Journal of Advanced Engineering Research
ISSN: 2393-8447
Volume 10, Issue 2, 2023, pp.278-281

Design and Analysis of Axial Flow Compressor Blade Profile using Optimized Airfoil Geometry for Maximum Aerodynamic Performance

Adarsh Aare[1]*, Joyal Dsouza[1], Dhruvika Solanki[1], Maitrik Patel[1]

[1]Department of Mechanical Engineering, St. Francis Institute of Technology, Mumbai-400103, India

*Corresponding author email: aadershganpataare75@gmail.com

Abstract

Increase in efficiency of axial for compressor has been quest for a long time among researchers. And the efficiency of blade of these compressors can be widely varied by type of airfoil being used. Generally, the airfoil model presented by Nasa is used which have found to be efficient and reliable. Here an attempt has been made to have some modifications to the airfoil and then the modified airfoil has been compared with standard airfoil to check the effectiveness of modification. Further in the paper the lift and drag coefficient is compared to standard airfoil which is the principal characteristic of a blade along with pressure distribution along the surface of the compressor blade observed. A standard Naca 64168 airfoil was modified by manipulating the airfoil the airfoil profile. The blade of the later stage of compressor was simulated therefore chord of the blade was taken to be 10cm. Ansys and xflr software was used which are widely used software for simulation purpose in the industries. It was seen that the desired characteristics were obtained which supports to increase the efficiency of axial flow compressor.

Keywords - Airfoil, Angle, Coefficient of drag and lift

1. INTRODUCTION

The design of a blade is a very complex process that has many variables, such as blade geometry, blade material, cooling factors, blade surface finish, clearance tip, and operating condition. Previously many studies have been on the design of axial flow compressor blade we referred to some of the paper which were useful for the study of blade were. In one of the paper axial flow compressor was designed using fundamentals of thermodynamics, gas dynamic, fluid mechanics, aerodynamic and some empirical relations were used. First annulus area using Continuity equation than by using thermodynamics relation pressure and velocities were related than by using velocity triangle angle were found was used flow was assumed to be 2 dimensional and free vortex (Shi). A five-stage compressor blade was designed, and thermodynamic and fluid mechanics were used. In this paper, a replica of a blade used in industry was simulated. This paper can be helpful in obtaining an important empirical relationship between chord and various angles (Jaiswal, 2013). It is a paper which helps to understand all the key parameters involved in blade selection. Blades profiles are nicely categorized by Mach number requirement. This paper also provides the assumptions with which analysis should be carried out to get satisfactory results (WRIGHT)The compare the two airfoils in a 2D simulation, so a detailed view of the above parameters is out of the scope of this paper, although the angle of attack has been taken into consideration. The Naca 65 series airfoil profile was chosen because it is suitable for subsonic flows. We chose NACA 65-(3) 618 (WRIGHT). We understood what parameters and how to test the blade by this research paper discusses the aerodynamic design and optimization of a single stage axial flow compressor for a gas turbine engine. The design is optimized using computational fluid dynamics (CFD) software for a constant tip diameter, power, and tip speed. The design is further optimized for minimum total pressure loss. The paper presents experimental validation of prototype blade cascades in a low-speed wind tunnel and compares the resulting data with the numerical analysis(chadauri).

2. INDENTATIONS AND EQUATIONS

Here some key characteristics of airfoil is compared. Coefficient of lift and drag and coefficient of pressure has been simulated for both the airfoil and then their value was compared as they are one of the key characteristics of airfoil (Boyce, 2006)

Coefficient of Lift

The coefficient of lift is a dimensionless value that represents the amount of lift generated by an airfoil. The coefficient of lift can be mathematically expressed as the ratio of the lift force acting on the object (an airfoil) to the dynamic pressure of the fluid flow.

$$C_L = \frac{L}{\frac{1}{2}\rho U_\infty{}^2 A_H}$$

where, L=Lift Force
ρ = Density of air
U_∞ = Free stream velocity
A_H = Horizontal projected area

Coefficient of drag

The coefficient of drag (C_D) is also a dimensionless value that represents the amount of drag generated by on an airfoil. The coefficient of lift can be mathematically expressed as the ratio of the drag force acting on the object (an airfoil) to the dynamic pressure of the fluid flow

$$C_D = \frac{D}{\frac{1}{2}\rho U_\infty{}^2 A_v}$$

D = Drag Force
A_v = Vertical projected area

Coefficient of Pressure

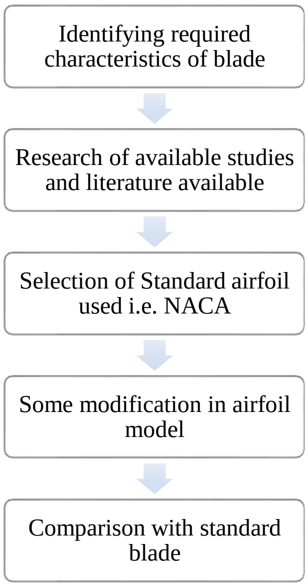
The coefficient of pressure (Cp) is a dimensionless parameter that is used in fluid mechanics to describe the pressure distribution over a body or surface (an airfoil) in a fluid flow. Cp is defined as the difference between the local pressure and the free-stream static pressure, normalized by the dynamic pressure of the fluid. It can be mathematically expressed as the ratio of difference between local pressure and free stream static pressure and dynamic pressure of fluid.

$$C_p = \frac{P - P_\infty}{\frac{1}{2}\rho U_\infty{}^2}$$

P = Local Pressure
P_∞ = Free stream static pressure

3. METHODOLOGY

Since we are comparing the two airfoils, we need to compare them on the parameters that are essential and critical to the performance of the compressor blades. Three main parameters essential for compression blades are Coefficient of lift Coefficient of drag and Coefficient of pressure, so further comparison of these parameters has been carried down by comparing them at same input condition of 100mm chord length and 65-(3) 618 Reynolds number. The selected standard airfoil was modified by increasing the camber and decreasing the overall thickness of the blade which should improve the efficiency of compressor blade(new). The velocity and pressure distribution were also checked whether they had the required characteristic to be able to be used in the compressor blade.



Coefficient of Lift

The coefficient of lift must be small for the efficiency of the compressor blade (Abbasi, 2019). So, by the comparison (Fig 1) (green lines represents naca and white modified), we can observe that the average coefficient of lift along the chord of the compressor blade is higher in the Modified airfoil than the Naca 65-(3) 618. Also, the nature of the coefficient of lift along defined coordinates is typically highest at the maximum thickness point of the blade and decreasing towards the leading and trailing edges, which is the similar for both the blades that can be seen in the graph.

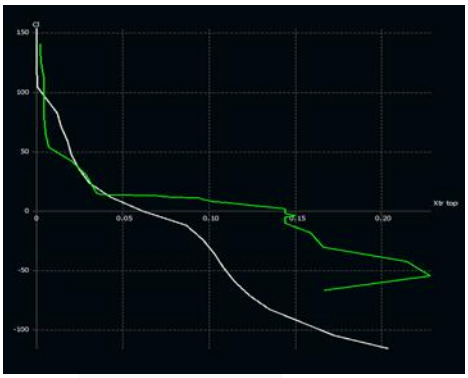


Fig. 1. C_L vs Chord length

Coefficient of Drag

Coefficient of Drag The coefficient of drag must be as low as possible to avoid the frictional loss of energy in the inlet air (Abbasi, 2019). By the comparison, we can observe (Fig2) that the average coefficient of drag along the chord of the compressor blade is less in modified air foil where the air velocity is high than the Naca 65-(3) 618. The profile of the coefficient of drag is typically that the coefficient of drag will be highest near the blade's leading edge and decrease towards the trailing edge, which is similar in the both airfoil when observed by the graph.

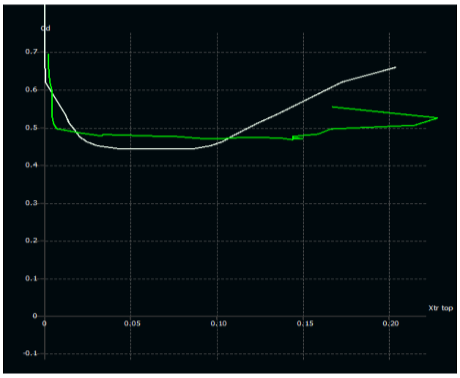


Fig. 2. C_D vs Chord length

Coefficient of Pressure

The coefficient of pressure must be uniform along the chord of the compressor blade, as if it is not uniform throughout the chord, it can cause inefficient airflow and generate areas of high drag, leading to a reduction in compressor efficiency. So, by comparing (Fig3) the nature of the coefficient of pressure along the chord, the variation of coefficient of pressure along the chord is identical.

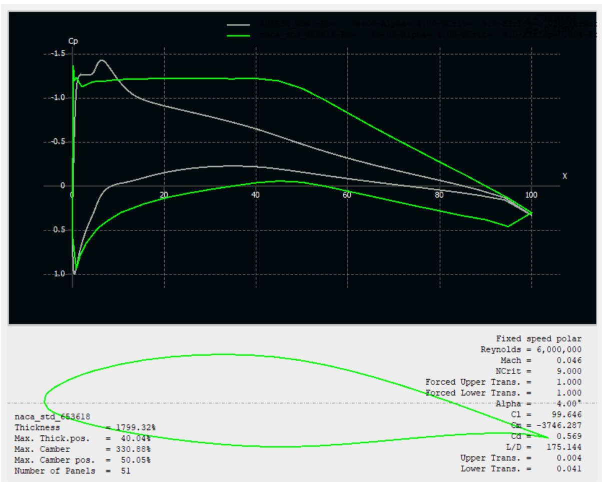


Fig. 3. Comparing C_p of Standard and Modifies airfoil

Velocity Distribution

The velocity at the inlet of the blade is low and gradually increases towards the outlet. This increase in velocity is due to the acceleration of the incoming air as it passes through the blade which is not seen in Naca but in modifies airfoil (Fig4, Fig5) it can be counted as one of the advantages.

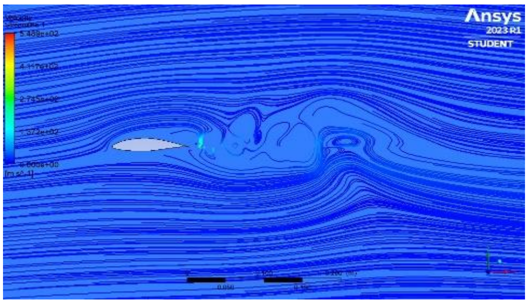


Fig .4. Velocity distribution (NACA 65-(3) 618)

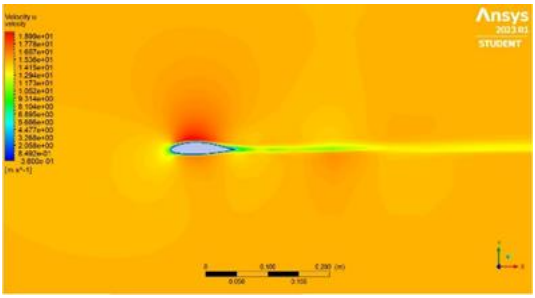


Fig. 5. Velocity distribution (Modified Airfoil)

Pressure Distribution

For axial flow compressor blade the pressure is highest near the leading edge of the blade and decreases towards the trailing edge This is due to the Bernoulli's principle, which states that as the velocity of a fluid increases, its pressure decreases which is partially true for modified the aero foil as seen by the below images(Fig6 and Fig7) i.e. Pressure increases again but it has negative pressure which helps in generating lift on the blade, while Naca has a uniform pressure distribution.

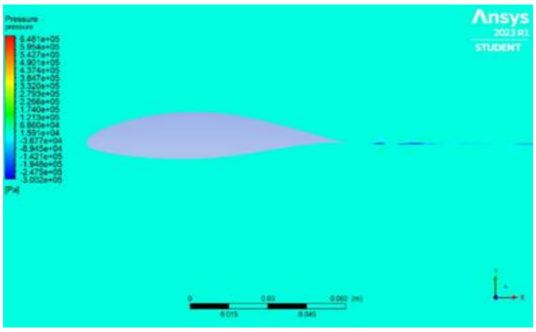


Fig. 6. Pressure distribution (NACA 65-(3) 618)

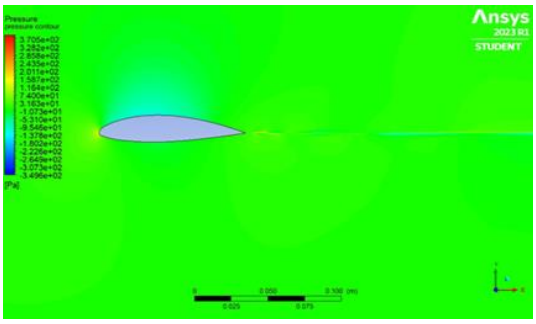


Fig. 7. Pressure distribution (Modified Airfoil)

4. RESULTS

From result it is evident that C_L is maximum for Naca but it more defined for modified aero foil which shows more ordered flow of air. C_D is lower in modified aero foil which is better for functioning of Compressor's. C_P profile is similar (not same) for aero foil which is desirable. Velocity in modified aero foil is also increasing along the chord While we have negative pressure at the top of axial low compressor which helps in generating lift. So, by all those parameters modified airfoil may increase the efficiency of axial flow compressor which was the aim of the paper.

	NACA 65-(3) 618		Modified Airfoil	
	Max	Min	Max	Min
C_L	153.2568	53.62307	64.4435	31.11545
C_D	0.692973	0.496514	0.545987	0.493935
C_p	1.36869	0.000645	1.10795	0.00194
V	166.4 m/s	0 m/s	18.9 m/s	-0.036 m/s
P	15910Pa	-3.002Pa	158.7Pa	-10.7Pa

Table. 1. Comparison results of standard and modified airfoil

5. CONCLUSION

After Simulation and comparing the result it was seen that some properties required for efficient compressor was found as decreased CL value and nature of the properties along the chord pf the Though CL for standard was seen to be more than modifies. So, to overcome some of the shortcoming in future the blade profile can be modified in any other way or the manufacturing process can be altered to get cooling vents and manufacturing of more complex geometry blade and can be check for improved characteristics.

ACKNOWLEDGEMENTS

We would like to thank all the faculties of St Francis Institute of Technology especially Our Guide MK Bysani for Helping us and guiding us through out the process. We would also like to thank all the authors of research paper whose papers we were able to successfully carry out for research.

REFERENCE

[1] Gaddam Srikanth, S.Srinivas Prasad, V.Mahesh Kumar, and B.Mounica Reddy. "Design Methodology of a Two Stage Axial Compressor." Journal of Engineering and Applied Sciences, vol. 12, no. 4, 2017, pp. 958-964.

[2] U. A. Jaiswal, "Design and analysis of stator, rotor and blades of the axial flow compressor," in Proceedings of the 2013 International Conference on Advances in Engineering and Technology (ICAET), Mumbai, India, 2013, pp. 1-6, doi: 10.1109/ICAET.2013.6559042

[3] L. C. Wright, "Blade selection for a modern axial compressor," presented at the 45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, Denver, CO, USA, 2009.

[4] M. Chaudhari, R. K. Dave, and N. Bhagat, "Design optimization of an axial flow compressor using CFD approach and experimental validation," in Proceedings of the 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, India, 2015, pp. 1-6, doi: 10.1109/ICECCT.2015.7226058

[5] M. Chaudhari, R. K. Dave, and N. Bhagat, "Design optimization of an axial flow compressor using CFD approach and experimental validation," in Proceedings of the 2015 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), Coimbatore, India, 2015, pp. 1-6, doi: 10.1109/ICECCT.2015.7226058

[6] M. P. Boyce, "2.0 Axial Compressor," in Gas Turbine Engineering Handbook, 3rd ed. Burlington, MA, USA: Butterworth-Heinemann, 2006