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THERMAL ANALYSIS OF STEAM TURBINE

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Abstract : Micro turbines are becoming widely used for combined power generation and heat applications. Their size varies from small scale units like models crafts to heavy supply like power supply to hundreds of households. Micro turbines have many advantages over piston generators such as low emissions less moving parts, accepts commercial fuels. Steam turbine cycle and operation of micro turbine was studied and reported. Brief description on CAD software and CATIA studied and reported. Different parts (Inlet. Storage, Nozzle, Rotor , coupling ,outlet ,clip ,housing) of turbine are designed with the help of CATIA (Computer Aided Three Dimensional Interactive Analysis) software. Then they were assembled to a single unit and coupled to a generator to produce power. The turbine is of Axial input and axial output type. Ansys is used for thermal analysis of a steam turbine and those results are extracted and following values are shown by applying known temperature when it is in working condition.

Key words: Steam turbine, CATIA, Rapid Prototype, parts of turbine, nozzle, rotor.

I.INTRODUCTION

Work on the small Steam bearing turbo expander commenced in the early fifties by Sixsmith at Reading University on a machine for a small air liquefaction plant. In 1958, the United Kingdom Atomic Energy Authority developed a radial inward flow turbine for a nitrogen production plant. During 1958 to 1961 Stratos Division of Fairchild Aircraft Co. built blower loaded turbo expanders, mostly for air separation service. Voth et. developed a high speed turbine expander as a part of a cold moderator refrigerator for the Argonne National Laboratory (ANL). The first commercial turbine using helium was operated in 1964 in a refrigerator that produced 73 W at 3 K for the Rutherford helium bubble chamber. A high speed turbo alternator was developed by General Electric Company, New York in 1968, which ran on a practical Steam bearing system capable of operating at cryogenic temperature with low loss.

Design of turboexpander for cryogenic applications‖ by Subrata Kr. Ghosh , N. Seshaiah, R. K. Sahoo, S. K. Sarangi focuses on design and development of turbo expander.The paper briefly discuses the design methodology and the fabrication drawings for the whole system, which includes the turbine wheel, nozzle, diffuser, shaft, brake compressor, two types of bearing, and appropriate housing. With this method, it is possible to design a turbo expander for any other fluid since the fluid properties are properly taken care of in the relevant equations of the design procedure.

Yang et. al developed a two stage miniature expansion turbine made for an 1.5 L/hr helium liquefier at the Cryogenic Engineering Laboratory of the Chinese Academy of Sciences. The turbines rotated at more than 500,000 rpm. The design of a small, high speed turbo expander was taken up by the National Bureau of Standards (NBS) USA. The first expander operated at 600,000 rpm in externally pressurized Steam bearings. The turbo expander developed by Kate et. Al was with variable flow capacity mechanism (an adjustable turbine), which had the capacity of controlling the refrigerating power by using the variable nozzle vane height.

India has been lagging behind the rest of the world in this field of research and development. Still, significant progress has been made during the past two decades. In CMERI Durgapur, Jadeja developed an inward flow radial turbine supported on Steam bearings for cryogenic plants. The device gave stable rotation at about 40,000 rpm. The programme was, however, discontinued before any significant progress could be achieved. Another programme at IIT Kharagpur developed a turbo expander unit by using aerostatic thrust and journal bearings which had a working speed up to 80,000 rpm. Recently Cryogenic Technology Division, BARC developed Helium refrigerator capable of producing 1 kW at 20K temperature.

RAPID PROTOTYPING:

Rapid prototyping is a revolutionary and powerful technology with wide range of applications. The process of prototyping involves quick building up of a prototype or working model for the purpose of testing the various design features, ideas, concepts, functionality, output and performance. The user is able to give immediate feedback regarding the prototype and its performance. Rapid prototyping is essential part of the process of system designing and it is believed to be quite beneficial as far as reduction of project cost and risk are concerned.

The first rapid prototyping techniques became accessible in the later eighties and they were used for production of prototype and model parts. The history of rapid prototyping can be traced to the late sixties, when an engineering professor, Herbert Voelcker, questioned himself about the possibilities of doing interesting things with the computer controlled and automatic machine tools. These machine tools had just started to appear on the factory floors then. Voelcker was trying to find a way in which the automated machine tools could be programmed by using the output of a design program of a computer.

In seventies Voelcker developed the basic tools of mathematics that clearly described the three dimensional aspects and resulted in the earliest theories of algorithmic and mathematical theories for solid modelling. These theories form the basis of modern computer programs that are used for designing almost all things mechanical, ranging from the smallest toy car to the tallest skyscraper. Volecker's theories changed the designing methods in the seventies, but, the old methods for designing were still very much in use. The old method involved either a machinist or machine tool controlled by a computer. The metal hunk was cut away and the needed part remained as per requirements.

II. STEAM TURBINE

A Steam turbine is a rotating engine that extracts energy from a flow of combustion Steams that result from the ignition of compressed air and a fuel (either a Steam or liquid, most commonly natural Steam). It has an upstream compressor module coupled to a downstream turbine module, and a combustion chamber(s) module (with igniter[s]) in between. Energy is added to the Steam stream in the combustor, where air is mixed with fuel and ignited. Combustion increases the temperature, velocity, and volume of the Steam flow. This is directed through a nozzle over the turbine's blades, spinning the turbine and powering the compressor Energy is extracted in the form of shaft power, compressed air, and thrust, in any combination, and used to power aircraft, trains, ships, generators, and even tanks.

A **steam turbine** is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. Its modern manifestation was invented by Sir Charles Parsons in 1884.

Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator – about 90% of all electricity generation in the United States (1996) is by use of steam turbines. The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency through the use of multiple stages in the expansion of the steam, which results in a closer approach to the most efficient reversible process.

Types of Steam Turbine

There are different types of Steam turbines. Some of them are named below:

1. Aero derivatives and jet engines
2. Amateur Steam turbines
3. Industrial Steam turbines for electrical generation
4. Radial Steam turbines
5. Scale jet engines
6. Micro turbines

The main focus of this paper is the design aspects of steam turbine.

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Steam turbines are made in a variety of sizes ranging from small <0.75 kW (1< hp) units (rare) used as mechanical drives for pumps, compressors and other shaft driven equipment, to 1,500,000 kW (2,000,000 hp) turbines used to generate electricity. There are several classifications for modern steam turbines.

Steam supply and exhaust conditions

These types include condensing, non-condensing, reheat, extraction and induction.

Condensing turbines are most commonly found in electrical power plants. These turbines exhaust steam in a partially condensed state, typically of a quality near 90%, at a pressure well below atmospheric to a condenser.

Non-condensing or back pressure turbines are most widely used for process steam applications. The exhaust pressure is controlled by a regulating valve to suit the needs of the process steam pressure. These are commonly found at refineries, district heating units, pulp and paper plants, and desalination facilities where large amounts of low pressure process steam are available. Reheat turbines are also used almost exclusively in electrical power plants. In a reheat turbine, steam flow exits from a high pressure section of the turbine and is returned to the boiler where additional superheat is added. The steam then goes back into an intermediate pressure section of the turbine and continues its expansion.

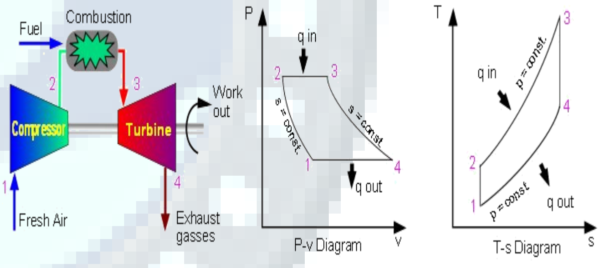
Extracting type turbines are common in all applications. In an extracting type turbine, steam is released from various stages of the turbine, and used for industrial process needs or sent to boiler feed water heaters to improve overall cycle efficiency. Extraction flows may be controlled with a valve, or left uncontrolled.

Casing or shaft arrangements

These arrangements include single casing, tandem compound and cross compound turbines. Single casing units are the most basic style where a single casing and shaft are coupled to a generator. Tandem compound are used where two or more casings are directly coupled together to drive a single generator. A cross compound turbine arrangement features two or more shafts not in line driving two or more generators that often operate at different speeds. A cross compound turbine is typically used for many large applications.

STEAM TURBINE CYCLE

The simplest Steam turbine follows the Brayton cycle .Closed cycle (i.e., the working fluid is not released to the atmosphere), air is compressed isentropically, combustion occurs at constant pressure, and expansion over the turbine occurs isentropically back to the starting pressure. As with all heat engine cycles, higher combustion temperature (the common industry reference is turbine inlet temperature) means greater efficiency. The limiting factor is the ability of the steel, ceramic, or other materials that make up the engine to withstand heat and pressure. Considerable design/manufacturing engineering goes into keeping the turbine parts cool. Most turbines also try to recover exhaust heat, which otherwise is wasted energy.



Idealized Brayton Cycle

Recuperators are heat exchangers that pass exhaust heat to the compressed air, prior to combustion. Combined-cycle designs pass waste heat to steam turbine systems, and combined heat and power (i.e., cogeneration) uses waste heat for hot water production. Mechanically, Steam turbines can be considerably less complex than internal combustion piston engines. Simple turbines might have one moving part: the shaft/compressor/ turbine/alternator-rotor assembly, not counting the fuel system. More sophisticated turbines may have multiple shafts (spools), hundreds of turbine blades, movable stator blades, and a vast system of complex piping, combustors, and heat exchangers.
The largest Steam turbines operate at 3000 (50 hertz [Hz], European and Asian power supply) or 3600 (60 Hz, U.S. power supply) RPM to match the AC power grid. They require their own building and several more to house support and auxiliary equipment, such as cooling towers. Smaller turbines, with fewer compressor/turbine stages, spin faster. Jet engines operate around 10,000 RPM and micro turbines around

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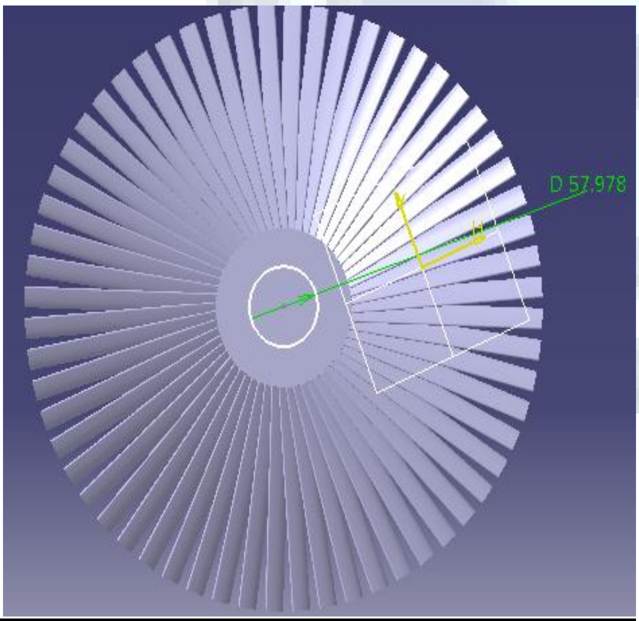
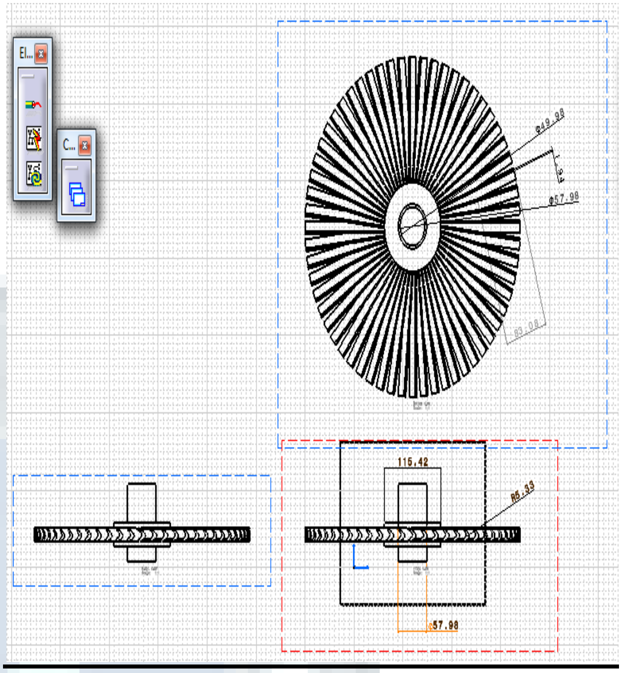
100,000 RPM. Thrust bearings and journal bearings are a critical part of the design. Traditionally, they have been hydrodynamic oil bearings or oil cooled ball bearings.

III. DESIGN OF DIFFERENT PARTS MICRO TURBINE

The two main parts of Micro turbine are the rotor and the nozzle. Rest of the parts like inlet storage, coupling, clip and housing can be made by easy machining like Turning in lathe, milling, drilling etc..The two main intrinsic parts like rotor and nozzle out structure can be done by turning in lathe. Rest the slotting and all can be done by using die sinking of EDM. For machining they are clamped in the rotary head of the EDM. A prismatic copper electrode having a cross section of Air channels is used as the electrode. The ele ctrode as described is produced by wire cut EDM. The major problem of the electrode is the wear the wear rate is not same in all direction and in particular time so at a fixed we ave to cut the electrode by a small amount to increase the accuracy.



Sketch the circle



Drafting of steam turbine

IV. EXPERIMENTAL RESULTS

The fabrication processes in a rapid prototyping can basically be divided into three categories which are additive, subtractive and formative. In the additive or incremental processes, the object is divided into thin layers with distinct shape and then they are stacked one upon other to produce the model. The shaping method of each layer varies for different processes. Most of the commercial Rapid Prototyping systems belong to this category. Such processes can also be called layered manufacturing (LM) or solid freeform fabrication (SFF). Layer by layer construction method in LM greatly simplifies the processes and enables their automation. An important feature in LM is the raw material, which can be either one-dimensional (e.g. liquid and particles) or two-dimensional (e.g. paper sheet) stocks. Whereas in case of subtractive RP processes three-dimensional raw material stocks are used. Stereo-lithography apparatus (SLA), three dimensional printing, selective laser sintering (SLS), contour crafting (CC), fused deposition modelling (FDM), etc. are few examples of LM. Subtractive or material removal (MR) processes uses the method of cutting of excessive material from the raw material stocks. There are not as many subtractive prototyping processes as that of additive processes. A commercially available system is DeskProto, which is a three-dimensional computer aided manufacture

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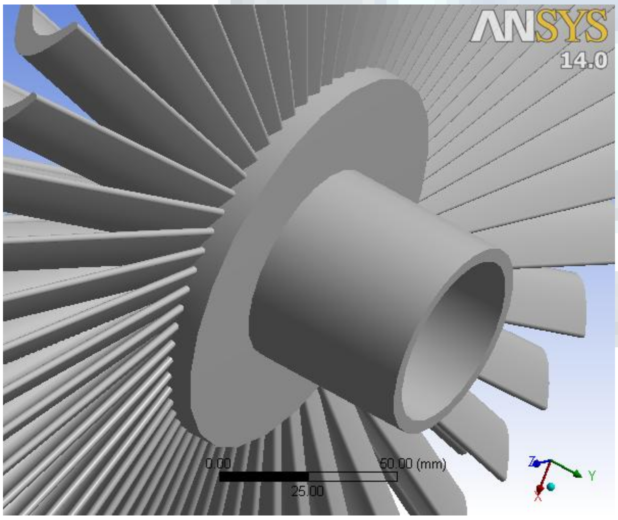
(CAM) software package for Rapid Prototyping and manufacturing. As in case of pure subtractive RP processes the model is made from a single stock, fully compact parts of the same material as per actually required for end use is possible. The other advantages like accuracy of the part dimensions and better surface quality can be achieved by the subtractive machining approach. However if we compare geometric complexity the MR processes are limited than the LM processes. Different types of cutting methods used are computer numerical control (CNC) milling, water-jet cutting, laser cutting etc. In formative or deforming processes, a part is shaped by the deforming ability of materials. At present there is no commercial forming-based RP system in the market. In case of LM process the geometric complexity of objects is relaxed upto a significant extent due to the layer by layer manufacturing. Some features which are difficult to obtain using MR process can be achieved using LM process. Raw material is one of the limitations in case of LM process. Both the LM and MR processes can be integrated to obtain more benefits. This integration creates a hybrid RP system which can produce better surface quality without tempering the manufacturability in case of complex features.

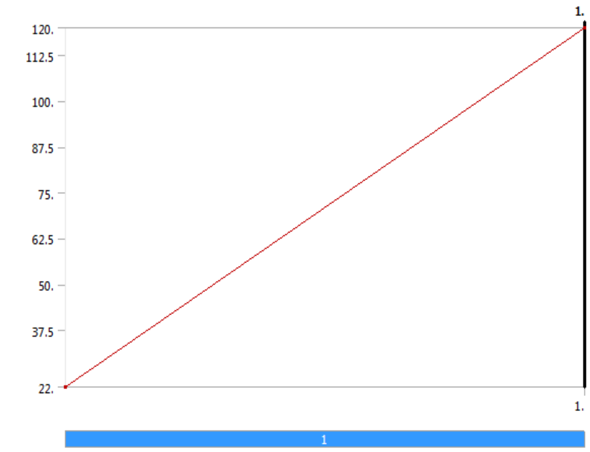


Unit System	**Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius**
Angle	**Degrees**
Rotational Velocity	**rad/s**
Temperature	**Celsius**

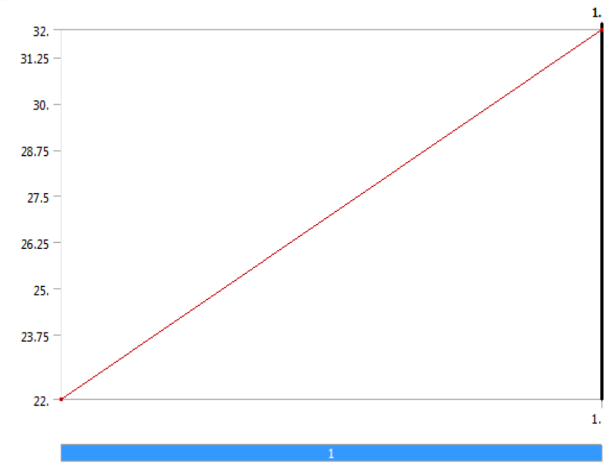
Model (A4) > Steady-State Thermal (A5) > Loads

Object Name	*Temperature*	*Radiation*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	
Definition		
Type	Temperature	Radiation
Magnitude	120. °C (ramped)	
Suppressed	No	
Correlation		To Ambient
Emissivity		1. (step applied)
Ambient Temperature		32. °C (ramped)

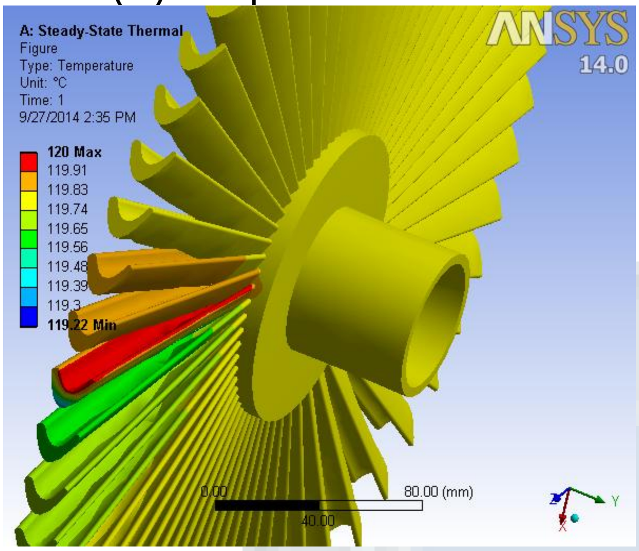
Model (A4) > Steady-State Thermal (A5) > Temperature



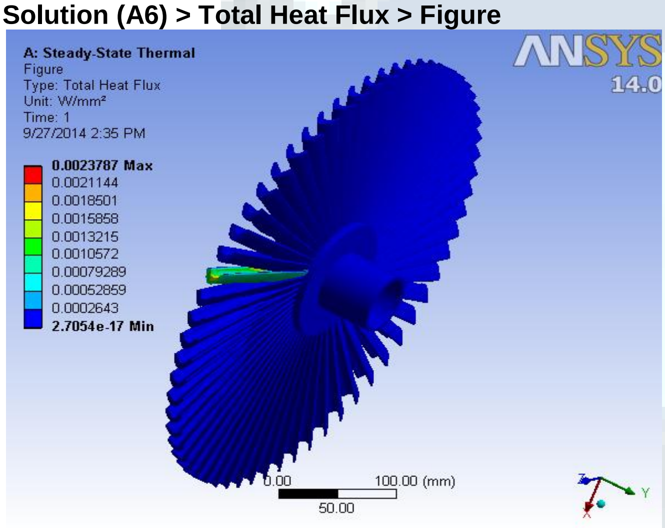
Model (A4) > Steady-State Thermal (A5) > Radiation



Model (A4) > Steady-State Thermal (A5) > Solution (A6) > Temperature >



Model (A4) > Steady-State Thermal (A5) > Solution (A6) > Total Heat Flux > Figure



V.CONCLUSION

The work presented in the report is an attempt at designing a micro turbine of a given dimension. Extensive literature review was carried out to study the various aspects and applications of micro turbines. A suitable design procedure was chosen from the available methods to design different parts of micro turbine. CATIA is used extensively for making parts with diff types of operations. Then all the parts are assembled for making a complete turbine in CATIA Assembly section. Before the model is sent to rapid prototyping, it is analysed by using ANSYS and its thermal properties are generated. Those results are taken into account and following changes are done if required. Then they are send for rapid prototyping .

Micro turbines are relatively new in the market and are attracting wide attention due to their varied applications. Development of a sophisticated engineering product like micro turbine is a continuous process. A lot of work is yet to be done on the design aspects before the micro turbine can be readied for market consumption. The design procedure has to take into various other parameters to make it suitable for practical applications. Also, manufacturing of such complex shapes of minute size is another ongoing research work. Further research into the design and manufacture process would result in production of even better micro turbines.

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