Design and CFD Analysis of Compressor Blade

T.Bharathan[1], M. T. Jaffar Sathiq Ali[2], D. Pio Casmir[3], A.Saravanan[4]
[1,2,3,4] *Assistant Professor, Department of Mechanical Engineering, Dhanalakshmi Srinivasan Institute of Technology, Trichy, India*

***Abstract* – This work deals with comparison of the two axial compressor blades to improve the strength in two different materials using the CFD software. Here Axial Compressor was chosen because of its high efficiency and performance. Titanium and Nickel based alloy was proposed to material and angle of axial compressor blade is 60° & 2.5 mm thickness and 45° & 2 mm thickness was considered for analysis. A detailed flow and structural analysis was carried by CFD software. Results showed that Titanium having more strength compared to Nickel based alloy and more pressure occurred at 60° & 2.5 mm thickness compressor blade.**

***Keywords* – Compressor, Blade Material, Gambit, Flow Analysis**

I. INTRODUCTION

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 [2]. Axial-flow compressors are used in medium to large thrust gas turbine and jet engines. The compressor rotates at very high speeds, adding energy to the airflow while at the same time compressing it into a smaller space. The design of axial flow compressors is a great challenge, both aerodynamically and mechanically [1]. (K.M.Pandey, S.Chakraborty 2012) Investigated the CFD Analysis of Flow through Compressor Cascade. The results is observed that maintaining a slightly positive angle of flow incidence of +2 to +6 degrees is advantageous.

(Reza Aghaei tog , A. Mesgharpoor Tousi 2007) Presented the Design and CFD analysis of centrifugal compressor for a micro gasturbine. The numerical results with respect to performance data showed quite good agreement with experimental data at and near the operating point of best efficiency. Computational Analysis of Compressor Blade was carried by (Sheik Ghouse .M, P. Manivannan 2015). It showed that the two dimensional and three dimensional results have been made by using various software's. Finally we compared to experimental result with analytical result so the experimental result and analytical result in two dimensional will be the same at last the experimental and analytical results have compared.

(Akinola A et al 2012) Investigated the CFD Modelling of Wakes on Cascade Compressor Blades.They present a Large Eddy Simulation and k-ω SST turbulence model to study wakes in the flow field of a linear cascade of compressor blades using ANSYS-CFX. Florin Iancu et al (2007) presented a Numerical Analysis of Blade Geometry Generation Techniques for Centrifugal Compressors. They are concluded Analysis of experimental results originally showed there was a potential difference in impeller geometry. When this difference was confirmed, it was evident that engineers must continue to be involved in the modeling of impeller geometry to insure that the design intent is maintained. This also means understanding the geometry modeling technique of the design code, but at the same time taking into account the impeller fabrication process.

In this case, engineering used an SLE-based design code. Unknowingly, a change in blade profile tolerance resulted in a difference in thickness between the two models—again leading to the conclusion that engineers must follow the drafting effort. Engineering would not have guessed that the differences in modeling techniques could have made such a difference in performance, especially since several span wise layers were provided to drafting. As this study shows, it was the fact that the SLE blade design was closer to the design intent, the goal being to control rates of diffusion through the blade based on design experience to achieve the best efficiency possible [7].

In this approach changing the compressor blade material the strength and temperature load will increase. For the change of blade we used high temperature and composite material. We have chosen axial flow compressor that working in aircrafts. In axial flow compressor there is no major Deviation in airflow, and the overall CPR also high. First we have modeled a blade with two different angles and thickness. Then we have done flow analysis in fluent software.

The modeling and meshing are done by the software Blade-gen and Gambit. And we added extra ingredient to our project by selecting two different types of high temperature material in compressor blades. Finally we have done structural analysis for the two materials in two different models of blades we designed. And we have chosen the best design and material by the comparison of deformation, stress and strain among them.

A Compressor Stall in a gas turbine engine is a condition in an axial-flow compressor in which one or more stages of rotor blades fail to pass air smoothly to the succeeding stages. A stall condition is caused by a pressure ratio that is incompatible with the engine rpm. Choked flow is a fluid dynamic condition associated with the Venture effect. When a flowing fluid at a given pressure and temperature passes through a restriction into a lower pressure environment the fluid velocity increases.

A. Single Stage Air Compressor

We are engaged in meeting the demands of Single Stage Air Compressors. Finding extensive application in areas like Mining Industries, Agriculture, Rubber factories, Chemical Plants, Automobile, Sewage disposal Plants, Shipyards, Fertilizer Plants and Paper Mills, these are manufactured using quality material and are well appreciated by clients for their application specific designs, precision functionality and durability standards.

B. Two Stage Air Compressor

We also offer customers Two Stage Air Compressors that are Precision manufactured and are well appreciated by clients for their high performance standards. These compressors are manufactured using latest technology & quality material that makes them deliver exceptional accuracy and performance in areas like Paper Mills, Sewage disposal Plants, Shipyards & Fertilizer Plants, Agriculture & Mining Industries. Note that the IGV also adds no energy to the flow. It is designed to add swirl in the direction of rotor motion to lower the Mach number of the flow relative to the rotor blades, and thus improve the aerodynamic performance of the rotor.

II. DESIGN

The design specification of the axial flow compressor such as Inlet flow angle, Stage flow coefficient, Hub tip ratio. Certain parameters in the compressor will vary in the compressor, namely;

1) *Tip clearance, e/c*
2) *Aspect ratio, h/c*
3) *Thickness chord ratio, t/c*
4) *Axial velocity ratio, AVR*
5) *Blockage factor, BLK*
6) *Diffusion factor, DF*

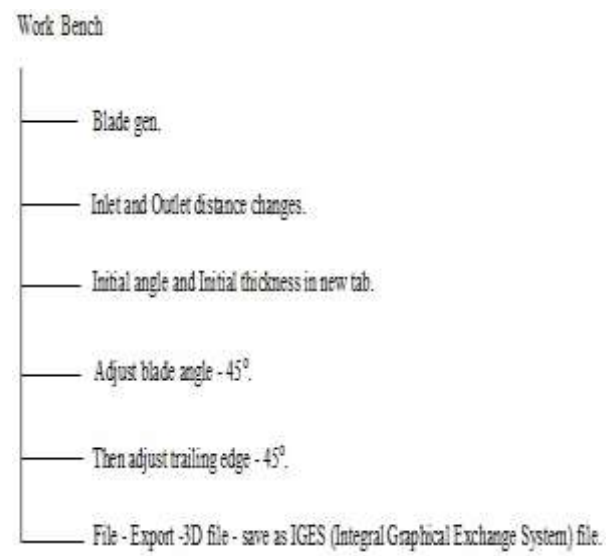
A. BLADE GEN – Modeling

Blade Modeler provides the essential link between blade design and advanced simulation including computational fluid dynamics and stress analyses. Blade Modeler contains a rich set of tools and functions for designing a turbo machinery blade from scratch, using industry-specific tools, workflow, and language that the blade designer expects.

With Blade Gen, the user can re-design existing blades to achieve new design goals or create completely new blade designs from scratch. When either re-designing or evaluating an existing blade design, BladeGen facilitates the import of blade geometry interactively or through user supplied files.

Blade - Gen allows sculpted or ruled element blades with linear or compound lean leading or trailing edges. Over/Under-Filing can be applied and leading and trailing edge shapes are easily specified as a full radius, an ellipse ratio, or a simple cutoff.

Blade Modeler represents a pivotal link between blade design, advanced analysis and manufacturing. Used in combination with ANSYS analysis software, users can rapidly evaluate the performance of a component. BladeGen model files can be imported into Design Modeler using the Blade Editor feature. Blade Editor provides a seamless path to both structural and fluid analysis, which enables the user to efficiently transition from preliminary blade design, to full 3-D viscous flow analysis, and finally to the users native CAD system.



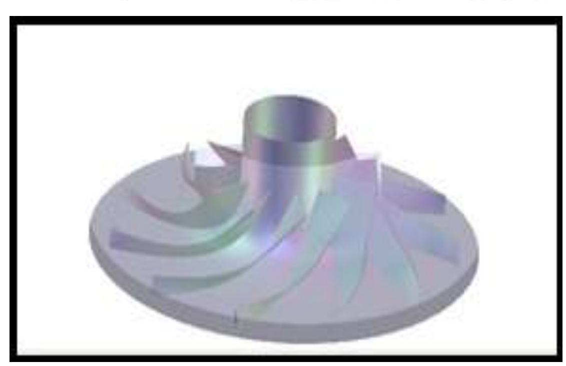
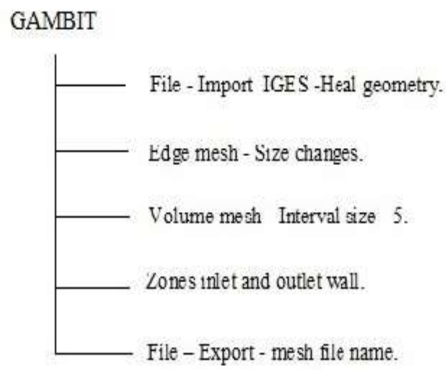


Fig. 1 Compressor Blade Model Diagram

B. Meshing



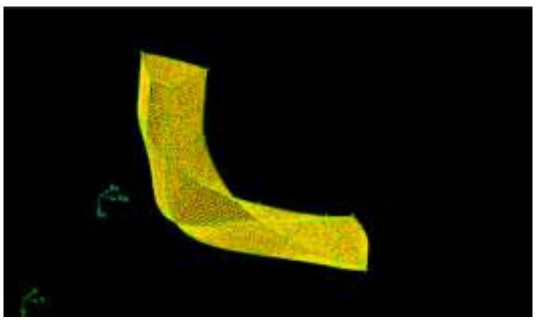


Fig. 2 Meshed Blade Diagram

III RESULTS

A. Fluent – Flow Analysis

The figure 3 indicates the flow analysis in first model of compressor blade. In above flow analysis the inlet pressure is 1034214 Pa applied in the first model of the compressor blade and the maximum pressure the blade can withstand is 9.99×10^{9} Pa.

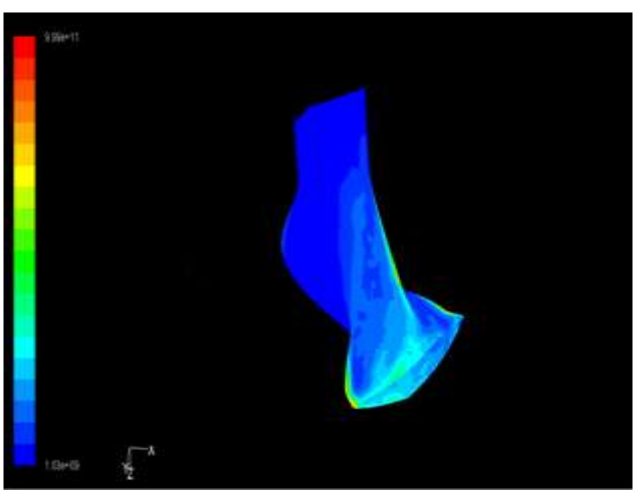


Fig. 3 Flow analysis in first model of compressor blade.

The figure 4 shows the flow analysis the inlet pressure is 1713214 Pa applied in the first model of the compressor blade and the maximum pressure the blade can withstand is 9.56×10^{9} Pa.

Table 1. Comparison of Two Blades.

MODEL ONE AT 60^{0} ANGLE & 2.5 mm THICKNESS	MODEL TWO AT 45^{0} ANGLE & 2 mm THICKNESS
Flow analysis (pressure)	
9.99×10^{5} Mpa	9.56×10^{5} Mpa
Structural analysis	
Nickel base alloy	
23436 mm deformation	1281.5 mm deformation
2.703×10^{7} MPa stress	8.3352×10^{6} MPa stress
74.376 strain	26.896 strain
Titanium	
73438 mm deformation	4068.9 mm deformation
2.8036×10^{7} MPa stress	8.1585×10^{6} MPa stress
226.28 strain	62.914 strain

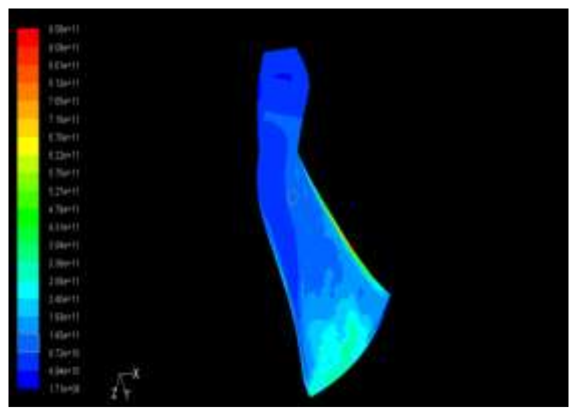


Fig. 4 Flow analysis in second model of compressor blade

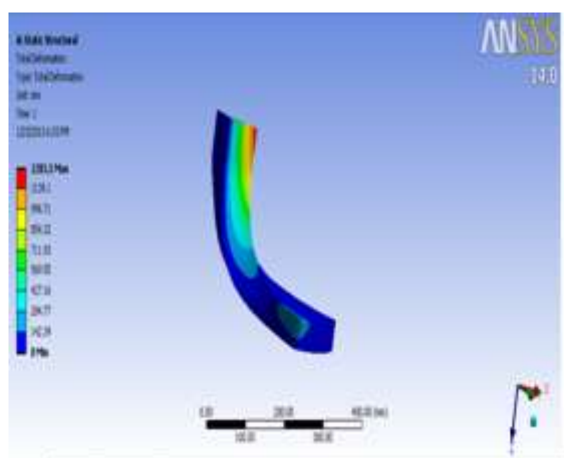


Fig. 5 Total deformation in second model blade with Ni based alloy.

The fig 5 repesents the total deformation in the second model blade with ni based alloy was 8.3352×106 MPa.

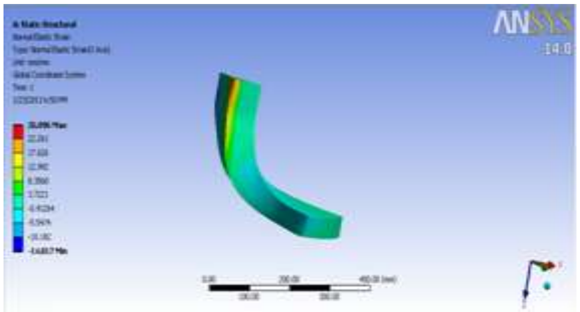


Fig. 6 Normal strain in second model blade with Ni based alloy

The fig 5 repesents the normal strain in the second model blade with ni based alloy was 26.896.

IV. CONCLUSION

The Analysis done on the axial compressor blade in two different angles and two different materials by using CFD software. Finally we compared to two results. The comparison of results showed that there was difference in strength in blade geometry and also blade materials. Titanium material has more strength in 60° blade angle & 2.5 mm thickness. The similar analysis may be considered by changing the parameters like influence of geometry, composite materials as scope for future research.

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