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SHOCK BUFFETING STUDIES ON AIRFOILS

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Abstract—This study proposes a flow over an airfoil which involves shock oscillations at certain critical Mach number in Transonic region. This is due to the shock wave interaction with airfoil boundary layer which results in shock buffeting. In the present study Energy equation has been used for the shock buffet and also the corresponding aerodynamic behaviour of NACA 0012 symmetric airfoil, NACA 2412 cambered airfoil, NASA SC (2)0714 supercritical airfoil, biconvex and double wedge airfoil. Energy computations have been performed at critical Mach number in the transonic region. The results obtained from the computational analysis have been compared with each other. Velocity contours and Mach number variation over the airfoils have been analysed and confirmed with the shock buffeting phenomena. The buffeting generated in airfoils reaches transonic Mach number with Zero AOA.

Keywords—*Critical Mach number, Shock wave, Energy equation, Shock Buffeting.*

1. INTRODUCTION

The flow over an airfoil is conducted with the shock waves which interacts with the boundary layer. At a critical Mach number, the flow reattaches when the boundary layer separates at the edge of the shock or the trailing edge. At a particular flow conditions, the shock oscillations alternatively occur along the airfoil surface edges. This frequently occurring flow induced shock motion is known as shock buffet which is constantly used for aerodynamics.

Several computational studies showed that buffet is influenced by the geometry and also the trailing edges of the geometry. It describes that the shock buffet occurs at the curved surfaces but not in the sharp edges. This is because of the geometry of the respective airfoils. The curved surfaces aerofoils are symmetric, cambered, supercritical and biconvex airfoils. Though double wedge is a diamond shaped airfoil which experiences sharp edges. By varying the Mach number, the shock buffet is viewed for the different airfoils. Somehow, these results have determined the range of the Mach number for the onset of shock buffet for the circular arc airfoils.

Moreover, supercritical airfoils are introduced to increase the drag divergence Mach number and to increase the buffet and finally several experiments showed that in airfoils, the shock buffet occurs at flight conditions. Space time equations of the pressure field are used for calculating the shock waves to travel the upstream within the separated region from the shock wave to the airfoil trailing edge and then back from the trailing edge to the shock over the separated region.

In the present study, the Energy equation with inviscid viscous model is applied to view the shock buffet over the NACA 0012 symmetric airfoil, NACA 2412 cambered airfoil, NASA SC (2)0714 supercritical airfoil, biconvex and double wedge airfoil. The Mach number is varied for the transonic region and the angle of attack is kept unchanged. The Shock buffet is determined by the fluctuation of the model in the aerodynamic properties. The entire analysis on the buffet phenomena with the shock oscillations are investigated for the certain conditions.

2. DESIGN METHODOLOGY

The design methodology is carried out using the CATIA and the analysis is carried out using ANSYS. The design of the symmetric, cambered and the supercritical airfoil is carried out by importing the airfoil coordinates. The design of the NACA 0012 symmetric airfoil, NACA 2412 cambered airfoil, NASA SC (2)0714 supercritical airfoil, biconvex and double wedge airfoil is given below.

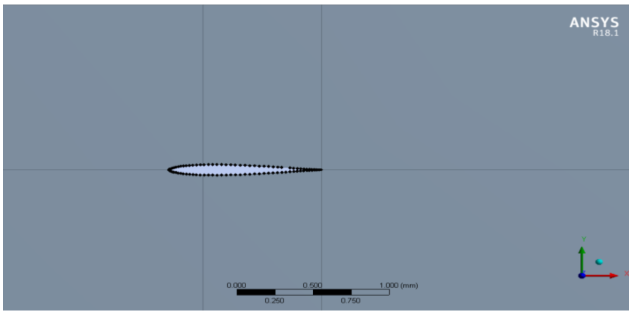


Fig 1. SYMMETRIC AIRFOIL

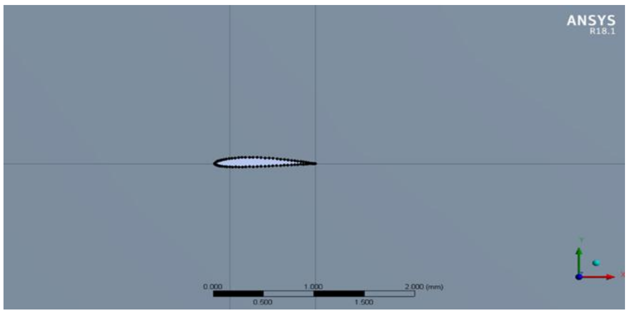


Fig 2. CAMBERED AIRFOIL

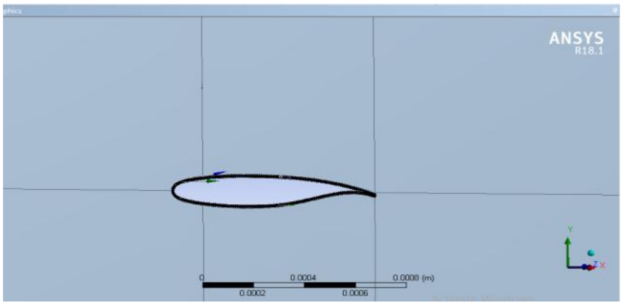


Fig 3. SUPERCRITICAL AIRFOIL

The above three airfoils are designed by importing the airfoil coordinates directly in ANSYS. The design of the biconvex and double wedge airfoil is carried out using CATIA. The design of the two supersonic airfoil is given below.

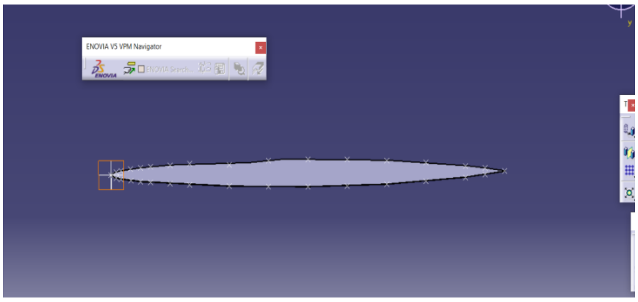


Fig 4. BICONVEX AIRFOIL

The design of the double wedge airfoil is a diamond wedge Shaped geometry. The design of the double wedge airfoil is given below.

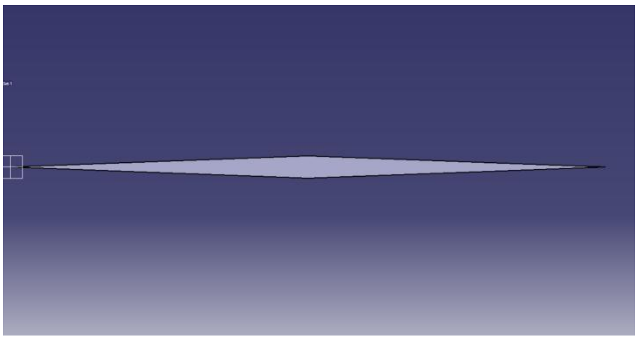


Fig 5. DOUBLE WEDGE AIRFOIL

This is the detailed design of the NACA 0012 symmetric airfoil, NACA 2412 cambered airfoil, NASA SC (2)0714 supercritical airfoil, biconvex and double wedge airfoil. The computational analysis is carried out in ANSYS. The detailed analysis of the buft flow will do for the supersonic airfoils. The Computational domain which refers the meshing and the boundary condition will be applied for the transonic buffet analysis. For this type of buffet analysis, the above mentioned airfoils results will be taken and compared with each other.

3. COMPUTATIONAL ANALYSIS

ANSYS Workbench is used for the analysis and the solver chosen is FLUENT. The generated airfoil model is imported into ANSYS for the Meshing. Meshing is done to divide the whole model into the finite number of small elements as per the requirement of the analysis. The Meshing of the above mentioned five airfoils are given below.

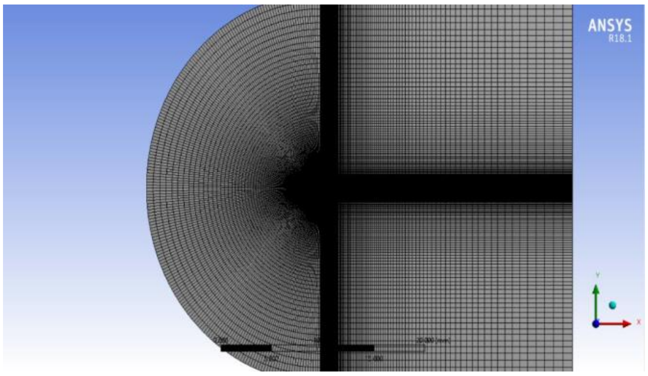


Fig 1. SYMMETRIC AIRFOIL

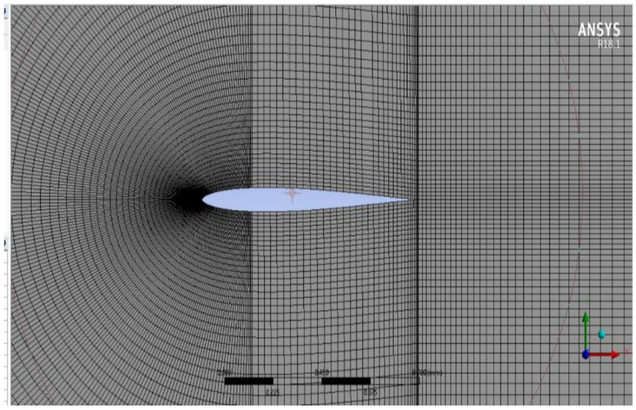
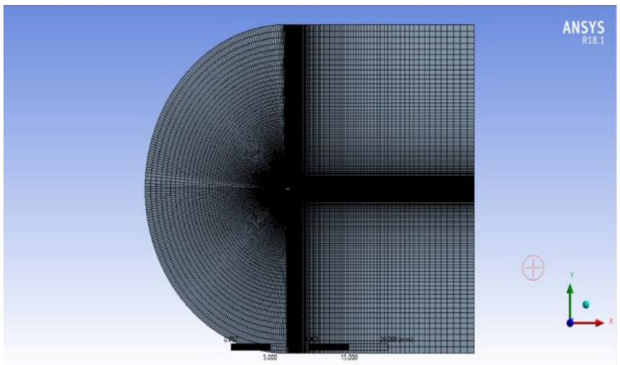


Fig 2. CAMBERED AIRFOIL



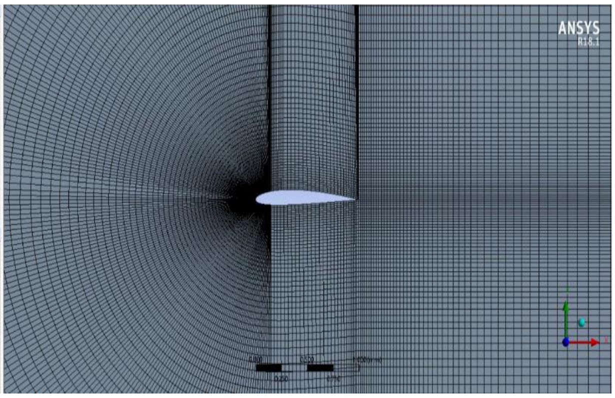
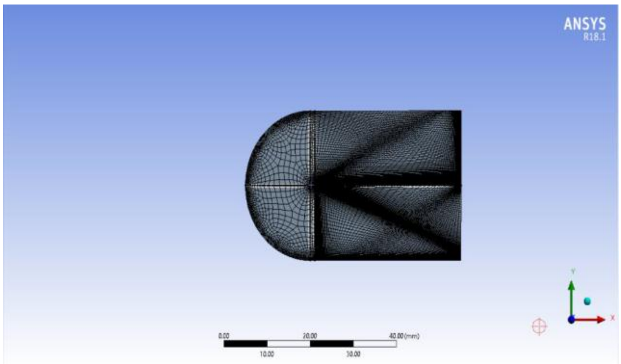


Fig 3. SUPERCRITICAL AIRFOIL



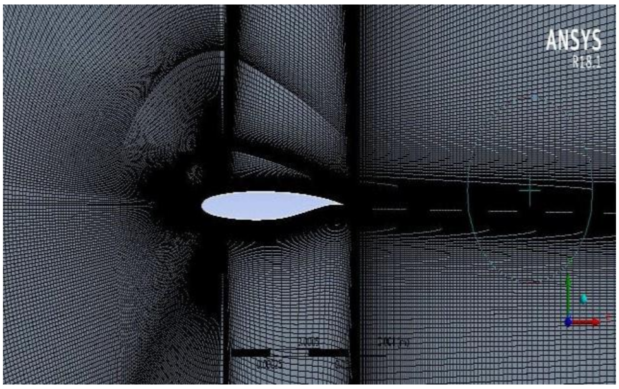
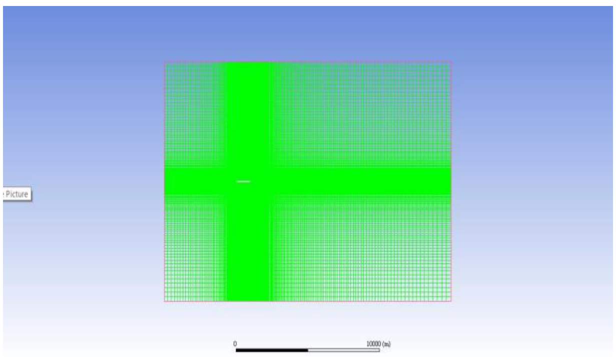


Fig 4. BICONVEX AIRFOIL



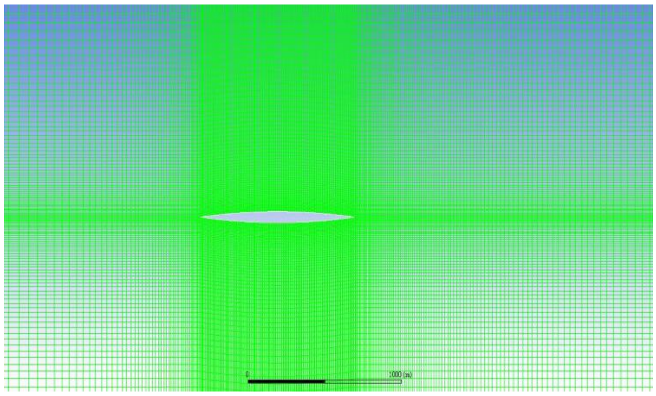
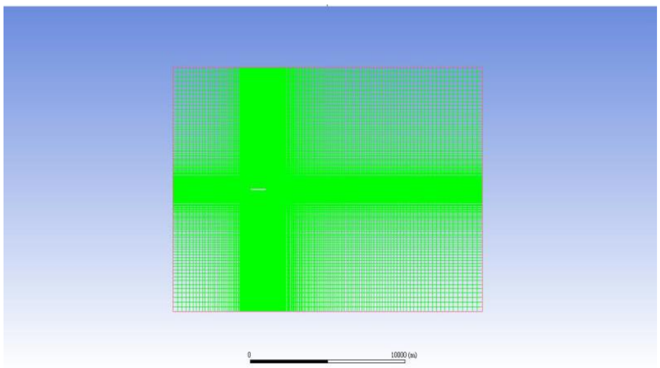
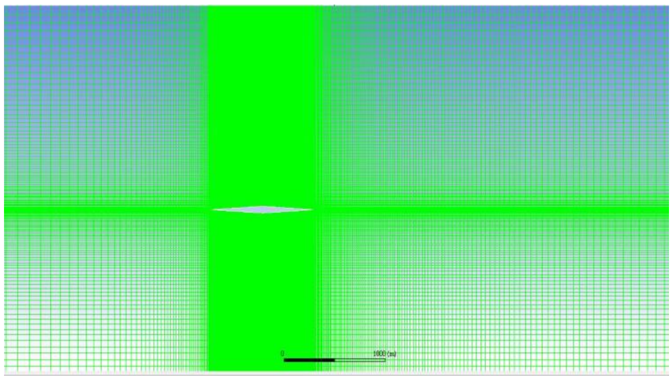


Fig 5. DOUBLE WEDGE AIRFOIL





Go to solution setup where the solver inputs are given and choose the type as density-based type and the analysis as steady state analysis. The viscous model used here is inviscid and in materials, air is selected and its values are kept unchanged.

Next, in boundary conditions the inlet condition given is pressure far-field and the inputs such as Gauge pressure, Mach number are given and the Angle of Attack kept unchanged.

Go to reference values and select compute from inlet and initialize the solution. After initialize the solution go to solution initialization and click the standard initialization and initialize the solution by selecting compute from inlet.

Finally, in Run Calculation tab and enter the number of iterations as 2000 and wait until the solution gets converged. After the solution gets converged, go for post-processing.

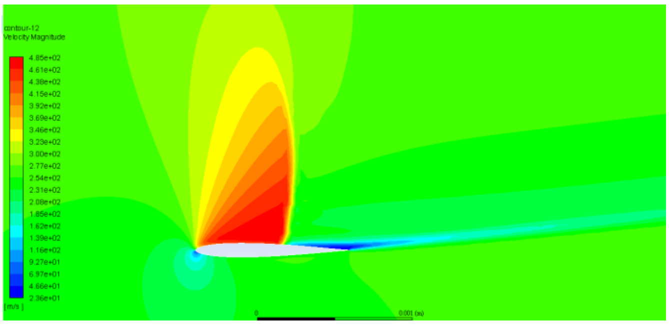
After completing one Mach number change the certain Mach number for viewing the buffet for different airfoils. On changing the Mach number, the buffet will be obtained and also the region at which the buffet is produced will be monitored.

4. RESULT AND DISCUSSION

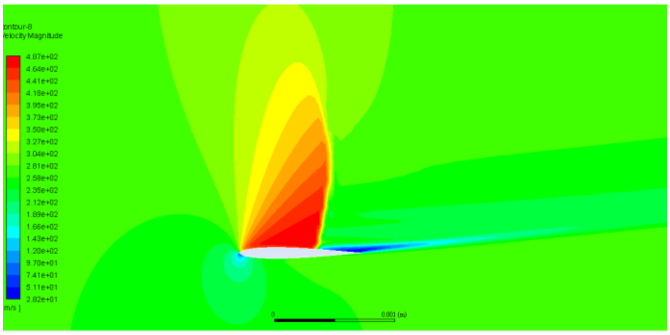
The governing equations of the analysis are solved and the shock buffet for different airfoils by changing the Mach number are done and the region in which the buffet phenomena occurs has been found out. Thus, the variation of shock buffet at different airfoils are given below.

Fig 1. SYMMETRIC AIRFOIL

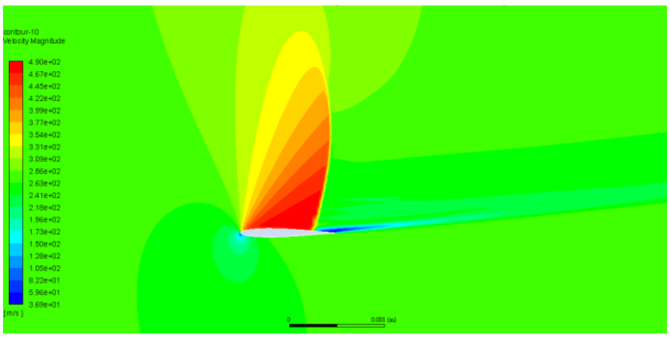
In symmetric airfoil it is found that shock buffet produced at the Transonic Mach ranged from 0.8 to 0.9.



Symmetric airfoil for M=0.8



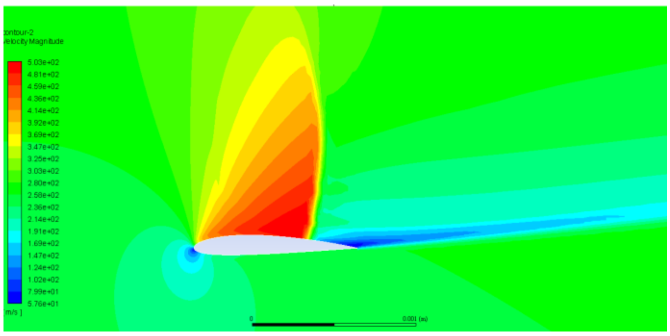
Symmetric airfoil for M=0.85



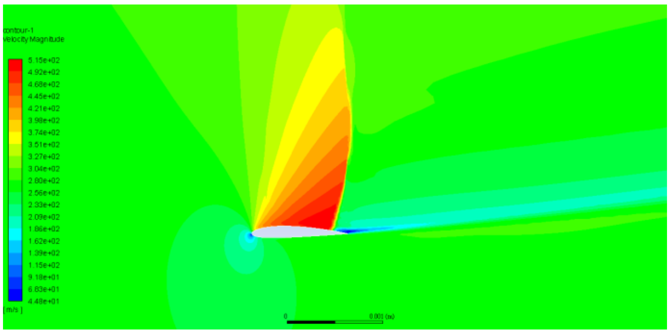
Symmetric airfoil for M=0.9

Fig 2. CAMBERED AIRFOIL

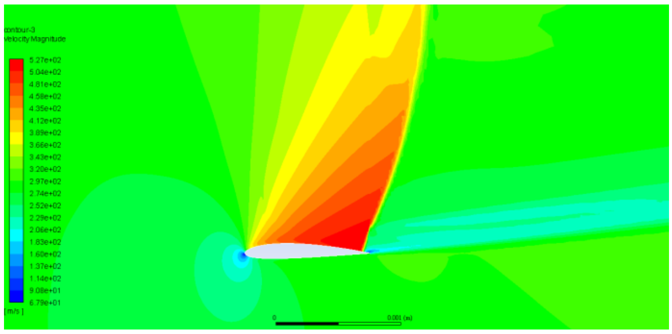
In cambered airfoil it is found that shock buffet produced at the Transonic Mach ranged from 0.75 to 0.85.



Cambered airfoil for M=0.75



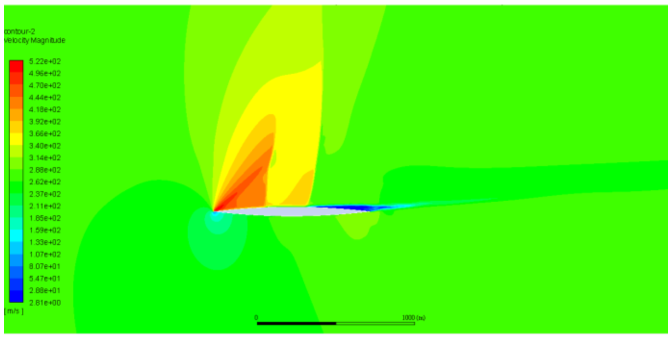
Cambered airfoil for M=0.8



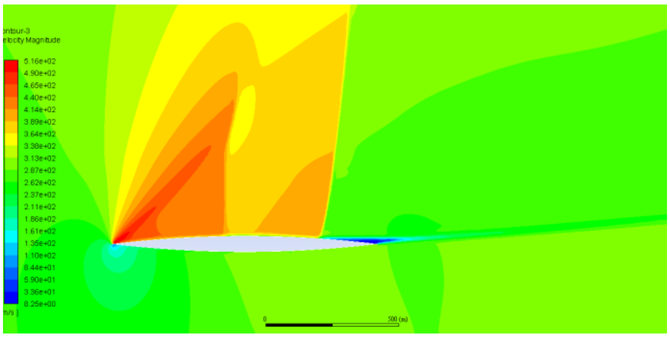
Cambered airfoil for M=0.85

Fig 3. BICONVEX AIRFOIL

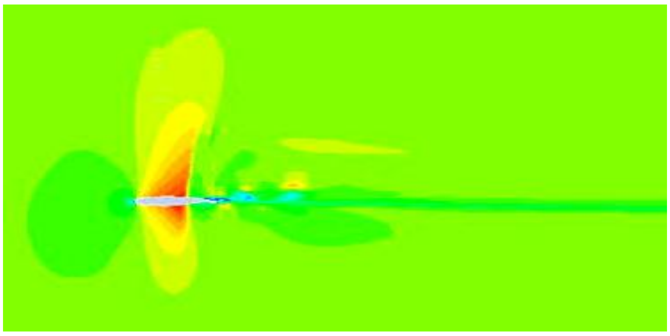
In biconvex airfoil it is found that shock buffet produced at the Transonic Mach ranged from 0.8 to 0.95.



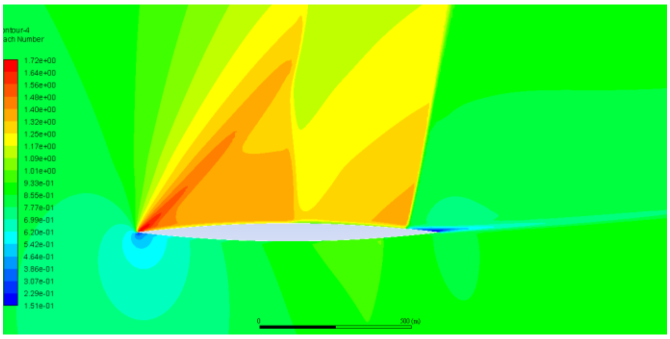
Biconvex airfoil for M=0.8



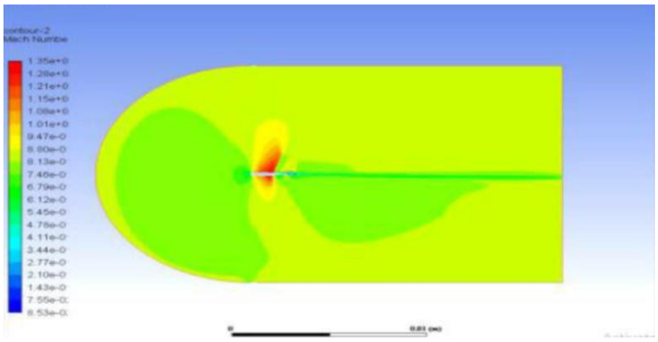
Biconvex airfoil for M=0.85



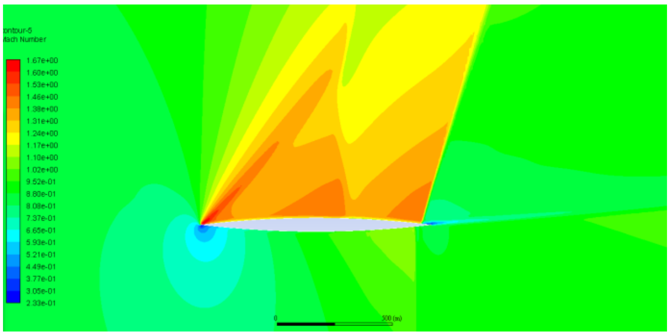
Supercritical airfoil for M=0.8 (zoomed image)



Biconvex airfoil for M=0.9

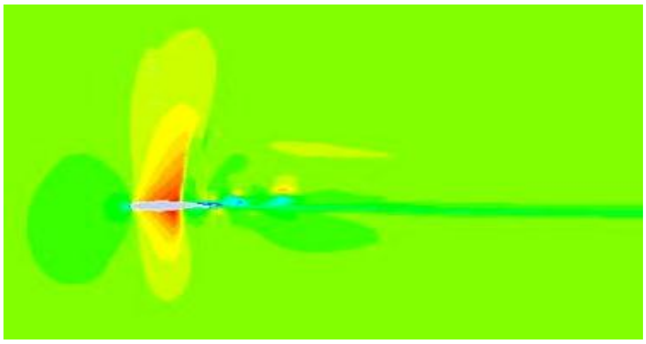


Supercritical airfoil for M=0.9



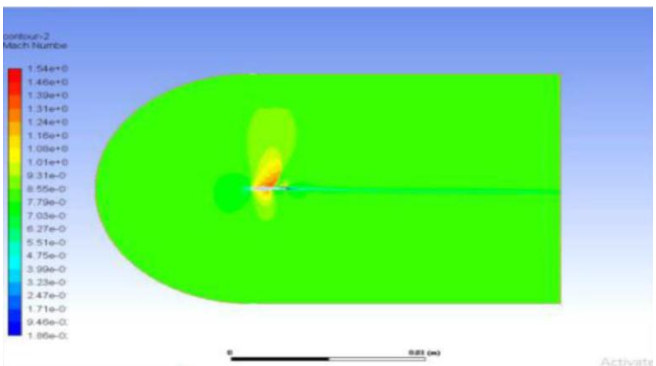
Biconvex airfoil for M=0.95

Fig 4. SUPERCRITICAL AIRFOIL



Supercritical airfoil for M=0.9 (zoomed image)

In supercritical airfoil it is found that shock buffet produced at Transonic Mach ranged from 0.8 to 0.9.



Supercritical airfoil for M=0.8

5. CONCLUSIONS

•This computational study using certain equations has been used to analyse the buffetting phenomena over certain airfoils by varying only Mach number not the Angle of Attack.

• In the present study the analysis is done by varying Mach number only.

• It is found that shock buffet produced at the trailing edge of a curved surface airfoil which means the double wedge airfoil cannot produce the shock buffet.

• Most of the shock buffet ranges from Mach 0.8 to 1.0.

• The shock buffet produces between the high subsonic to the transonic region.

• The computational results show that the shock buffet occurs at the transonic region.

6. REFERENCES

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