DESIGN OF THE STEAM TURBINE FOR SMALL SCALE POWER PLANT

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Abstract

The aim of this study is to design a steam turbine for a small scale steam power plant and industrializes the design, the turbine driven by the energy of coconut shells; a renewable energy source with lower cost, as the source of energy. The study was concentrated on steam cycle, type of turbine, requirements of a perfect output power of the turbine, design and operation, turbine rating, elements of the turbine and steam condition. In addition analysis was done on on-going small scale power plane projects in Sri Lanka.

In this Impulse turbine design we consider steam turbine blade stress failure (tensile and bending stress partly) due to the centrifugal force as a result of high rotational speeds and partly due to high pressure, temperature and speed steam loading. And we consider the blade efficiency and the angle for blade design parameter. The steam cycle was designed according to the available data and the turbine calculations were done by using trial and error method using ASME turbine design manual, Solid work and the software ANSYS.

Over view of the project design is: Available power of the plant 100kW, isentropic efficiency 80 ⁒, Cycle power output 115kW, Turbine output 122.5kW, Gear efficiency 90%, Generator efficiency 90%, generator speed 3000rpm, turbine blade length 200mm, blade radius 300mm, Nozzle diameter 3.15mm, maximum angle of nozzle 63.09˚, shaft length 240mm, Shaft diameter 40mm,shaft speed 3000rpm,rated load 680N, Inlet Flow rate 0.144 kg/s, Cycle efficiency 25.2 ⁒,Overall efficiency 19 ⁒, Water tube boiler Efficiency 80%, Inlet pressure 30 bar, Design pressure 32.4 bar, Overall heat transfer coefficient 235.06 W/m²°C.

Keywords: American society of mechanical engineers,Carbon steel,Centrifugal stress, CH-self-aligning.

1. Introduction

A steam turbine defined as a form of heat engine in which the energy of the steam is transformed into kinetic energy by expansion through nozzles, and the kinetic energy of resulting jet is in turn converted into force doing work on rings of blades mounted on a rotating disc the majority of steam turbines have, therefore two important elements the nozzle and the blade (rotor). The design took away as cycle design, classification of the steam turbine, blades of the turbine design, nozzle, and condenser design. Steam turbine depends completely upon the dynamic action of the steam. Working principle of the power in a steam turbine is obtained by the rate of change in momentum of a high velocity jet of steam and hit on a curved blade, which is free to rotate by using newton's 2nd law f=m (c1+c2)/t, F = rate of change of momentum. In blade the stream of steam particles has its direction and hence its momentum changed. A blade force results from the difference between the momentum entering and the momentum exiting of the rotor blade row. The blades are attached to the rotating element of the machine or rotor shaft. The resultant of blade forces is then converted into shaft power to drive the load. On the other hand, the nozzles are attached to the stationary part of the turbine (casing) the rotor blades facing the steam will carry most of the flow loading. Hence to design these blades, the flow has to be studied first, flow forces to be estimated and blade stresses to be evaluated. Turbine rotor blades are positioned in a very harsh environment .They the incoming, hot, fast and high pressure streams exiting from the nozzles. The loading on a rotating turbine blade is composed of Centrifugal force due to rotation, bending force due to the fluid pressure and change of momentum and centrifugal action, which resulting from that the centroids of all section do not lie along a single radial line.

Transmission shafts are transmit power between the source and the machines absorbing power for example machine shafts these shafts form an integral part of the machine itself for example crank shaft Stress in shaft due to shear stress due to the transmission of torque, bending stress due to the forces acting upon machine elements, stress due to combined torsional and bending loads. For the bearing selection there are two purposes of bearings are used in steam turbine. First one to support journal bearings is used to support the weight of the turbine rotors and to locate the rotors of steam turbines. Thrust bearings axially locate the turbine rotors. The steady state stress at any section of a parallel sided blade is a combination of direct tensile load due to centrifugal force band the bending load due to steam force, both of which are acting on that portion of blade between the section under consideration and the tip section. The direct tensile stress is maximum at the blade root. It is decreasing towards the blade tip. The tensile stress (CS) depends on the mass of material in the blade, blade length, rotational speed, and the cross sectional area of blade. Impulse blades are subject to bending stresses from centrifugal force if the centroids of all sections do not lie a long a single radial line and the tangential force exerted by fluid. While Reaction blades have an additional bending stress that is due to the large axial thrust resulting from the pressure drop which occurs in the blade passages. The bending stress is maximum at the blade root. The combined tension and bending stress is also maximum at blade roots and diminishes with radius. If the blade is tapered, the direct tensile stress diminishes rapidly towards the blade tips, while the bending stress can be made to increase at greater radii. It is therefore possible to design the blade as a cantilever, with constant tensile stress (CS) and bending stress. The blade material is much more effectively utilized there. Provision must be made in the blade design to get a blade that withstands all these stresses encountered in operation at an acceptable long service life.

For the condenser design the type of the heat exchangers are parallel flow heat exchangers, counter flow heat exchanger, cross flow heat exchanger. The selected heat exchanger is shell & tube heat exchanger. Shell and tube heat exchangers are built of round tubes mounted in cylindrical shells with their and parallel to that of the shell.

2. Methodology

Participated in actual ongoing turbine measurements and evaluation work was helped to prepared in this project. More detailed design and performance calculations were done by turbine manual. The experimental tests and evaluation were used to study the distinguished aero thermodynamic phenomena related to small-scale steam turbines that are concluded in the literature study.

Initially overall cycle studies with advanced steam conditions for small-scale facilities were to be considered. Because of the lack of sufficient reference material for small-scale plants, several commissioned and projected large-scale advanced power plants were studied. Conclusions were made and possible parallelisms between large-scale and small-scale facilities are discussed. Problems and possibilities for the key issues are the turbine system as a whole, where surrounding equipment such as: alternator, inlet valve, layout etc. is included and the interior of the turbine flow losses.

Materials used for shaft are should have high strength, good machinability, low notch sensitivity factor, It should have good heat treatment properties; It should have high wear resistant properties. The material used for ordinary shafts is carbon steel of grades 40C8, 45C8, 50C4, 50C12

Table 1: Mechanical properties of steels used for shaft

Indian standard designation	Ultimate tensile strength. MPa	Yield strength. MPa
40C8	560-670	320
45C8	610-700	350
50C4	640-760	370
50C12	700 Min	390

The shaft design on the basis of strength following cases is considered. Shaft subjected to a twisting moment only (here shaft diameter obtained by torsion equation $T/j= \tau /r$, T=twisting moment, j=polar moment of inertia, τ= torsional shear stress), Shaft subjected to a bending moment only (here shaft diameter obtained by bending equation $M/I= \sigma b /y$), Shaft subjected to axial loads in addition to combined torsional and bending load, Shaft subjected to combined twisting moment and bending moment. When the shaft is subject to combined twisting moment and bending moment, then the shaft must be design on the basis of the two moments simultaneously. Various theories have been suggested to account for the elastic failure of the materials when they are subjected to various types of combined stresses. The following two theories are important from the subject point of views are maximum shear stress theory or Guest’s theory; It is used for ductile materials such as mild steel. And maximum normal stress theory or Rankine’s theory, It is used for brittle materials such as each iron.

3. Results and Discussion

Turbine Inlet conditions Pressure=30bar, Temperature=620^{0}c, Fluid Super-heated steam Flow rate=0.144kg/s and Enthalpy=3710kJ/kg, Outlet conditions: Pressure=0.5 bar, Temperature=83^{0}c, Enthalpy=2646kJ/kg. Turbine selection: isentropic efficiency=80%, Output power of the turbine=122.46kW, Gear efficiency=90%, Available power of the plant =100kW,Design Turbine wheel diameter=400mm, turbine blade length=300mm , Mass flow rate=0.144 kg/s, Total energy available for mechanical work=153.07kW, outer radius of nozzle=3.51mm , Relative blade speed=94.2 ms-1, maximum angle of nozzle=63.09, The total weight=18.6 kg, equal torque=1.22 kN, Shaft diameter=40mm, Rated load = 680N, Shaft speed=3000 rpm. Based on these data we can select a CH4 journal bearing in CH bearing system and Based on these data we can select a CH4 thrust bearing in CH bearing system.

3.1. Velocity diagram for impulse turbine

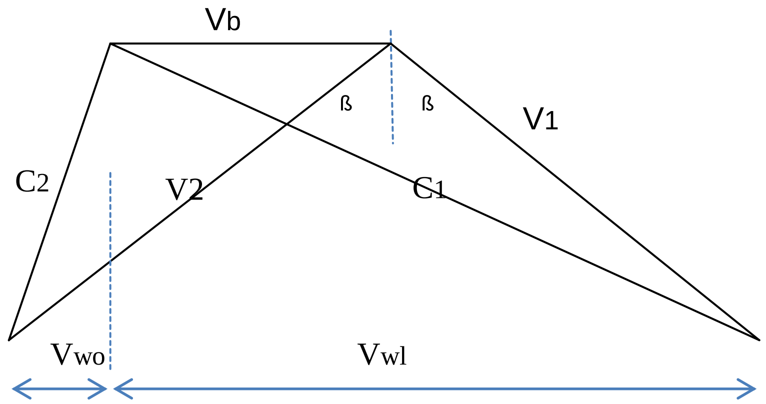


Figure 1: Velocity diagram for the impulse turbine

V_{wi} = 1030ms$_{-1}$, V_{wo} = 798 ms$_{-1}$, V_b = 95 ms$_{-1}$, V_1 = 1455 ms$_{-1}$, Assumed ß = 55°

3.2 Stresses in Shaft

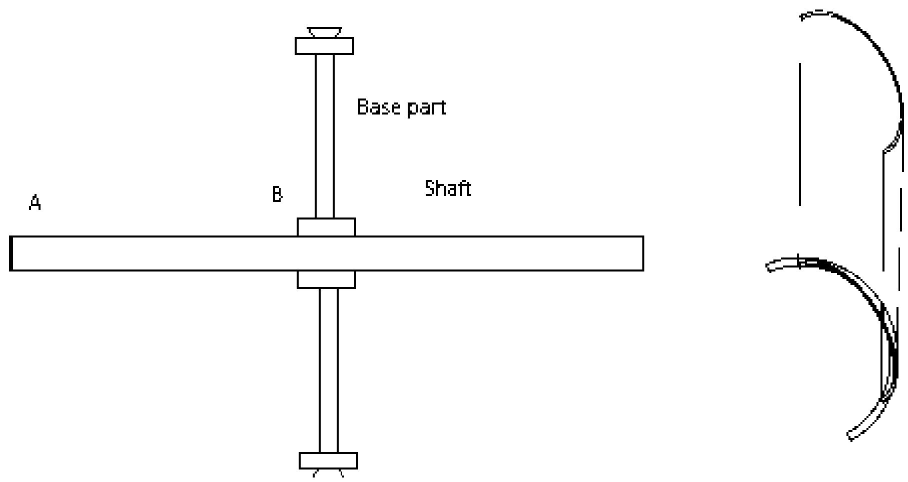


Figure 2: Diagram along the shaft

Vertical acting force diagram

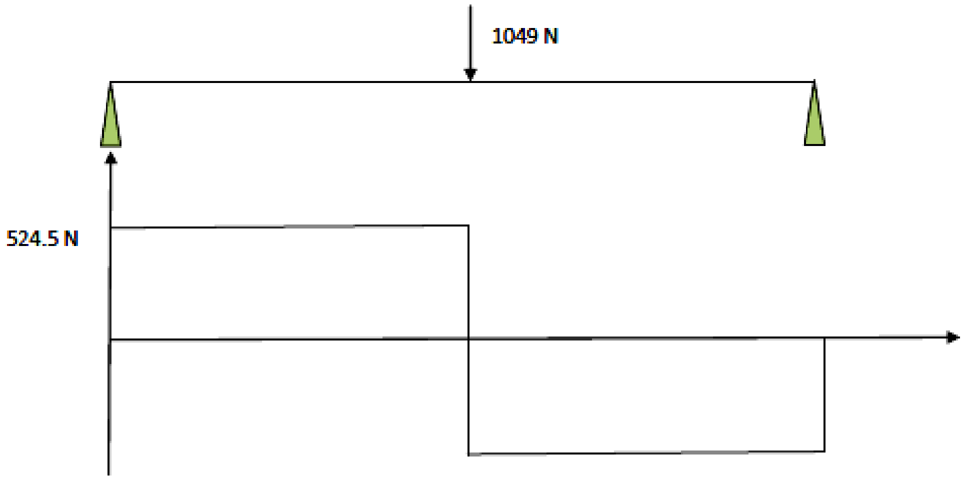


Figure 3 : Vertical forces diagram along the shaft

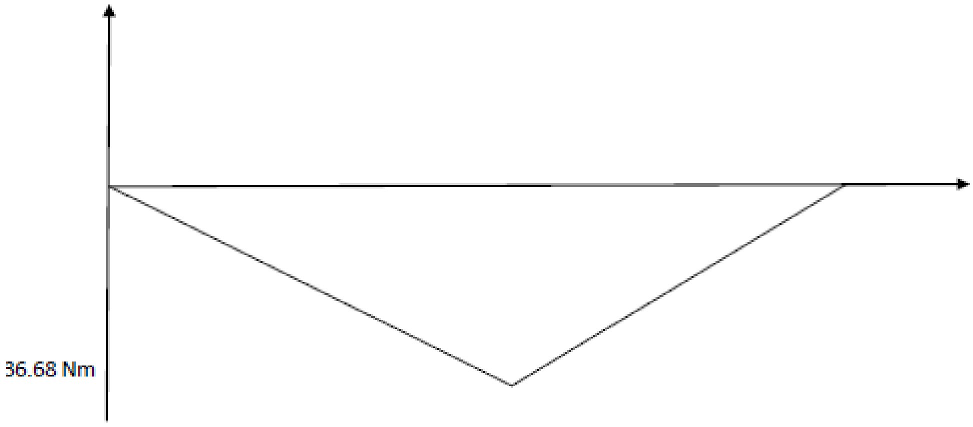


Figure 4 : The bending moment by vertical force diagram along the shaft

Horizontal acting force diagram

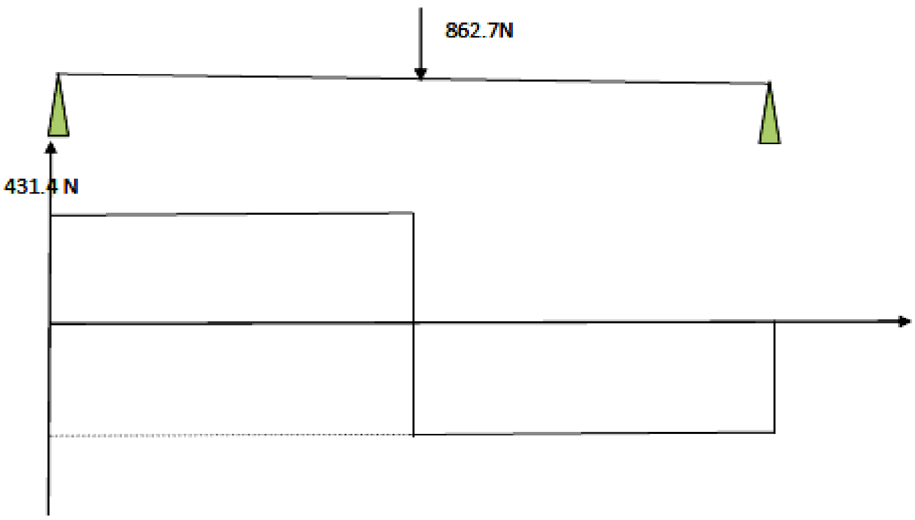


Fig 5: Horizontal force along the shaft

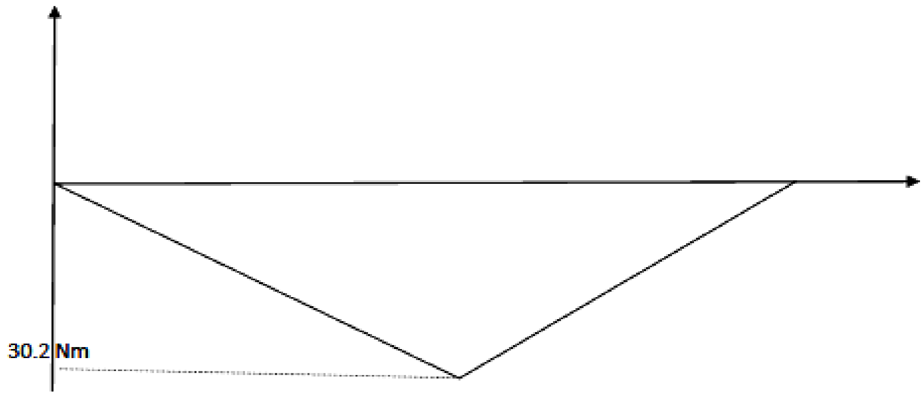
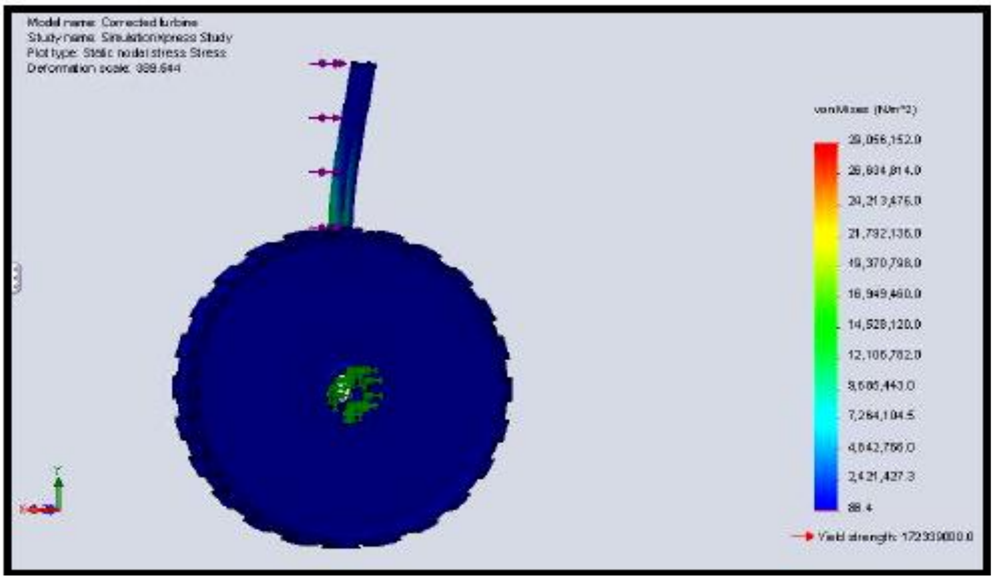


Figure 6: The bending moment by horizontal forces diagram along the shaft.

Stress Analysis



In our turbine design we mainly consider the blade, shaft and nozzle design. In blade design we consider stress failures and efficiency and angle for the blade design parameters. In condenser design we considered that overall heat transfer is constant and mean temperature different concept. We prepaid excel sheet for the condenser design. And we use solid works software to analysis the stresses in the blade.

4. Conclusion

Coconut shell is a widely available energy source in Srilanka. The cost of the coconut shell is cheap because it is a byproduct of coconut and it is not a seasonal product so we can find whole of the year. So we can run this power plant through the whole year. This proposed study has shown positive initial result in utilizing the biomass energy to generate electricity. And it is help to understand the power plant designs and components selection and component design.

For small-scale turbines it is attractive and possible to improve the isentropic efficiency. Such an improvement has notable effect already at present inlet conditions, but becomes more important for advanced steam conditions. High part-load turbine efficiency is important for small-scale steam turbines, better understanding of losses induced by the small volumetric flow and partial admitted flows are considered necessary.

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Acknowledgement

The authors would like express their gratitude to Supervisors, Department of Mechanical Engineering, University of Peradeniya for providing their fullest support to use their resources. Finally authors' thanks go to the ICSBE 2012 Conference Management System for calling our project research to the International conference on sustainable built environment

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