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Design and Structural Analysis of Turbine Blade and Analysis Design for Cooling Turbine Blade

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ABSTRACT :

Cooling of gas turbine blades is a major consideration because they are subjected to high temperature working conditions. Several methods have been suggested for the cooling of blades and one such technique is to have radial holes to pass high velocity cooling air along the blade span. The forced convection heat transfer from the blade to the cooling air will reduce the temperature of the blade to allowable limits. Finite element analysis is used in the present work to examine steady state thermal & structural performance for stainless steel. Four different models consisting of solid blade and blades with varying number of holes (7,8,9 & 10 holes) were analyzed in this project to find out the optimum number of cooling hole. It is observed that as the no. of holes increases the temperature distribution increase. The structural analysis is carried out after the thermal analysis in solid works. It is observed that blade with 10 holes has showing more stresses than the remaining blades in SOLID WORKS STIMULATION. Finally the blade with 9 holes has giving optimum performance for prescribed loading conditions with average temperature of 514.1K at the trailing edge and von misses stresses as 17.7 Mpa.

INTRODUCTION :

A turbine, from the Greek τύρβη, tyrbē, ("turbulance"), is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. A turbine is a turbomachine 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. Early turbine examples are windmills and waterwheels.

Gas, steam, and water turbines usually have a casing around the blades that contains and controls the working fluid. Credit for invention of the steam turbine is given both to the British engineer Sir Charles Parsons (1854–1931), for invention of the reaction turbine and to Swedish engineer Gustaf de Laval (1845–1913), for invention of the impulse turbine. Modern steam turbines frequently employ both reaction and impulse in the same unit, typically varying the degree of reaction and impulse from the blade root to its periphery.

The word "turbine" was coined in 1822 by the French mining engineer Claude Burdin from the Latin turbo, or vortex, in a memoir, "Des turbines hydrauliques ou machines rotatoires à grande vitesse", which he submitted to the Académie royale des sciences in Paris.[3]Benoit Fourneyron,

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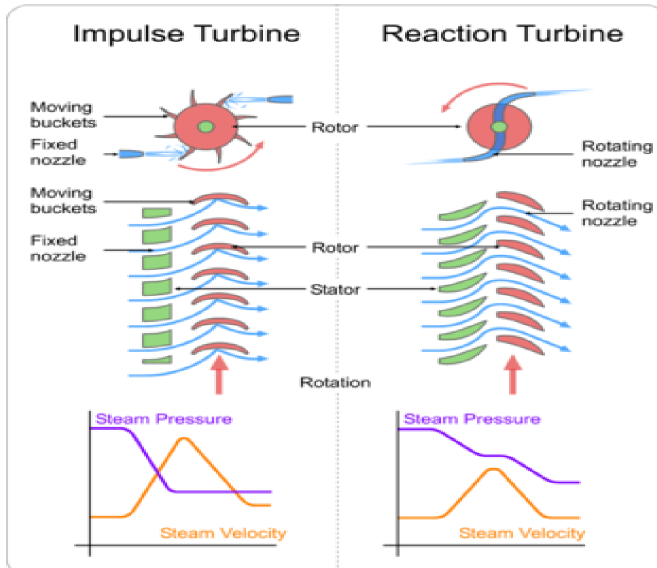
a former student of Claude Burdin, built the first practical water turbine.

OPERATION THEORY :

A working fluid contains potential energy (pressure head) and kinetic energy (velocity head). The fluid may be compressible orincompressible. Several physical principles are employed by turbines to collect this energy:

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 wheelsand 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 blading on the rotor. Newton's second law describes the transfer of energy for impulse 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 turbinesuse 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.

TYPES OF TURBINES :

- Steam turbines are used for the generation of electricity in thermal power plants, such as plants using coal, fuel oil or nuclear power. They were once used to directly drive mechanical devices such as ships' propellers (for example the *Turbinia*, the first turbine-powered steam launch) but most such applications now use reduction gears or an intermediate electrical step, where the turbine is used to generate electricity, which then powers an electric motor connected to the mechanical load. Turbo electric ship machinery was particularly popular in the period immediately before and during World War II, primarily due to a lack of sufficient gear-cutting facilities in US and UK shipyards. Gas turbines are sometimes referred to as turbine engines. Such engines usually feature an inlet, fan, compressor, combustor and nozzle (possibly other assemblies) in addition to one or more turbines.

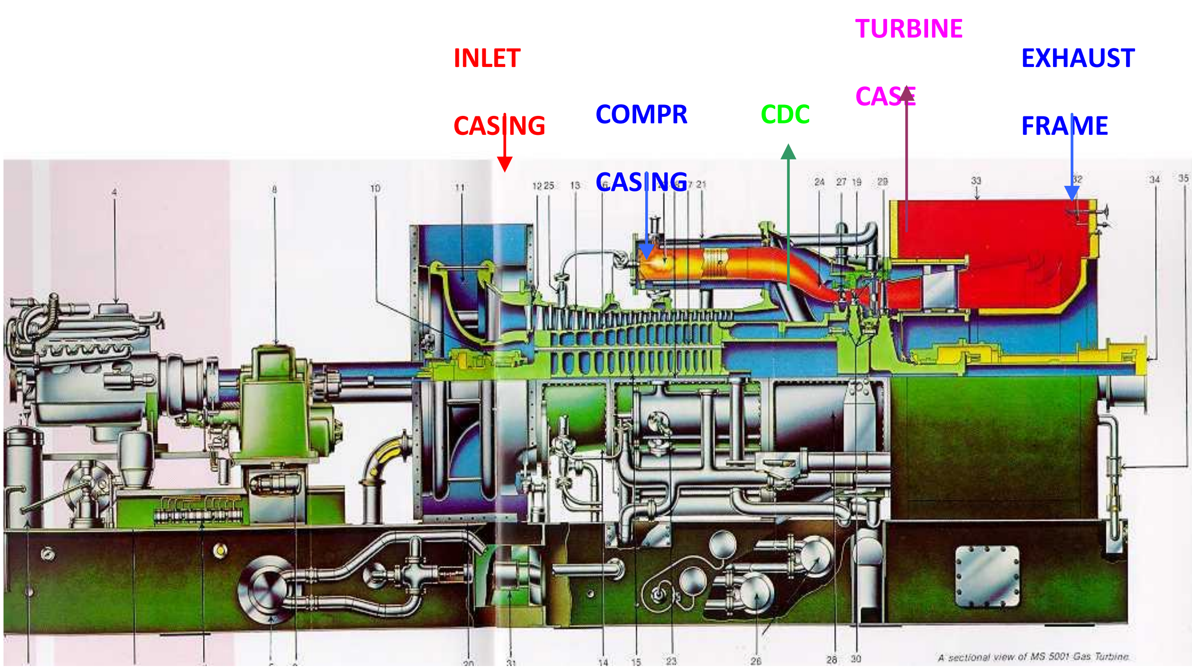
Water turbines

- Pelton turbine, a type of impulse water turbine.
- Francis turbine, a type of widely used water turbine.
- Kaplan turbine, a variation of the Francis Turbine.
- Turgo turbine, a modified form of the Pelton wheel.
- Cross-flow turbine, also known as Banki-Michell turbine, or Ossberger turbine.

Wind turbine. These normally operate as a single stage without nozzle and interstage guide vanes. An exception is the Éolienne Bollée, which has a stator and a rotor

Gas turbines in simple cycle mode

The gas turbine is the most versatile item of turbomachinery today.It can be used in several different modes in critical industries such as power generation, oil and gas ,process plants, aviation,as well domestic and smaller related industries.A gas turbine essentially brings together air that it compresses in its compressor module ,and fuel,that are then ignited. Resulting gases are expanded through a turbine. That turbine's shaft continues to rotate and drive the compressor which is on the same shaft, and operation continues. A separator starter unit is used to provide the first rotor motion, until the turbine's rotation is up to design speed and can keep the entire unit running. The compressor module, combustor module and turbine module connected by one or more shafts are collectively called the gas generator. The figure below illustrate a typical gas turbine sectionalview.



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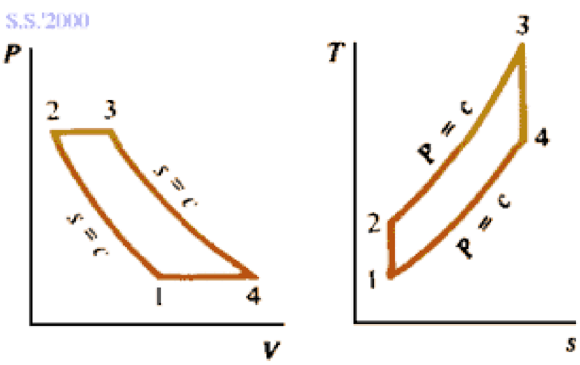
General

A single-shaft gas turbine , is mounted on a platform or base which supports the basic gas turbine unit. The various assemblies , systems and components that comprise the compressor, combustion and turbine sections of the gas turbine are described in the text which follows.

A. Detail Orientation

By definition ,the air inlet of the gas turbine is the forward end ,while the exhaust is the aft end. The forward and aft ends of each component are determined in like manner wuth respect to its orientation within the complete unit.The right and left sides of the turbine or of a particular component are



determined by standing forward and looking aft.

Fig. the basic gas turbine cycle [Brayton cycle]

APPLICATIONS OF GAS TURBINES

Direct drive and mechanical drive

With land-based industries, gas turbines can be used in either direct drive or mechanical drive application. With power generation, the gas turbine shaft is coupled to the generator shaft, either directly or via a gearbox " direct drive " application. A gearbox is necessary in applications where the manufacturer offers the package for both 60 and 50 cycle applications. The gear box will use roughly 2 percent of the power developed by the turbine in their cases.

Fig : 100MW simple cycle gas turbine plant

Power generation applications extend to offshore platform use. Minimizing weight is a major consideration for this service and the gas turbines used are generally " aeroderivatives ". For mechanical drive applications, the turbine module arrangement is different. In these cases, the combination of compressor module, combustor module and turbine module is termed the gas generator. Beyond the turbine end of the gas generator is a freely rotating turbine. It may be one or more stages. It is not mechanically connected to the gas generator, but instead is mechanically coupled, sometimes via a gearbox, to the equipment it is driving.

Fig : Gas turbine in offshore service
Fig : Marine gas turbine for Indian navy

CONCLUSIONS

In this project using finite element analysis as a tool ,the thermal and structural analysis is carried out sequentially. The blade with different no. of holes 7, 8, 9and 10 were used for analysis.

- The gas turbine blade is modeled in a 3D cad tool called **Solidworks 2014** by using extrude feature.
- Then gas turbine blade with different holes such as 7,8,9 and 10 has been modeled on the blade span.
- The blade with different no. of holes 7, 8, 9and 10 were used for thermal analysis in solidworks simulation tool. It is observed that as the no. of holes increases the temperature distribution increase.
- The structural analysis is carried out after the thermal analysis in **SOLID WORKS SIMULATION TOOL.** It is observed that blade with 10 holes has showing more stresses than the remaining blades.
- Finally the blade with 9 holes has giving optimum performance for prescribed loading conditions with average temperature of 514.1K at the trailing edge and von misses stresses as 17.7 Mpa.

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