iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68805

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Flow Separation Analysis of a Turbine Blade NACA 63-415

Dr. Ajith V S[1], Anjitha V[2], Keerthick K[3], Praveena Prasannan[4], Saniga Ram E[5]
[1]Assistant Professor, [2, 3, 4, 5]UG Scholar, Department of Aeronautical Engineering, Jawaharlal College of Engineering and Technology, Lakkidi, Mangalam P O, Palakkad, Kerala, India – 679301

Abstract: This paper investigate the flow separation behavior of a turbine blade using NACA 63-415 airfoil in three arrangements- without slot, with single slot, with double slot. Computational fluid dynamic simulation are used to study airfoil behavior at 0 to 20 degree angle of attack.to investigate how separation begins and develops.

The study targets determination of significant angle of attack at which the flow separation initiates since it influences both the efficiency and performance of the turbine blade. Important aerodynamics factors like pressure distribution, velocity contours and the impact of turbulence are assesses to determine the change in airfoil patterns. Further the research explores whether slot modification at the leading edge are efficient in controlling or postponing flow separation and hence aerodynamic efficiently can be improved. Single and double slot existence is explored to find their effectiveness in enhancing lift to drag ratio, lowering turbulence intensity and ensuring smoother airfoil on the blade surface.

This analysis enables design enhancement for achieving more stable and efficient operation of turbines. This study conclusion promote the design of turbine blade with a target to reduce losses in energy and enhance overall efficiency. The work has major repercussions in industries depending on turbine powered applications. This research supports advancing the durability of turbines, stability of running operations as well as their efficiency in using energy.

Keywords: slotted airfoil, double slot, flow separation, NACA 63-415

I. INTRODUCTION

This research examines the influence of leading edge slots on turbine blade airfoil aerodynamic performance, specially on flow separation control. The study compares a reference NACA 63-415 airfoil with single slot and double slot leading edge configurations. The aim is to alter airfoil behaviour, postpone flow separation, and enhance turbine efficiency by increasing lift and decreasing drag. By creating these slots, the research is looking to enhance flow attachment and re-energize the boundary layer. Perfoemance is measured at different angle of attack in order to determine the most effective design to manage flow separation.

A. Aerodynamic Flow Seperation

Flow separation happens when the boundary layer separates from a surface and forms a turbulent wake. In turbo machinery, this can decrease turbine efficiency by adding drag and reducing lift. Flow separation must be managed for turbine blades, which have high speed and high temperature operating conditions, in order to maximize turbine efficiency and lifespan. Figure 1.1 illustrates flow separation on an airfoil.

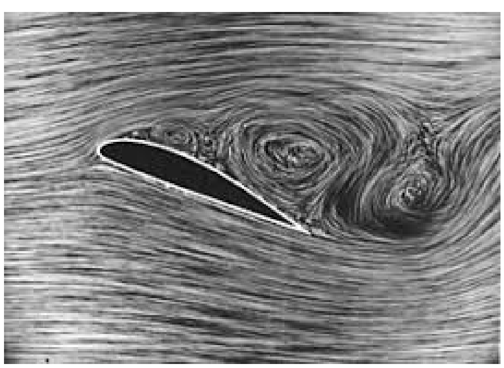


Fig. 1.1 Flow Separation

B. Flow Separation Control

Flow separation is when air separates from a surface and forms turbulence and vortices which raise drag and lower lift particularly at high angle of attack. Flow separation is important in aerodynamic devices such as aircraft wings, turbine blades and car bodies. Reducing flow separation enhances lift to drag ratio, stability and overall efficiency in these systems.

i. Mechanisms of Flow Separation

Flow separation usually happens when the pressure gradient along the airfoil becomes adverse, i.e, the pressure rises in the direction of flow. At larger angle of attack the flow cannot sustain its attachment to the surface because there is not enough momentum to overcome the adverse pressure gradient, causing detachment and creating a turbulent wake.

ii. Importance of Flow Separation Control:

- Enhanced Lift: Postponing separation enables airfoils to sustain greater lift at higher angle of attack which is important during takeoff and landing.
- Reduced Drag: Through separation control, induced drag is reduced and enhancing fuel efficiency.
- Stability and Control: Stable control of separation of flow avails against stability and problems such as stalling which ensurers control over aircraft or other structures that are aerodynamic.
- Performance Optimization: Separation control in wind turbines improves energy harvesting and efficiency.

iii. Techniques for Flow Separation Control:

➢ Geometric Modifications:
- Leading-Edge Slots: Leading edge slots or flaps energize the boundary layer, enabling airflow to stay attached longer and postponing separation.
- Vortex Generators: Small mechanical components that induce vortices to distribute high energy air into boundary layer, postponing separation.

➢ Surface Modifications:
- Surface Roughness: Applying controlled roughness can induce turbulence in the boundary layer developing its energy and enhancing flow attachment.
- Airfoil Shaping: Shaping the airfoil to optimize it minimize separation hazards.

➢ Active Flow Control:
- Suction and Blowing: Suction (removing air) or blowing (injecting air) into the boundary layer can can control flow behavior using extra energy but efficiently delaying separation.
- Electrohydrodynamic (EHD) Control: This new technology employs electric fields to control the boundary layer minimizing separation without the use of moving parts.
- Adaptive Systems: Sophisticated systems involving sensors and actuators dynamically adjust airfoil parameters in real time to ensure best performance.

C. NACA 63-415

The NACA 63-415 airfoil from the NACA 6-series is optimized to achieve laminar flow and hence to minimize drag at high speeds. It is largely applied in design applications such as high speed airplane wings, propeller and turbine blades for its low drag and high performance efficiency. It is chosen to be used for this paper, so that flow separation in turbine blades can be observed.

- "6": Refers to 6 series, which is characterized by fostering laminar flow and minimizing skin friction drag.
- "3": Indicates the location of minimum pressure around 30% of the chord length which is favorable for laminar flow.
- "4": Indicates a lift coefficient of 0.4% suited for moderate lift and minimal drag.
- "15": Indicates a maximum thickness of 15% of chord length.

The NACA 63-415 is selected due to its high lift to drag ratio and smooth flow behavior which makes it a good candidate for flow separation control study in turbine blades. Its moderate thickness and chord length provide a good balance between aerodynamic efficiency and structural strength. A large amount of experimental and numerical data on this airfoil exists, making it easy to validate and compare the results of the paper.

D. Leading-Edge Slots

Advanced slots are created to enhance airfoil over an airfoil by controlling or delaying flow separation. The small leading edge openings provide a path for air to enter energizing the boundary layer and maintaining airflow attachment longer even at higher angle of attack. This retards flow separation and increases aerodynamic performance.

The performance of the slots relies on the position, size and quantity. Although a single slot can have a profound impact on flow dynamics a double slot arrangement might have even more to provide by allowing for more controlling flow manipulation. Yet the double slot arrangement is less frequently employed and its effects are not well characterized so it represents an area of new research. This research compares the performance of double and single slot configuration in flow separation control at different angle of attack with the purpose of identifying which configuration enhances the aerodynamic performance of the airfoil.

II. DESIGNING OF NACA 63-415

In the beginning of this research, the NACA63-415 airfoil design was given prime importance since this airfoil is widely utilized in the turbine blade applications. The airfoil was designed for different angles of attack to realize its aerodynamic characteristics under different flight conditions. The first step was getting the NACA63-415 coordinates either from software such as Airfoil Tools or calculating the X and Y points with the NACA equations. They are the points that describe the upper and lower surfaces of the airfoil.

In AutoCAD, a fresh 2D drawing was established, and the X and Y coordinates of the airfoil were plotted with the aid of the point tool. The positive Y-values were used for plotting the upper surface, and negative Y-values for plotting the lower surface. Each point for both surfaces was labeled according to the data given.

After the coordinates were graphed, the spline tool was applied to connect the points smoothly and create the upper and lower surfaces of the NACA63-415 airfoil.

The airfoil shape (upper and lower surfaces)was selected as a whole, and the COPY command was applied to duplicate it. The duplicate airfoil was translated upward in the drawing space to ready it for modifications.

Yo insert a slot, the original and duplicated airfoils were altered. The leasing edge of the original airfoil was chosen, and the TRIM or CUT tool was use to divide the airfoil at this point, resulting in an opening

In the original airfoil (the bottom portion), the part from the leading edge to the slot end was removed. This formed the open area required for the slot.

In the replicated airfoil(the top half), the portion from the leading edge to the end of the slot was cut away, exposing only the top surface.

The two halves of the airfoil were disconnected with the MOVE tool. A narrow gap was left between them, signifying the slot opening at the leading edge.

The size of the gap was precisely set according to the required flow behavior, usually creating a small gap close to the leading edge of the airfoil. After creating the gap, the upper and lower parts were reconnected using the JOIN command. The upper surface of the duplicate airfoil was smoothly aligned with the lower surface of the original airfoil. Refinement were made using the TEIM and FILLET tools to ensure clean edges and a proper slot shape.

This design approach describes in detail the method of stepwise modification of the NACA63-415 airfoil involving the generation of single and double slot configuration intended to optimize the aerodynamic characteristics for use as turbine blades.

Fig 2.1 shows the NACA 63-415 airfoil design without slot , Fig 2.2 shows with single slot and Fig 2.3 shows with double slot design.

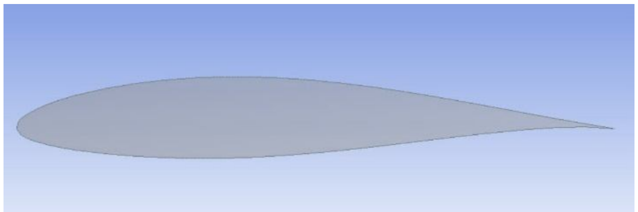


Fig 2.1 NACA 63-415 Airfoil without slot

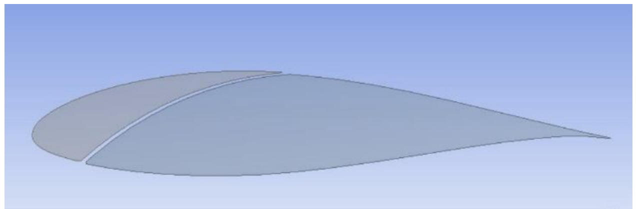


Fig 2.2 NACA 63-415 Airfoil with single slot

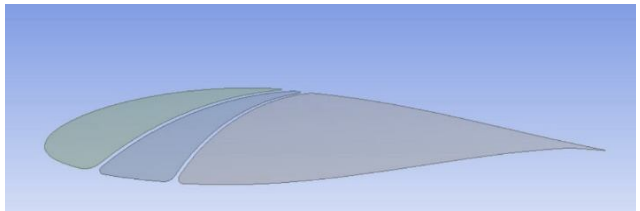


Fig 2.3 NACA 63-415 Airfoil with double slot

III. MESH AND ANALYSIS

Mesh generation is an essential part of the Computational Fluid Dynamics procedure wherein the airfoil geometry along with such alterations as the slot is divided into discrete elements. The discretization permits the solution of the complex fluid flow around the airfoil numerically through the fluid dynamics governing equations. After mesh generation the flow analysis initiates. In this phase different parameters are analyzed such as the aerodynamic characteristics of the airfoil at different angle of attack. The impact of the slot on flow separation is also thoroughly analyzed. By changing the flow conditions for example, variation in AoA, the analysis seeks to comprehend how these changes affect the performance of the airfoil, especially lift, drag and floe separation. Not only does this analysis give insights into the aerodynamic performance of the airfoil as a whole but it also identifies the effect of particular design variations such as the slot on managing flow separation. These results are of prime importance in maximizing turbine blade designs allowing for increased efficiency and stability for uses like wind turbine blades in industrial settings.

A. Geometry

1) Geometry Importing

Export from AutoCAD: The 2D airfoil shape including the slot was initially drawn in AutoCAD and exported as DXF. This format provides a guarantee that all geometric aspects of the airfoil such as the slot design are retained.

Import to ANSYS DesignModeler: The DXF file was then imported into ANSYS DesignModeler, and final edits were done to clean up the geometry and prepare it for CAD simulations. This is important in order to eliminate any errors or flaws that might have occurred in the imported geometry and would affect the simulations accuracy.

2) Computational Domain Creation

Domain Setup: A rectangular computational domain was established around the airfoil to reproduce the flow behavior. The domain setup consisted of the following main specifications:

- Inlet Boundary: Placed 10 times the chord length upstream of the airfoil to permit fully developed flow conditions.
- Outlet Boundary: Located 20 chord lengths downstream of the airfoil to give enough space for the flow to leave the domain without the influence of the boundary.
- Side Boundaries: Fixed at 5 times the chord length from the airfoil to make sure that the side flow effects do not contaminate the results.
- Symmetry: Used along the airfoil centerline for 2D analysis to minimize computational expense while maintaining a correct description of the flow behavior.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

B. MESH

Mesh generation is an important process of Computational Fluid Dynamics (CFD) simulations in which the geometry of the turbine blade is resolved into small cells to solve the governing fluid flow equations. In this project, we concentrate on creating good-quality meshes of three turbine blade configurations: no slot, single slot, and double slot, through the use of ANSYS Fluent. The mesh should be made finer in the critical regions, including the leading edge and flow separation regions, to accurately record flow behavior. We describe below the mesh generation process, refinement strategies, and important considerations for each design configuration.

During CFD analysis, the mesh refinement and quality play a significant role in ensuring accuracy. The mesh generation in each turbine blade design includes the following significant sizing and refinement strategies:

- Edge Sizing 1: Element Size: 5×10^{-3} m. This specifies the element size in the mesh along the edges of the geometry to have better resolution near the leading edge so that the flow dynamics in this key region are captured well.
- Body Sizing : Element Size: 0.2 m. This establishes the element size for most of the geometry. It balances the need to keep sufficient resolution with the need to maximize computational efficiency for the majority of the airfoil's larger areas.
- Edge Sizing 2: Number of Divisions: 10. This parameter splits the edges into 10 parts, providing a more detailed mesh in regions with important flow behavior, like separation and turbulence, where increased resolution is required for precise results.
- Inflation Boundary Layer (Close to the Airfoil):

Growth Rate: 2.4. This regulates the growth of the inflation layers close to the airfoil surface, allowing the boundary layer flow behavior to be captured with greater accuracy.

Maximum First Layer Height: 2.84×10^{-6} m. This will allow the first layer of the mesh close to the airfoil to be thin enough to capture the boundary layer and model the flow close to the surface accurately.

These mesh specifications are optimally selected to facilitate the simulation of the intricate flow phenomena in and around the turbine blade with satisfactory computational efficiency.

Figures 3.1, 3.2, 3.3,and 3.4 illustrate the mesh designs for the NACA 63-415 airfoil, showcasing the detailed structure of the mesh and inflation layers that help to resolve key aerodynamic features.

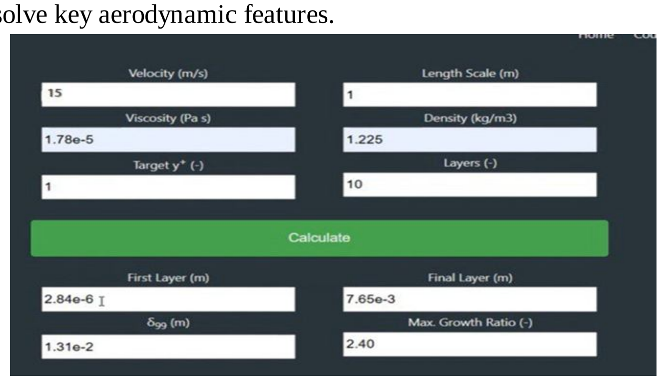


Fig 3.1 Inflation layer calculation

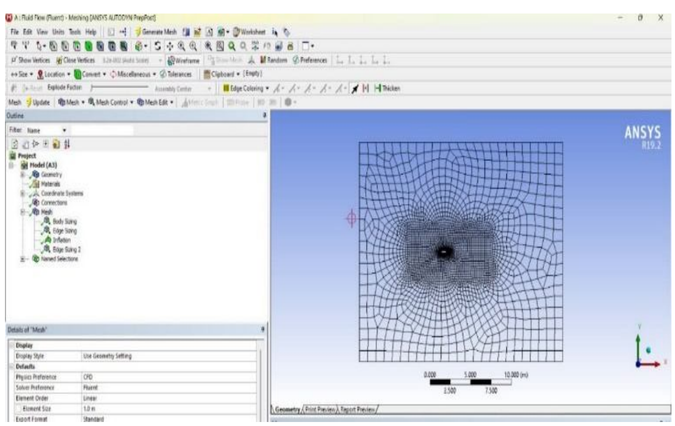


Fig 3.2 Without slot airfoil mesh

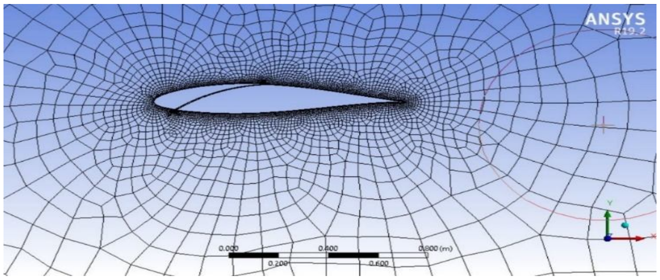


Fig 3.3 Single slot airfoil design

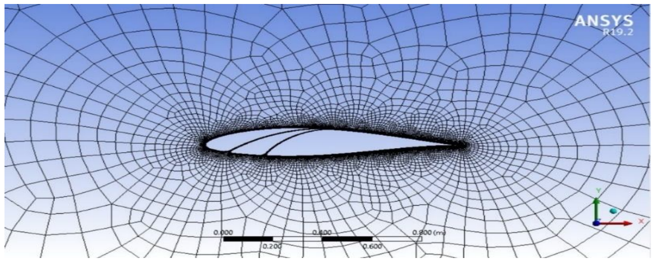


Fig 3.4 Double slot airfoil design

C. Setup

In this research, the fluid flow around the airfoil governing equations were solved based on the k-omega SST turbulence model within the commercial Ansys Fluent CFD package. This model was chosen because of its capacity to properly capture turbulent flow, particularly in wall bounded flows and regions of flow separation which is crucial for simulating airfoils with slots.

The following simplifying assumptions and conditions were applied to the simulation to ensure consistency and accuracy:

- Solver: A pressure-based solver was employed which solved the governing equations for incompressible flow common in analyzing airfoils under the subsonic regime.
- Turbulence Model: The K-omega SST model was used with the production limiter to accurately model turbulence as well as manage flow separation particularly in areas close to the airfoil surface.
- Inlet Velocity: The inlet velocity was specified as 15 m/s imitating general operating conditions for the airfoil.
- Formulation: The second-order upwind formulation was utilized for spatial discretization with greater accuracy of convection terms of governing equations compared to first order schemes.
- Angle of Attack (AoA): Computation was carried out at varying AoA ranging from 0 to 20 degree in order to investigate the airfoil aerodynamic performance at varied flow conditions.
- Monitored Parameters: The drag and lift coefficients were observed during the simulation to evaluate the aerodynamic performance and identify the influence of the slot at the leading edge on the behavior of flow.
- Initialization: A hybrid approach was utilized to initialize the flow field, ensuring stable and accurate convergence of the solution.
- Number of Iterations: The simulation was executed for 1000 iterations to facilitate the convergence of the solution.
- 2D Analysis:The simulation was performed in 2D, which made analysis easier and permitted an in depth examination of the major aerodynamic impacts of the slot and angle of attack.

D. Analysis Result

The CFD result of the three turbine blade geometries without slot, with single slot and with double slot will be discussed and examined. The examination is performed on Ansys Fluent with attention to the aerodynamic performance of the NACA 63-415 airfoil at different AoA from 0 to 20 degree. A complete grid of computational mesh is generated for every design so that the result of the simulation are accurate and reliable. After mesh generation the simulation results are discussed with the major emphasis on the flow separation characteristics, pressure distribution and aerodynamic coefficients for every design at various AoA. The aim is to determine the impact of the changes slots in the leading edge have on flow control and eventually the aerodynamic performance of the turbine blade.

1) Without Slot Airfoil

Velocity contour, pressure contour, and velocity streamline of NACA63-415 airfoil without slot at 10 degree angle of attack shown below,

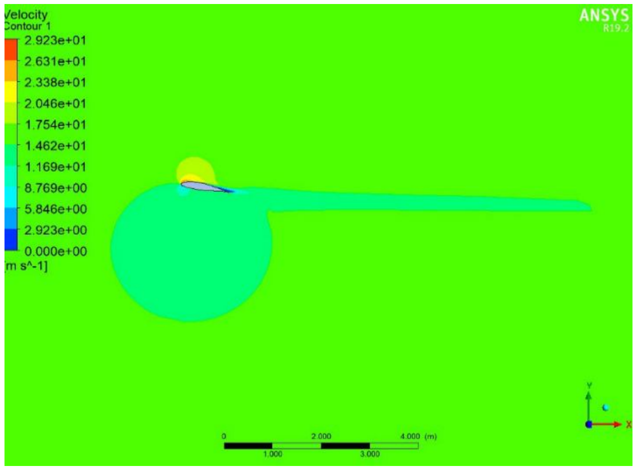


Fig 3.5 Velocity contour 10 AOA

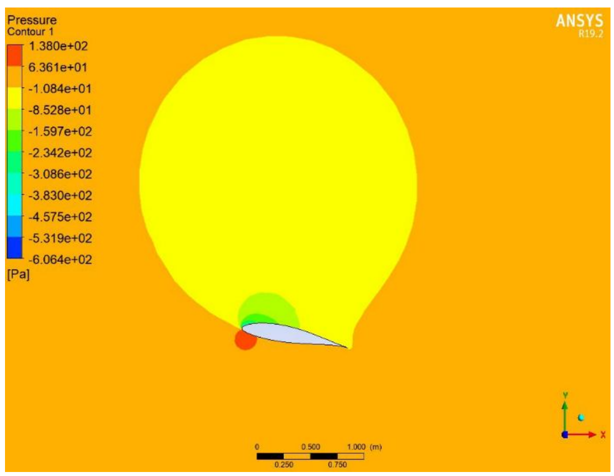


Fig 3.6 Pressure contour 10 AOA

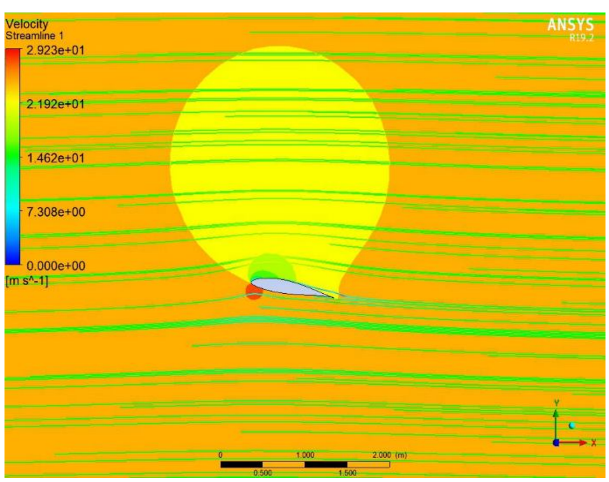


Fig 3.7 Velocity streamline10 AOA

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

2) With Single Slot Airfoil

Velocity contour, pressure contour, and velocity streamline of NACA63-415 airfoil with single slot at 15 degree angle of attack shown below,

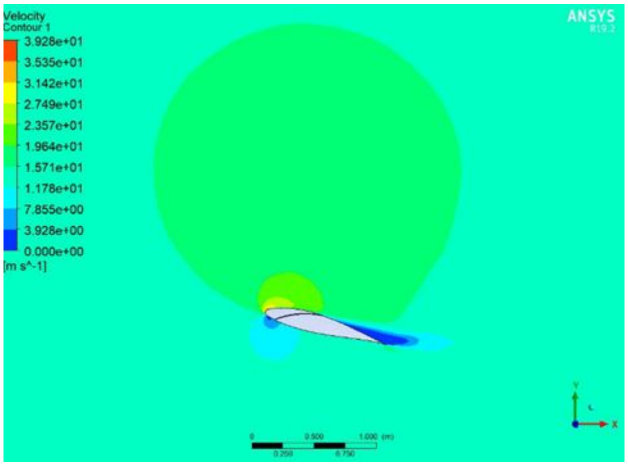


Fig 3.8 Velocity contour 15 AOA

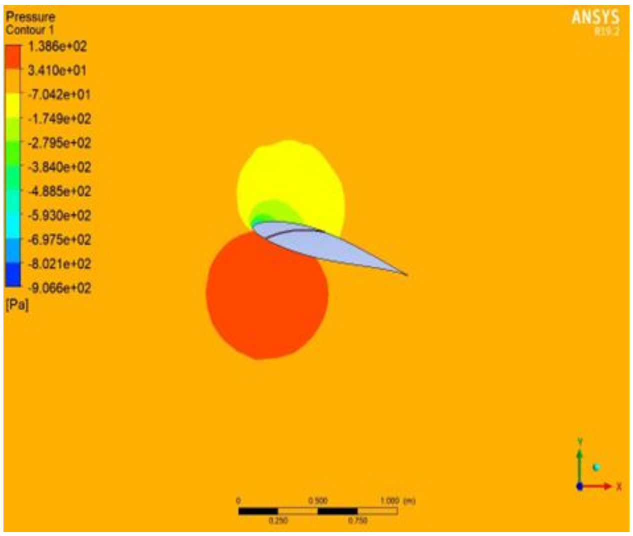


Fig 3.9 Pressure contour 15 AOA

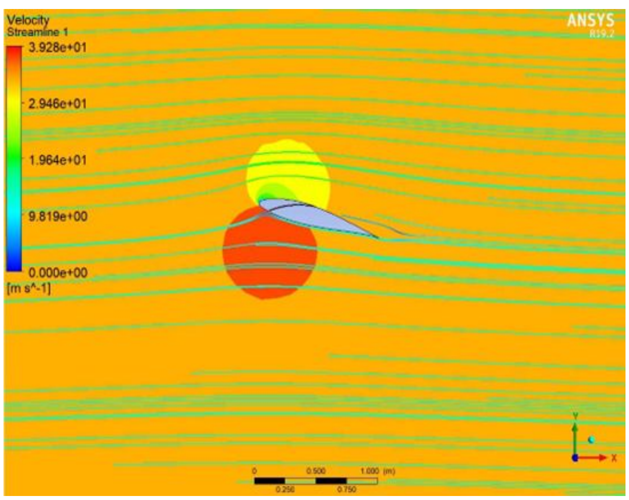


Fig 3.10 Velocity streamline 15 AOA

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

3) With Double Slot Airfoil

Velocity contour, pressure contour, and velocity streamline of NACA63-415 airfoil with double slot at 15 degree angle of attack shown below,

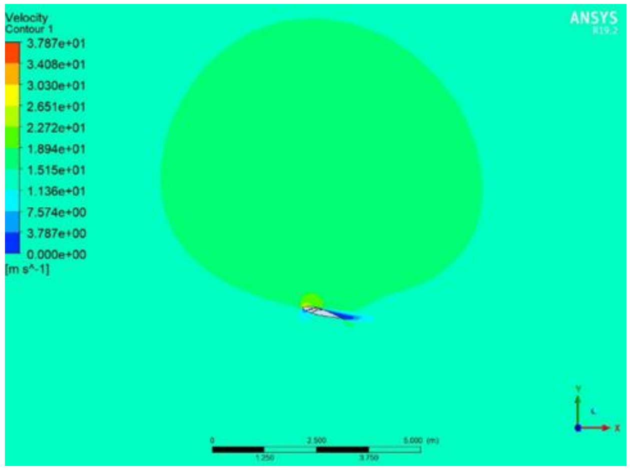


Fig 3.11 Velocity contour 15 AOA

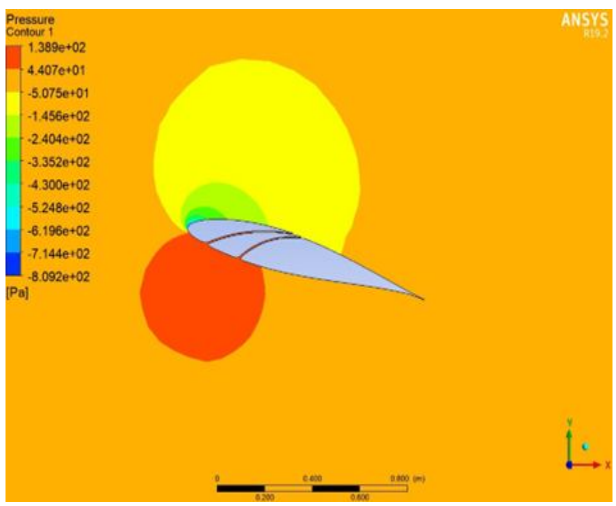


Fig 3.12 Pressure contour 15 AOA

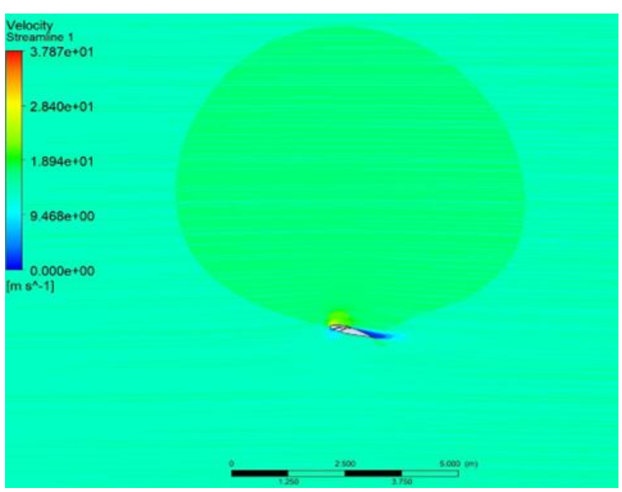


Fig 3.13 Velocity streamline 15 AOA

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

IV. OPTIMIZATION

The blade design optimization is an essential process to improve aerodynamic performance and achieve efficient energy conversion. it will emphasize the enhancement of turbine blade flow separation control by adjusting their geometric parameters, especially slot configurations at the leading edge. Having examined the baseline designs(no slot, single slot , and double slot),the next step is to refine these designs to get the optimum aerodynamic performance at all operating conditions, including a wide range of angles of attack (AOA).

Flow separation, a condition where the boundary layer breaks away from the airfoil surface, has a major effect on the efficiency of a turbine blade. If left unaddressed, flow separation results in increased drag, loss of lift, and overall performance degradation. Therefore, design optimization to delay or control flow separation is essential to achieve maximum aerodynamic efficiency of turbine blades.

Through numerical simulations using codes like ANSYS Fluent and optimization algorithms, we will endeavour to optimize the blade geometric particularly the slot configurations to better promote flow attachment and postpone separation, thereby bettering the lift-to-grag ratio and total efficiency of the turbine blade under different angles off attack. make an effort to determine the optimal blade design not only to successfully control flow separation but also exhibit a considerable boost in performance in actual turbine operational conditions.

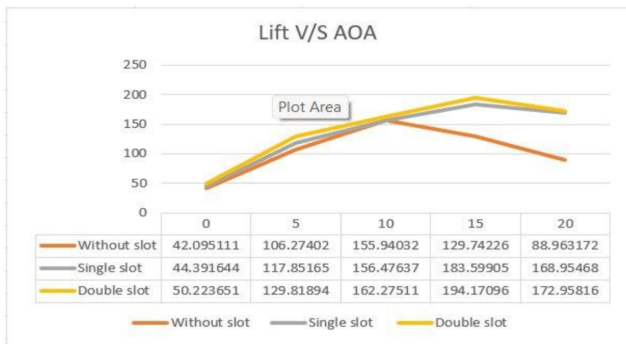


Fig 8.1 Lift v/s AOA

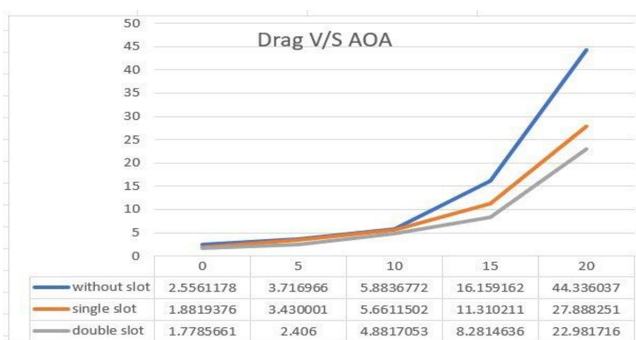


Fig 8.2 Drag v/s AOA

V. RESULT

The comparison of airfoil designs_no slot, single slot,and double slot_demonstrated that the double-slotted airfoil consistently achieved better flow separation control. This improved performance is largely a result of enhanced boundary layer energy, where the two leading -edge slots introduce high-speed airflow that energizes the boundary layer and postpones separation.the first slot re-energizes the low-velocity boundary layer, and the second enhances this effect further, promoting flow attachment. ANSYS Fluent simulations corroborated that separation of flow was postponed at every angle of attack, particularly higher than 10°. Even at an angle of attack of 12°, the airfoil without the slot had flow detachment early, whereas the double -slotted profile had attached flow for a more extended surface area, resulting in improved lift response. This concept also lowered the drag considerably, by approximately 15% when at 15° AOA, while it's lift increased by approximately 8%, reflecting more efficient aerodynamic.

Also, the double -slot configuration allowed for the generation of strong vortices that promoted flow reattachment and reduced separation, particularly in areas of high adverse pressure gradients. pressure distribution analysis revealed a lower adverse pressure gradients close to the leading edge,postponing boundary layer detachment. Flow visualization also verified more streamlined flow, a reduced wake area, and regulated vortex formation in the double -slotted airfoil. Overall,these conditions led to its better aerodynamic properties in comparison to the other designs.

VI. CONCLUSION

Here, the control of flow separation over a turbine blade with three different leading edge slot configurations- without slot, with single slot, with double slot has been studied by employing the NACA 63-415 airfoil and CFD software Ansys Fluent. The analysis was performed over a variety of angle of attack range from 0 to 20 degree with a particular focus on learning how these slot arrangements will affect flow behaviour, aerodynamic performance and flow separation. The unslotted design exhibited minimal flow separation at lower AoA but experienced marked separation as AoA increased, particularly at higher angles resulting in a substantial loss of aerodynamic efficiency and an increase in drag. The single slot design showed improvements in flow separation control particularly at mid to high AoA as it retarded the start of separation and stabilized the pressure distribution, leading to lower drag and overall improved performance. Still, the double slot concept was the most beneficial having the best overall flow separation control, especially at higher AoA. This arrangement substantially retarded flow separation, providing a smoother and more uniform airflow over the blade surface which led to enhance aerodynamic performance throughout the entire AoA range. For lower AoA all three designs had similar performance, but when the AoA rose above 10 degree, the single and double slot designs were superior to the no slot design, with the double slot arrangement still having the highest aerodynamic efficiency. This design continually improved the lift to drag ratio and had more controlled flow features which are essential in turbine blade applications where stable and efficient performance must be achieved under a range of operation conditions. From the result, the double slot design proved to be the most suitable option for turbine blade applications, especially for situations calling for reliable and consistent performance under higher AoA.

VII. ACKNOWLEDGMENT

The authors extend their sincerest thanks to Dr. Ajith V S for his great guidance and support during the duration of this work. We are also thankful to the members of the faculty in the Aeronautical Engineering Department for their regular encouragement and sharing of knowledge, which highly supplemented our insight. We offer our sincerest thanks to Mr. Mrunal Krishnan, Department of Aerospace and Geodesy, Technische Universität München, for his guidance and intellectual contributions. As an esteemed graduate from our department (2010–2014), his contribution has been key in informing our strategy. Last but not least, we would like to thank our friends and families for their unremitting support and motivation along the way.

REFERENCES

[1] Abdolrahim Rezaeiha, Hamid Montazeri, Bert Blocken (2019) CFD Investigation of Separation Control on a Vertical Axis Wind Turbine: Steady and Unsteady Suction Journal of Physics: Conference Series doi:10.1088/1742-6596/1618/5/052019(2019)

[2] Ajay Veludurthi ,Venkateshwarlu Bolleddu(2020) Experimental Study on Modal and Harmonic Analysis of Small Wind Turbine Blades Using NACA 63-415 Aerofoil Cross-Section Energy Engineering DOI: 10.32604/EE.2020.010666(2020)

[3] Amit Kumar, Shivasheesh Kaushik, Kundan Kumar, Vikas Chauhan (2017) Study and Analysis of the Flow Field around the Horizontal Wind Turbine Blade International Journal of Scientific & Engineering Research Volume 8, Issue 8 (2017)

[4] A Wang,H Lai (2023) Control of separated flow at low Reynolds number around NACA0012 airfoil by boundary layer suction Journal of Physics: Conference Series doi:10.1088/1742-6596/2707/1/012122 (2023)

[5] Bahador Bakhtiari Nia, Mohammad Ja'fari, Adel Rezaei Ranjbar, Artur J. Jaworski (2023) Passive control of boundary layer flow separation on a wind turbine airfoil using vortex generators and slot Ocean Engineering 283 (2023) 115170 https://doi.org/10.1016/j.oceaneng.2023.115170 (2023)

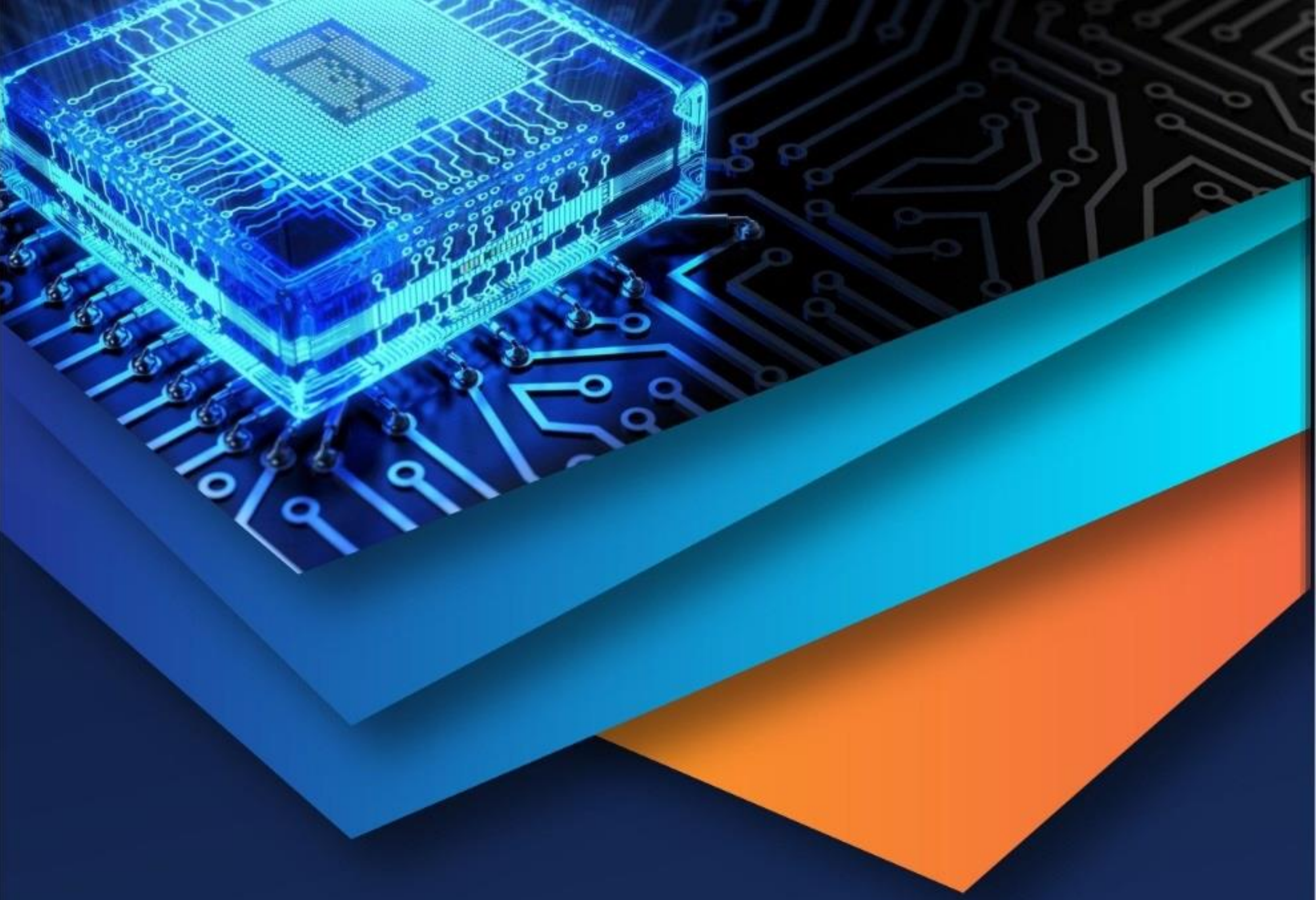
[6] Brett R. Hiller, Richard L. Campbell, and Michelle N. Lynde (2015) Design Exploration of a Slotted-Wing Common Research Model NASA Langley Research Center, Hampton, VA, 23681(2015)

[7] Bak, C., Fuglsang, P., Johansen, J., & Antoniou, I. (2000). Wind tunnel tests of the NACA 63-415 and a modified NACA 63-415 airfoil. Denmark. Forskningscenter Risoe. Risoe-R No. 1193(EN) (2000)

[8] Cody Perkins, Zhi Yang†, Ilker Topcuoglu, Dimitri Mavriplis Aerodynamic Analysis of a Slotted, Natural-Laminar-Flow Transonic Trussed-Braced Wing Aircraft Configuration University of Wyoming, Laramie, WY 82070, United States DOI: 10.2514/6.2022-2536(2022)

[9] Dhaval H. Parmar, Umang J. Patdiwala(2020) Analysis of NACA 63-415 Airfoil with Modified NACA 63-415 using CFD Analysis Vol 11, Issue 6,June/ 2020 (2020)

[10] Iham F. Zidane, Khalid M. Saqr, Greg Swadener, Xianghong Ma, Mohamed F. Shehadeh (2017) Computational Fluid Dynamics Study Of Dusty Air Flow Over Naca 63-415 Airfoil For Wind Turbine Applications
[11] S. Ram Sai,K. Sai Priyanka, R. Sabari Vihar(2021) Computational Analysis Over NACA-23015 Airfoil for Flow Separation Delay using Passive Flow Separation Technique ,International Journal of Engineering Research & Technology (IJERT)(2021)
[12] Sreetha P S, Prajeeth Kumar. K. P , Jinshah B S(2016) Suitability of NACA 63212, 63215 and 63415 airofoils for small horizontal axis wind turbine with a brimmed diffuser,International Journal of Scientific & Engineering Research, Volume 7, Issue 4 (2016)
[13] Ru-Bing Liu, Wen-Tao Wei, Hai-Peng Wan, Qi Lin, Fei Li, Kun Tang(2022)Experimental study on airfoil flow separation control via an air-supplement plasma synthetic jet,Advances in Aerodynamics (2022) 4:34,https://doi.org/10.1186/s42774-022-00126-w(202 2)
[14] P. Satyannarayana Murthy, T. Naveen Kumar, A. Vinutha(2017) The Effect of Icing on the Performance of NACA 63415 Wind Turbine Blade International Journal of Current Engineering and Technology, Vol.7, No.3 (2017)
[15] Frederik Zahle, Niels N. Sørensen, Jeppe Johansen Risø National(2002) CFD study of a NACA 63-415 aerofoil fitted with stall strips,Denmark. Forskningscenter Risoe. Risoe-R No. 1370(EN) (2002)



10.22214/IJRASET

INDEX COPERNICUS

45.98

ISRA JIF

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)