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Design and Analysis of Turbo Jet Engine

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ABSTRACT:In the modern world's aviation system and transport system gas internal combustion engines plays a main role because of its excellent advantages and applications mainly the speed which provides to the vehicle. This paper gives the deep introduction to the turbo jet engine as this mainly works on the Newton's 3rd rule. For this work a simple turbo jet engine is designed by referring some other sources, this design consists of inlet vanes. Compressor vanes, centre rotating shaft where the vanes are located, inner walls of combustion chamber. Here we also mention the objectives of the turbo jet engine based on their applications. This work is concentrated on the structural static analysis work and the modal analysis of the designed turbo jet engine. The main objective of this work is to find out the stresses, strains, strain energy, and fatigue life of the designed model by structural static analysis when we use structural steel as a material and we also tend to find out the structural vibrations through modal analysis in which the structure deform in particular shapes when excited in their natural frequencies.

KEYWORDS: Aviation, jet engine, static analysis, Modal analysis.

I. INTRODUCTION

Turbo jet is an engine which is mainly used in aircrafts. The jet engine is nothing but gas turbine which works at high RPM. Jet engine works on Newton's 3rd law which states that for every acting force on the blades that produces equal and opposite reaction forces. All gas turbine engines work on the basis of thermodynamic Bryton cycle. Every gas turbine works on the same principle that the air enters the engine then it compressed there and mixed with fuel then combustion takes place then the expansion takes place with the help of rotating turbine.

Nowadays the turbo-jets are playing the major role in the aviation because of production of auxiliary power for ground and aircraft systems, propelling military aircrafts at supersonic speed. Design and Construction of a gas turbine demands accuracy, informed material selection, knowledge of thermodynamics, and the ability to model and machine metal components. Gas Turbine Engine components experience the extreme temperatures and high rotational speeds hence the designing and construction of the engine is very important parameters. Modern gas turbines for full size aircraft generally utilize axial compressors and turbines with multiple stages of blades. As material processing techniques advanced, it became possible to manufacture Gas turbine engines small enough to power radio controlled (RC) airplanes.

II. LITERATURE REVIEW

A.P. Haran, C. Lindon Robert Lee, S. Antony Raja and D. Raja Joseph published a paper which is related to jet engine which is entitled as "Analysis of an After Burner in a Jet Engine" in the year 2011. In their paper they showed the types of turbojet engines which are using nowadays and also which are not in use nowadays commercially. They also mentioned role of fuel used in the engine, explained sections involved in the jet engine the main sections are cold section, common section, hot section and mentioned importance of nozzles and exhausts used in the jet engines. They concentrated on the analysis work of the after burners. By their paper we come to know how different types of after burners used in the different types of engines. And also explained how trust will affect the aircrafts while landing and take-off.

In the year 2014 Kamal Kumar Pradhan, Bhoumika Sahu, Hemrani Gajendra published review paper on Adaptive Work Performance Analysis of Turbojet Engines. Here they described the operational and structural advantages with the different designs of adaptive jet engines. They gave their more attention to the double rotor engines which shows the maximum performance than other engines. In their work they showed the resulting configuration schematically, jet engines performance, and energy balance by real cycle of a turbo jet adaptive engine. They came up with some graphs which shows the work cycle sensitivity within the thermal cycle to variation of the engine compression, process efficiency of compression and double factor used.

Simon Fahlström, Rikard Pihl-Roos from Uppasala universitet shows the design and construction of simple turbo jet engine in the year 2016. They worked on researching, designing and building of a simple commercial jet engine. They mainly concentrated on self-sustaining combustion chamber which located in the engine. They choose annular type of combustion chamber for their study because of its evenly distribution of combustion as compared to other chambers. They designed and manufactured the combustion and its parts they manufactured the engine by taking steel as their major material for shaft, combustion chamber and housing. Aluminium also used here for the manufacturing inlets, compressor plates and turbine plates. They choose radial compressor for their compressor; they took it from the automotive engine's turbo charger. Also, they showed pressure v/s air flow rate graph, they explained how each component work in engine and how it interacts with other parts.

In the year 2016 Irina-Carmen ANDREI, Mihai Leonida NICULESCU, Mihai Victor PRICOP, Andreea CERNAT published a paper on turbo jet engine named "study of the turbojet engines as propulsion systems for the unmanned aerial vehicles". In this thorough research they focused on single spool turbo jet performance analysis. In Unmanned Aerial Vehicles (UAV's) the turbo jet engine used as propulsion system is an actual challenging work. To calculate the performance of turbo jet for specified Mach number and flight altitude they used one dimensional cycle design. Engine operating maps, universal engine maps are calculated. By these graphs the objective of this work is fulfilled. By comparing the in-house codes with engine data catalogues the engine performance is calculated.

III. OBJECTIVES OF TURBO JET ENGINE

- Employ Active cooling.
- Designing better materials and alloy which retains strength at high temperature.
- Smart structure and materials which changes their shape and properties in flight.
- Design engines which shift from SC Ram Jet to Ram Jet.
- Complex structure.
- High Efficiency.
- Oxygen from atmosphere for combustion.
- Liquid Fuel.

IV. WORKING OF TURBO JET ENGINE

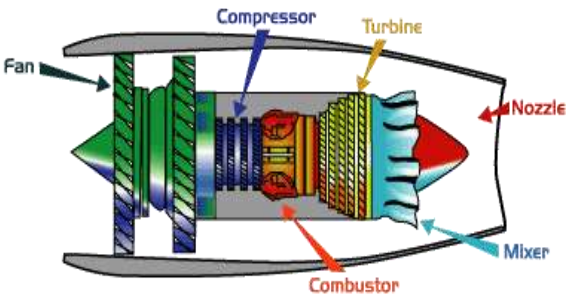

Fig 1: - Shows turbo-jet engine

Turbo jet engine works in similar way as the fuel engines, in this case air from the atmosphere enters into the compressor with the help of rotating fans which are located Infront of compressor during intake. Compressor consist series of vanes and stator, vanes rotate with the help of centre rotating shaft at high speed and stator is stationary. The air is compressed here with the help of rotating vanes. The speed of vanes and the temperature of air increases gradually with respect to time. The compressed air from the compressor is mixed with the fuel with the help of fuel injector. In fuel burner the mixture of fuel and air is ignited by the electric spark plug. Which is located at the top of the fuel burner. Then this mixture enters into the combustion chamber then there will be increase in temperature and pressure of the mixture inside the engine chamber then this mixture enters into the turbine.

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The turbine works in a similar way as the conventional wind mill. The blades of the turbine gain energy from hot and pressurized mixture which passes over them. The moment produced here is used to power the compressor. The hot air from the turbine is rushes out of nozzle with high pressure. The hot air rushes out at very high speed. The force produced because of exhaust by turbo jet engine move the aeroplane forward with grade force that is produced thrust which cause the plane to fly very fast.

V. DESIGN

The figure below shows the design of the turbo-jet for this work. The design is made by referring and analysing the jet engines which are used commonly nowadays. This design is mainly consisting of intake compressor vanes and a combustion chamber and turbine vanes. Here in this analysis, we mainly concentrated on the centre rotating shaft, the vanes of the engine and the inside walls of the combustion chamber. The design is made using Catia v5.

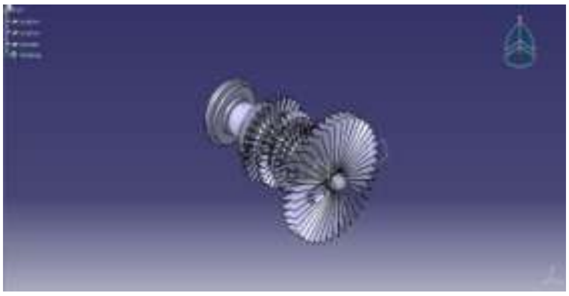

Fig 2: - Shows the design of the turbo jet engine

VI. RESULTS AND DISCUSSIONS

Meshing: -

The designed part represents the whole continuous part/object which have infinite degrees of freedom. The object which has infinite degrees of freedom is not possible to solve. To overcome this problem meshing is done. Here the whole continuum part is converted into a finite element model by discretization. This discretization is done by meshing.

Fig: - Meshed part of the turbo jet engine

The model which is designed in Catia v5 is then imported to ANSYS Work bench R15.0. Then this imported model is converted into FEM model by meshing the designed part using quad mesh. The meshed part is shown above figure. In meshing several numbers of nodes and elements are created. After meshing the model is ready to solve then the modal analysis and static analysis are carried out.

Modal analysis: -

Modal analysis is a study of dynamic properties of system in the frequency domain. A typical example would be testing structures under vibration excitation. The modal analysis is a field of measuring or calculating and analysing the dynamic response of structures or other system during excitation. Here we are done total 5 mode shape as per convenience.

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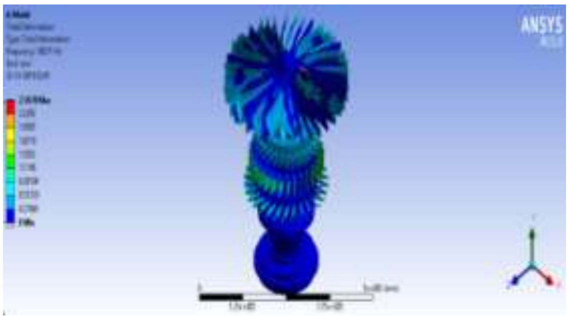

Fig: -Total Deformation of Mode Shape 1

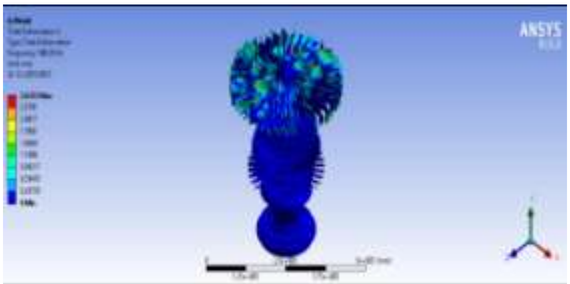

Fig: -Total Deformation of Mode Shape 2

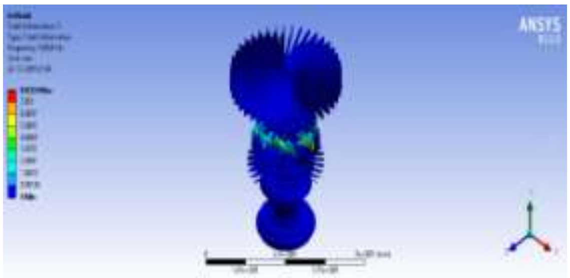

Fig: -Total Deformation of Mode Shape 3

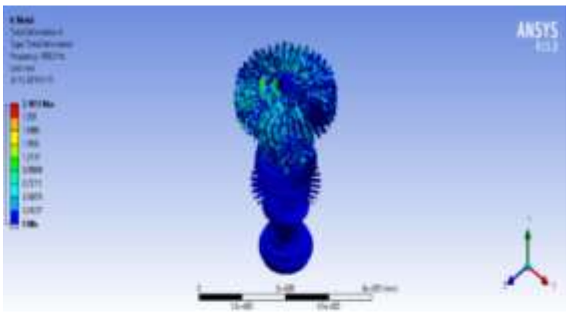

Fig: -Total Deformation of Mode Shape 4

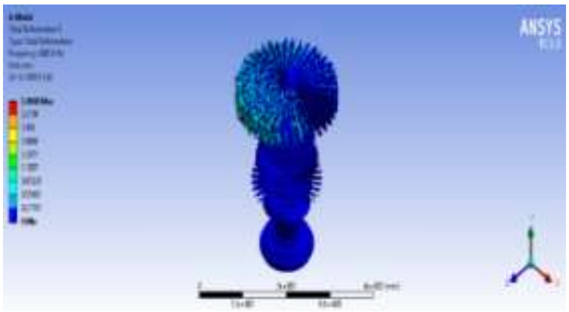

Fig: -Total Deformation of Mode Shape5

Table 1: -Frequencies obtained from ANSYS

Sl. No	Mode Shape	Frequency in Hz
1	1	100.71
2	2	500.28
3	3	1200.4
4	4	1950.3
5	5	2610.6
6	6	3301.1

Modal analysis is used to determine the vibration characteristics of a designed structure which gives us the natural frequencies and mode shapes. For modal analysis no external forces are applied but for boundary condition the constraints are given to fix the part. The natural frequencies which are obtained from modal analysis are as shown in the table above.

Static analysis: -

Static analysis is done to find out how the designed part will be affected by constant loads of the structure which is done by ignoring the shocks which are produced by rapidly changing loads and also by neglecting the inertia. By static analysis we can find out total deformation, stresses, strains, fatigue life and strain energy of a designed part. The results obtained from the static analysis of the turbo jet engine are shown below

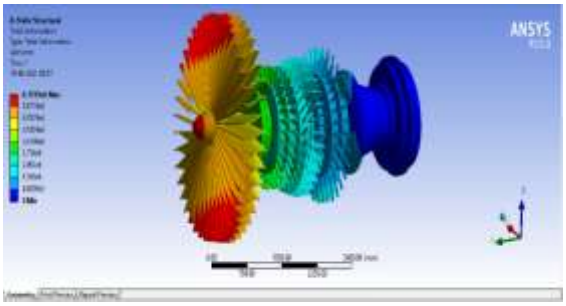

Fig: - Total deformation

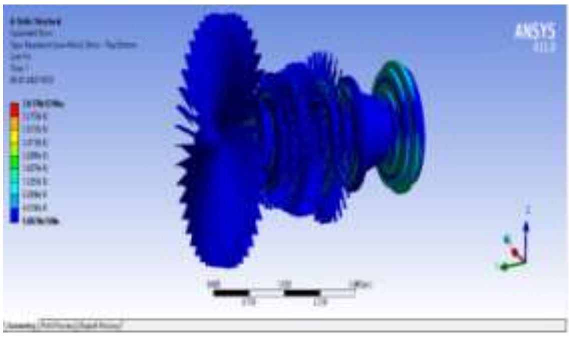

Fig: - Equivalent stress contour plot

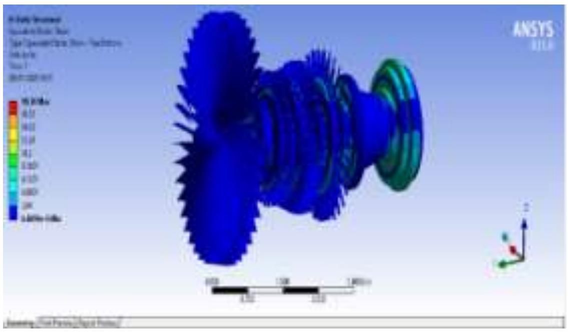

Fig: - Equivalent Elastic Strain

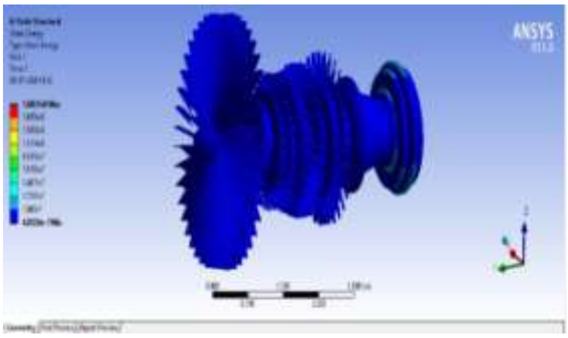

Fig: -Strain Energy

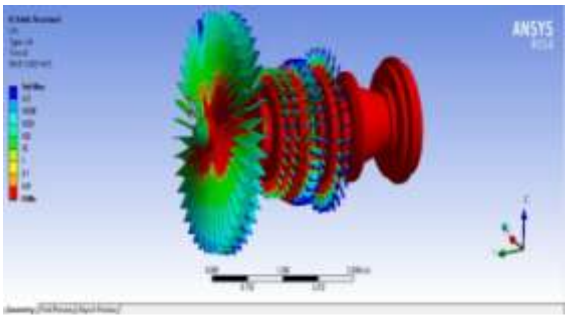

Fig: -Fatigue life

The result figures which are obtained from static structural analysis are as shown above figures. In our case we find out total deformation, equivalent stress, equivalent strain, strain energy, fatigue life.

From this analysis we come to know that some portions of the turbojet engine vanes are got displaced because of forces and the temperature acting on them, the maximum deformation recorded here is 6.155mm at the tip of some vanes. The equivalent stresses are also developed on the part because of the external variables during working, the maximum equivalent stresses produced here is 3.6178e12 pa and the minimum equivalent stress produced here is9.8878e12 pa. Equivalent strains also produced because of the deformations occurred when stresses are created. The maximum equivalent strain produced is 18.36 and minimum equivalent strain produced here is 6.469e-6. Because of high temperature and pressure inside the chamber the strain energy is created, here the highest strain energy created is 1.682e8 Joules.

VII. CONCLUSION

In this work turbo-jet engine is designed by referring some of the commercial engines which are currently using nowadays. Design is done by using Catia V5 and the analysis is done by using ANSYS R15. For analysis we given structural steel material for the turbo jet machine. The structural modal analysis and the structural static analysis is conducted for this design. The frequencies which are obtained from the modal analysis are shown in table 1.

In static analysis we got values of deformation, stresses, strains, strain energy. Here the maximum equivalent stress produced is 3.6178e12 pa, the maximum equivalent strain produced here is 18.36 and the maximum strain energy produced her is 1.682e8 Joules. In practice nickel and titanium alloys are used here we tried structural steel instead of those to check the how it will behave to the maximum temperature and pressure. As we saw in the results steel will react more quickly and it is affected more than the other alloys. On this topic there are very less literature available so we conducted this work to check the modal analysis results and static behaviour of the engine which done by using steel material, people who are working or doing research on turbo jet engine can go through this work. Here ANSYS gives relatively good results.

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