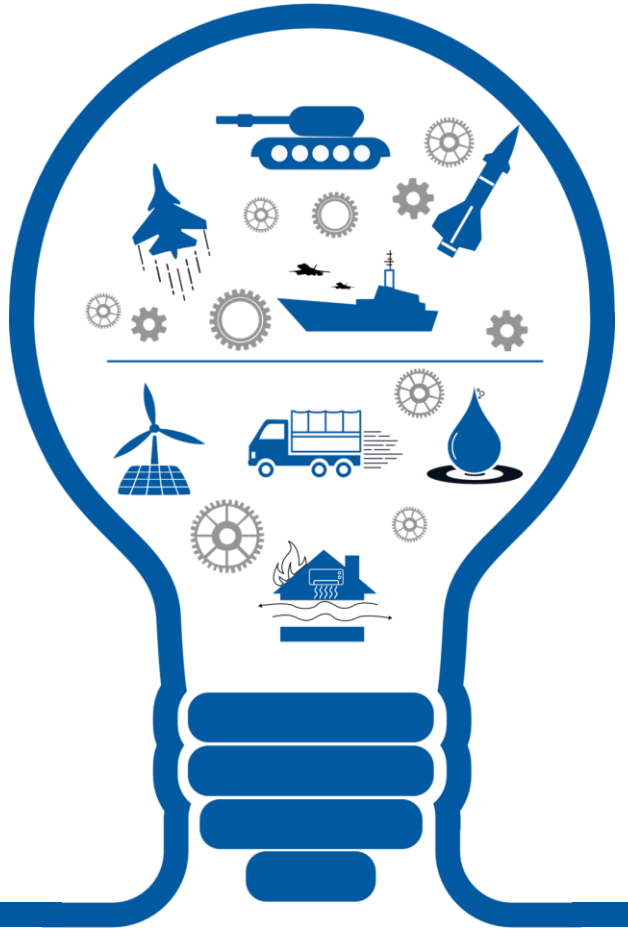
ZEUSNUMERIX

Kaplan Water Turbine

REFERENCE MANUAL



https://labs.zeusnumerix.com/kaplan-water-turbine/

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Introduction

- This application arrives at design parameters for an axial water turbine based on the flow & head available.
- For design purposes, some parameters are fixed viz. RPM, Hub to tip diameter ratio, Solidity.
- The cascade geometry, blade arrangement, power and mechanical design are the output generated from this tool.
- The power developed in the turbine arises due to the difference in the product of the radius and velocity at the exit and inlet of the turbine times the angular velocity of the turbine and the amount of fluid passing through the turbine
- Two separate methods are used here for arriving at turbine design.

Governing Equations

- Euler's turbomachinery equations are used to describe the power and torque characteristics of the turbine.

$$P = T\omega = \omega\dot{m}(v_c r_c - v_b r_b).$$

- The angles of the turbine blades are defined with the use of the elementary cascade theory, which also takes into account the generation of lift in the blades. As the air enters the turbine, it is turned through an angle α_m which can be found using the inlet and exit angles from the velocity triangle diagram. This angle, along with the coefficients for lift and drag of the blade can be used to retrieve the efficiency of the cascade.

$$(\eta_b)_{\text{turb cascade}} = \frac{1 - \frac{C_D}{C_L}\tan\alpha_m}{1 + \frac{C_D}{C_L}\cot\alpha_m}$$

Web App - Usage

- User needs to upload the input file containing details of flow conditions & bounds related to rotor and blade design along with the mechanical material property data and length of the shaft.
- Upon execution, following outputs are generated:
  1. The design parameters of the turbine using numerical analysis method.
  2. The design parameters of the turbine using pico-hydro design method.
  3. The physical properties of the rotor shaft.
- The User can download the raw output data in text format for future reference.

Input File Description

Parameter	Default Value	Unit	Description
Head	20	m	Hydraulic head provided to the turbine.
Mass_flow_rate	200	kg/s	Amount of water in kg passing through the turbine per second
Tip_diameter	0.30	m	The diameter of the tip of the stator/rotor
Hub_diameter	0.24	m	The internal diameter of the stator/rotor
Angular_velocity	1500	RPM	The speed of rotation of the rotor in rotations per minute
Solidity	1	-	The ratio of the blade chord length to the spacing of the blades
Number_of_blades	8	-	The amount of blades on the rotor/stator
Efficiency	0.8	-	The ratio of mechanical power extracted from the hydropower.

Input File Description (Contd.)

Parameter	Default Value	Unit	Description
Yield_strength	600	MPa	The maximum stress before plastic deformation occurs.
Ultimate_strength	700	MPa	The maximum stress the material can withstand before failure
Shear_modulus	80000	MPa	The ratio of the stress to strain when subjected to shear forces
Density	7850	kg/m^3	The density of the material that is to be used
Factor_of_safety	10	-	The factor by which the structure can support the design load
Subjected_torque	100	Nm	The torque the shaft is loaded with
shaft_length	1	m	The total designed length of the shaft.

Output File Description

- Three output files are generated from the tool. Two of which provide various blade angles, dimensions and forces and the third which gives the dimensions of the rotor shaft from material property values.
- The blade angles, dimensions and forces are output in both the files in the form of a table. The table illustrates the variation of these properties along the span of the blade, (i.e) from the centre of the hub to the tip of the rotor.
- The dimensions of the rotor shaft are given for a solid and a hollow variant, the outputs in this file is the dimensions of the shafts, angle of twist in each shaft and the mass of the shafts.
- The three files are:
    1. Output_Mechanical_Design.txt
    2. Output_Numerical_Analysis_design.txt
    3. Output_Pico_Hydro_design.txt

Output File Description

Parameter	Default Output	Unit	Description
HydroPower	39240	W	The input power of the water when entering the turbine.
Pitch	94.25	mm	The distance between consecutive blades.
Chord length	94.25	mm	The distance between the leading and trailing edge of the blade.
Blade setting angle	53.24	deg	The angle between the blade and the line along the length of the blade.
Angle of attack	1.87	deg	The angle between the flow and the chord line of the blade.
Stagger angle	60.30	deg	The angle between the chord and the line along the length of the blade.
Angle of incidence	7.06	deg	The angle between the flow and the camber line of the blade.
Flow Turning Angle	14.12	deg	The angle by which the flow is diverted by the blade.
Torque	199.85	Nm	The torque generated by the turbine.
Lift force generated	1665.40	N	The linear force generated by the fluid on the blade.
Power generated	31392	W	The power generated by the turbine.
Stator exit angle	53.24	deg	The angle at which the flow exits the stator.

Output File Description (Contd.)

Parameter	Default Output	Unit	Description
Diameter of solid shaft	24.47	mm	Outer diameter of the solid shaft
Inner Diameter of hollow shaft	17.24	mm	Inner diameter of the hollow variant of the shaft
Outer Diameter of hollow shaft	34.47	mm	Outer diameter of the hollow variant of the shaft
Angle of twist in solid shaft	0.0022	deg	The angle by which the shaft rotates due to torsion
Angle of twist in hollow shaft	0.0006	deg	The angle by which the hollow shaft rotates due to torsion
Mass of solid shaft	3.69	kg	The mass of the solid shaft
Mass of hollow shaft	5.49	kg	The mass of the hollow variant.

References

- Chamil Abeykoon and Tobi Hantsch - Design and Analysis of a Kaplan Turbine Runner Wheel. Proceedings of the 3rd World Congress on Mechanical, Chemical, and Material Engineering (MCM'17), June 2017.
- Joel Titus and Bakthavatsalam Ayalur - Design and Fabrication of In-line Turbine for Pico Hydro Energy Recovery in Treated Sewage Water Distribution Line. 5th International Conference on Power and Energy Systems Engineering, CPESE 2018, Japan, September 2018.

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Thank You !

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