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Wind Tunnel Testing of NACA 0021 Aerofoil with Co- Flow Jet

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Abstract: *The performance augmentation of an aircraft is possible by delaying the flow separation which causes stall. This research paper discusses the flow control method to increase the performance of the aircraft by inducing the circulation. The flow characteristic over an airfoil to control the flow separation using co-flow jet (CFJ) is investigated using analytical and experimental methods. The concept of CFJ airfoil is to open an injection slot near leading edge and suction slot near trailing edge which induces circulation control to the flow field over the aerofoil. The results obtained upon performing the experiments indicate that co-flow jet airfoil with injection and suction slot has better performance characteristics.*

I. INTRODUCTION

The projected substantial increase of air traffic in next 20 years, the air transportation system which needs to reducing emission and noise, airport capacity, and reliability of operation to minimize flight interruption due to severe weather conditions. High aerodynamic efficiency with reduced emission is needed for the next generation airplane, which is provided by blended wing body or flying wing configurations still mostly rely on optimizing geometry shapes without flow control. The conventional heavy high lift system used only for take-off and landing still needs to be carried for the whole flight mission, which is very inefficient. Lift is provided by modifying the wing surfaces configuration either with slat, mid-wing or flap. The control of flow is achieved by both passive and active means.
The Active flow control technique co-flow jet (CFJ) is considered for improving the effectiveness of the aerofoil. The co-flow jet aerofoil has an injection slot near leading edge and a suction slot near trailing edge. Enhancement of lift, reduces drag and increases stall margin is done by providing the co-flow jet. The CFJ airfoil recirculates the air mass flow and hence can significantly reduce the penalty to propulsion system by reducing the drag. The schematic representation of Co-flow jet (CFJ) aerofoil is shown in the figure 1.

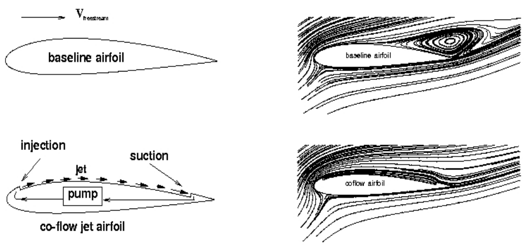

Figure 1. Schematic Representation of Co-Flow Jet Aerofoil and Its Effect on Flow Field

II. LITERATURE REVIEW

Xi Xia et. al. experimentally investigated the synthetic jets in a co flow wake. A round synthetic jet issuing into a co flow wake is investigated experimentally in this research. The flow field of the jet is measured using hot-wire anemometry. The spreading and decaying of the synthetic jet is studied after taking into account the effect of the wake velocities. The stream wise variation of centreline velocity show good agreement with the semi empirical integral model. By verifying the theoretical model, it can be concluded that the jet decay is not affected by the presence of ambient co flow. [1]

Dano et. al. investigated the study of CFJ airfoil using discrete jets. Aerodynamic forces measured and DPIV measurements show that the Discrete CFJ airfoil can achieve up to a 250% increase of maximum lift, and simultaneously generates a tremendous thrust. Nearly 80% of the injection momentum is converted to drag reduction, which indicates that CFJ airfoils are highly energy efficient. The stall angle of attack is also significantly increased. [2]

Riajun Noor et. al. numerically investigated the flow characteristics over an airfoil to control the flow separation by Co-Flow Jet technique. CFD study over NACA 2415 airfoil is carried on the basis of 2-D compressible Navier-Stokes equations with 2-equation standard k-ε turbulent model and standard wall function. The grid used for the study is shown in the figure 2. From the simulation result it is observed that that the CFJ airfoil delay flow separation over the airfoil and allows the aircraft to cruise with very high aerodynamic efficiency and also enhance the performance of taking off and landing within short distance. [3]

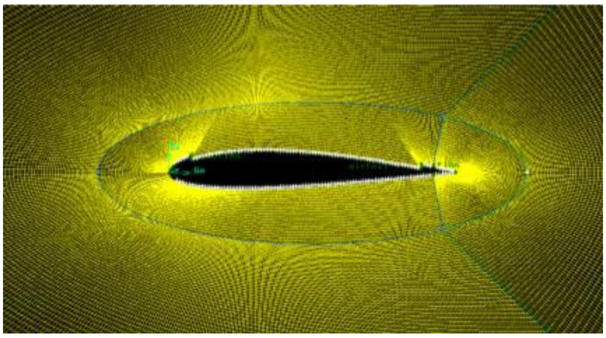

Figure 2. Mesh around the co flow jet airfoil [3]

Amzad Hossain et. al. carried out the wind tunnel testing of baseline airfoil NACA 0015 and CFJ0015-065-065 with the primary goal to investigate and compare the airfoil aerodynamic characteristics over a wide range of Angle of Attack (AOA) and with a wind tunnel free stream velocity of 12m/s , Re = 1.89×105, Cμ = 0.07 at M = 0.030 kg/s. The CFJ increases C_{Lmax} by 82.5% and decreases Drag by 16.5% at Stall AOA when compared to the baseline airfoil. [4]

Abdul khalid sherief et. al. described Co-Flow Jet as an alternative for civil aircraft high lift configuration. The major aim of this research was to present an alternative for the existing high lift devices in the conventional passenger aircraft. The objective was to use a flow control method, which would be incorporated in the wing to attain the same required value of LIFT, thus there by relieving off the additional penalty in terms of movable control surfaces. [5]

Ge-Cheng Zha et. al. investigated the CFJ aerofoil with the bleed air from the power plant and CFJ aerofoil with the suction from the aerofoil flow field. The computational fluid dynamics solutions based on the Reynolds-averaged Navier–Stokes model are used to provide the breakdowns of lift and drag contributions from the airfoil surface force integral and jet duct's reactionary forces. The results are compared with experiment for validation. The study indicates that the suction occurring on the airfoil suction surface of the co flow jet airfoil is more beneficial than the suction occurring through the engine inlet such as the airfoil with injection only. The co-flow jet airfoil with both injection and suction yields stronger mixing, larger circulation, more filled wake, higher stall angle of attack, less drag, and lower energy expenditure. [6]

Y. Cui et. al. investigated numerically and experimentally the implementation of Co-Flow Jet on aerofoil with low Reynolds Number**.** The experimental study has shown that it does not always give better performance in comparison with that of suction or jet injection only. To use CFJ concept effectively, the momentum coefficient is found to be in the range of 5% to 13%. When the momentum coefficient is less than 5%, the use of suction alone is recommended, while for the momentum coefficient is higher than 13%, the implementation of jet injection alone is a better option. [7]

A. Abdullah et. al. studied the Lift/Drag ratio enhancement using continuous normal suction by the wind tunnel testing. The wing model with NACA-0015 has been made to achieve normal suction from the wing upper surface by means of four slot channels. The satisfaction of the suction is done by using vacuum pump. The tests are to be done for incompressible flow over wing with and without a continuous normal suction for three different angle of attack 8^0,12^0 and 16^0 and for three different Reynolds numbers 13.6×104, 20.4×104 and 24.5×104. The results showed continuous normal that the suction can significantly increase the lift to drag force ratio, and this ratio is increasing more as the strength of the suction increases. [8]

The objective of this research paper is to the aerodynamic characteristic with co flow jet aerofoil and baseline aero foil. First fixing the baseline aerofoil in the wind tunnel and find out pressure coefficient values similarly co flow jet aerofoil is also tested along the test

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section. The aerofoil's are analyzed at various angle of attack to measure the values of pressure coefficient with the help of fourteen column manometer.

III. EXPERIMENTAL SETUP

The wind tunnel of suction type with an axial flow fan driven by 28880rpm, 15HP, 440V, 50 cycles, 3 phase AC motors as shown in the figure 3 is used for the study. It consists of an entrance section with a fuel mouth inlet containing flow straightness and screens. This section is followed by it contraction, test section and a diffuser. The duct contains butterfly value for controlling air velocity inside the duct along with rough calibration of wind velocity mark on the duct and containing zframes the complete wind tunnel expect that the test section is made of mild steel and plexy glass wind for visual observation of flow phenomenon the electrical control panel.

Figure 3.Wind Tunnel used for the study

The CFJ airfoils used for testing at the Karpagam institute of technology was a modified NACA 0021. The NACA 0021 airfoil was chosen for its ease of manufacturing and relative thickness and also it was used for the baseline study. The thickness made it easier to fit all instrumentation and duct work into the airfoil given the size constraints imposed by the 30cm × 30cm wind tunnel test section. However the CFJ concept can be implemented on any airfoil geometry. The modified NACA 0021 airfoil used in testing had a span of 22cm and a chord length of 25.5cm. As shown in figure 4, the airfoil was modified by recessing the suction surface (upper surface). This recession opened up a slot towards the leading edge of the airfoil (injection slot) and another slot towards the trailing edge (suction slot). The slot towards the leading edge was used to inject air tangentially over the suction surface, while the slot towards the trailing edge was used to remove air tangentially from the suction surface. One airfoil was manufactured with this modification. The airfoil had a 1.5cm or 1.67% chord length injection slot height. The airfoils are named by their injection and suction slot sizes according to the convention CFJ4digit-INJ-SUC. So the airfoil with the 1.5cm injection slot was named CFJ0021-167-167. The reason the suction slot size was larger than the injection slot is because the density of the air being removed by the suction slot is less than the density of the air being injected. Therefore, to balance the mass flow rates, the suction area has to be larger or the velocity greater. But the velocity is limited because the flow will eventually become choked. The location of the injection slot and suction slot are respectively, 7.11% and 83.18% of the chord length from the leading edge. The slots are positioned perpendicular to the suction surface making them parallel to the flow direction. The Factor driving the geometry of the injection and suction cavities are the aerodynamic characterises of the internal structure. It was important to have negligible losses, if any from the flow entering the inside of the aerofoil to the jet exiting the injection slot. This would allow for the most accurate mass flow, pressure and temperature reading across the slot. Fourteen pressure taping have been used along the aerofoil. The seven taps located upper surface of the aerofoil and similarly seven taps located lower surface of the aerofoil. Sheet metal has been used for the fabrication of CFJ aerofoil with injection and suction slots. A nylon tube has been used for the connecting the blower with injection and suction slots.

IV. RESULTS AND DISCUSSION

This research is successfully find out by the experimental set up of subsonic wind tunnel test taken for the coefficient of pressure measurement. the CFJ aerofoil was tested in many angle of attack . These will be described by the curve of graph.

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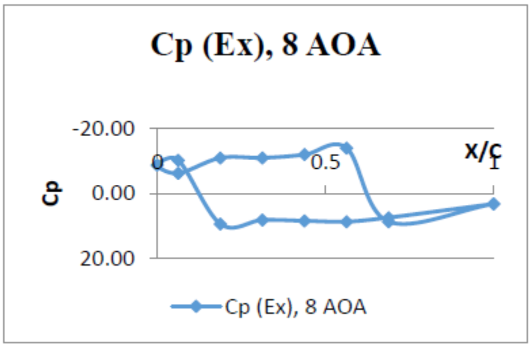

Figure 4. C_p Plot of CFJ Aerofoil

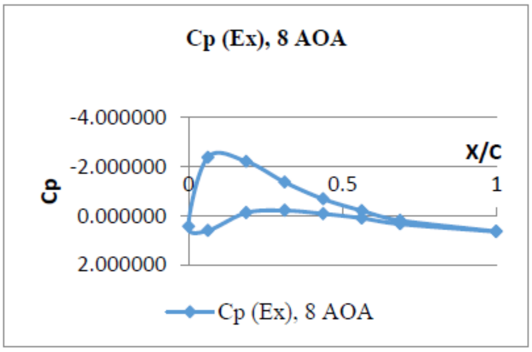

Figure 5. C_p plot of Baseline Aerofoil

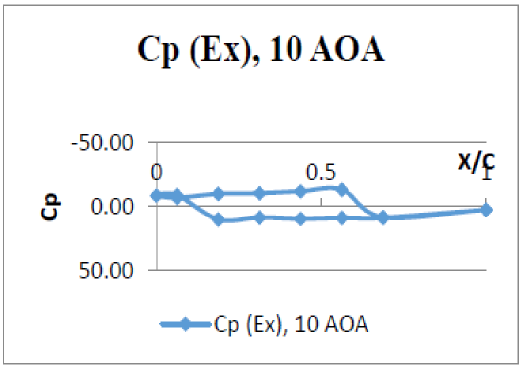

Figure 6. C_p plot of CFJ Aerofoil

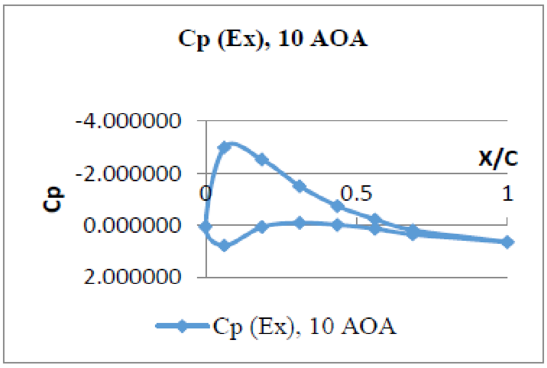

Figure 7. C_p plot of Baseline Aerofoil

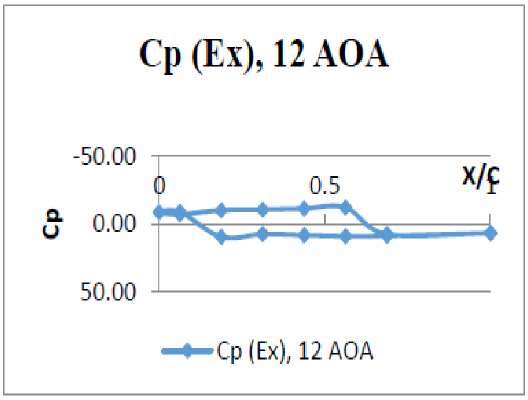

Figure 8. C_p plot of CFJ Aerofoil

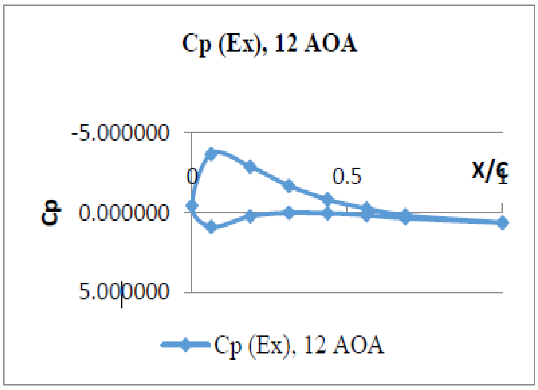

Figure 9. C_p plot of Baseline Aerofoil

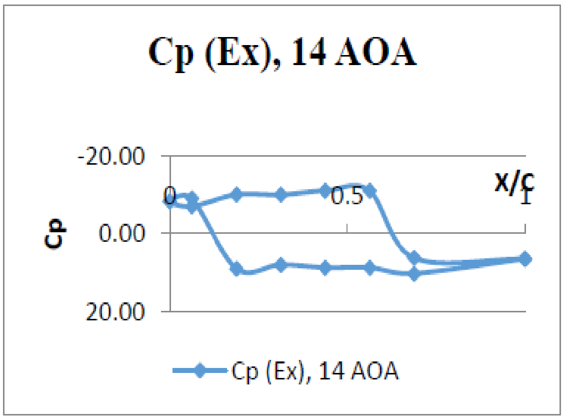

Figure 10. C_p plot of CFJ Aerofoil

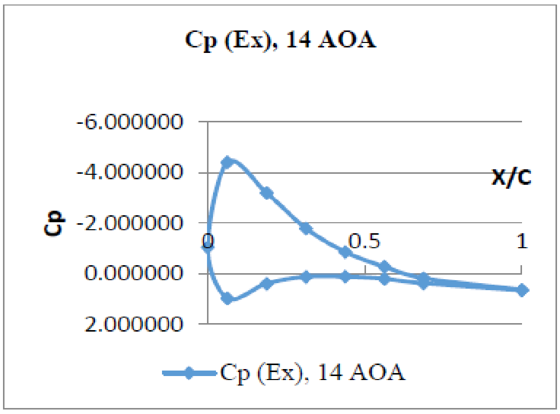

Figure 11. C_p plot of Baseline Aerofoil

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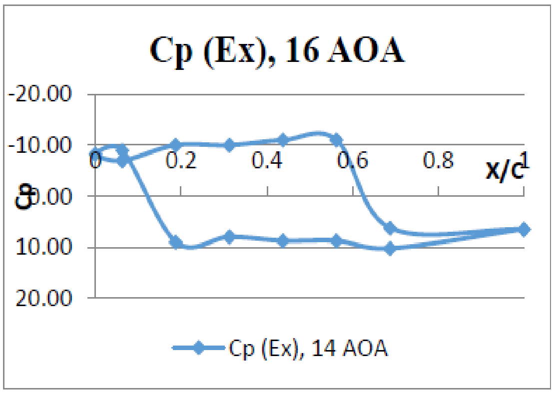

Figure 12. C_p plot of CFJ Aerofoil

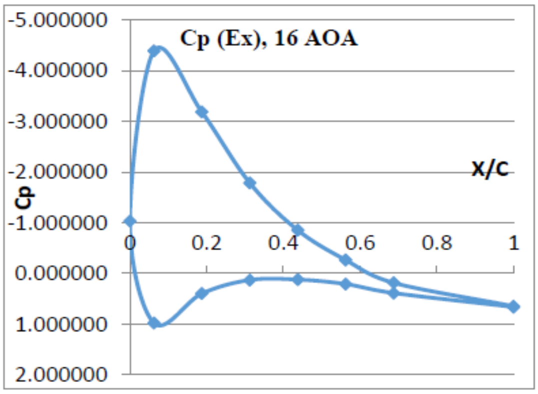

Figure 13. C_p plot of Baseline Aerofoil

Various angles of attacks the pressure values are plotted in above graphs for CFJ and base aerofoil. The coefficient of pressure value will changes from base aerofoil. The percentage of coefficient of pressure value for CFJ is greater when compared with base aerofoil

V. CONCLUSION

The research described in this paper successfully demonstrates how the CFJ airfoil is design and tested in the wind tunnel testing. The research proved the high performance capabilities of the CFJ airfoil. It was shown the CFJ airfoil performed better than the baseline airfoil with respect to maximum lift and stall margin. It was also declare that the lift for a given angle of attack and drag reduction

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