CFD Approach of Joukowski Airfoil (T=12%), Comparison of its Aerodynamic Performance with NACA Airfoils Using k-ε Turbulence Model with 3 Million Reynolds Number

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Abstract:- *In aircraft, airfoil role is very important to create the require lift to carry the aircrafts. Aerodynamic characteristic of an airfoil is based on design but it desired performance of the airfoil is based on design but is results is not so easy. In present time airfoil design is tested randomly for the flow of the aircraft and first time wright brothers design cambered airfoil and In early days NACA provides a proper definition of an airfoil and tell us their property and how they economical. In this study of NACA0012, NACA4412 and JOUKOWSKI (T=12%) airfoil, at various angle of attack and 43.822 m/s flow velocity in the ANSYS - fluent. The very important aim of this study is to know about fluid flow behavior situated on every side of an airfoil and determine the aerodynamics performance characteristic at high Reynolds Numbers (3 million) and AOA vary from 2 degree to 18 degree. The lift and drag coefficients for all airfoil is calculated by observing at measuring surface pressure on the various airfoil. In this work aerodynamic performance of an airfoil are plotted against AOA and how they are different from experimental results. In this study we examine the comparative analyses of k- epsilon turbulence model and experimental results.*

Key Words: *NACA airfoil, Joukowski airfoil Ansys, Computational fluid dynamics, k-ε Turbulence model*

1. INTRODUCTION

In the early time, Transportation is totally dependent upon the locomotion like Rail, Bus, Motorbike, but if we want more effortless, faster and luxurious way of travelling it will be only air transport. There are many invention are going on aircraft and it is the best and fastest mode of transport .It used since world war II then It gain more popularity after this popularity many invention and R&D develop more better and economical aircraft .An airfoil define as a cross-section of wing of an aircraft. Its main work is to generate required lift for an Airplane during take-off and while flight in air. But, there is one bad effect known as Drag force which create resistance of the motion of an aircraft. [1].

1.1 Aerodynamics Science

Aerodynamics is the branch of sciences which describe the behavior of the aircraft with the air, when it is connected to a solid body called airfoil. It is the sub-part of gas dynamics and fluid dynamics and various domain of aerodynamics speculation are related to fluid flow fields. In 1903, Wright brothers designed the cambered shape airfoil for lighter aircraft.

An airfoil (American English) or aero foil (British English) is known as the shape of a wing, blade corner as cross-section-area of an aircraft. A solid object like airfoil body travel throughout air domain. The forces which is perpendicular and parallel to all the aerodynamics force is called lift and drag forces. The lift force generated by the airfoil is totally dependent upon shape and size. [2]

1.2 Airfoil Theory –Terminology and Definition

The study of various terms in airfoils are described in the Figure 1.1.

- **Leading edge: -** It is defined as the edge for an airfoil face the way of movement of an aircraft. It is basically round shape in front and diverts the fluid in a direction then Fluid velocity on upper surface of an airfoil is greater than velocity of fluid on the lower side of an airfoil [3].
- **Trailing edge: -** It's defined as corner of the airfoil which is located in the air. It's situated at back portion of an airfoil.
- **Chord line: -** It is defined that the line which joins the leading to trailing edge is known as chord.[3]
- **AOA: -** It's defined as angles which make between the line of chord and the aircraft direction. It's a very important characteristic which affect the lift and drag.[4]
- **Lift (C_L) and Drag (C_D) coefficient: -** These are coefficient which are dimensionless that develop the lifting and dragging force on an airfoil to its flow velocity and suction pressure.
- **Maximum Thickness: -** Maximum Thickness known as maximum distance from the bottom to the top surface of an airfoil.
- **Lift: -** It is known as the perpendicular component to the total aerodynamic force to the relative air.

- **Drag: -** It is known as the parallel component to the total aerodynamic force to the relative air.

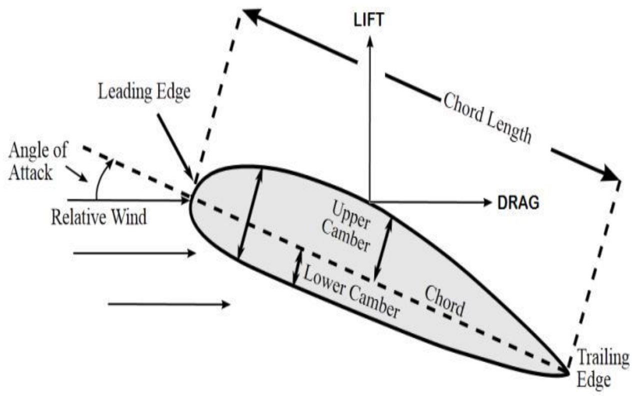

Figure 1.1 General Section of an airfoil [2]

2. PROBLEM FORMULATION

After a wide ranging study of the existing literature work, many problem have been observed in airfoil. Problem formulation is only one of the prime objective of literature review in many aspects. The sole purpose always constant are shown below:

- Provides a wide range of contexts for the latest and innovative research.
- It is ensure that research work should be new.
- Research work should be full of knowledge.
- A good researcher also learn from the previous work which is already done by someone.

After studying previous work it was observed that in current time only NACA airfoils is using in all aircraft, wind turbine, hovercraft. Some of the NACA airfoil which is generate less lift and more drag like symmetrical airfoil. In past an airfoil its name was Joukowski airfoil using in the aircraft. It thought that can it replace this airfoil in the place of NACA symmetrical airfoil than It decided to compare the aerodynamic performance parameter between NACA and Joukowski same thickness airfoil. After that it decided go through the k-ε turbulence model and want to check the performance characteristics of all the airfoils.

3. RESULTS AND DISCUSSION

3.1 K-Epsilon Turbulence Model

The k-ε models solve for two variables, the first one is 'k' is known as the turbulence kinetic energy and second one is 'ε' is known as the rate of dissipation of turbulence kinetic energy.

3.2 Numerical Results of NACA0012, NACA4412, JOUKOWSKI (T=12%) airfoils

Figure 3.1, 3.2, 3.3 represents that how lift and drag coefficient is varying by AOA and where is the maximum C_L/C_D ratio for NACA0012, NACA4412 and JOUKOWSKI (T=12%) airfoil .Lift and Drag force are calculated by formula which is given below.

Lift force (L) = $\frac{1}{2}\rho c C_L V^2$ 3.1

Drag Force (D) = $\frac{1}{2}\rho c C_D V^2$ 3.2

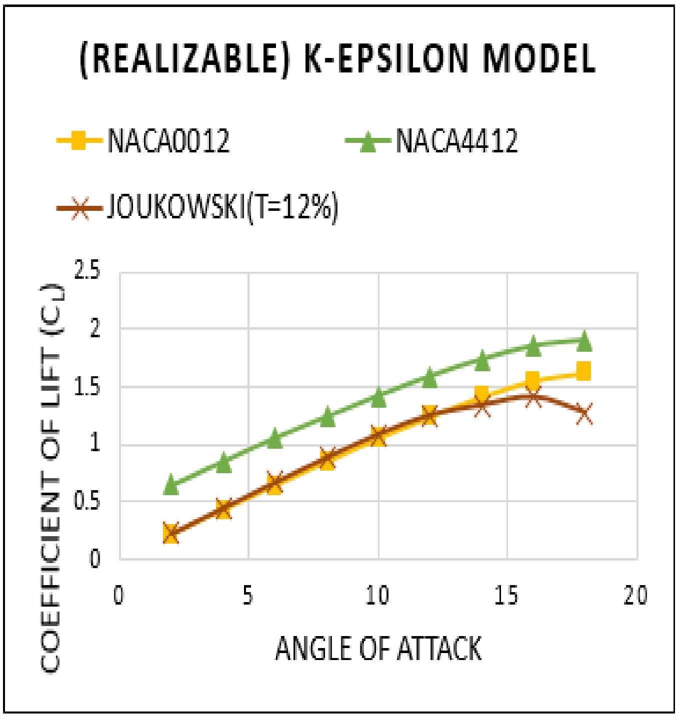

Figure 3.1- Coefficient of lift (C_L) vs Angle of attack

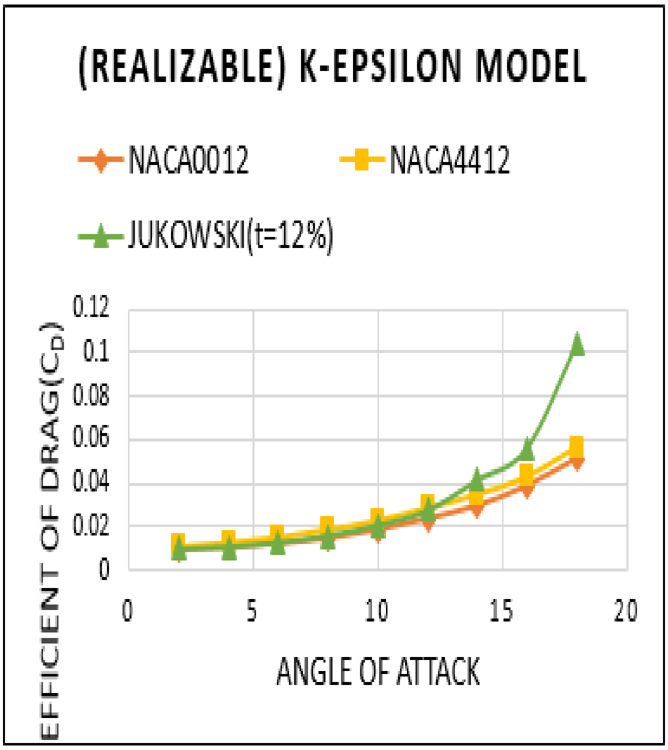

Figure 3.2 - Coefficient of drag (C_D) vs Angle of attack

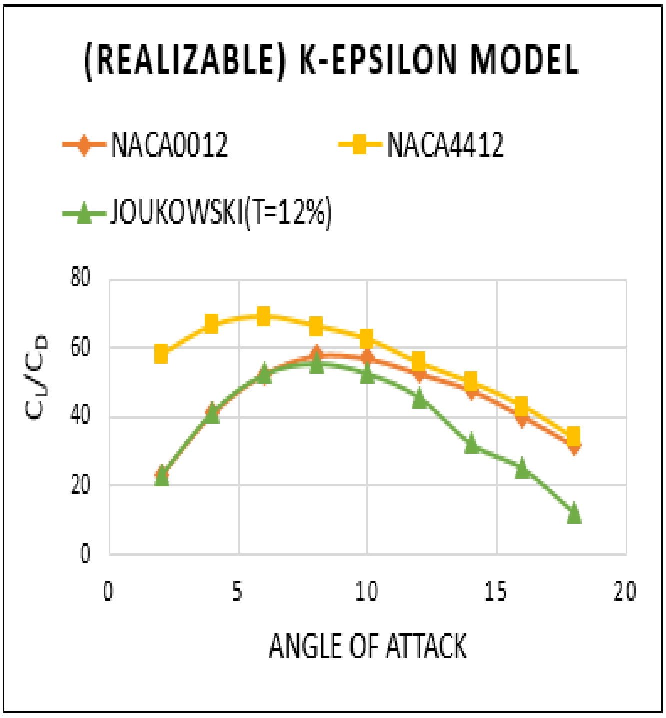

Figure 3.3 C_L/C_D Ratio vs Angle of attack

3.3 Surface Pressure Distribution

Figure 3.4,3.5,3.6 represents relation between coefficient of pressure (C_P) and Chord length X(m) of respectively NACA0012, NACA4412, JOUKOWSKI (T=12%) airfoil in k-ε turbulence model in fluent.

The distribution of pressure over the surfaces of the airfoil is observed by the dimensionless Parameter known as pressure coefficient

Cp =Pressure/ (0.5*1.225[kg/m^3]*(43.822[m/s]) ^2) (4.7)

The Coefficient of pressure has a more suction peaks on suction side surfaces (SS) closer to leading edges and after that gradually increase in suction pressure.

The coefficient of pressure calculate maximum value at pressure side closer to the leading edge. At $\alpha=2^0$, Pressure vary on the side of suction surface pressure on the airfoil showing a distributions. Suction peak of the suction surface side were in the ranges from -0.5 to -12.5 for NACA0012 ,-0.5 to -10.5 for NACA4412 and -0.5 to -8.5 for JOUKOWSKI (T=12%) airfoil by using k-ε turbulence model from 2^0 to 18^0 AOA.

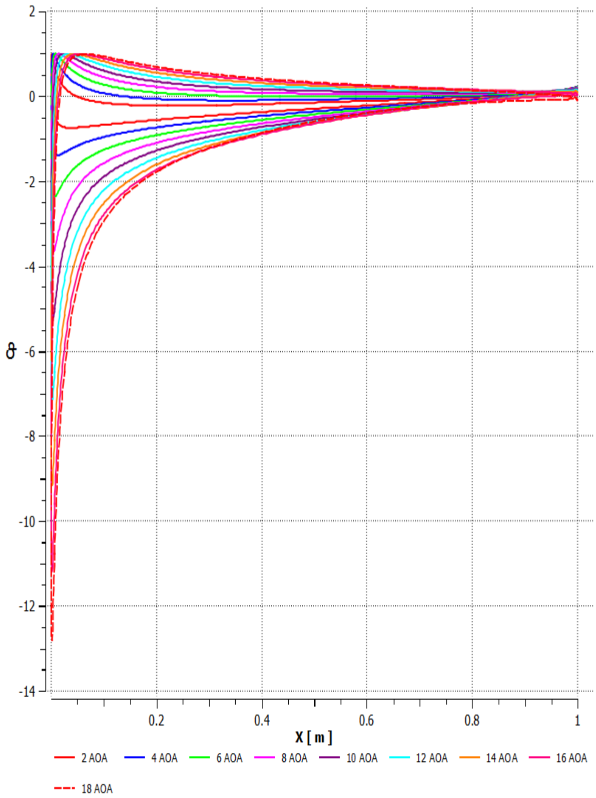

Figure 3.4 AOA vs Cp for NACA0012

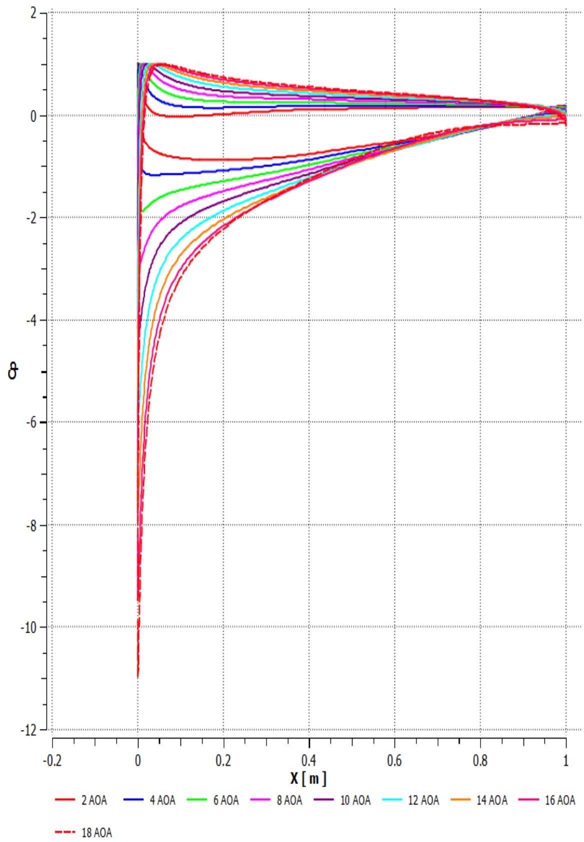

Figure 3.5 AOA vs Cp for NACA4412

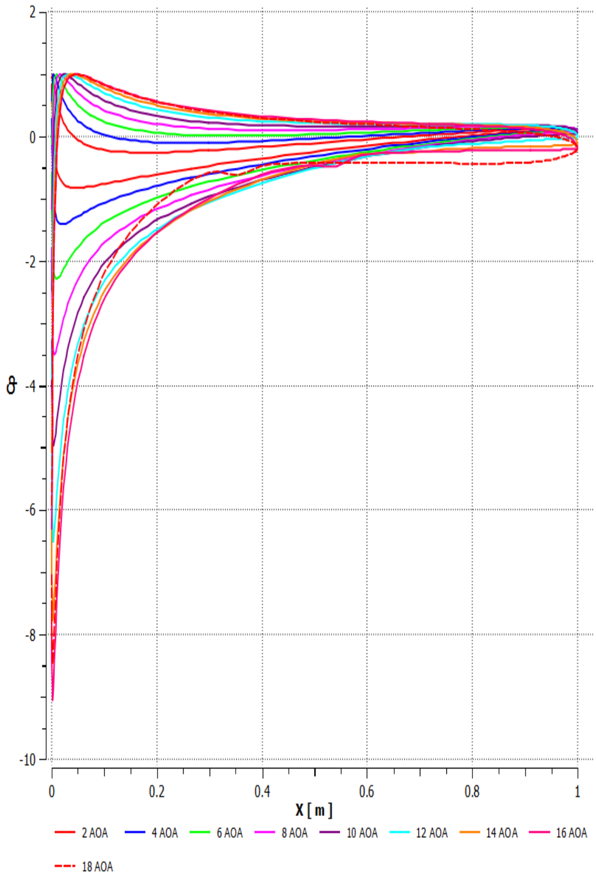

Figure 3.6 AOA vs Cp for JOUKOWSKI (T=12%) airfoil

4. CONCLUSIONS

Based upon numerical results of NACA0012, NACA4412 and JOUKOWSKI (T=12%) airfoil, there are several points as follows:

- This paper presents computational study of the mean flows and Reynolds stress results of NACA0012, NACA4412 and JOUKOWSKI (T=12%) airfoil, cover the boundary layer around the airfoil
- It is clear that there is more less negative pressures (in Pascal) develop on the upper surfaces of all airfoil .The pressure value is -15097.5 in NACA0012, -12916.5 in NACA4412 and -9982.86 JOUKOWSKI (T=12%)
- It is clear that there was maximum velocity (in m/s) developed on the upper surface of all aifoil.The velocity value is 155.774 in NACA0012, 144.842 in NACA4412 and 128.828 in JOUKOWSKI (T=12%)
- It is clear that there was maximum C_L/C_D ratio developed by the 57.85435892 in NACA0012, 68.9648031 in NACA4412 and 55.67686939 JOUKOWSKI (T=12%)
- The better airfoil has always a higher C_L/C_D ratio compared with all other airfoil. The study of this work , It observed that NACA 4412 having higher C_L/C_D ratio other than NACA0012 and JOUKOWSKI airfoil so it observed that NACA4412 is better suitable for all aerodynamic application than NACA0012 and JOUKOWSKI airfoil with higher C_L/C_D ratio and less wake generation.
- It is observed that some Joukowski airfoil results are similar to NACA0012 symmetrical airfoil. Now it can say that in future if we work on the design section of the Joukowski airfoil. It will give some good results closer to the same thickness NACA symmetrical airfoil and further it will use in modern aircraft.

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