is an aerofoil-powered generator.

The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Arrays of large turbines, known as wind farms, are becoming an increasingly important source of renewable energy and are used by many countries as part of a strategy to reduce their reliance on fossil fuels.

For the overall development of any nation be it the social, economical or technological, electrical power has found itself to be of essence. The majority of the electrical power is found to be generated from the conventional sources of energy. Due to the rapid exhaustion of the conventional fossil fuels there has been widespread power shortage throughout the globe hindering the upward progressive trajectory of developing nations. In order to solve this problem, the tangible option is to focalize on development of renewal sources of energy. From the different available renewable sources of energy, we chose to study the scope of hydal (water) energy for solving problems of power generation.

Hydal energy is the fastest growing energy resource and most importantly is, easily available. Keeping in view all the vital factors low cost hydal energy has been a primary solution. Earlier practices used turbines, but to meet the requirements of task, we choose a different approach in hydal power generation, in small scale power generation and being environmental friendly. This review is a complied study of different in pipe turbines power generation alternatives and selecting the most efficient option.

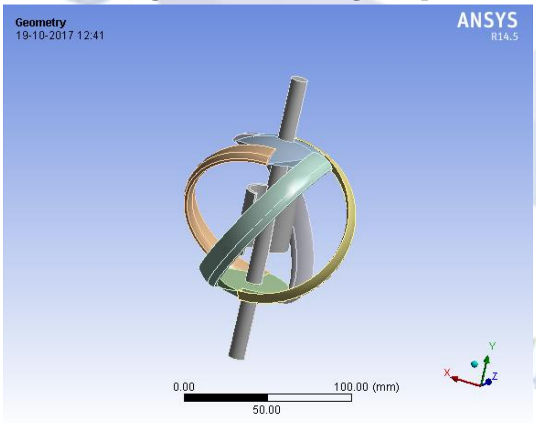
Water is a source of renewable energy similar to wind and solar energy. This untapped energy is extractable using underwater turbines capable of converting water kinetic energy into mechanical energy. A turbine with a low cut-in speed is needed to get maximum energy from the water. In this paper, a Spherical - S turbine based on the Darrieus and Savonius vertical axis turbine has been introduced which exploits good features of both turbines. The design procedure elaborates the Hybrid structure of a four curved bladed Darrieus (lift type) turbine along with a Savonius (drag type) turbine. The Savonius turbine is placed on the middle of Darrieus turbine on the same shaft. The model of Spherical – S turbine is created using CREO2.0 software. CAD model is then imported into ANSYS software for analysis.

II. DESIGNING OF SPHERICAL – S TURBINE

SPHERICAL – S TURBINE SPECIFICATIONS

Materials = Structural Steel, Stainless Steel and Aluminium Alloy

The Spherical – S turbine is designed giving dimensions into modelling software CREO 2.0 . The geometry of piston is designed in CREO 2.0 and imported to the analysis software in the IGES format. The figure of the designed piston is below



Design of Spherical – S turbine

III. ANALYSIS OF SPHERICAL – S TURBINE

The piston is analysed by giving the constraints they are

1. Boundary conditions
2. Forces or structural analysis

STRUCTURAL ANALYSIS OF SPHERICAL – S TURBINE

Water in the pipe exerts force on the blades of the turbine during flow in pipe. The force will be taken as boundary condition in structural analysis using ANSYS 14.5 Workbench. Fixed support has given on the shaft, because the spherical – S turbine will rotate on the shaft. So whatever the load is applying on turbine due to water travel that force causes to failure of turbine blades (inducing bending stresses).

Taking the boundary conditions as,

A. Constraints the shaft.
B. Force acting on Spherical equals to 0.05251N as shown in figure.

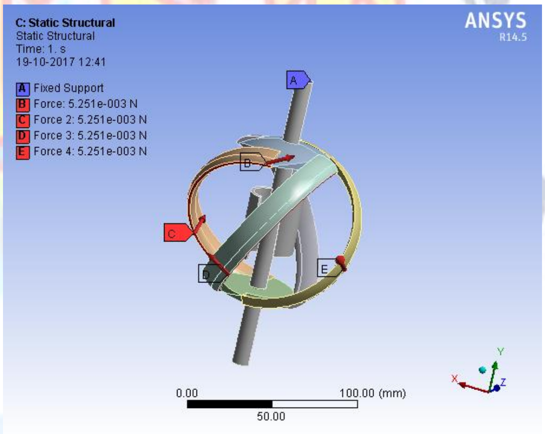


Figure showing forces

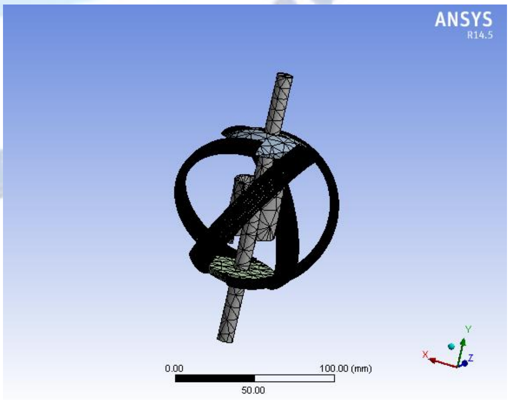
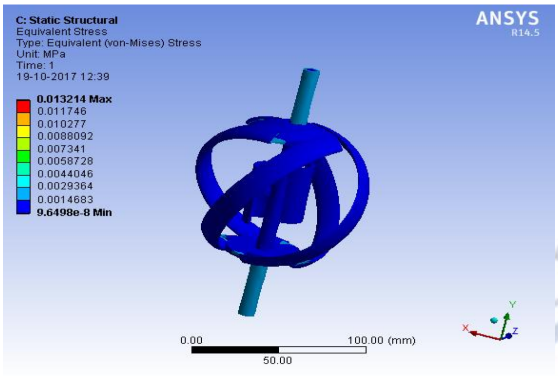
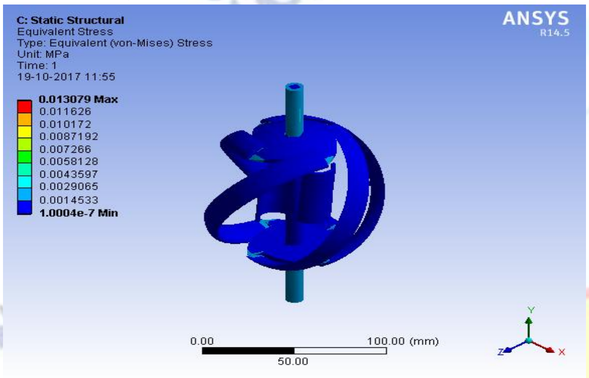


Figure showing meshed model

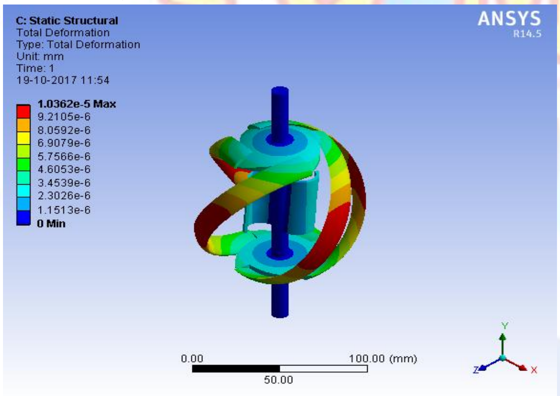
IV. RESULTS OF STRUCTURAL ANALYSIS OF SPHERICAL – S TURBINE



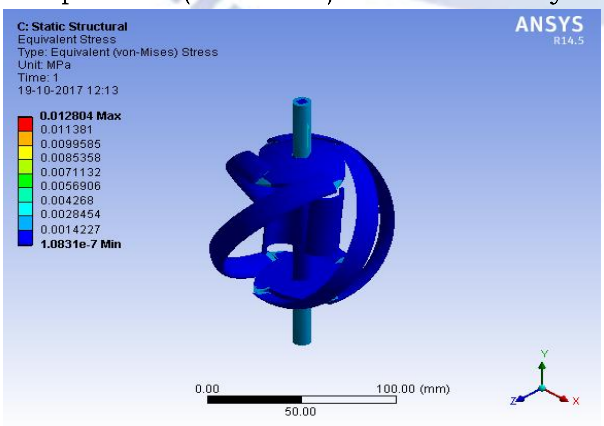
Equivalent (Von-Mises) Stress in Structural Steel



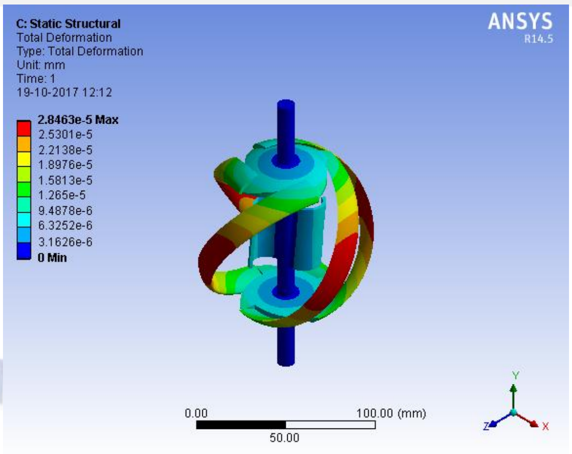
Equivalent (Von-Mises) Stress in Stainless Steel



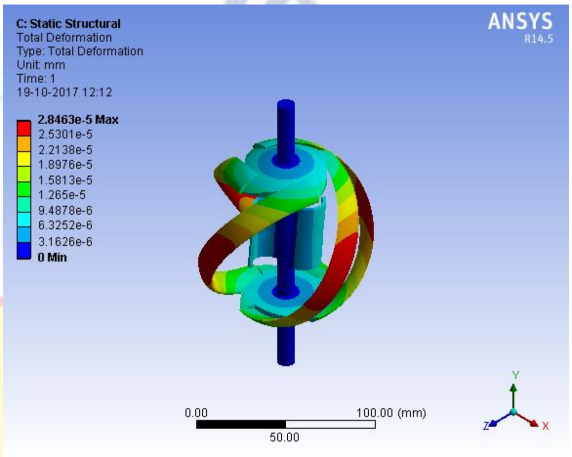
Equivalent (Von-Mises) Stress in Al Alloy



Total deformation in Structural Steel



Total deformation in Stainless Steel



Total deformation in Al Alloy

STATIC ANALYSIS COMPARISON TABLE

Equivalent (Von-Mises) Stress

CONTENTS	**STRUCTURAL STEEL**	**STAINLESS STEEL**	**ALUMINIUM ALLOY**
Minimum	9.6498e-008 MPa	1.0004e-007 MPa	1.3079e-002 MPa
Maximum	1.3214e-002 MPa	1.3079e-002 MPa	1.2804e-002 MPa

Total Deformation

CONTENTS	**STRUCTURAL STEEL**	**STAINLESS STEEL**	**ALUMINIUM ALLOY**
Minimum	0. mm	0. mm	0. mm
Maximum	9.9454e-006 mm	1.0362e-005 mm	2.8463e-005 mm

Equivalent Elastic Strain

CONTENTS	**STRUCTURAL STEEL**	**STAINLESS STEEL**	**ALUMINIUM ALLOY**

Minimum	1.6833e-012 mm/mm	1.7635e-012 mm/mm	4.9061e-012 mm/mm
Maximum	7.4942e-008 mm/mm	7.6945e-008 mm/mm	2.0518e-007 mm/mm

V. CONCLUSION

In present work, a Spherical – S turbine is modeled by using CREO 2.0, Then Static analysis is done by using ANSYS WORKBENCH. In present study, Structural Steel, Stainless and Aluminum alloy are compared.

The various parameters (i.e., geometry) are considered, by changing the shape of the Spherical – S turbine shape from the conventional geometry.

The results shows, by Spherical – S turbine with material stainless steel is better since the stresses and deformation is less compared to other.

FUTURE SCOPE

- CFD analysis for the spherical – S turbine cane be done
- Applying the spherical turbine in different applications for testing

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