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Design and Modelling of Francis Turbine by Using Generative Shape Design

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ABSTRACT: The Francis turbine is a type of water turbine. 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 and can achieve over 95% efficiency. Francis turbines are primarily used for electrical power production. The power output of the electric generators generally ranges from just a few kilowatts up to 1000 MW, though mini-hydro installations may be lower. The best performance is seen when the head height is between 100–300 meters (330–980 ft). Penstock (input pipes) diameters are between 1 and 10 m (3.3 and 32.8 ft). The speeds of different turbine units range from 70 to 1000 rpm. A wicket gate around the outside of the turbine's rotating runner controls the rate of water flow through the turbine for different power production rates. Francis turbines are usually mounted with a vertical shaft, to isolate water from the generator. This also facilitates installation and maintenance. In this paper, we are using static structural analysis. The analysis focuses on stress distribution in the runner blades. It has been found that the maximum stresses due to the water pressure are located at the trailing edge of the runner blade towards the transition between the blade and the crown.

Key words: Design, Modelling, Penstock, Francis turbine, reaction turbine

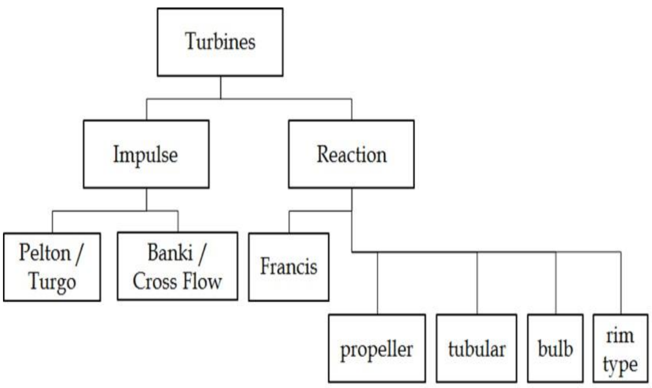
I. INTRODUCTION

TURBINE

Turbines convert hydraulic energy or hydro-potential into mechanical energy. Mechanical energy developed by turbines is used to run electric generators coupled to the shaft of turbines. Hydroelectric power is the cheapest source of power generation. Poncelet first introduced the idea of the development of mechanical energy through hydraulic energy. Modern hydraulic turbines have been developed by L.A. Pelton (impulse), G. Coriolis and J.B. Francis (reaction) and V `Kaplan (propeller).

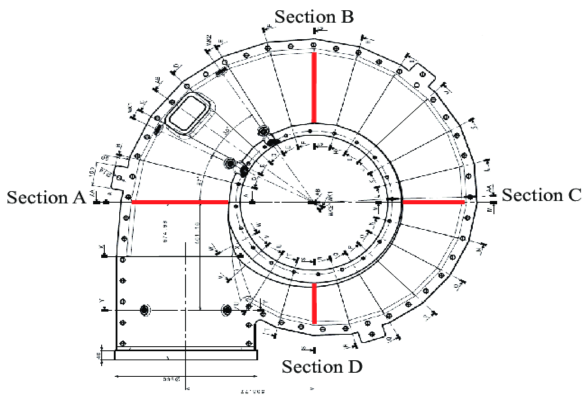
TYPES OF TURBINES

Classifications and types



Major Components of Francis Turbines

- Spiral Casing
- Stay Vanes
- Guide Vanes
- Runner Blades
- Draft Tube
- Spiral Casing



The spiral casing is the inlet medium of water to the turbine. The water flowing from the reservoir or dam is

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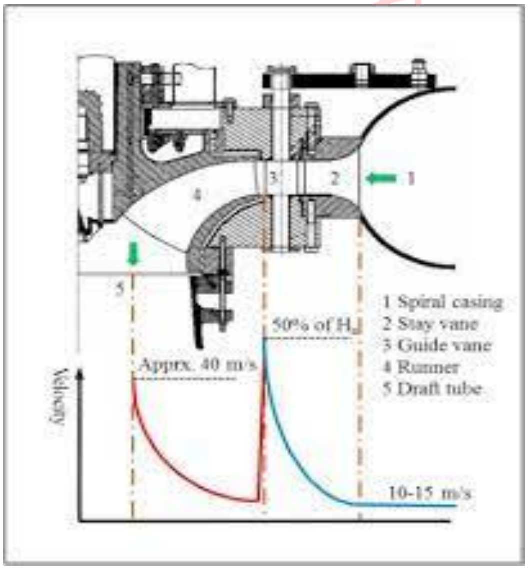
made to pass through this pipe with high pressure. The blades of the turbines are circularly placed, which means the water striking the turbine's blades should flow in the circular axis for efficient striking. So, the spiral casing is used, but due to the circular movement of the water, it loses its pressure. To maintain the same pressure the diameter of the casing is gradually reduce, thus, uniform momentum or velocity striking the runner blades

Stay Vanes

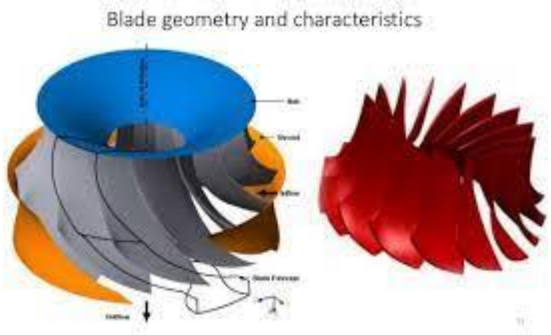
Stay and guide vanes guide the water to the runner blades. Stay vanes remain stationary at their position and reduces the swirling of water due to radial flow, as it enters the runner blades, thus, making the turbine more efficient.

Guide Vanes



Guide vanes are not stationary, they change their angle as per the requirement to control the angle of striking of water to turbine blades to increase the efficiency. They also regulate the flow rate of water into the runner blades thus controlling the power output of a turbine according to the load on the turbine.

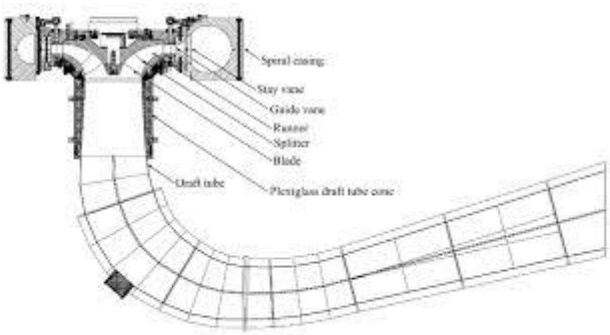
Runner Blades



Runner blades are the heart of any Francis turbine. These are the centers where the fluid strikes and the tangential force of the impact causes the shaft of the turbine to rotate, producing torque. Close attention to the design of blade angles at inlet and outlet is necessary, as these are major parameters affecting power production.

The runner blades have two parts. The lower half is made in the shape of a small bucket to rotate the turbine by using the impulse action of water. While the upper part of the blades uses the reaction force of water flowing through it. The runner rotates through these two forces.

Draft Tube



The pressure at the exit of the runner of the reaction turbine is generally less than atmospheric pressure. The water at the exit, cannot be directly discharged to the tailrace. A tube or pipe of the gradually increasing area is used for discharging water from the exit of the turbine to the tailrace.

This tube of the increasing area is called Draft Tube. One end of the tube is connected to the outlet of the runner. However, the other end is submerged below the level of water in the tail-race.

II. LITERATURE REVIEW

Francis turbine embraces a radial flow runner in which the water strikes the runner blades radially and departs axially along its axis through a draft tube. The Francis turbine is a mixed flow-type turbine in which the water passes through the curved guide vanes and creates a high curved rotational flow at the outlet. A draft tube is connected at the end of the turbine, and this draft tube aids to improve the overall efficiency of the reaction turbine by pacifying the excess kinetic energy of the fluid. Modern Francis turbines exhibit

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peak efficiencies between 80% and 95%; however, they can be further improved between 90% and 95% when the turbine is well designed [26]. These turbines are generally suitable for a medium head with moderate discharge. However, in some cases, Francis turbines can be used instead of impulse turbines for high head installations. The world's largest dam “The Three Gorges” uses 32 Francis turbines in its core producing approximately 22,500 MW of electricity with an operating head of 61–113 m [27]. China is producing about 6500 MW from a hydropower plant located at Xiangjiaba [28]. The plant comprises of eight Francis turbines with head ranging from 82.5 to 113.6 m.

CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

CATIA competes in the CAD/CAM/CAE market with Siemens NX, Pro/E, Autodesk Inventor, and Solid Edge as well as many others.

III. RESULT

Rotational velocity

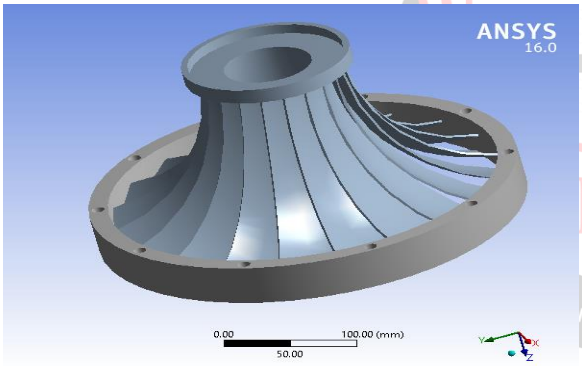


FIGURE 1

Model (A4) > Static Structural (A5) > Rotational Velocity

Object Name	*Pressure*	*Frictionless Support*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	94 Faces	4 Faces
Definition		
Type	Pressure	Frictionless Support
Define By	Normal To	
Magnitude	40. MPa (ramped)	
Suppressed	No	

Pressure

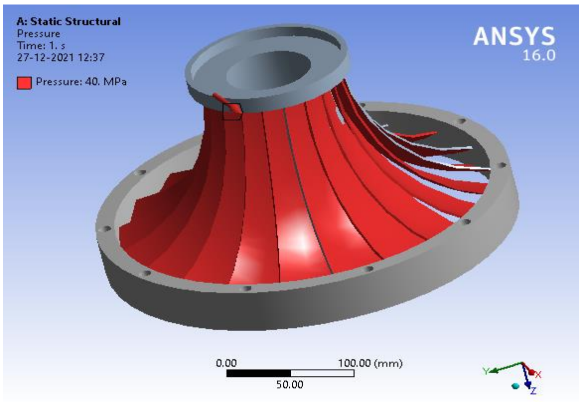
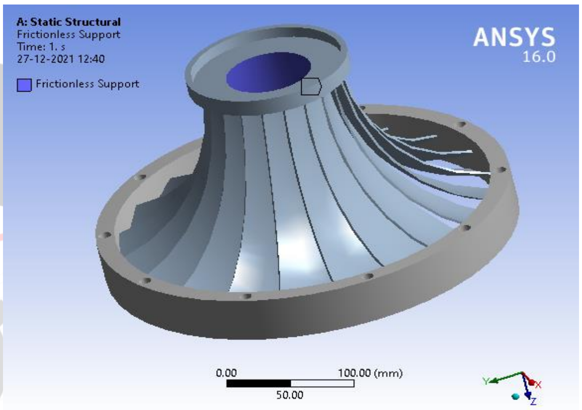


FIGURE 2

Model (A4) > Static Structural (A5) > Pressure

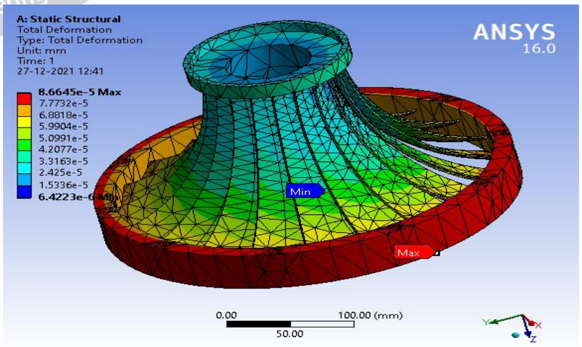
Frictionless support



Total deformation

FIGURE 3

Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation



Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]
1.	6.4223e-006	8.6645e-005

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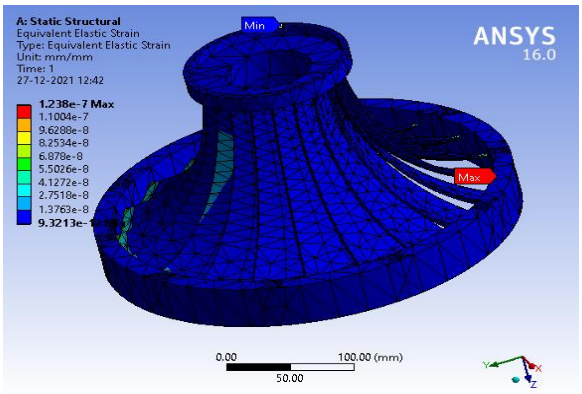
FIGURE 4

Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

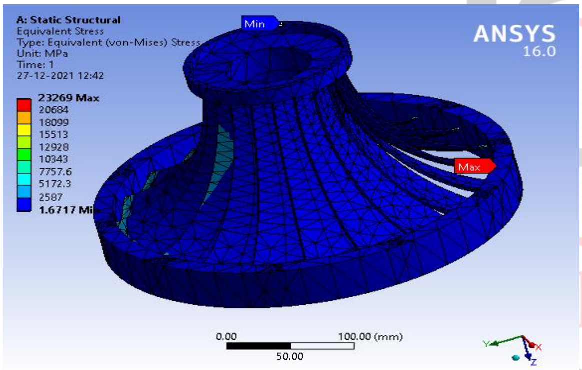


Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	9.3213e-012	1.238e-007

FIGURE 5

Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress



Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	1.6717	23269

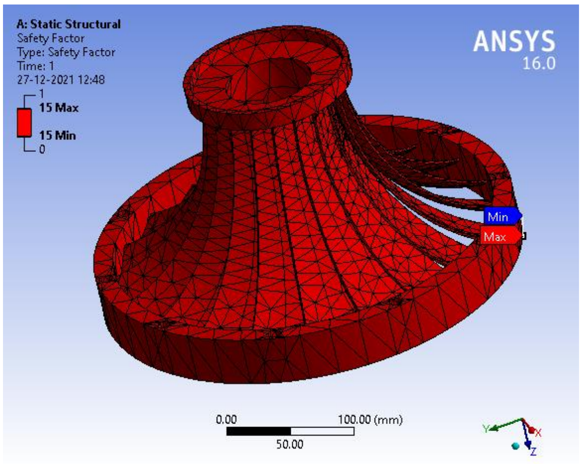
Model (A4) > Static Structural (A5) > Solution (A6) > Stress Safety Tools

Object Name	*Stress Tool*
State	Solved
Definition	
Theory	Max Equivalent Stress
Stress Limit Type	Tensile Yield Per Material

Model (A4) > Static Structural (A5) > Solution (A6) > Stress Tool > Results

FIGURE 6

Model (A4) > Static Structural (A5) > Solution (A6) > Stress Tool > Safety Factor

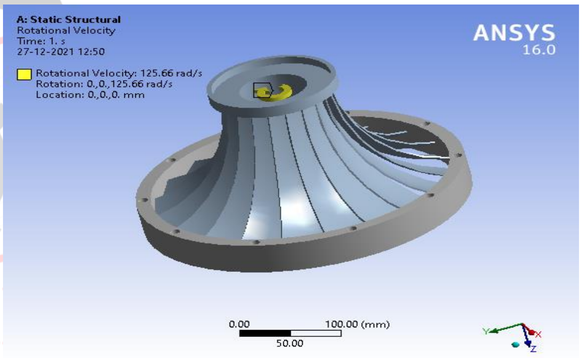


Model (A4) > Static Structural (A5) > Solution (A6) > Stress Tool > Safety Factor

Time [s]	Minimum	Maximum
1.	15.	15.

STAGE 2

Rotational velocity



FIGURE

Model (A4) > Static Structural (A5) > Rotational Velocity

Model (A4) > Static Structural (A5) > Loads

Object Name	*Pressure*	*Frictionless Support*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	94 Faces	4 Faces
Definition		
Type	Pressure	Frictionless Support
Define By	Normal To	
Magnitude	50. MPa (ramped)	
Suppressed	No	

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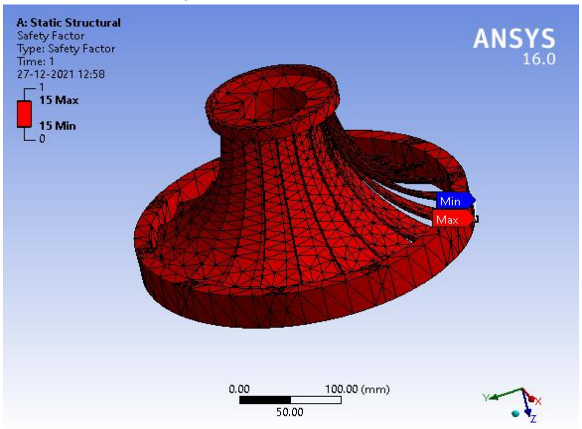
FIGURE

Model (A4) > Static Structural (A5) > Solution (A6) > Stress Tool > Safety Factor



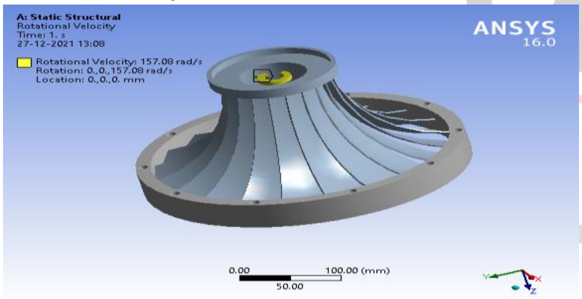
TABLE

Model (A4) > Static Structural (A5) > Solution (A6) > Stress Tool > Safety Factor

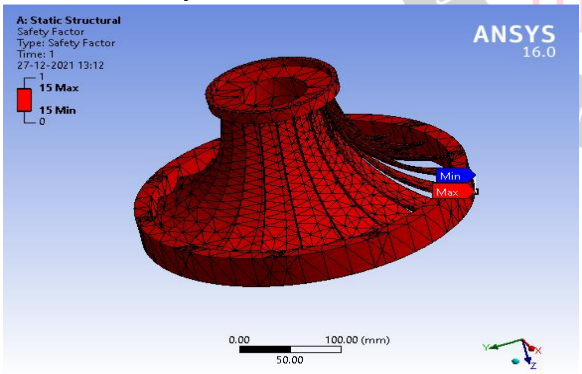
Time [s]	Minimum	Maximum
1.	15.	15.

Stage 3

Rotational velocity



Model (A4) > Static Structural (A5) > Solution (A6) > Stress Tool > Safety Factor



IV. CONCLUSION

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. The turbine's exit tube is shaped to help decelerate the water flow and recover the pressure. In this paper we have designed Francis turbine. and using Catia v5 r20 software design of with standard measurements and observing the above modeling creating the 2D sketches using Catia sketcher then converting into 3D solid model using part design. we have saved the part file in Initial Graphics Exchange (IGS) and we have imported in Ansys work bench. In Ansys work bench we have used Static Structural Analysis System to validate the strength of our design, we have done static structural analysis on the Francis turbine. We have done analysis by varying the pressure and rotational velocity, material with stain less steel with varying the different loads.

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

In Ansys we have applied force, total deformation, equivalent stress, equivalent strain and factor of safety for Stain less steel.

Hence, we have used stain less steel

Stage 1

S NO	material	Solutions	Min	max
1	Stain less steel	Total Deformation	6.4223e-006	8.6645e-005
2	Stain less steel	Equivalent Elastic Strain	9.3213e-012	1.238e-007
3	Stain less steel	Equivalent Stress	1.6717	23269
4	Stain less steel	Factor of safety	15.	15.

Stage 2

S NO	material	Solutions	Min	max
1	Stain less steel	Total Deformation	8.028e-006	1.0831e-004
2	Stain less steel	Equivalent Elastic Strain	1.1839e-011	1.5474e-007
3	Stain less steel	Equivalent Stress	2.1288	29086
4	Stain less steel	Factor of safety	15.	15.

Stage 3

S NO	material	Solutions	Min	max
1	Stain less steel	Total Deformation	8.028e-006	1.0831e-004
2	Stain less steel	Equivalent Elastic Strain	1.1839e-011	1.5474e-007
3	Stain less steel	Equivalent Stress	2.1288	29086
4	Stain less steel	Factor of safety	15.	15.

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V. References

[1] Angehrn, R., Holler, K. and Barp, B., A comparison of theoretical stress calculation with experimental verified stresses on Francis turbine runners of high specific speed, Escher Wyss News, v 50, n 1, pp. 25-28, 1977.

[2] Nava, J. M. F., Gómez, O. D., Hernández J. A. R. L., Flow induced stresses in a Francis runner using ANSYS, International ANSYS Conference Proceedings, 2006.

[3] Farhat, M., S. Natal, Avellan, F., Paquet, F., Lowy's, Py., Couston, M., Onboard measurements of pressure and strain fluctuations in a model of low head Francis turbine part 2: Measurements and preliminary analysis results, Proceedings of the 21st IAHR Symposium on Hydraulic Machinery and Systems, Lausanne, pp. 873-880, 2002.

[4] Ikeda, K., Inagaki, M., Niikura, K., Oshima, K., 700-m 400-MW class Ultrahigh-head Pump Turbine, Hitachi Review Vol. 49, No. 2, pp. 81-87, 2000.

[5] Bjorndal, H., Moltubakk, T. and Aunemo, H., Flow induced stresses in a medium head Francis runner - strain gauge measurements in an operating plant and comparison with finite element analysis, 10th International Meeting of the IAHR Work Group on the Behaviour of Hydraulic Machinery Under Steady Oscillatory Conditions, Trondheim, Norway, 2001.

[6] Ivanchenko, I. P., Smelkov, L. L., Pupko, T. E., Timashkov, A. Ya., Vapnik, B. K., Stress – strain state of Francis turbine blades, Power Technology and Engineering, Springer, New York, pp. 755-762, 1982.

[7] Fattah, S. S., Khoshnaw, F. M., Saeed, R. A., An investigation about preventing cavitation damage and fatigue failure in Derbendikhan power station, Fluid Structure Interaction and Moving Boundary Problems, Spain, Vol 84, pp. 97-106, 2005.

[8] Dubas, M. and Schuch, M., Static and dynamic analysis of Francis turbine runners, Sulzer Technical Review, Switzerland, v 69, No.3, pp. 30-32, 1987.

 DOI : 10.35291/2454-9150.2022.0263