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Full Length Article

Computational Modelling and Structural Analysis of Scimitar Shaped Compressor

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ABSTRACT: In this project compressor rotor blade is employed with new design of scimitar shaped rotor blades. Analyzed using FEA software –ANSYS and studied the parameters like stress and failure point occurring in the rotor blade section. The basic requirements of the compressor for aircraft gas turbine application are well known .In generally,they include high air flow capacity per unit frontal area, high efficiency and easily stackable to obtain the required pressure ratio. The fan and compressor of modern aircraft engine must be capable of operation over widely diverse conditions and improving the flow margin between the fan operating range of the compressor ,under many circumstances unstable flow conditions are initiated in the tip region of a fan or compressor thus if stall in the tip region can be delayed ,the weight flow range of the fan or compressor may be increased.

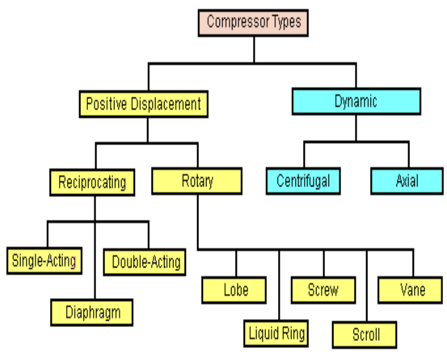
Keywords: compressor, rotor blade, scimitar shaped, leading edge sweep.

1 Introduction

Currently, the principal type of compressor being used in aircraft gas turbine power plants is the axial flow compressor. Particularly for high speed and long range application, has been the axial type
The efficiency and stability margin of an axial compressor is mainly defined by aero thermal design.

In order to improve the gas turbine engine performance, including efficiency, and to extend its stable operating range, many advanced 3-Dimensional design strategies have been employed to delay the onset of rotating stall and surge.. The sweep can be imparted either by shifting the blade sections opposite to the flow direction (forward sweep) or along the flow direction (backward sweep) or blade tip sweeping with respect to the hub section. Also, the blade sections can be shifted in the tangential direction, gives rise to blade lean.

A blade sweeps at the tip which looks like a scimitar. The aim of this project is to analysis the structural behavior of scimitar blade at fixed condition of the transonic axial compressor.



Flowchart 1.1 compressor types

1.1. Stall and Surge

Axial flow compressors suffer from inherent aerodynamic instabilities known as surge and stall, which can severely limit the compressor performance. Stall is a flight condition wherein the airflow separates from the airfoil surface, or the airflow around the airfoil becomes turbulent, causing the airfoil to lose lift. It is usually a result of insufficient airspeeds or excessive angle of attack.

Surge is the reversal of flow within a dynamic compressor that takes place when the capacity being handled is reduced to a point where insufficient pressure is being generated to maintain flow. Compressor stall manifested as rotating stall, individual stall of each blade, or stall flutter may, in most cases, be classified as either progressive or abrupt. Progressive stall results in a gradual reduction in stage pressure ratio and efficiency as the flow is decreased, whereas abrupt stall results in an abrupt or apparently discontinues drop in compressor pressure rise and efficiency.

1.2 Scimitar Propeller

A scimitar propeller Fig. 1.1 is shaped like a scimitar sword, with increasing sweep along the leading edge. Prop fan engines use contra-rotating scimitar propellers to achieve turboprop efficiency levels at high subsonic air speeds comparable to that of turbofans.

In the 1940s, NASA started researching propellers with similar sweep. Since the inside of the prop is moving more slowly than the outside, the blade becomes progressively more swept toward the outside, leading to a curved shape similar to that of a scimitar.

Figure 1.1 Scimitar Propeller

1.3 Scimitar Blade

The scimitar compressor blade is which the compressor rotor blade is swept along its leading edge.

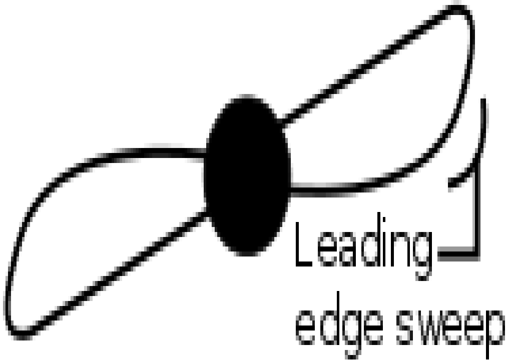


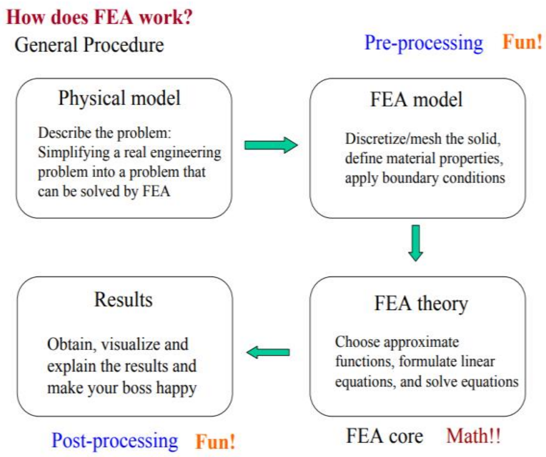
Figure 1.2. Scimitar Propeller Blade

2. METHODOLOGY

2.1 Introduction to CATIA

CATIA (Computer Aided Three-Dimensional Interactive Application) is a multi-platform CAD/CAM/CAE Commercial software suite developed by the French company Dassault System and marketed worldwide by IBM. Written in the C++ programming language, CATIA is cornerstone of the Dassault System product lifecycle management software suite.

2.2 Introduction to ANSYS (FEA)



Flowchart 2.1 FEA Work

2.3 Specification of the baseline compressor

The specification of the axial flow research compressor stage at National Aerospace Laboratories is as follows and the geometrical dimensions are considered for the CAD modeling of the compressor stage.

- Type of compressor : Single Stage Axial Flow Transonic
- Corrected rotational speed : 12930 rpm
- Corrected mass flow rate : 22 kg/s
- Stage total pressure ratio : 1.35
- Stage adiabatic efficiency : 89%
- Number of blades :21(Rotor), 18(Stator)
- Rotor tip diameter : 450 mm

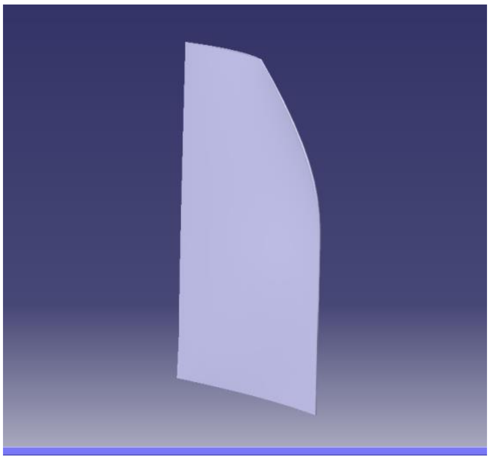


Figure 2.2 2-D Drawing of Scimitar Blade

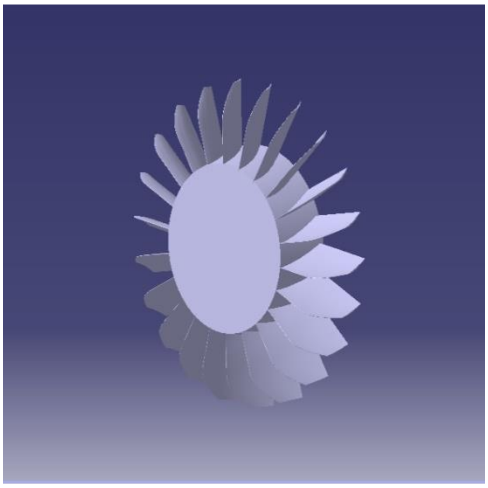


Figure 2.3 3-D Drawing of scimitar blade

2.4 Stress Analysis

Input Data:

RPM: 12930
Pressure Force: 1.35E+05
Mass flow rate: 22 kg/s
Mesh Nodes: 991090
Elements: 644584

MATERIAL	DENSITY-kg/m3	YOUNG MODULUS-MPa	POISSION RATIO
Titanium alloy	4700	110000	0.3
Nickel alloy	13400	235000	0.382
Chromium steel	7700	200000	0.32

Table 2.1 Density, Poission ratio Value

3. Result and Discussion

3.1 Titanium Alloy

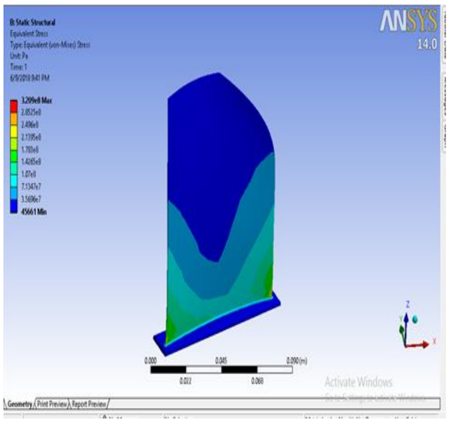


Figure 3.1 Stress Analysis for Titanium alloy

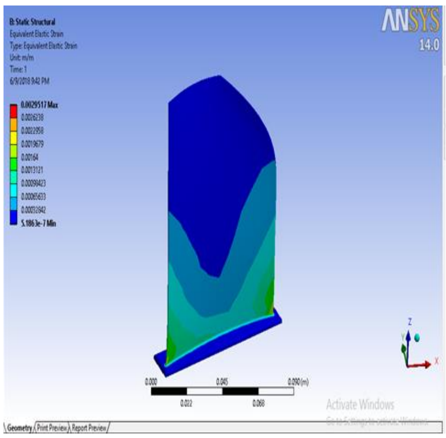


Figure 3.2 Strain Analysis for Titanium alloy

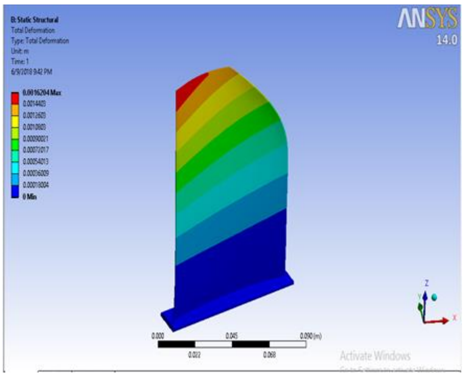


Figure 3.3 Total Deformation Analysis for Titanium alloy

3.2 Nickel Alloy

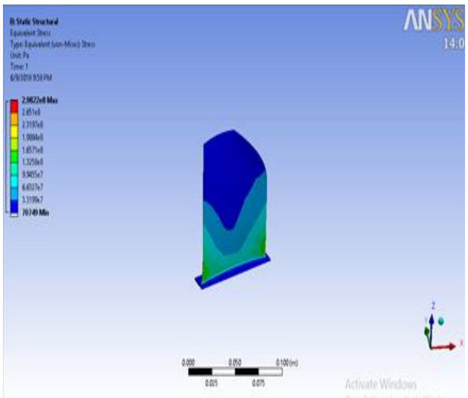


Figure 3.4 Stress Analysis for Nickel alloy

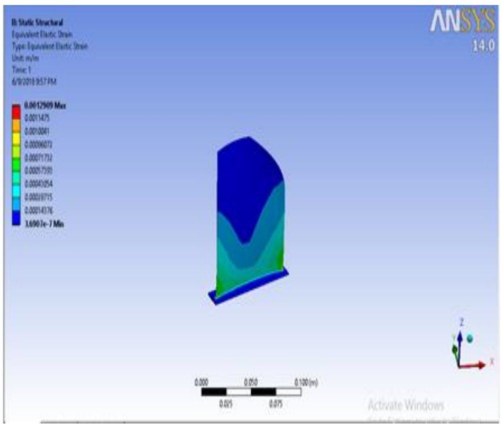


Figure 3.5 Strain Analysis for Nickel alloy

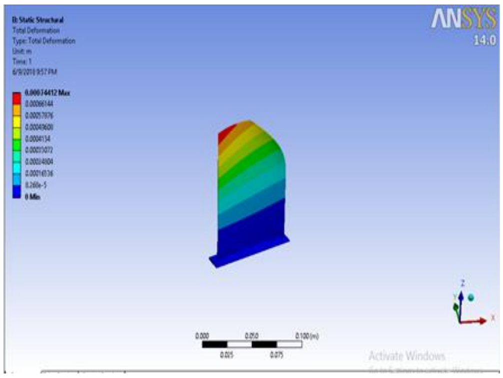


Figure 3.6 Total Deformation Analysis for Nickel alloy

3.3 Chromium Alloy

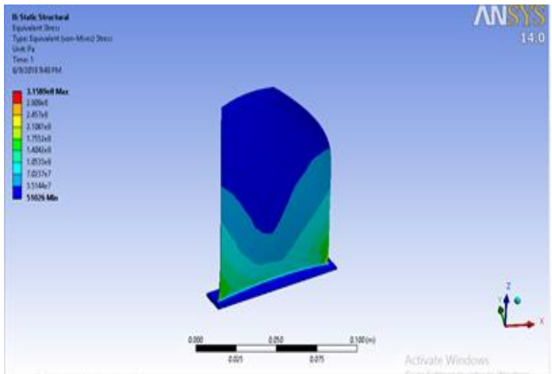


Figure 3.7 Stress Analysis for chromium steel

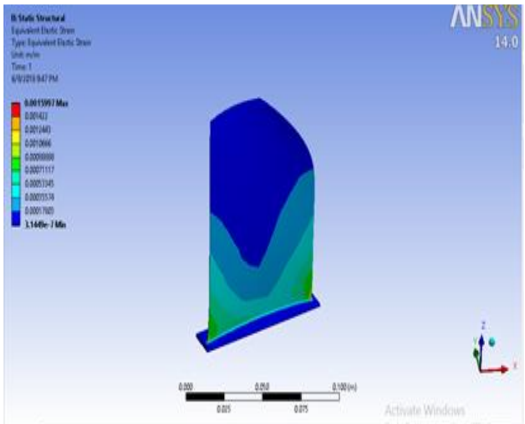


Figure 3.8 Strain Analysis for Chromium steel

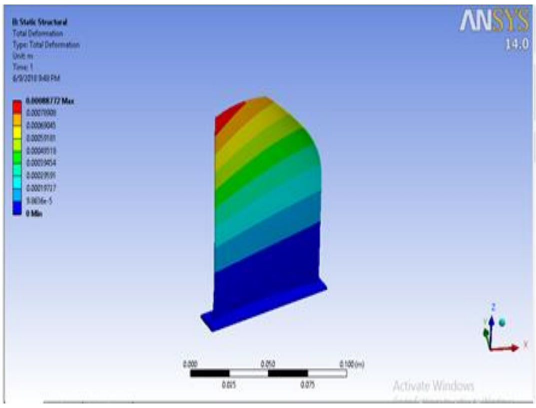


Figure 3.9 Total Deformation Analysis for Chromium steel

4. Summary and Conclusion

The research was done aimed at investigating the effect of blade leading edge sweep (scimitar shaped blade) on the high stress zones acting on the compressor blade. Modeling of blades are done using CAD tool CATIA. The model is then analyzed using FEA Package ANSYS to obtain the stress concentration at fixed and rotating condition of the compressor. Obtained the overall performance map of the modified rotor blade design.

MATERIAL	STRESS	STRAIN	DEFORMATION
Titanium alloy	3.209E+8	0.0030	0.00162
Nickel alloy	2.982E+8	0.0011	0.00066
Chromium steel	3.158E+8	0.00159	0.00088

Table 4.1 Stress, Strain value

Thus, best suitable material for the scimitar shaped compressor blade is Nickel alloy. Because nickel alloy gives lowest stress,strain and total deformation for these shaped blade.

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