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Static Model And Analysis of Micro Gas Turbine Using Autodesk Inventor And Autodesk Nastran Software

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Abstract : *In this project development of Micro gas turbine with three different materials are tested and designed using Autodesk inventor and Autodesk nestron software. Generally micro gas turbine is a size so they are compactable and easy maintains compared to large turbines. in this project three different materials like Aluminium and Stainless steel and Tiatanium are used for turbine blade .the solid model is created using Auto desk inventor software and analysis is is done by using Autodesk nestron Software. the micro gas turbine are few rotating parts so the frictional losses and pollution is less compared to other power generating elements. the micro gas turbine are quicker to respond to output power requirements and also more efficient than other machine elements. Micro turbine being small in size as compared to large turbine, such that less weight which reflects on pressure ratio, low cost and easy maintenance.*

Keywords : *Micro gas turbine rotor, Stress analysis, Strain analysis*

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I. Introduction

A gas turbine, also called a combustion turbine, is a type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in between.

The basic operation of the gas turbine is similar to that of the steam power plant except that air is used instead of water. Fresh atmospheric air flows through a compressor that brings it to higher pressure. Energy is then added by spraying fuel into the air and igniting it so the combustion generates a high-temperature flow. This high-temperature high-pressure gas enters a turbine, where it expands down to the exhaust pressure, producing a shaft work output in the process. The turbine shaft work is used to drive the compressor and other devices such as an electric generator that may be coupled to the shaft. The energy that is not used for shaft work comes out in the exhaust gases, so these have either a high temperature or a high velocity. The purpose of the gas turbine determines the design so that the most desirable energy form is maximized. Gas turbines are used to power aircraft, trains, ships, electrical generators, and tanks

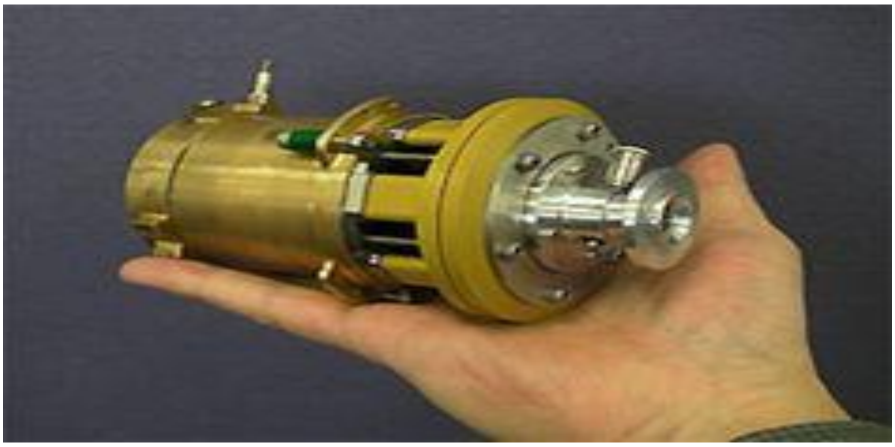


Figure 1: Micro gas turbine

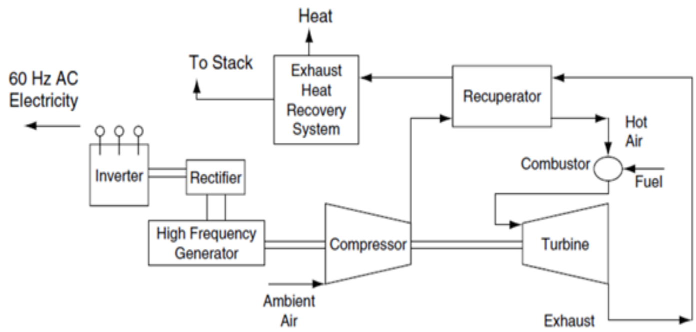
Types of Micro turbine
Micro turbines are classified by the physical arrangement of the component parts:
1. Single shaft or two-shaft,

2. Simple cycle, or recuperated,
3. Inter-cooled, and reheat. The machines generally rotate over 50,000 rpm. The bearing selection—oil or air—is dependent on usage. A single shaft micro turbine with high rotating speeds of 90,000 to 120,000 revolutions per minute is the more common design, as it is simpler and less expensive to build. Conversely, the split shaft is necessary for machine drive applications, which does not require an inverter to change the frequency of the AC power.

Types of Micro turbine
Basic Parts of Micro turbine
1. Compressor
2. Turbine
3. Recuperator
4. Combustor
5. Controller
6. Generator
7. Bearing

4.4 Advantages
Micro turbine systems have many advantages over reciprocating engine generators, such as higher power density (with respect to footprint and weight), extremely low emissions and few, or just one, moving part. Those
designed with foil bearings and air-cooling operate without oil, coolants or other hazardous materials. Micro turbines also have the advantage of having the majority of their waste heat contained in their relatively high temperature exhaust, whereas the waste heat of reciprocating engines is split between its exhaust and cooling system. However, reciprocating engine generators are quicker to respond to changes in output power requirement and are usually slightly more efficient, although the efficiency of micro turbines is increasing. Micro turbines also lose more efficiency at low power levels than reciprocating engines. Micro turbines offer several potential advantages compared to other technologies for small-scale power generation, including: a small number of moving parts, compact size, lightweight, greater efficiency, lower emissions, lower electricity costs, and opportunities to utilize waste fuels. markets such as compression and air conditioning.

Applications
Gas Turbine Cycle :
Micro turbines are used in distributed power and combined heat and power applications. With recent advances in electronic, micro- processor based, control systems these units can interface with the commercial power grid and can operate ―unattended



Microturbine based combined heat and power system

Figure 2 Microturbine based combined heat and power system

The simplest gas 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. movable stator blades, and a vast system of complex piping, combustors, and heat exchangers.

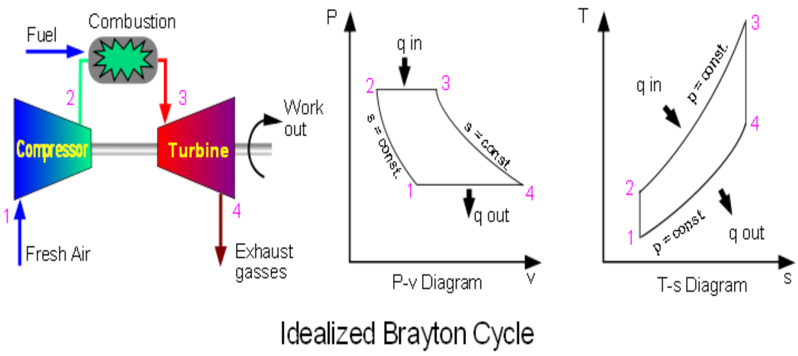


Figure 3: Idealized Brayton Cycle

II. Literature Review

The micro gas turbine is a widely used element in air driers and Refrigerators and there is a wide scope for improving the performance of the Turbine by changing several parameters. Basic idea from the book 'Design of micro turbine For Energy Scavenging from Gas Turbine by Amanda NASA[4] gives the brief interdiction about the Micro gas turbine the parts and working of gas turbine. 'Development of Mixed Flow compressor Impeller for micro gas Turbine Applications by the Olaf Herbert Ferdinand diener[1] In this details the development of a mixed-flow compressor impeller to be used in a micro gas turbine (MGT) delivering 600 N thrust. Today's un manned aerial vehicles (UAVs) demand high thrust-to-weight ratios and low engine frontal area. This combination may be achieved using mixed-flow compressors. The initial mixed-flow compressor impeller design was obtained using a 1-dimensional turbo machinery layout tool. A multi-point optimization of the impeller aerodynamic performance was completed. Thereafter a mechanical optimization was conducted to reduce mechanical stresses in the impeller.

In the 3D Modeling &Analysis Of micro gas Turbine Compressor blade by Ajin Elias alex and Ndeeva M[2] they done Micro turbine being small in size as compared to large turbine, such that less weight which reflects on pressure ratio, low cost and easy maintenance. Design and analyze of the micro turbine compressor blade is carried out in this thesis. With different material and rotational speed, compressor blade of the micro turbine is analyzed. Based on the given micro turbine output power, the dimension sand physical properties of the compressor blade were calculated. Titanium, Aluminium and Stainless steel alloys, this materials effect on compressor blade are found out by carrying stress and modal analysis.. The variation of rotational speed is a representation of various operating conditions, depending on the required output. By analysis software ANSYS 12, stress and modal analysis are done.

In the Turbine blade design of micro gas turbine by Bhagwat yedla , sanchit nawal and shereehari muralis[6] The introduction of small drones, missiles and small, made micro gas turbines fairly ubiquitous The project refers to the design of a micro gas turbine blade. Micro gas turbines are smaller versions of Jet Engines typical used to propel aircrafts of medium to high sizes and capacity. The Blade is theoretically designed and further rendered in Solid works 2014. CFD analysis has been carried out using ANSYS Fluent and ANSYS ICEM CFX, meshing done by ANSYS Mesh and results shown by CFX Post.

III. Materials

1.Aluminium
2.Stainless steel
3.Titanium

Material ID	**E**	**G**	**NU**	**RHO**	**ALPHA**	**T-REF**
Aluminium:	6.89E+04	2.586E+04	0.33	2.7E-09	2.4E-05	0.0

Material ID	**E**	**G**	**NU**	**RHO**	**ALPHA**	**T-REF**
Stainless steel:	1.93E+05	8.6E+04	0.3	8.E-09	1.E-05	0.0

Material ID	**E**	**G**	**NU**	**RHO**	**ALPHA**	**T-REF**
Titanium	1.028E+05	4.4E+04	0.361	4.51E-09	9.E-06	0.0

NOMICULATURE
E Young's modules
G shear modulus or modulus of rigidity

NU Poisson's ratio
RHO Resistivity
ALPHA Thermal expansion coefficient
T-REF Reference temperature

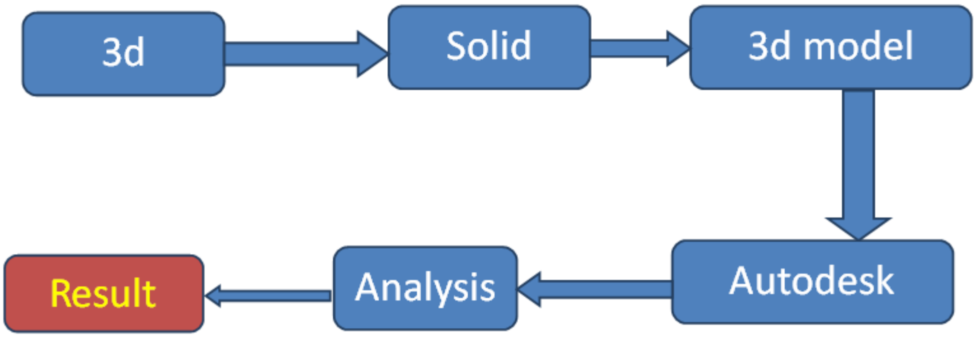
IV. Objective Of Study

The objective oft his study is to model a micro turbine rotor blade and conduct stress analysis as well as strain analysis based on force acting on blade. Here the force is in the form of pressure (M.Pa).

V. Geometrical Modeling

Solid works is used for the modeling purpose. This are the geometric parameter used for modeling. The report documents design and analysis using Autodesk Nastran engineering simulation software. A linear static analysis was performed using the finite element model.

A linear static analysis was performed using the Autodesk Nastran Version 10.3.0.716 finite element solver on the rotor structure. The finite element model contained mainly elements and consisted of 26190 degrees of freedom.1 loading condition was analyzed.



VI. Autodesk Inventor

Autodesk inventor developed by U.S. based software company Autodesk, is a computer-aided design application for creating 3D digital prototypes used in the design, visualization and simulation of products. It uses shape Manager, their proprietary geometric modeling kernel. Autodesk Inventor competes directly with Solid Works and Solid Edge.

Autodesk introduced the newest version of its desktop 3D CAD product, Autodesk Inventor 2016, which provides a trio of modeling tools: parametric, direct editing and freeform design tools. Inventor 2016 also enables users to associatively connect their Inventor data to non-native CAD formats so their electrical and mechanical data can be integrated into one single design environment.

Turbine Inlet:

1. Inlet hollow cylinder = 12 mm dia.
2. Length = 10.265 mm.
3. Outlet Diameter = 13.8 mm
4. Length = 6.4 mm
5. Octagonal diameter = 18..3 mm
6. Length = 4.42 mm

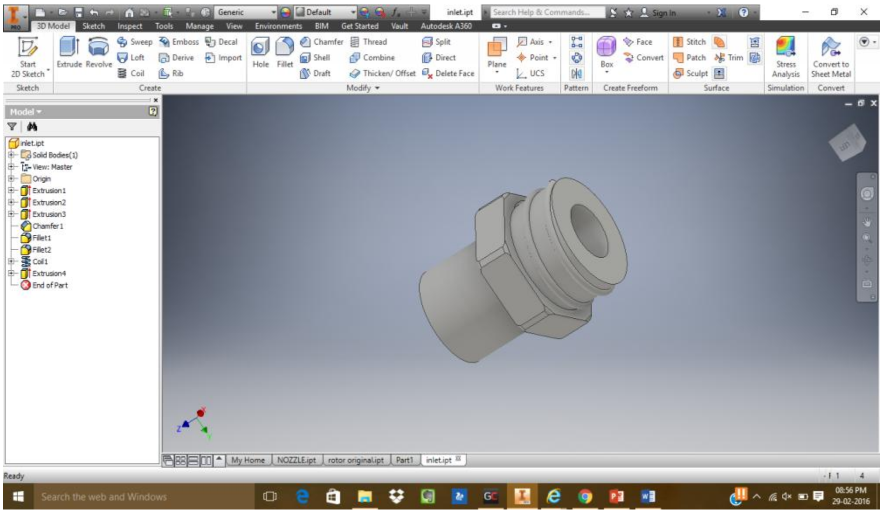


Figure 4 INLET

Storage:
This is basically a hollow cylinder which used as a temporary storage of hot gases .It lies between the Inlet and the nozzle.
Its Outer diameter = 14 mm
Inlet diameter = 12 mm
Length = 7 mm

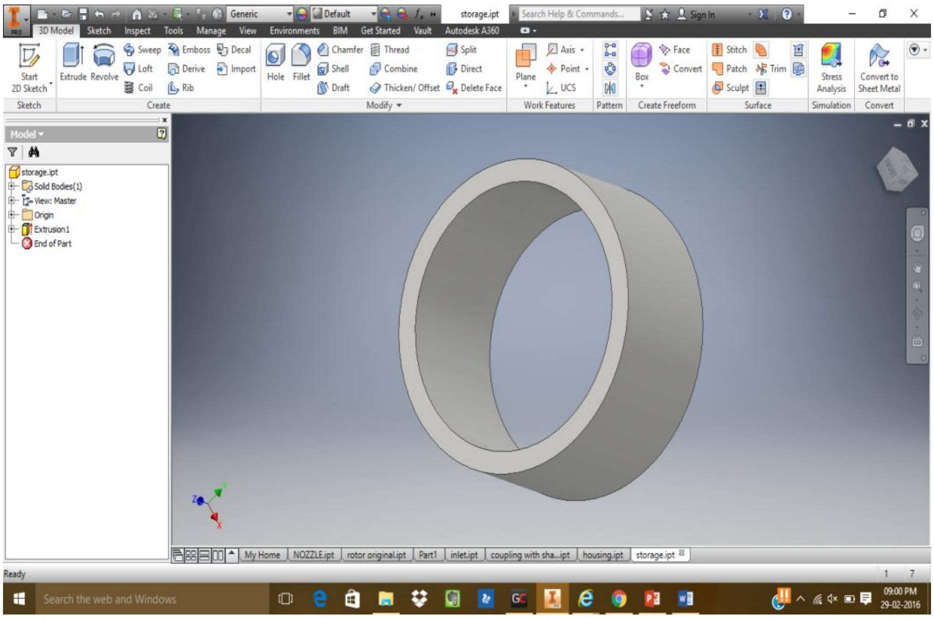


Figure 5 STORAGE

Nozzle:
No. of nozzles = 10 It has two phases 1st 1.263 mm has a diameter of 13.66 mm and 2nd 7.1 mm has a diameter of 12.4 mm.
The nozzles expand the inlet gas isentropic ally to high velocity and direct the flow on to the wheel at the correct angle to ensure smooth, impact free incidence on the wheel blades. A set of static nozzles must be provided around the turbine wheel to generate the required inlet velocity and swirl. frequency well beyond the operating speed and to reduce the overall magnitude of the peak force.

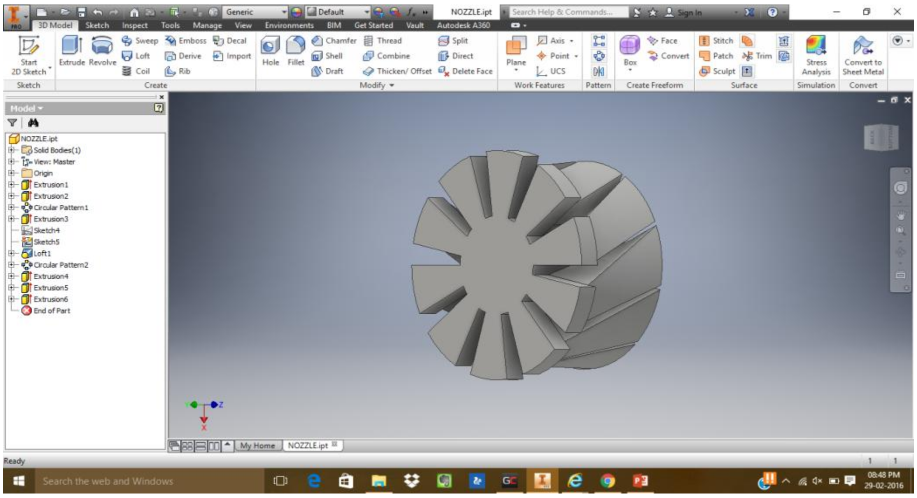


Figure 6 NOZZLE

Rotor:
Diameter = 12 mm
Length = 3.474 mm

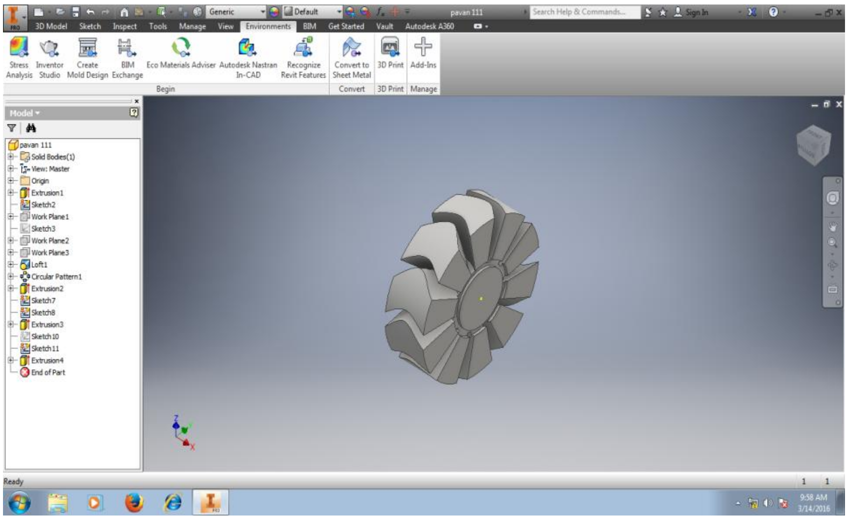


Figure 7 ROTOR

Coupling with shaft:
It has basically 2 parts one is the rod and the other is the coupling which is in turn attached to the counter part of the Generator.
Rod diameter = 2.6 mm
Length = 25 mm.
Coupling main shoe diameter = 8 mm
Individual coupling hole diameter = 1.5 mm.

The force acting on the turbine shaft due to the revolution of its mass center and around its geometrical center constitutes the major inertia force. A restoring force equivalent to a spring force for small displacements, and viscous forces between the gas and the shaft surface, act as spring and damper to the rotating system. The film stiffness depends on the relative position of the shaft with respect to the bearing and is symmetrical with the center-to-center vector.

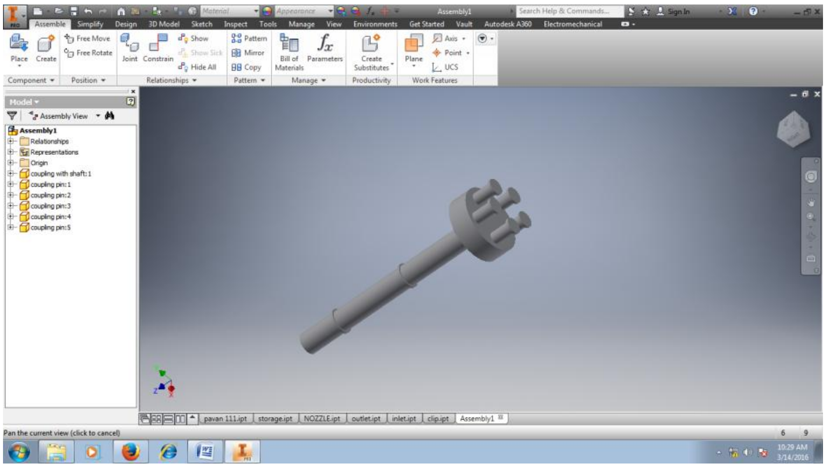


Figure 8 Coupling with shaft

Outlet:

Main solid diameter = 12.42 mm
Central hole diameter = 2.6 mm
4 holes of diameter = 1.56 mm
Width is = 3.6 mm

It basically the 2nd last part of turbine mainly used to put out the exit gases to outside easily. It holds to the housing tightly inside a slot.

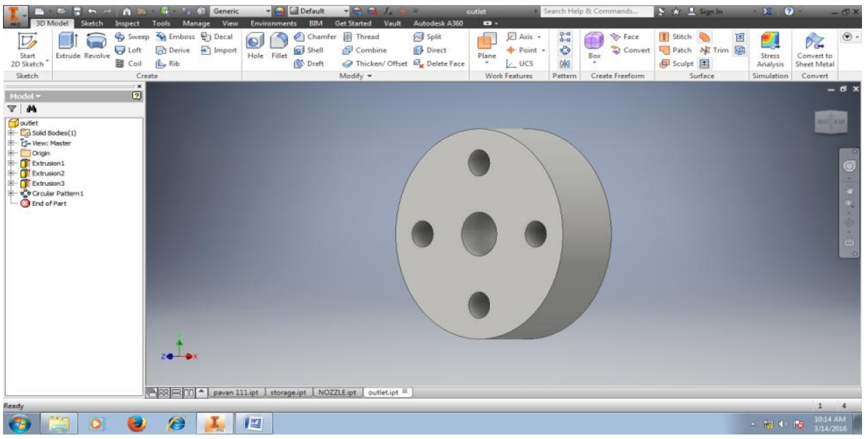


Figure 9 OUT LET

Clip:

Clip is the part which is used to fixing the housing with the help of screws. Generally it was placed in particular slot placed inner side of housing

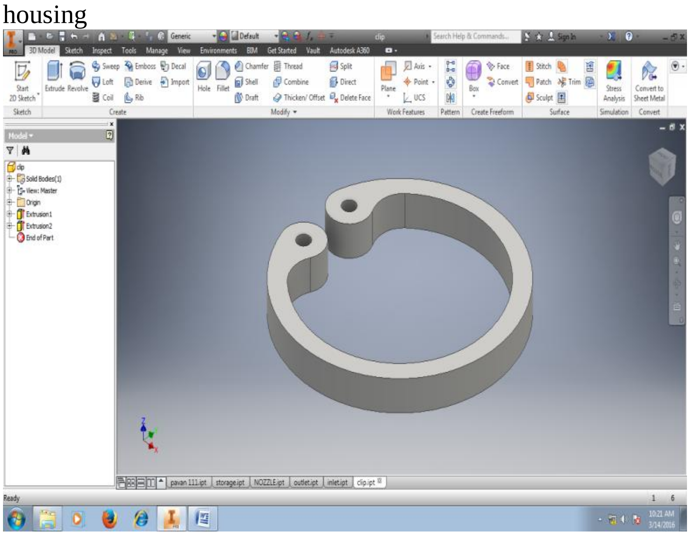


Figure 10 CLIP

Housing/Cover:

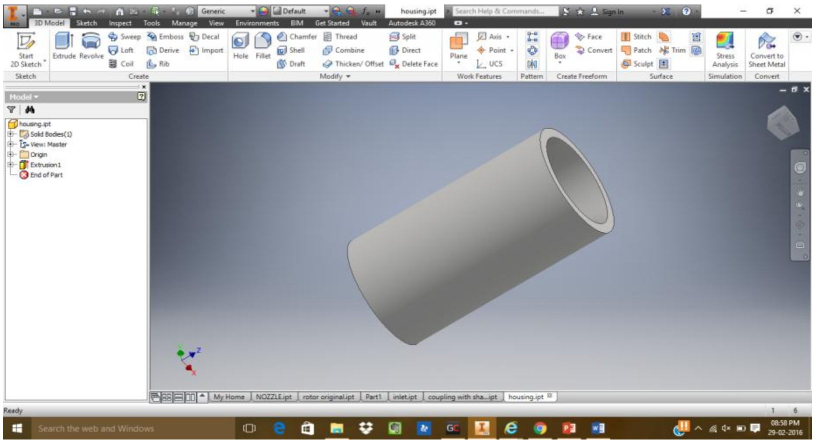


Figure 11 Housing/Cover

This is the outer most part of the turbine which covers all the components outside. The cut mark is given for easy viewing of parts after assembly.

Outer diameter = 17 mm

Diameter for diff. parts to be fixed is different.

Total Length = 32 mm (Which is turbine length indirectly).

Generator with coupling:

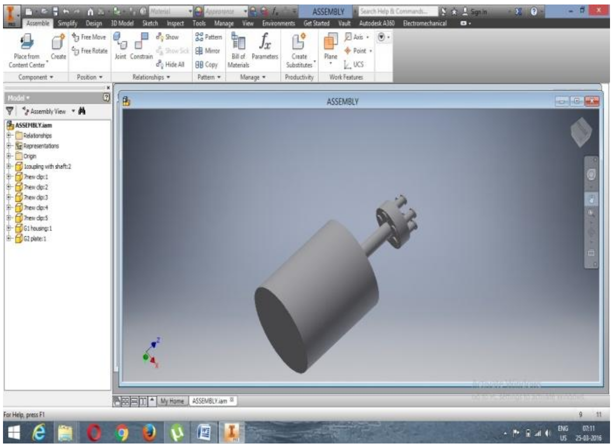


Figure 12 Generator with coupling

Assembly of parts :

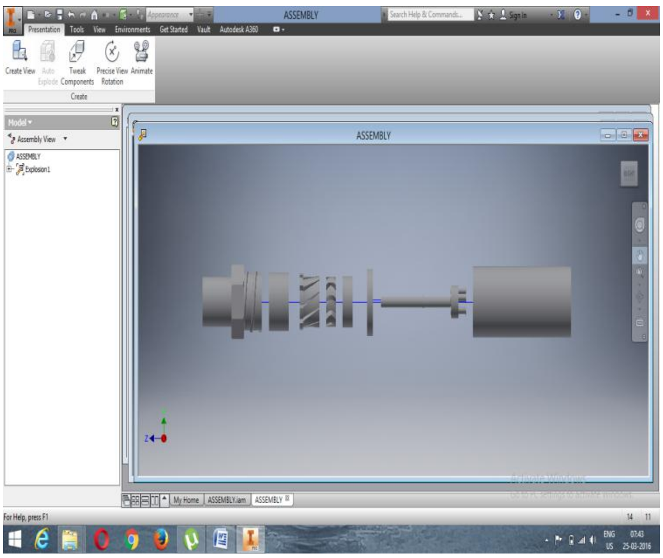


Figure 13 Assembly of parts

Compact packing of all the parts to make the assembly

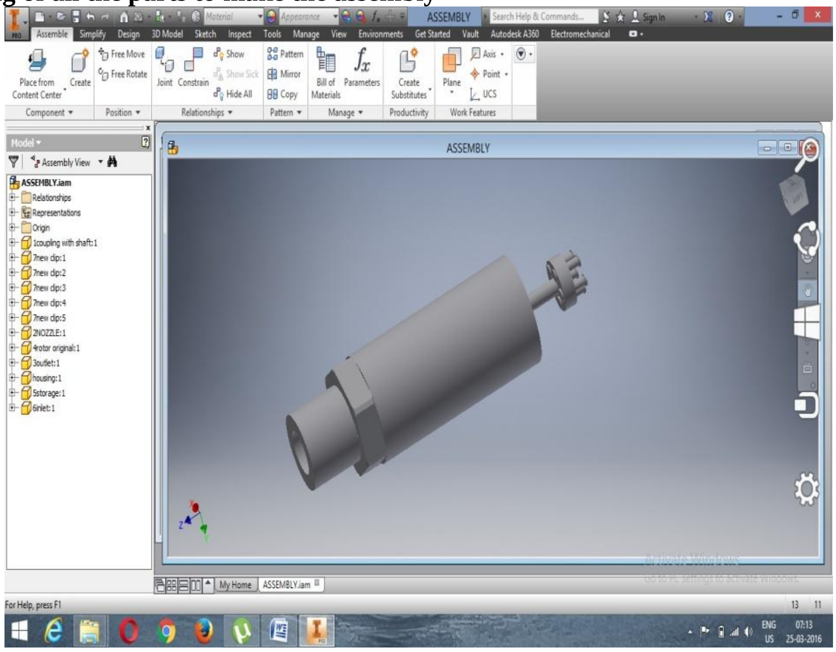


Figure 14 Compact packing of all the parts to make the assembly

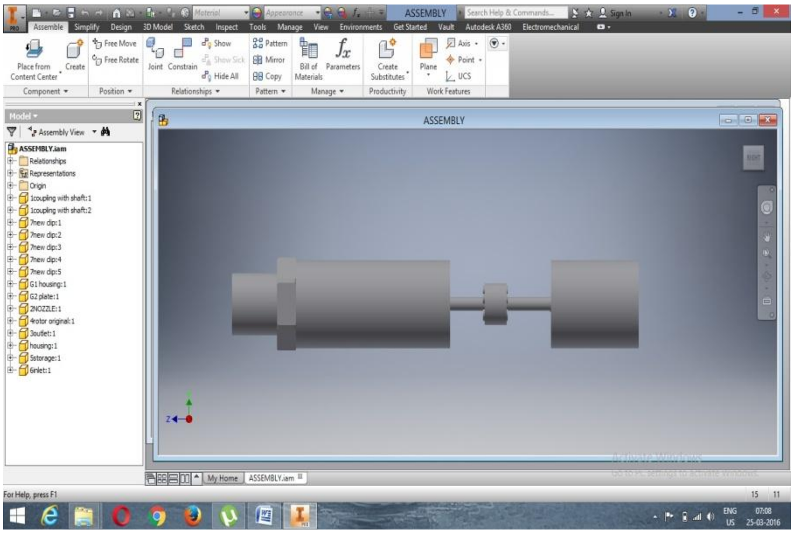


Figure 15 The Generator is coupled to the Micro turbine

VII. Introduction To Autodesk NASTRAN IN-CAD

Autodesk® Nastran® In-CAD finite element analysis (FEA) software uses the Autodesk Nastran solver and integrates with compatible software to simulate real-world behavior. Simulate a wide range of analysis types before you begin manufacturing NASTRAN is a finite element analysis (FEA) program that was originally developed for NASA in the late 1960s by Stephen Burns of the University of Rochester under United States government funding for the Aerospace industry.

NASTRAN is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software Implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

VIII. Stress And Strain Analysis Of Different Materials

Aluminum:

Stress Analysis of Aluminum

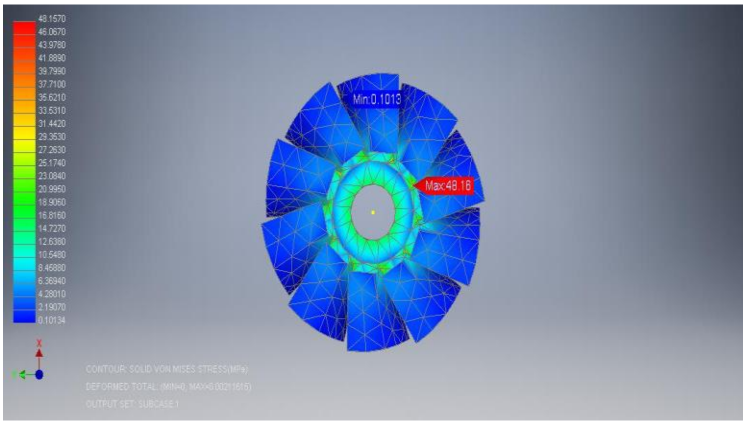


Figure 16 stress analysis of Aluminum

The Aluminium material at 0.8 M.Pa (8 bar) creates maximum stress of 48.16 M.Pa and minimum stress of 0.1013 M.Pa.

Strain Analysis of Aluminium

The Aluminium material 0.8 M.Pa (8 bar) createsmaximumstrainof6.197E-06 and minimum strain of 1.304E-04.

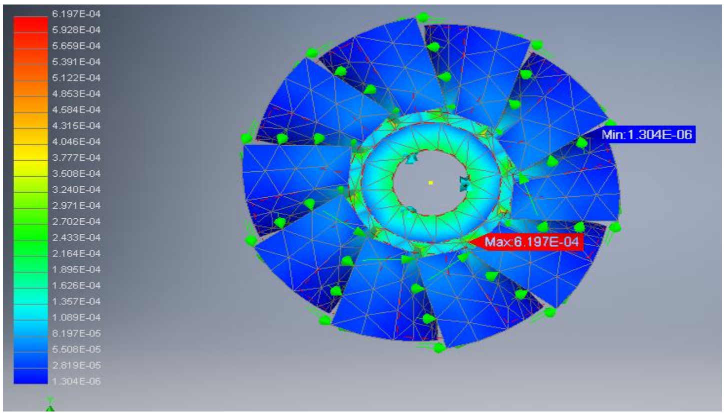


Figure 17 Strain analysis of Aluminum

Stainless steel :

Stress Analysis of stainless steel

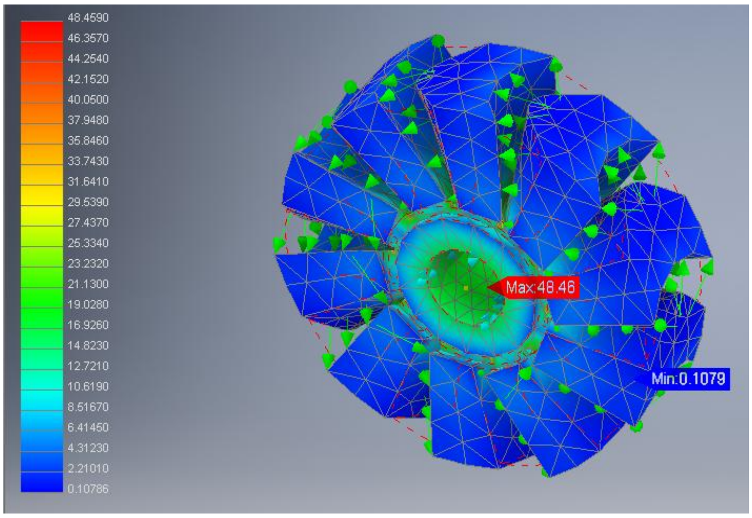


Figure 18 stress anlysis of stainless steel

The stainless steel material at 0.8 M.Pa (8 bar) creates maximum stress of 48.46 M.Pa and minimum stress of 0.1076 M.Pa.

Strain Analysis of stainless steel

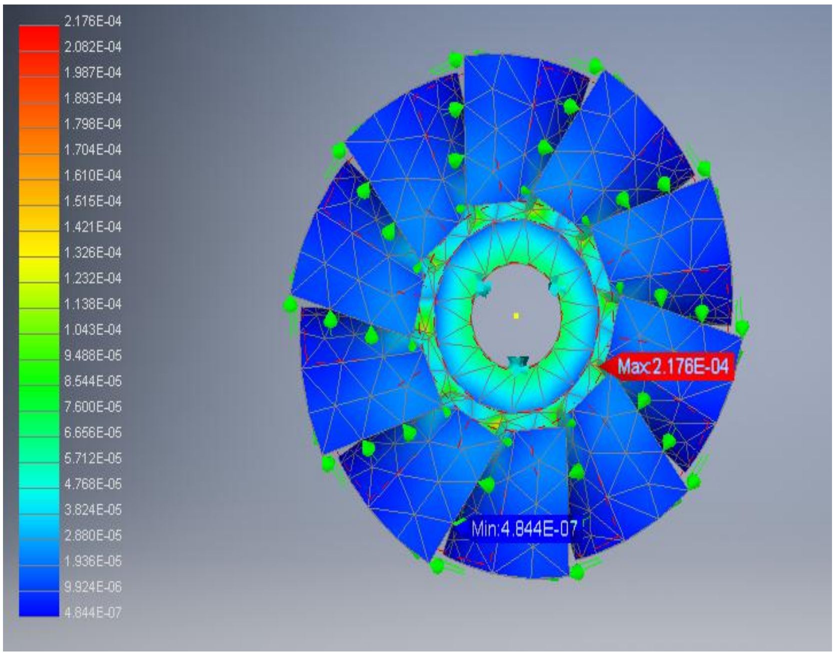


Figure 19 strain analysis of strainless steel

The stainless steel material at 0.8 M.Pa (8 bar) creates maximum strain of 2.176E-04 and minimum strain of 4.844E-07.

Titanium

Stress Analysis of Titanium

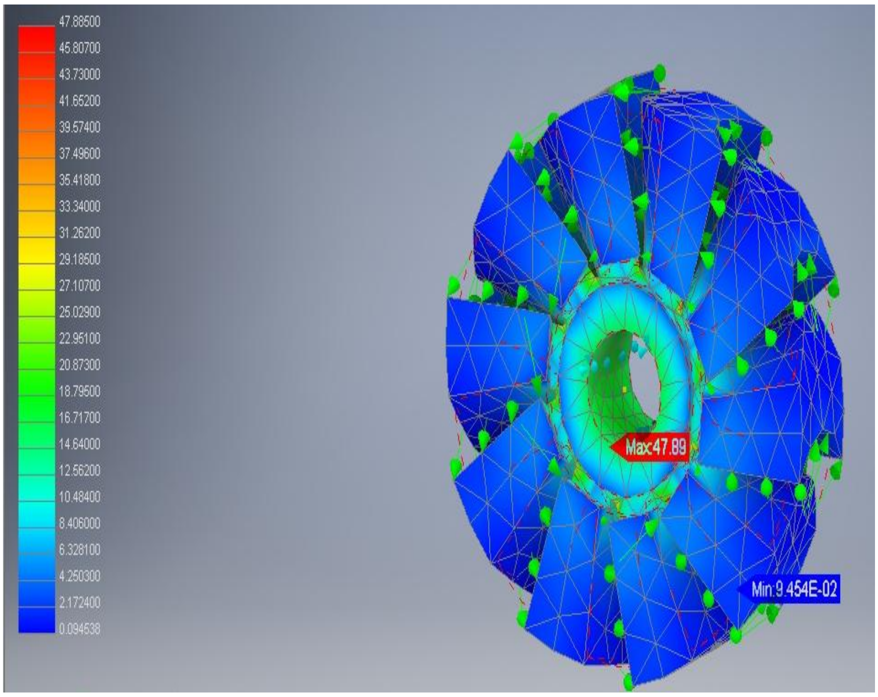


Figure 20 Stress Analysis of Titanium

The stainless steel material a t 0.8 M.Pa (8 bar) creates maximum stress of 48.46 M.Paand minimum stress of 0.1076 M.Pa.

Strain Analysis of Titanium

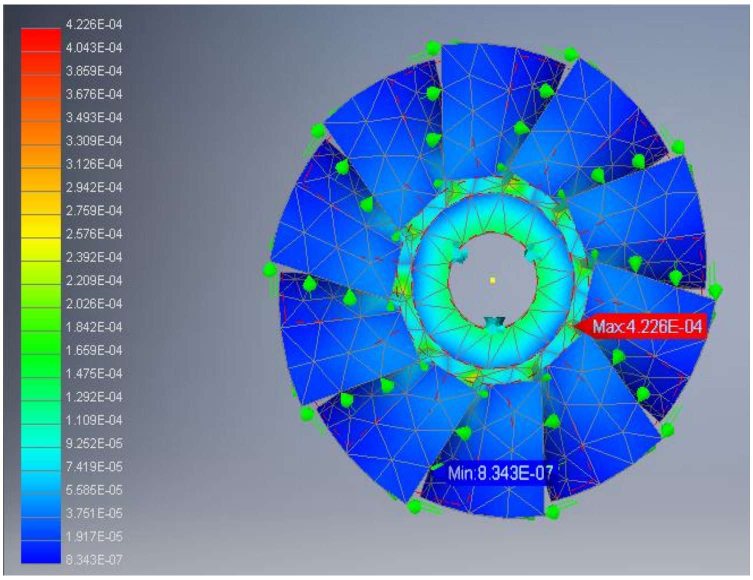


Figure 21 strain Anlaysis of Titanium

The Titanium material at 0.8 M.Pa (8 bar) creates maximum strain of 4.226E-04 and minimum strain of 8.343E-07.

IX. Tabular Column

Stress Analysis:

S No	Material Id	Load(M Pa)	Max Stress (M Pa)	Min Stress (M Pa)
1	Aluminum	0.8	48.16	0.1013
2	Stainless Steel	0.8	48.46	0.1076
3	Titanium	0.8	48.46	0.1076

Strain Analysis:

S No	Material Id	Load(M Pa)	Max Strain (M Pa)	Min Strain (M Pa)
1	Aluminum	0.8	6.197E-6	1.304E-4
2	Stainless Steel	0.8	2.176E-4	4.844E-7
3	Titanium	0.8	4.226E-4	8.343E-7

X. Conclusion

The turbine rotor blade is modeled by using AUTODESK INVENTOR Software. In this case stress analysis and strain analysis of different materials is carried out using analysis software AUTODESK NASTRAN 2016.Thisanalysis shows that Stainless steel rotor blade gives better safety factors compared to other alloys. The stress characteristics from model analysis we absorbed very little amount of variation in all materials. The simulation showed that the stresses are concentrated on the blade attachment to the hub .A better safety factor would be obtained when the pressure on blade is decreased. The simulation showed that the stresses are concentrated on the blade attachment to the hub, caused by the centrifugal stresses. Another point observe this that a higher pressure will result in greater stresses to be borne by the structure ,which indicates that a better safety factor would be obtained when the pressure is decreased.
Considerations about the limiting pressure are also of importance .Because of the need to have a particular output power, the designated pressure needs to be predicted, since structural strength is limited by the various pressures. Thus for this purpose ,Stainless steel, with a much better results compare to Aluminum and titanium, its hustle safe material obsessed because they have the higher Young's modulus(E).

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