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Design and Optimization of Axial Flow Compressor

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ABSTRACT

An axial flow compressor is one in which the flow enters the compressor in an axial direction (parallel with the axis of rotation), and exits from the gas turbine, also in an axial direction. The axial-flow compressor compresses its working fluid by first accelerating the fluid and then diffusing it to obtain a pressure increase. In an axial flow compressor, air passes from one stage to the next, each stage raising the pressure slightly. The energy level of air or gas flowing through it is increased by the action of the rotor blades which exert a torque on the fluid which is supplied by an electric motor or a steam or a gas turbine. In this thesis, an axial flow compressor is designed and modeled in 3D modeling software Pro/Engineer. The present design has 30 blades, in this thesis it is replaced with 20 blades and 12 blades. The present used material is Chromium Steel; it is replaced with Titanium alloy and Nickel alloy. Structural analysis is done on the compressor models to verify the strength of the compressor. CFD analysis is done to verify the flow of air.

KEYWORDS : *Axial Flow, Ansys, Compressor, CFD, Gas Turbine, PRO-E*

I. INTRODUCTION

Axial Compressor

An **axial compressor** is a machine that can continuously pressurize gases. It is a rotating, airfoil-based compressor in which the gas or working fluid principally flows parallel to the axis of rotation. This differs from other rotating compressors such as centrifugal compressors, axi-centrifugal compressors and mixed-flow compressors where the fluid flow will include a "radial component" through the compressor.

Transonic Axial Compressor : Transonic axial flow compressors are today widely used in aircraft engines to obtain maximum pressure ratios per single-stage. High stage pressure ratios are important because they make it possible to reduce the engine weight and size and, therefore, investment and operational costs.

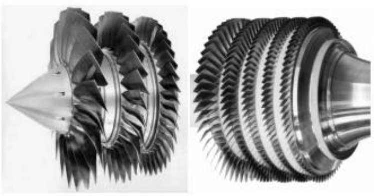

Fig 1 Transonic lpc (left) and hpc (right) eurofighter typhoon engine EJ200

Three-dimensional shaped blades : The preceding paragraph has shown that a certain maturity in transonic compressors has been reached regarding the general airfoil aerodesign. But the flow field in a compressor is not only influenced by the two-dimensional airfoil geometry. The three-dimensional shape of the blade is also of great importance, especially in transonic compressor rotors where an optimization of shock structure and its interference with secondary flows is required. Many experimental and numerical works can be found in the literature on the design and analysis of three-dimensional shaped transonic bladings.

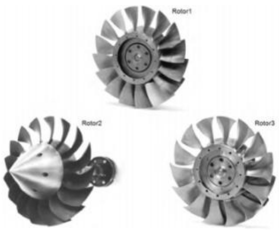

Fig 2 Transonic Compressor Test Rotors

III. THEORETICAL CALCULATIONS

Pressure = 0.904N/mm^2 ; Temperature = 288K

Absolute Velocity

$$C_1 = \frac{C_{a_1}}{\cos \alpha_1} = \frac{150}{\cos(12)} = 177.75\text{m/s}$$

C_{a_1}= Constant axial velocity

α_1 = Radius between blade to blade

IV. MODELING IN PRO-E

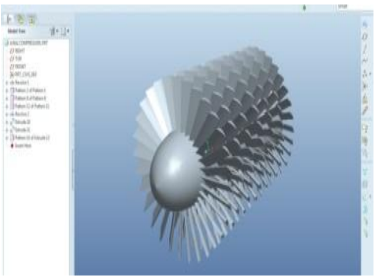

Fig 3: 30 blades

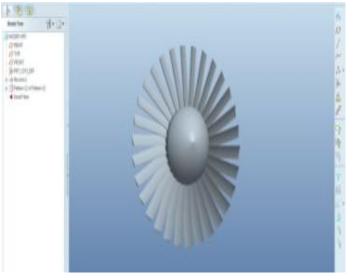

Fig 4:20 blades

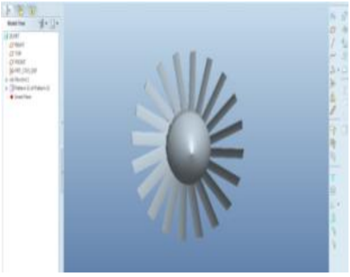

Fig 5: 12 blades

V. RESULTS & DISCUSSION

Analysis of Compressor 30 Blades
Nickel Alloy

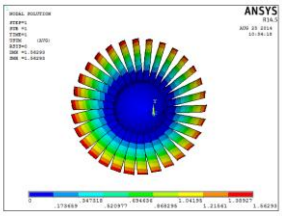

Fig 6: Displacement vector

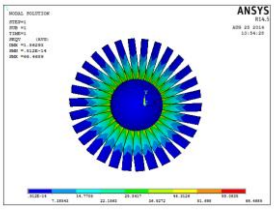

Fig 7: Stress vonmises vector

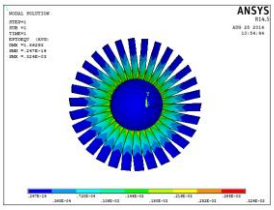

Fig 8: Strain vonmises vector

5.1.2 Titanium

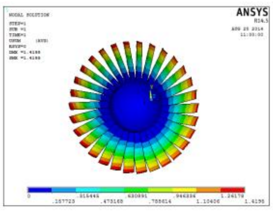

Fig 9: Displacement vector vector

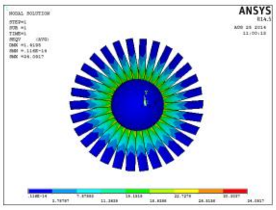

Fig 10: Stress vonmises vector

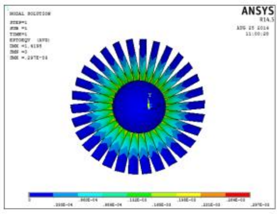

Fig 11: Strain vonmises

5.1.4 Steel

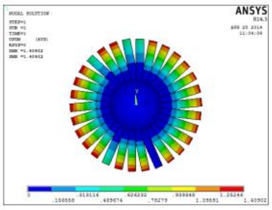

Fig 12: Displacement vector vector

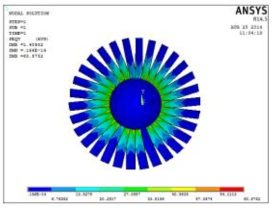

Fig 13: Stress vonmises vector

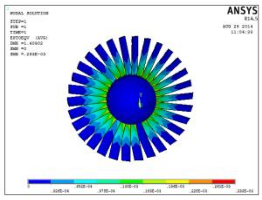

Fig 14: Strain vonmises

5.2 Analysis of Compressor 20 blades

5.2.1 Nickel alloy

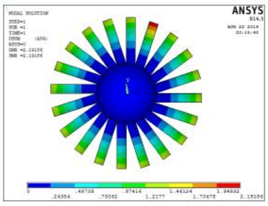

Fig 15: Displacement vector vector

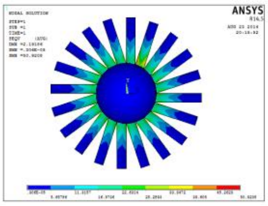

Fig 16: Stress vonmises vector

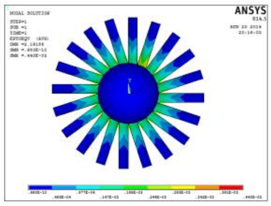

Fig 17: Strain vonmises

5.2.2 Titanium

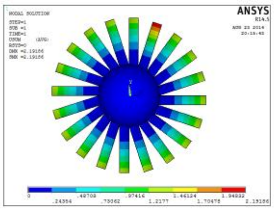

Fig 18: Displacement vector vector

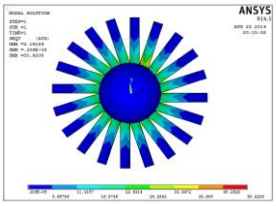

Fig 19: Stress vonmises vector

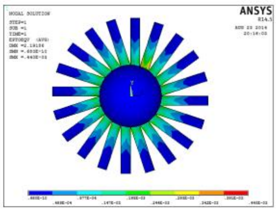

Fig 20: : Strain vonmises

5.2.3 Steel

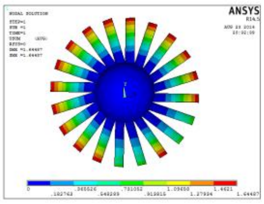

Fig 21: Displacement vector

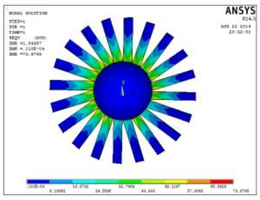

Fig 22: Stress vonmises vector

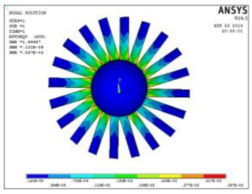

Fig 23: Strain vonmises vector

5.3 12 Blades

5.3.1 Nickel alloy

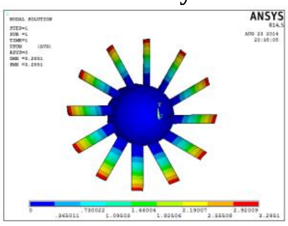

Fig 24:Displacement vector

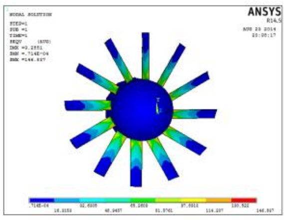

Fig 25: Stress vonmises vector

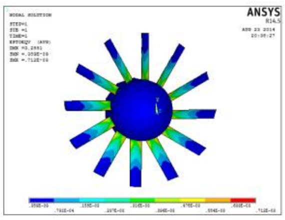

Fig 26: Strain vonmises vector

5.3.2 Titanium

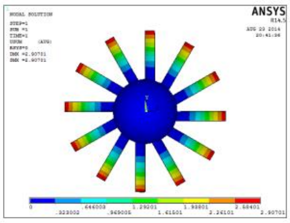

Fig 27: Displacement vector

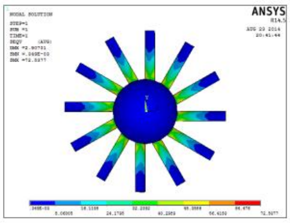

Fig 28: Stress vonmises vector

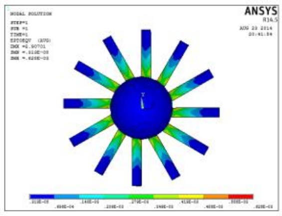

Fig 29: Strain vonmises vecto

5.3.3 Steel

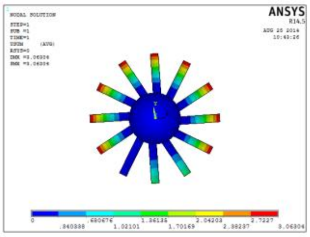

Fig 30: Displacement vector

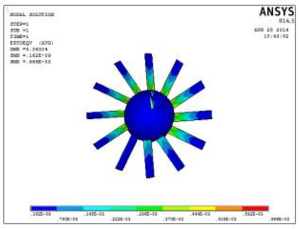

Fig 31: Stress vonmises vector

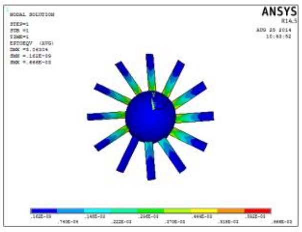

Fig 32:Strain vonmises vector

6. CFD Analysis

6.1 30Blades

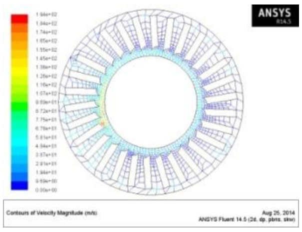

Fig 33: Velocity magnitude

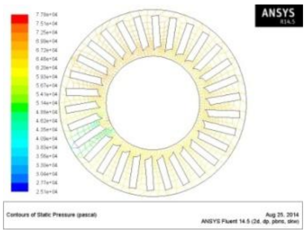

Fig 34: Static pressure

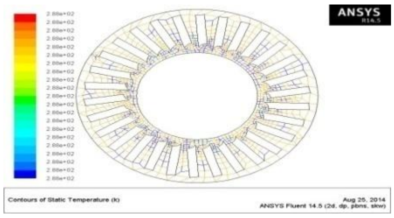

Fig 35: Temperature

6.2 20 Blades

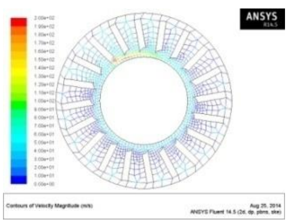

Fig 36:magnitude

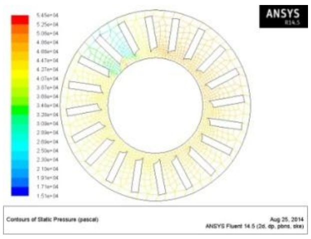

Fig 37: Static pressure

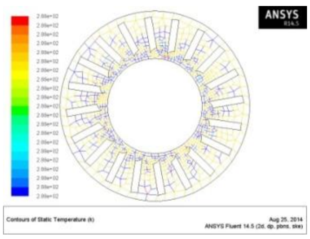

Fig 38: Temperature

6.3 12 Blades

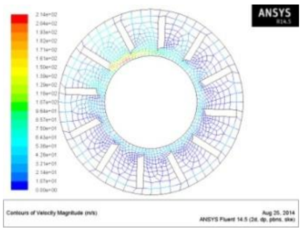

Fig 39: magnitude

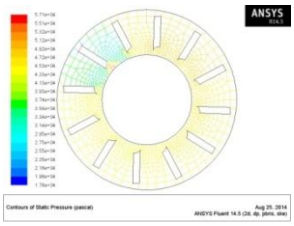

Fig 40:Static pressure

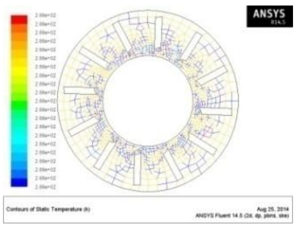

Fig 41:Temperature

VI. RESULTS TABLE

7.1 At 30 blades

	Displacement(mm)	Stress(N/mm^2)	Strain
Nickel alloy	1.56293	66.4689	0.324e-03
Titanium	1.4195	34.0917	0.29e-03
Steel	1.40902	60.8752	0.29e-03

Table 1: Result of 30 blades

7.2 At 20 blades

	Displacement(mm)	Stress(N/mm2)	Strain
Nickel alloy	2.06664	99.2341	0.485e-03
Titanium	2.19186	50.920	0.440e-03
Steel	1.64487	73.6795	0.357e-03

Table no 2 Result of 20 blades

7.3 At 12 blades

	Displacement(mm)	**Stress(N/mm^2)**	**Strain**
Nickel alloy	3.2851	146.837	0.712e-03
Titanium	2.90701	72.5377	0.628e-03
Steel	3.06304	138.669	0.666e-03

Table no 3 Result of 12 blades

7.4 CFD Results

	30 blades	**20 blades**	**12 blades**
Velocity (m/s)	1.94e^{+02}	2.00e^{+02}	2.14e^{+02}
Pressure(N/mm^2)	7.78e^{+04}	5.45e^{+04}	5.71e^{+04}
Temperature(k)	2.88e^{+02}	2.88e^{+02}	2.88e^{+02}
Mass flow rate (kg/s)	0.081484798	0.1520251	0.23096226

Table no 4 CFD Result

VII. CONCLUSION

In this thesis, an axial flow compressor is designed and modeled in 3D modeling software Pro/Engineer. The present design has 30 blades, in this thesis it is replaced with 20 blades and 12 blades. The present used material is Chromium Steel, it is replaced with Titanium alloy and Nickel alloy. Titanium alloy and Nickel alloy are high strength materials than Chromium Steel. The density of Titanium alloy is less than that of Chromium Steel and Nickel alloy. So using Titanium alloy for compressor blade decreases the weight of the compressor Structural analysis is done on the compressor models to verify the strength of the compressor. The stress values for less than the respective yield stress values for Titanium alloy and Nickel alloy. The stress value is less for titanium alloy than Nickel alloy, so using Titanium alloy is better. By using 12 blades the stresses are increasing, but are within the limits. CFD analysis is done to verify the flow of air. The outlet velocity is increasing for 12 blades, pressure is more for 30 blades and mass flow rate is more for 12 blades.

So it concluded that using Titanium alloy and 12 blades is better for compressor blade.

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