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DESIGN AND ANALYSIS OF SUPERSONIC WING

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Abstract

Designing supersonic wing has its own challenges with respect to shock wave formation and flow separation in the high speed stream. However, we have manipulated an unorthodox aerofoil design which is a conventional curved shape on bottom surface and a wedge shaped diamond orientation at the top surface. By having this wing, the drag produced due to the shock formation is compensated by the flow acceleration behind the expansion waves at the wedge corner. We have also considered the case that the increase in velocity at the upper surface lowers the pressure which is below the pressure at bottom surface. These results in the creation of lift and there by obtain faster flight.

Keywords : Advanced Wing, Modified Diamond Wing, Supersonic Wing..,

Introduction

All the fighter aircrafts are made in order to fly at supersonic speed. For attaining the supersonic speed many alterations are made in airfoil shapes which reduces the wave drag and let us to fly faster. At supersonic speed the main problem that we are facing in the shock wave formation which induces dramatic drag rise. By making the airfoil thinner the wave drag is reduced and another modified airfoil shape is diamond shaped in which the wave drag is reduced greatly. However the drag is needed to be reduced further. In supersonic flight the thrust required goes up due to the sudden raise of wave drag. We modified the airfoil shape which highly reduces wave drag and reduces the specific fuel consumption even at supersonic flight. The hybridization of conventional airfoil and diamond shaped airfoil produces the new pattern of flow and reduces drag. Figure-1 Shows the shape of an airfoil.

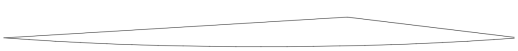

Figure-1 Airfoil shape.

Theory

In our conceptual wing design, the top surface has half diamond with wedge at stream and the bottom surface has curved profile. At the supersonic stream the wedge produces expansion corner behind it and the expansion waves are generated at the sharp corner as in the diamond airfoil. As the result of expansion waves, the flow behind it is accelerated and pressure drop occurs.

The pressure at the top surface becomes lower than pressure at the bottom surface which results in continuous lift generation. Then the coefficient of the lift increases and there by the stalling speed increases. This let us to fly faster without any structural deformation. The slower motion of flow behind the wing is the reason for the wave drag. Here the wing creates the acceleration at its trailing edge due to expansion waves and thus the wave drag is greatly reduced.

As the wave drag is decreased, the thrust required to compensate the wave drag is highly reduced, the specific fuel consumption is reduced and let us to fly the long range with same one loaded fuel. Figure-2 shows the designed model of our wing.

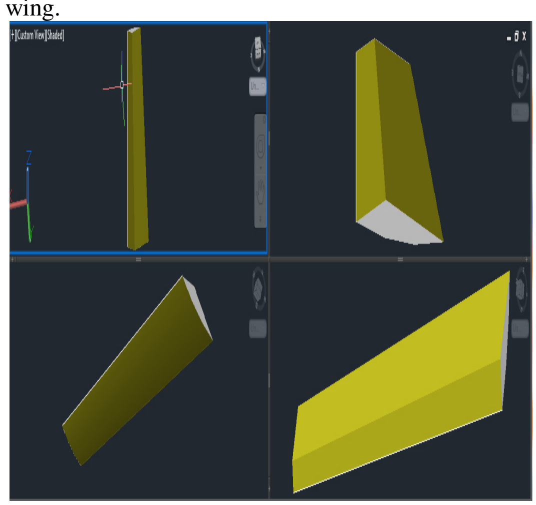

Figure-2 CAD model.

Design of the wing:

Before fixing the geometry, several hand calculations are made for better performance. The leading edge is made sharper with the wedge angle of about 10 degree. Generally to the velocity drop behind the oblique shock at leading edge is affected by this wedge angle. Lowering the wedge angle will lower the velocity drop. Thus the leading edge is made sharper. But below 10 degree wedge angle, the structure is impossible.

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The flow after expansion corner never attach to the profile, so the wedge is designed to place at the 65% of the chord .The chord length is assumed to be 6m at root and 3m at the tip. This gives us the swept back wing with 10 degree sweep angle. The thin airfoil may create the flow acceleration due to expansion waves at the line of chord. This gives the equal acceleration at the both surfaces of the wing at considerable stability. CATIA and AUTOCAD design software are used to design the wing. Figure-3&4 shows the airfoil with dimensions and plane view of wing respectively. The Airfoil Follows NACA3616 series.

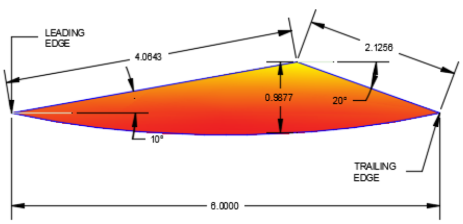

Figure-3 Airfoil with dimensions.

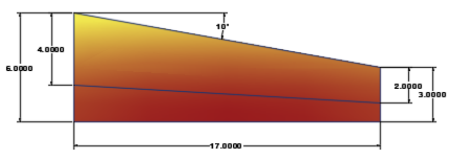

Figure-4 Plane view of wing.

CFD Model Setup

The designed wing model is computationally analyzed by using fluent workbench in ANSYS 15.0. Initially the designed model should be made compatible to fluent workbench by saving the model is made in (.igs/.iges) extension and then imported. The geometry will be treated as the ideal solid wall. So the fluid domain must be defined by using enclosure command. The enclosure with 10m around the wing model is created and named the faces respectively. Figure-5 shows the completely import geometry along with the enclosure into ANSYS.

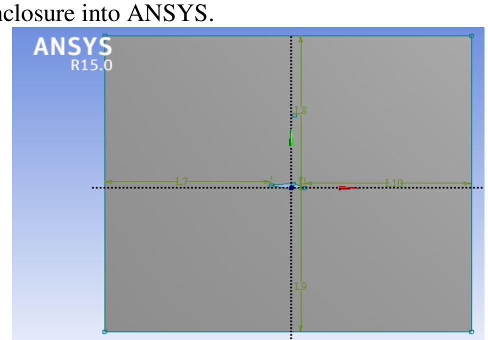

Figure-5 Imported geometry in ansys.

The geometry with enclosure is meshed finely with default cell shape. The mesh method is converted to tetrahedral for better performance. The mesh over wing surface refined again to get more accurate result over the wing. Figure-6 shows the meshed geometry and figure-7 shows the refined mesh around the wing profile.

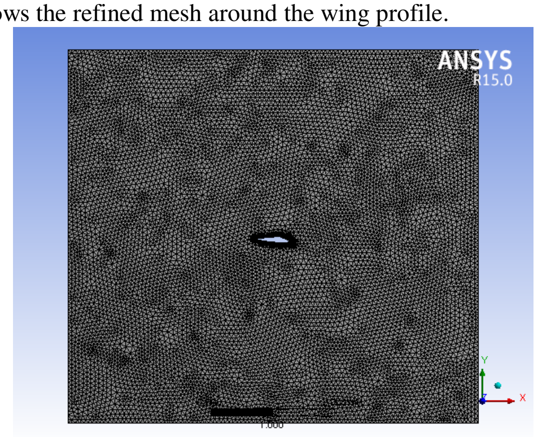

Figure-6 Meshed geometry.

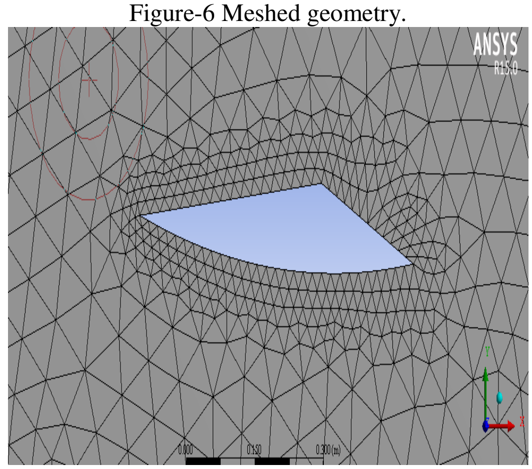

Figure-7 Mesh refinement.

Now the solver setup is going to be defined for supersonic stream. The solver is insisted to consider the energy equation and the model is defined with default k-epsilon solver to get result in supersonic field. The wing is assumed to test at certain altitude and thus the air properties are changed according to the altitude. The density and temperature of upcoming air is fixed as 0.8 kg/m3 and 298 K respectively. The wing material is defined as aluminum with default properties in the solver.

The second order upwind scheme is defined for solving. The inlet is defined as velocity inlet with the velocity if 1000 m/s and the outlet face is defined as pressure outlet with the pressure of 101625 Pa. rest of the surfaces are considered as wall with no slip. But the wing surface wall is defined with specified wall shear. The solving is started by fixing the number of iteration as 1000 run the calculation. The solver converged at 910th iteration.

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Result

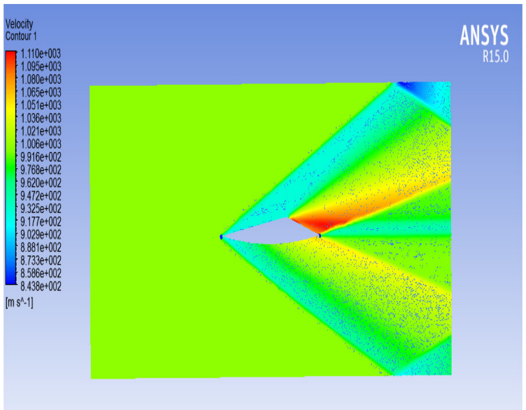

Figure-8 Velocity contour.

Figure-8 shows the velocity contour of solved flow. This shows the velocity raise in red color behind the expansion corner. The velocity magnitude behind expansion corner is 1100 m/s and thus the flow is accelerated.

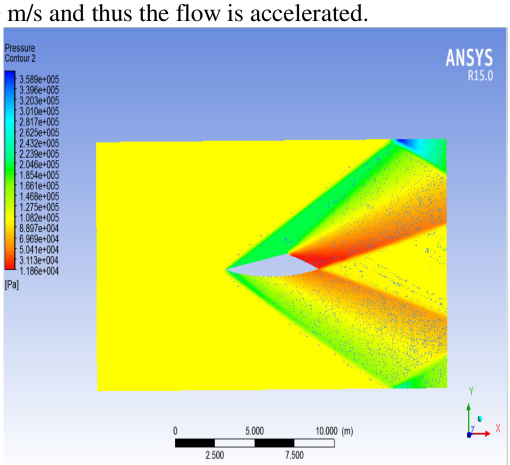

Figure-9 Pressure contour.

Figure-9 shows the pressure changes which produces lift. The pressure at top surface is lower than the bottom surface. Thus the desirable lift generation and velocity raise is achieved.

Comparison

The new designed wing is compared with the existing wing without wedge. The wing without wedge for same dimensions is designed using catia. It is tested in ansys fluent with same boundary condition and the result is shown in figure.

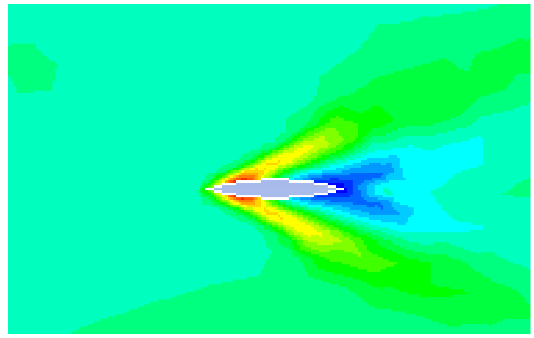

Figure-10 Pressure contour.

From the figure-10 we came to know that there is no pressure difference on both the surface at supersonic speed. Thus no possibility for lift generation.

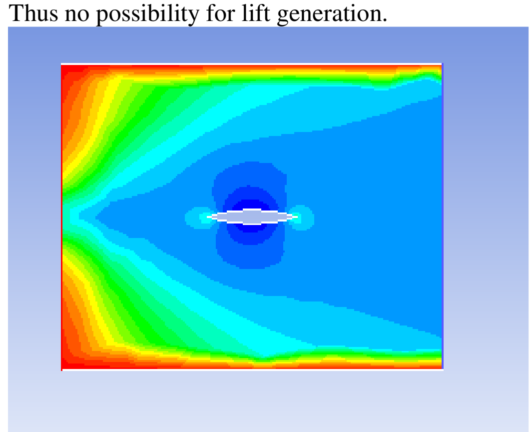

Figure-11 Velocity contour.

From Figure-11 we came to know that the velocity is dropped at supersonic speed. Sudden velocity drop behind the oblique shock decelerates the flow and wave drag is produced. These problems are overcome by this wedged wing.

The co efficient of lift for normal wing and wedged wing is 2.25 and 4.5 respectively which is obtained from ansys fluent. Thuswe obtain a lot of lift.

Conclusion

The implementation of this wing profile led us to fly in supersonic speed with minimum wave drag. The raise in co-efficient of lift makes us to fly for the longer range with same loaded fuel. The high lift generation made us easy to carry huge load for long range at faster flight.

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