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Performance Evaluation of low Pressure energy recovery Tesla turbine

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Abstract - *In many applications of process industry where the processing of a fluid stream (gas / air) requires its pressure to be reduced. This process is accomplished by using a device known as throttling valve. In this process, energy of fluid stream is lost. Nowadays, awareness about effective energy usage is increased in process industries. Due to this awareness, areas in process industry where loss of energy of fluid stream are closely monitored and different methods of energy are being investigated. This problem creates challenge for developing of effective low pressure recovery system. Current project work includes design, development and analysis of a bladeless turbine.*

***Key Words*: Pressure reduction, low pressure recovery, bladeless turbine, reliable, easy to install.**

1. INTRODUCTION

Waste heat to power (WHP) is the process of capturing heat discarded by an existing industrial process and using that heat to generate power (see Figure 1). Energy intensive industrial processes - such as those occurring at refineries, steel mills, glass furnaces and cement kilns - all release hot exhaust gases and waste streams that can be harnessed with well established technologies to generate electricity. The recovery of industrial waste heat for power is a largely untapped type of combined heat and power (CHP), which is the use of a single fuel source to generate both thermal energy (heating or cooling) and electricity. CHP generally consists of a prime mover, a generator, a heat recovery system and electrical interconnection equipment configured into an integrated system. CHP is a form of distributed generation, which unlike central station generation, is located at or near the energy-consuming facility. CHP's inherent higher efficiency and its ability to avoid transmission losses in the delivery of electricity from the central station power plant to the user result in reduced primary energy use and lower greenhouse gas (GHG) emissions. The most common CHP configuration is known as a topping cycle, where fuel is first used in a heat engine to generate power, and the waste heat from the power generation equipment is then recovered to provide useful thermal energy. As an example, a gas turbine or reciprocating engine generates electricity by burning fuel and then uses a heat recovery unit to capture useful thermal energy from the prime mover's exhaust steam and cooling system. Alternatively, steam turbines generate electricity using high-pressure steam from a fired boiler before sending lower pressure steam to an industrial process or district heating system. Waste heat streams can be used to generate power in what is called bottoming cycle CHP another term for WHP. In this configuration, fuel is first used to provide thermal energy in an industrial process, such as a furnace, and the waste heat from that process is then used to generate power. The key advantage of WHP systems is that they utilize heat from existing thermal processes, which would otherwise be wasted, to produce electricity or mechanical power, as opposed to directly consuming additional fuel for this purpose.

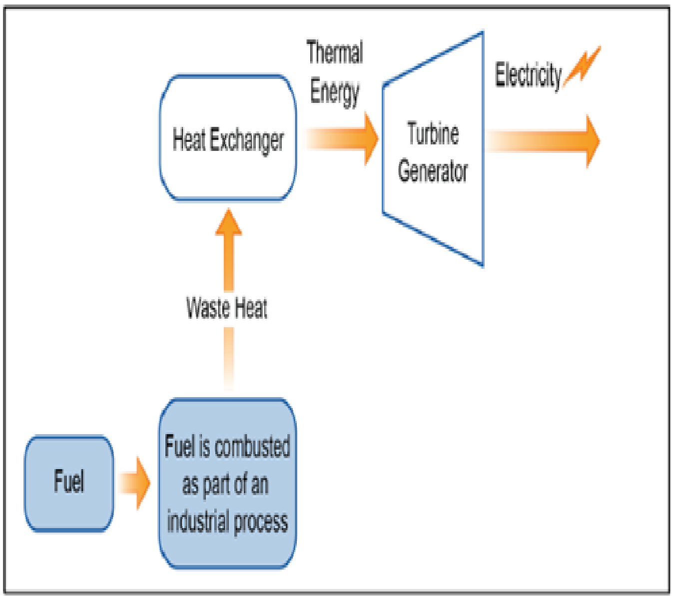


Fig.-1: Waste Heat to Power Diagram

1.1 Problem Statement

Turbine used in the waste heat and pressure recovery systems operates in the range of 25 to 60 bar and pressure energy in the range of 4 to 12 bar is wasted due to lack of efficient device to tap this energy and convert it to electricity.

1.2 Objective

Development of Tesla turbine at various input pressures in range of 4 to 12 bar.

2. LITERATURE REVIEW

In order to get the idea about the area of research it is essential to discuss the some of the previous study undertaken in this field. Review of the literature shows that different researchers and experts in the fields of condition monitoring of machines have discussed various aspects of the monitoring of machines. This study is an attempt to address the issues related to machines health condition and the problems associated with respective causes.

3. GAP ON LITERATURE REVIEW

From papers which studied for literature review, it's observed that there is no study did to find the solution of development of low pressure waste heat recovery system. So there is still scope for the research to develop the low pressure waste heat recovery turbine to generate the power. After careful study of literature it is found that low pressure and heat recovery systems are need of the time, but no significant work is seen in this regard. The project work aims at design development, analysis and performance evaluation of the low pressure recovery Tesla turbine were in low pressure from 4 bar to 8 bar can be effectively used to run a small generator thereby producing electricity. The project will develop in aluminum casting so as to withstand elevated temperatures 80 to 90 degrees which is normal exhaust range for many process equipment.

4. CONCEPT AND WORKING

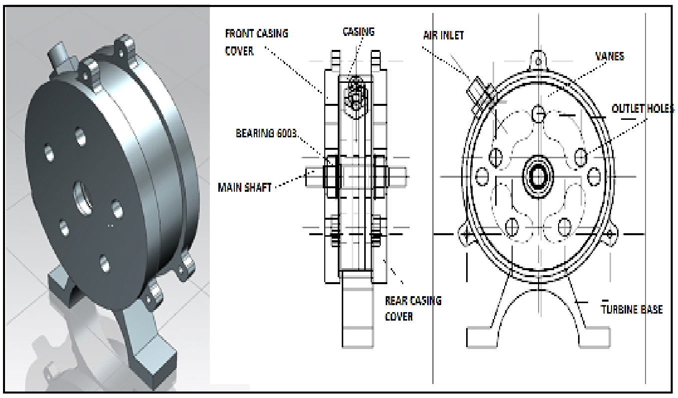


Fig.-2: Tesla Turbine

Turbine take low pressure input (2 bar to 8 bar) from the inlet and passed over three turbine disk such that the air entry is radial where as air exit is axial thereby creating a reaction that makes the turbine disk and there by the turbine shaft to rotate at high speed. The turbine shaft is further connected to the electric generator which produces electricity.

4. TESLA TURBINE EXPERIMENTAL SETUP FOR ELECTRICTY GENERATION

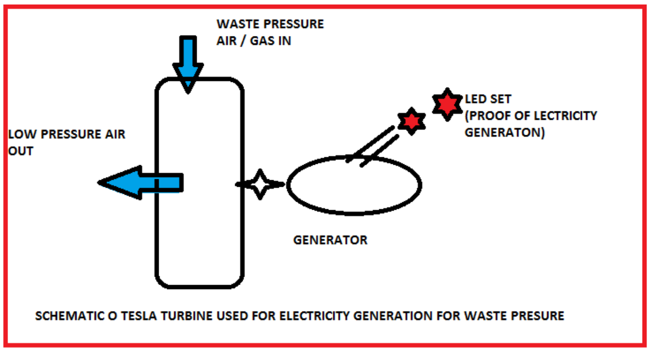


Fig.-3: Experimental setup for electricity generation

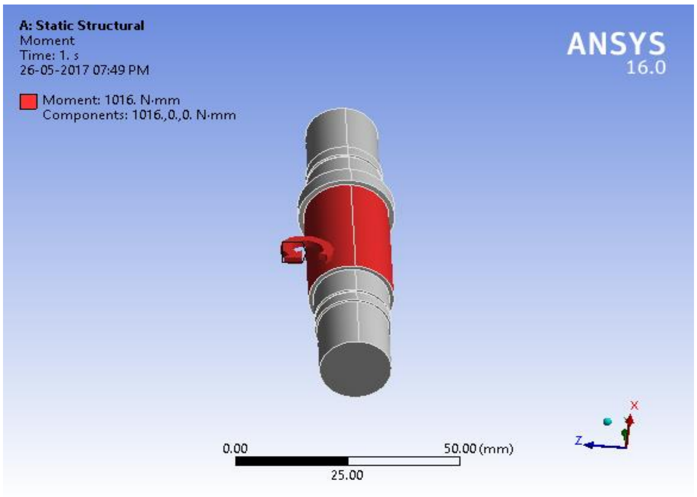
Here the experimental setup will be used to determine and prove the electricity generation form waste pressure. Here input parameter will be Pressure of inlet air and output parameter will be

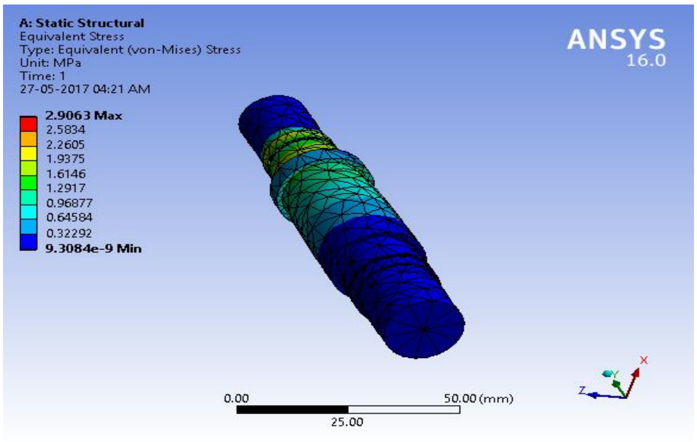
a. Voltage (V)
b. Current (I)
c. Output Power (P) = V x I

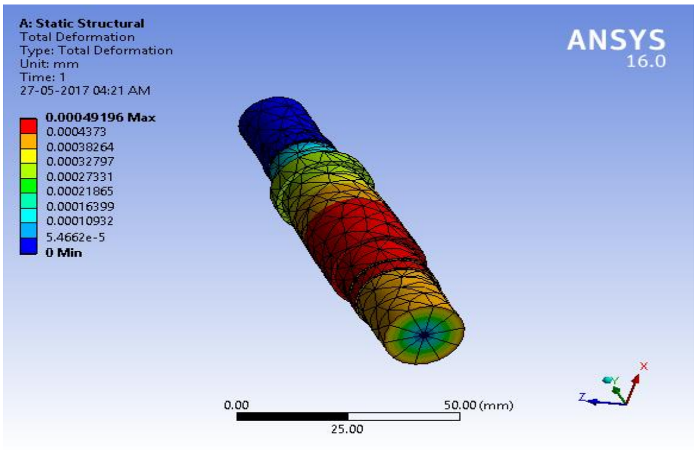
5. DESIGN AND ANALYSIS OF TURBINE PARTS

5.1 Main Shaft

Material: EN24
From design work, T_{design} = 1.16 N-m,
Allowable stress = 97.5 MPa
Maximum theoretical stress =1.26 MPa







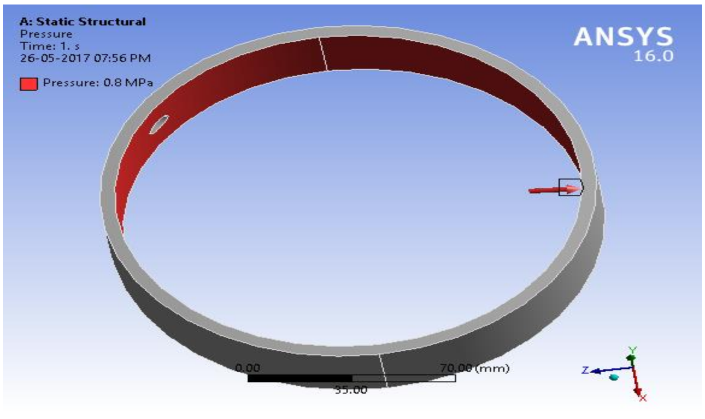
Result-

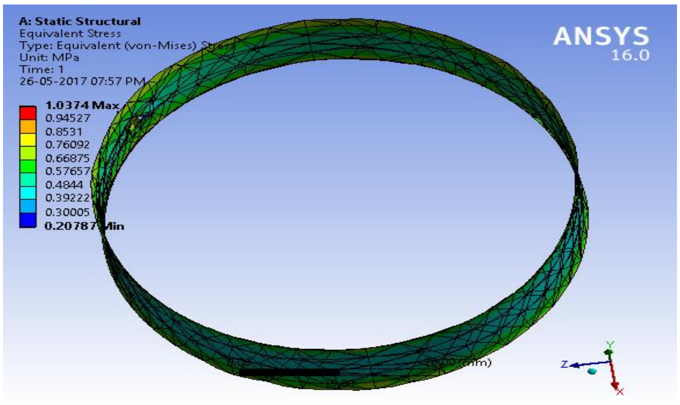
From analytical work, Maximum analytical stress= 3 MPa
Total deformation=5x10^{-4} mm

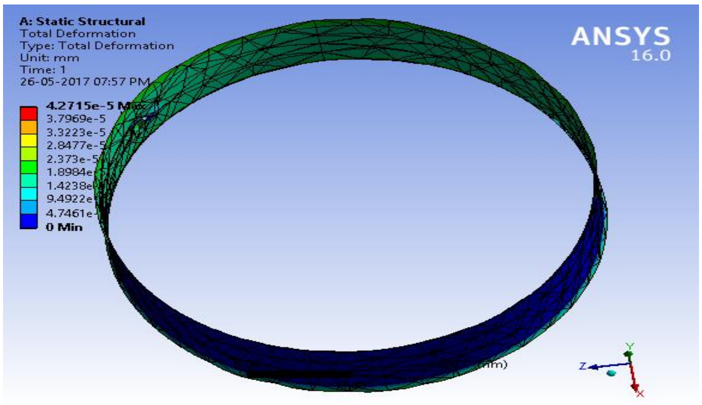
As the maximum theoretical stress and maximum analytical stress is well below allowable limit, the shaft is safe.

5.2 Casing

Material: Aluminum
Maximum theoretical stress = 0.08 MPa







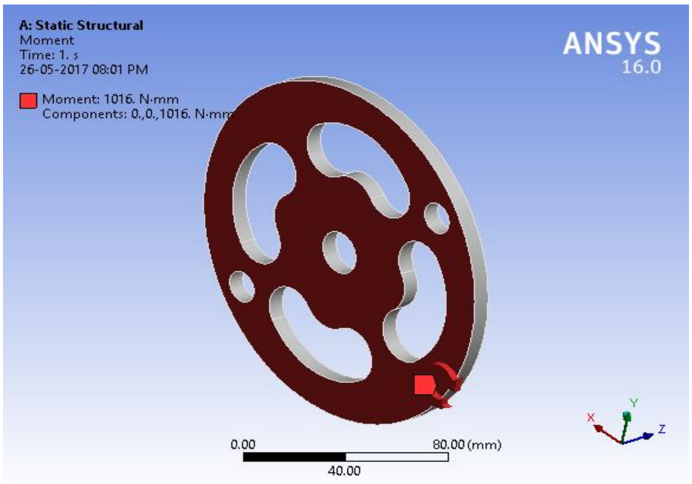
Result-

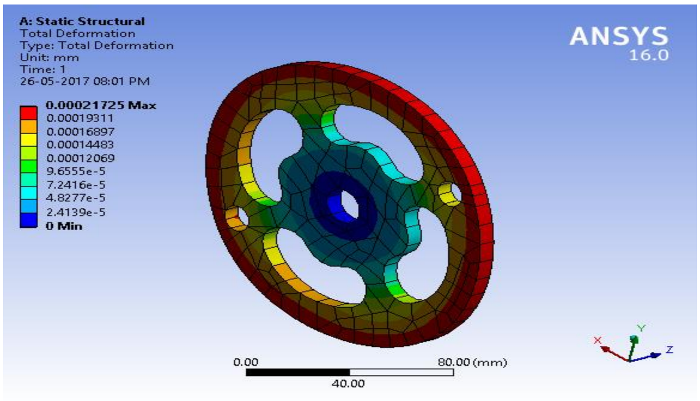
From analytical work, Maximum analytical stress=1 MPa
Total deformation=4x10-5 mm

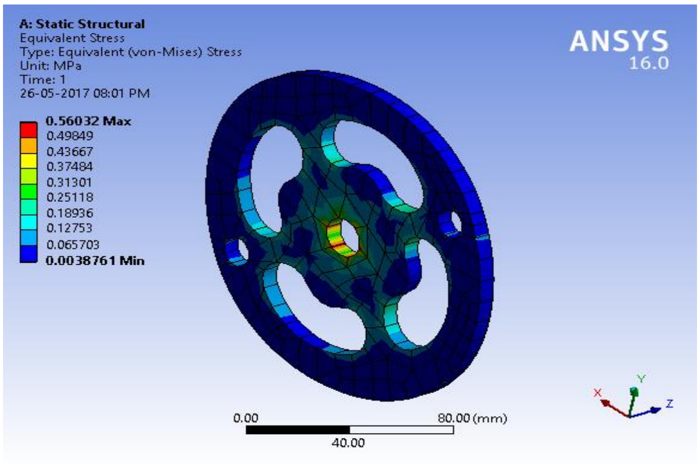
As the maximum theoretical stress and maximum analytical stress is well below allowable limit the casing is safe.

5.3 Turbine Disc

Material: Aluminum
From design work, T design = 1.016 N-m,
Maximum theoretical stress = 0.00136MPa







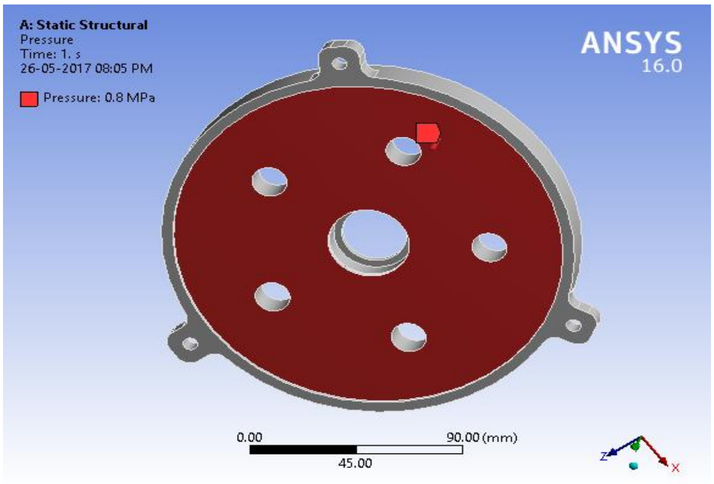
Result-

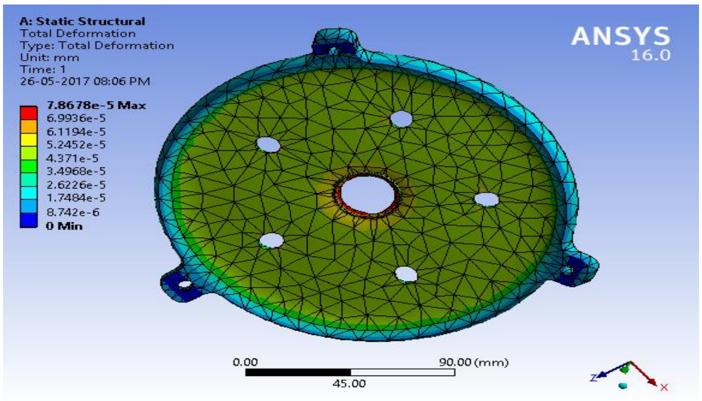
From analytical work, Maximum analytical stress= 0.5 MPa
Total deformation= 2x10-4 mm

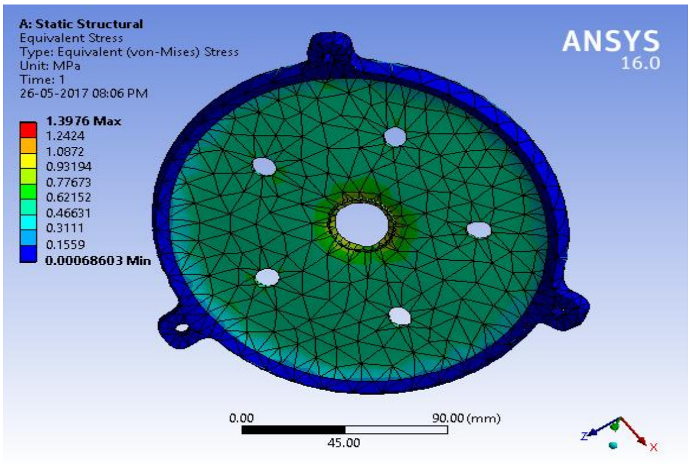
As the maximum theoretical stress and maximum analytical stress is well below allowable limit the turbine disk is safe.

5.4 Front Cover

Material = Aluminum
Maximum theoretical Stress = 0.08 MPa







Result-

From analytical work, Maximum analytical stress=1.5 MPa
Total deformation=8x10^{-5} mm

As the maximum theoretical stress and maximum analytical stress is well below allowable limit the front cover is safe.

Table-1: Maximum Analytical stress & Total Deformation

Parts	Von-Misses Stress (MPa)	Deformation (mm)
Main Shaft	3	5x10^{-4}
Casing	1	4x10^{-5}
Turbine Disc	0.5	2x10^{-4}
Front Cover	1.5	8X10^{-5}

6. TEST AND TRIAL ON TESLA TURBINE

Maximum operating pressure = 5 bar
Procedure of trial:

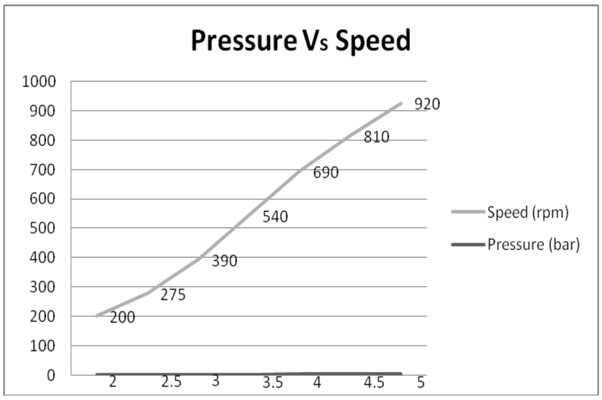
1. Start Pressure regulator
2. Maintain Pressure at 2 bar
3. Maintain flow rate at 10 cfm
4. Note Speed using tachometer
5. Note Voltage

6. Note Current
7. Change pressure setting and repeat set of readings

Table-2: Observations

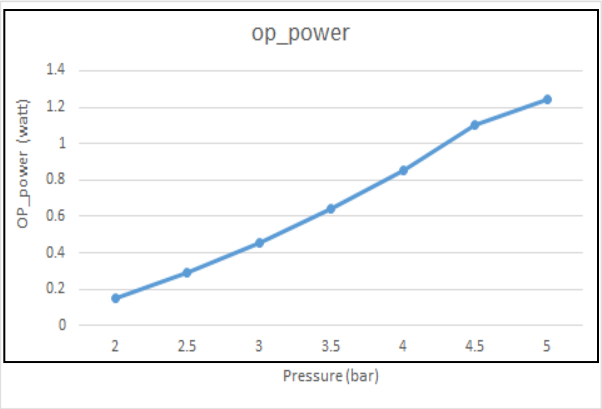
Pressure (bar)	Flow (cfm)	Speed (rpm)	Voltage (V)	Current (A)	O/P Power (watt)	Efficiency %
2	10.6	200	1.5	0.1	0.15	25
2.5	10.6	275	2.89	0.1	0.289	38.5
3	10.6	390	3.5	0.13	0.455	50.5
3.5	10.6	540	4.6	0.14	0.644	61.3
4	10.6	690	6.1	0.14	0.854	71.1
4.5	10.6	810	7.36	0.15	1.104	81.7
5	10.6	920	8.3	0.15	1.245	83

6.1Graph of Pressure v^s Speed –



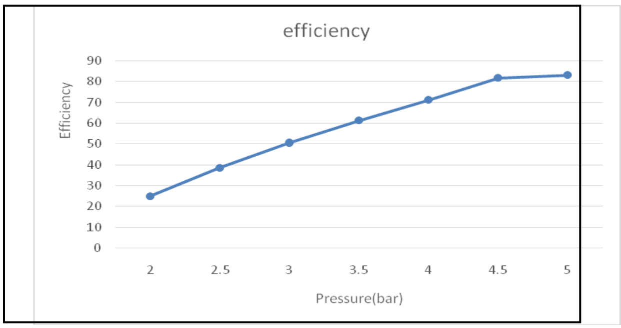
Result- Output speed increases with the increase in input pressure to the turbine

6.2Graph of Pressure v^s Output Power –



Result- Output power increases with the increase in input pressure to the turbine

6.3Graph of Pressure v^s Efficiency –



Result- Efficiency increases with the increase in input pressure to the turbine

7. RESULTS AND DISCUSSION

1. The design and analysis of Shaft shows that shaft is safe under given system of forces.
2. The design and analysis of Casing shows that casing is safe under given system of forces.
3. The design and analysis of Turbine disk shows that it is safe under given system of forces.
4. Output speed increases with the increase in input pressure to the turbine.
5. Output power increases with the increase in input pressure to the turbine.
6. Efficiency increases with the increase in input pressure to the turbine.

8. CONCLUSION

The project work aims performance evaluation of the low pressure recovery Tesla turbine where low pressure from 2 bar to 5 bar can be effectively used to run a small generator thereby producing electricity.

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