Flow Investigation over a Diverterless Supersonic Inlet

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Abstract

A diverterless supersonic inlet consists of a bump and a aft closing cowl which helps in diverting the boundary layer air form the inlet. The bump is an isentropic compression surface raised outward from the body of an aircraft which forms the portion of the inner surface of the inlet. In this paper the performance characteristic of a diverterless supersonic inlet are given near its design mass flow rate. The subsonic characteristics are evaluated at M_∞=0.6 and the supersonic characteristic are evaluated at M_∞=2. The result will show the effective boundary layer diversion due to the presence of bump. The calculated subsonic and supersonic total pressure recovery characteristic are agreeable under the evaluated conditions.

Keywords: aft closing cowl, boundary layer diversion, bump, diverterless supersonic inlet, isentropic compression.

1. Introduction

The purpose of engine inlet is to supply required air during various flight conditions. When an inlet have high pressure recovery and low distortion then it is said to be a good inlet design. Pressure recovery is the ratio of average total pressure at the engine face to free stream total pressure (Farooq Akram et al, 20100Pressure recovery is affected by flow separation, boundary layer formation and shock interaction. So to reduce the formation of boundary layer various methods were introduced.

For most fighter aircrafts the engines are attached with the body. Therefore the airflow travelling along the body of the aircraft will form boundary layer which is not bodacious. So to prevent this we use a boundary layer diverter like the one on JAS39 Gripen shown in figure 1. A boundary layer diverter is has inlet that diverts the low pressure boundary layer air from entering the engine.

This method is not preferred now a days due to the increase in cost, drag and maintenance. Another method to control the boundary layer is the boundary layer bleed. In this method the boundary layer is reduced by suction through small holes in the structure. The bleed system works in a manner similar to the diverter, except instead of skimming off the boundary layer air, the bleed system takes that air on board, then vents it up through the airplane and exhausts it through a bleed exit on the aircraft. The usage of bleed system inlet is also limited due to the additional weight, cost and complexity. In addition to the bleed system and diverter some conventional inlet systems use an overboard bypass system. At high speeds the engine airflow will claim cuts back to a level below that required for the inlet to work normally. Therefore the bypass system will compensate by dumping the excess air overboard.

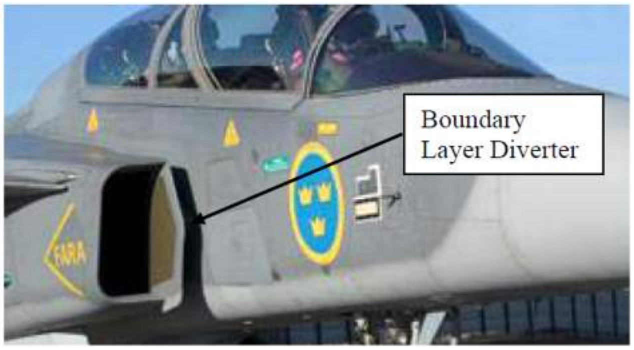

Figure 1 : JAS 39 Gripen with boundary layer bleed

Considering the above mentioned disadvantages into account a inlet is designed which is called diverterless supersonic inlet (DSI) of the Lockheed Martin Joint Strike Fighter(JSF) as shown in figure 2.

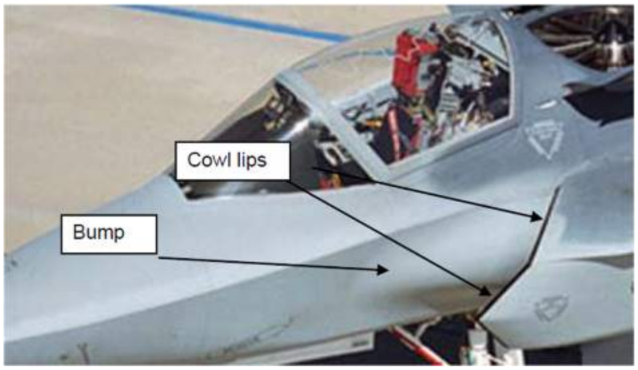

Figure 2 : F-35 Lightning II with diverterless supersonic inlet.

Fundamental researches on this inlet configuration have been continued since the mid 1990s. In this inlet a three dimensional surface or a bump act as a compression surface and creates a pressure distribution that helps in pushing the boundary layer air away from the inlet. The inlet cowl lip is designed to allow boundary layer flow to spill out of the aft notch.

The advantages of this design is that it does not require a boundary layer diverter or a splitter plate, a bleed system or a bypass system. Furthermore it has no moving parts which reduces aircrafts empty weight, production cost and maintenance requirements. This inlet also increase the stealth of the aircraft because of the low radar cross section(RCS). Another technical advantage of this inlet is that it is adaptable to virtually any supersonic aircraft.

2. Methodology

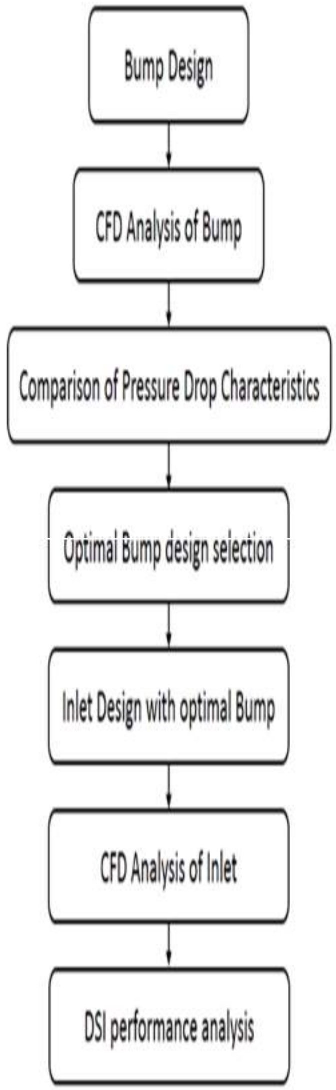

Figure 3: workflow chart

2.1 *Model Description*

The bump is designed using a modeling software. Totally eight bumps were designed by changing the height and location of the bump. They are 20-150,20-200,30-150,40-150,40-200,50-150,50-200(All the values are in millimetre). Where the first term denotes the height and second term denotes the location.

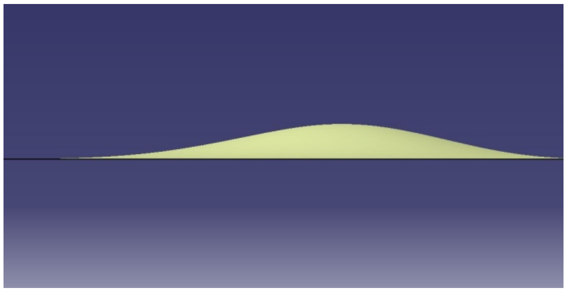

Figure 4 : Bump of height 20 and location 150

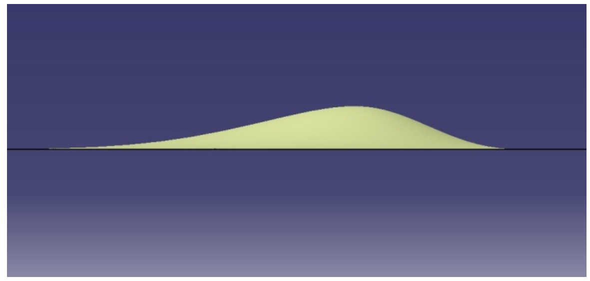

Figure 5 : Bump of height 20 and location 200

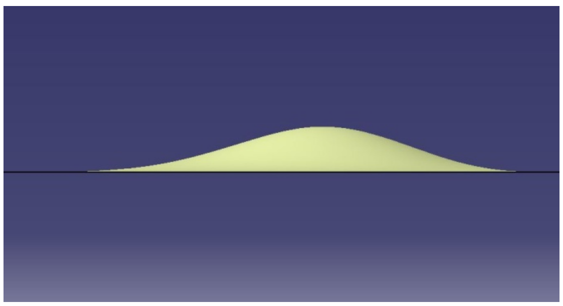

Figure 6: Bump of height 30 and location 150

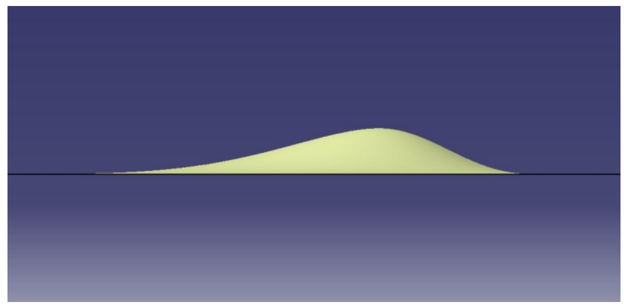

Figure 7 : Bump of height 30 and location 200

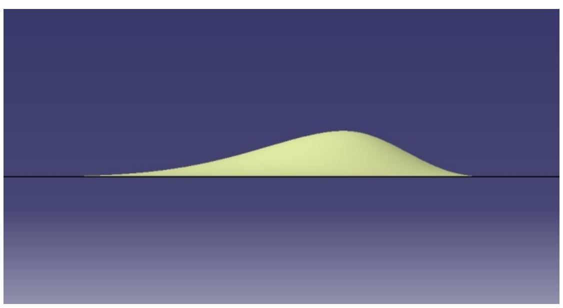

Figure 8 : Bump of height 40 and location 150

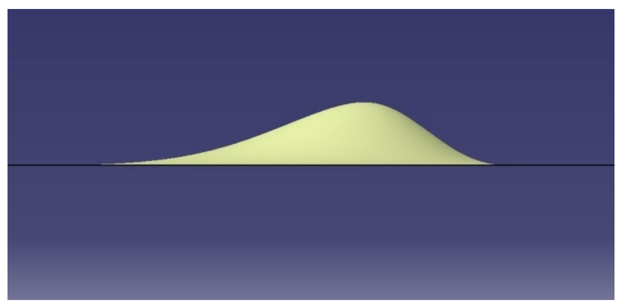

Figure 9 : Bump of height 40 and location 200

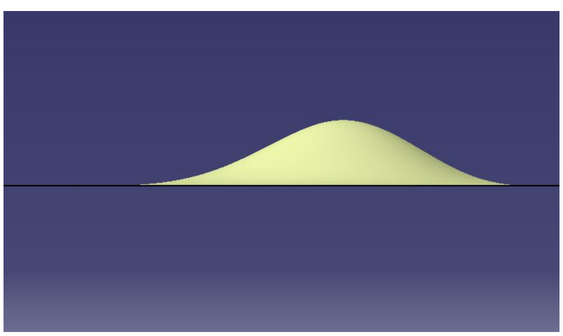

Figure 10 : Bump of height 50 and location 150

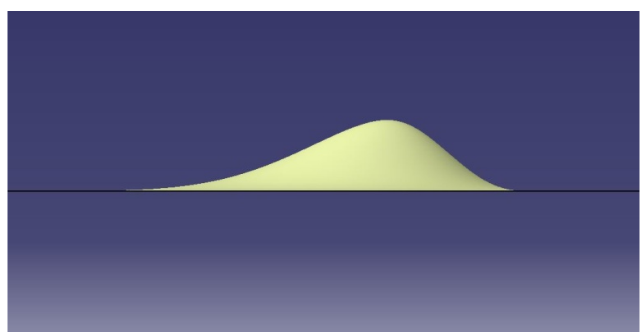

Figure 11 : Bump of height 50 and location 200

2.2 Grid Generation

Before generating grid a far filed is created for all the eight bumps. The far filed is created for approximately six times of the bump so as to avoid far filed pressure boundary influence the pressure distribution of the bump. Auto meshing is done for the bump since it does not have any complicated structure.

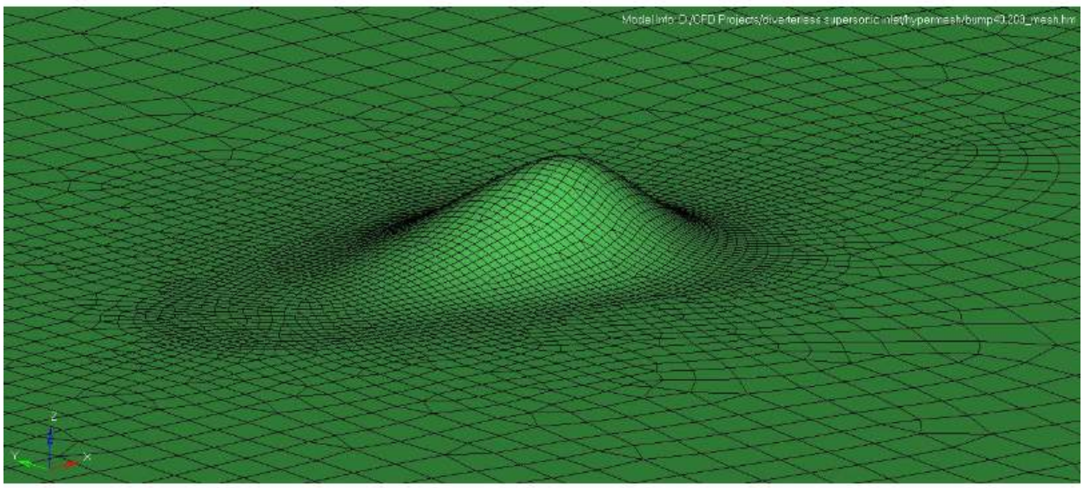

Figure 12:Meshed image of the bump

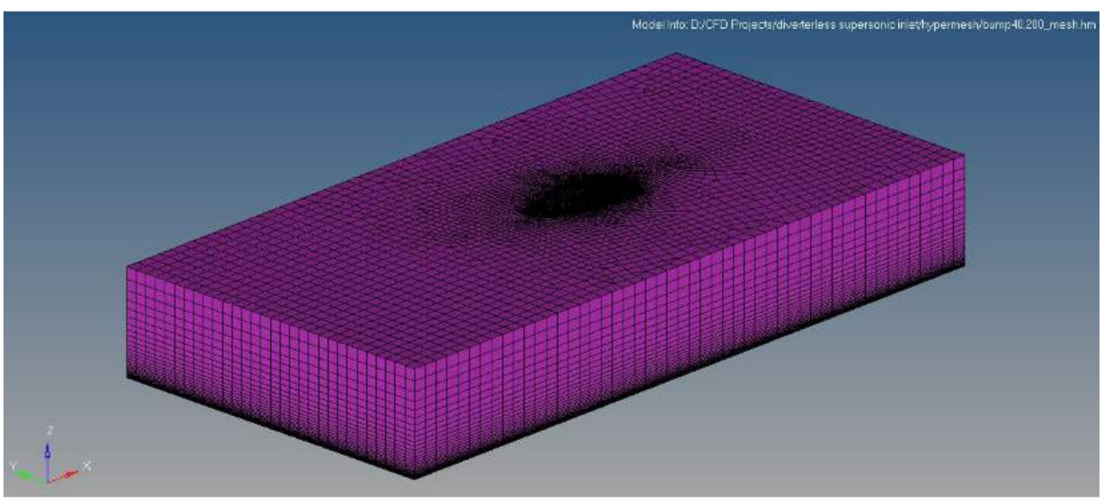

Figure 13:Meshed image of the bump with far filed

2.3 Modal Analysis

These bumps are analyzed using an analyzing software to know the pressure variation across the surface of the bump. The bumps are analyzed at Mach number 0.6 at sea level pressure and temperature.

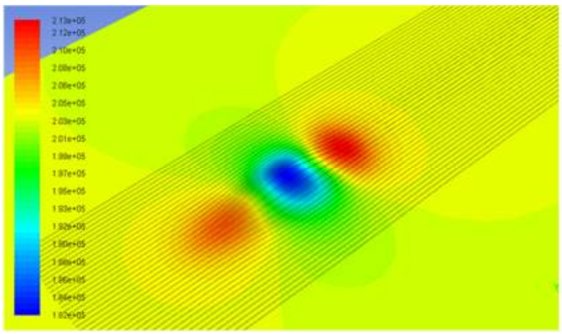

Figure 14 :Pressure Contour of bump 20 -150 at $M_\infty = 0.6$

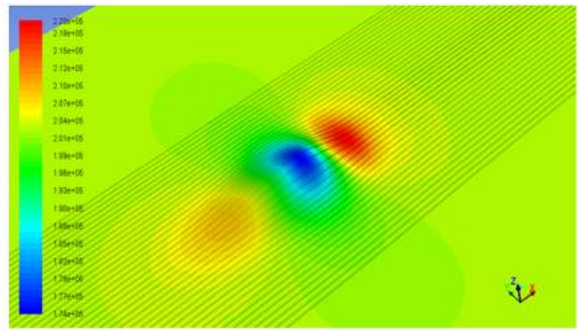

Figure 15 :Pressure Contour of bump 20 -200 at $M_\infty = 0.6$

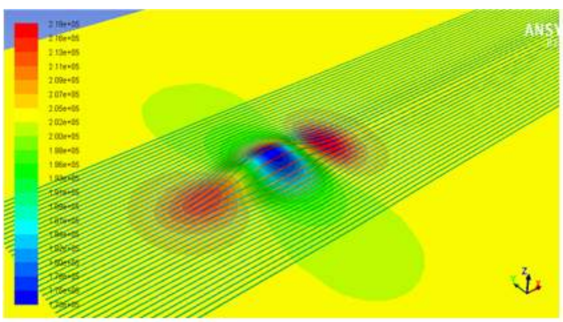

Figure 16 :Pressure Contour of bump 30 -150 at $M_\infty = 0.6$

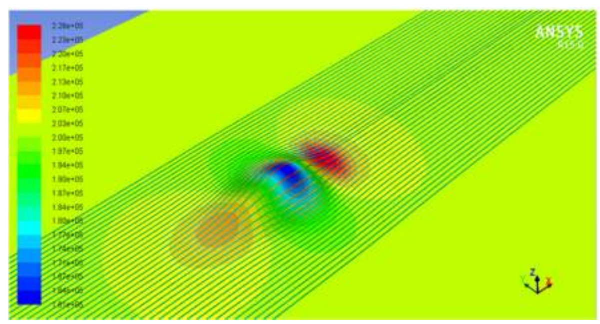

Figure 17 :Pressure Contour of bump 30 -200 at $M_\infty = 0.6$

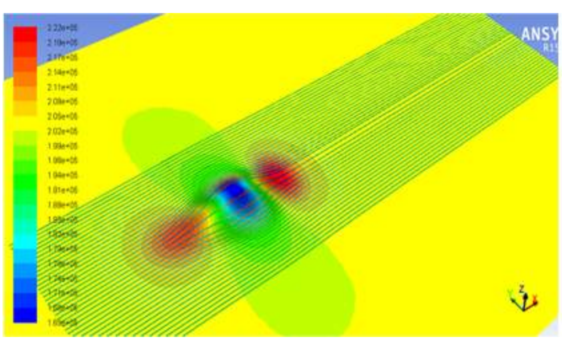

Figure 18 :Pressure Contour of bump 40 -150 at $M_\infty = 0.6$

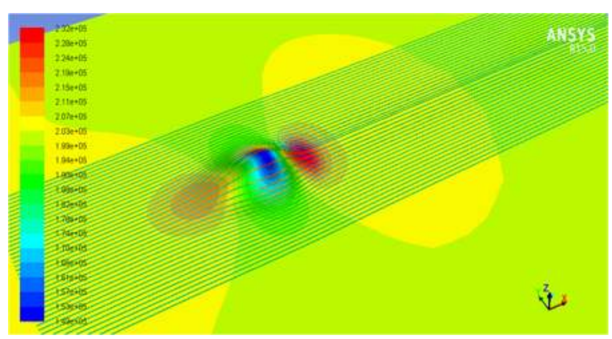

Figure 19 :Pressure Contour of bump 40 -200 at $M_\infty = 0.6$

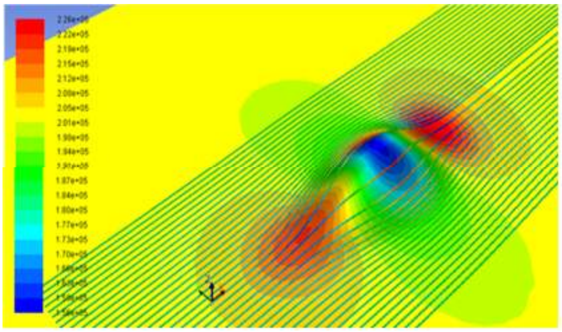

Figure 20 :Pressure Contour of bump 50-150 at $M_\infty = 0.6$

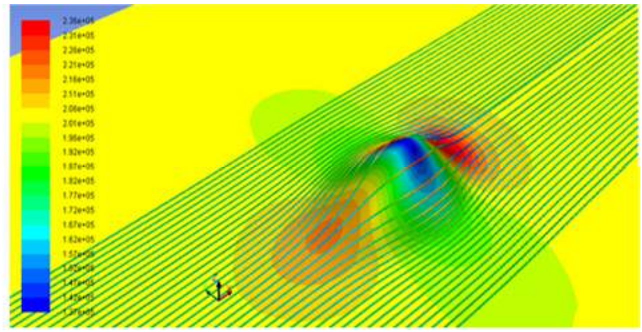

Figure 21: Pressure Contour of bump 50-200 at $M_\infty = 0.6$

Similarly we have to find the pressure contour for all the eight bumps for mach number 2. Now for each bump calculate the pressure difference. To do that note down the pressure value in fore point and aft point of the bump, the difference between these two point will give the difference in pressure. Likewise we have to calculate the pressure difference for all the eight bumps for both $M_\infty = 0.6$ and $M_\infty = 2$. The calculated pressure difference values are given in the table 1 and table 2 given below

Table 1: Pressure difference of bumps for $M_\infty = 0.6$

Model	Fore Point	Aft Point	Pressure Diff
20,150	204113.39	206894.68	2781.29
20,200	203129.63	210196.41	7066.78
30,150	203670.41	208840.63	5170.22
30,200	203175.25	213673.11	10497.86
40,150	203982.51	210839.98	6857.47
40,200	203360.59	217241.55	13880.96
50,150	204343.53	212618.31	8274.78
50,200	203806.69	214799.75	10993.06

Table 2: Pressure difference of bumps for $M_\infty = 2$

Model	Fore Point	Aft Point	Pressure Diff
20,150	202649.84	262040.59	59390.75
20,200	202649.92	274460.51	71810.59
30,150	202649.77	293934.51	91284.74
30,200	202649.92	318259.72	115609.8

40,150	202649.75	322255.06	119605.31
40,200	202649.69	353971.72	151322.03
50,150	202649.81	346648.51	143998.7
50,200	202649.81	348441.56	145791.75

With the help of the obtained pressure difference values graphs are plotted as shown in figure 21 and 22

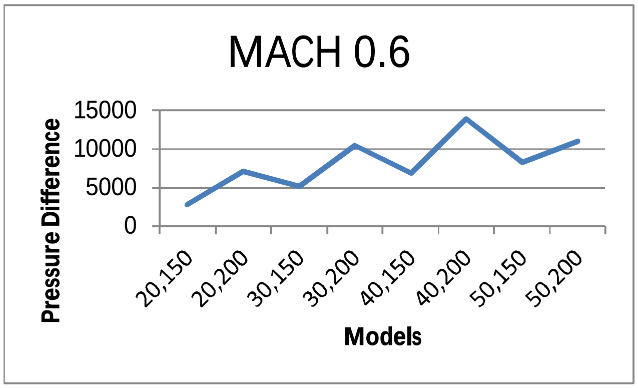

Figure 22 : Pressure Difference for M_∞= 0.6

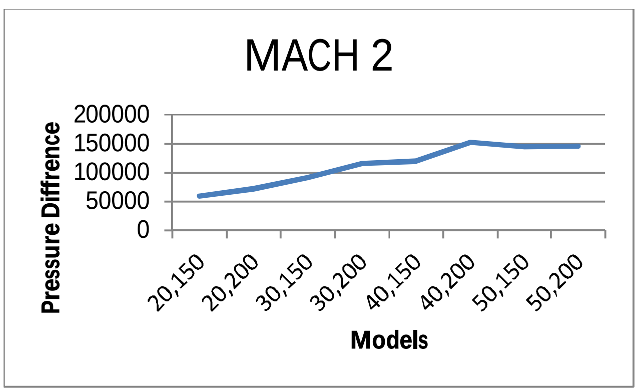

Figure 23 : Pressure Difference for M_∞= 2

3. Results and Discussions

In the presence study computations were carried out for Mach numbers $M_\infty = 0.6$ and $M_\infty = 2$ to see the subsonic and supersonic performance of DSI. For this we consider the bump 40, 200 which is optimum for both mach numbers. This bump is now attached to the inlet to visualize the behavior of the bump along with the inlet. The subsonic flow filed around the bump and intake consists of free stream flow which is modified by the presence of the bump and the inlet. The flow near the inlet usually follows the contour while far away it merges with the free stream flow.

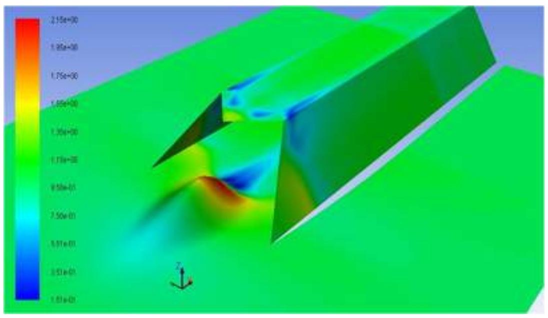

Figure 24: Mach contour at $M_\infty = 0.6$

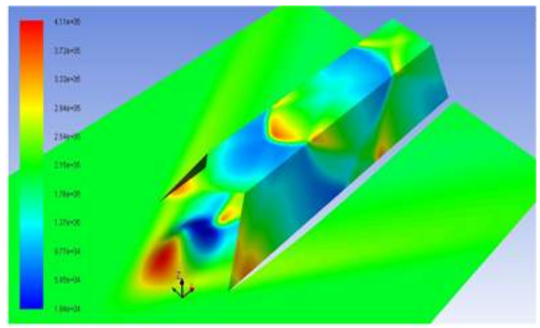

Figure 25: Mach contour at $M_\infty = 2$

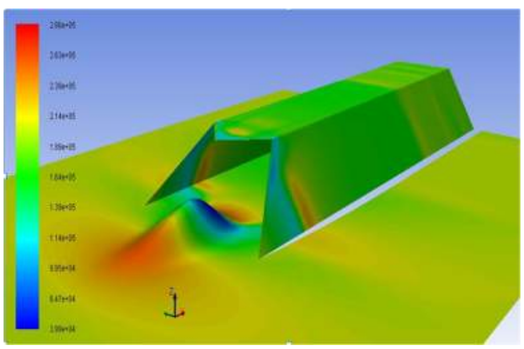

Figure 28: Pressure contour at $M_\infty = 0.6$

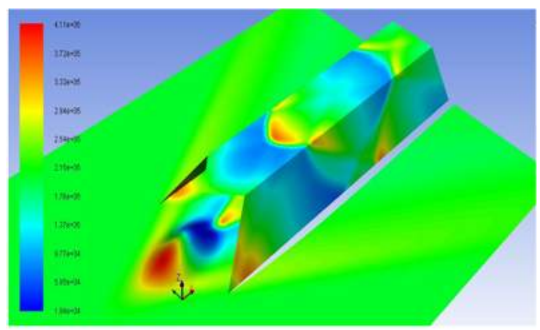

Figure 27: Pressure contour at $M_\infty = 2$

4. Conclusion

In this paper the flow and performance characteristics of an diverterless supersonic inlet are computed. The flow details found are in greater detail than that can be extracted from a wind tunnel test data. The operating mechanism of a diverterless supersonic inlet is to get rid of upstream boundary layer at subsonic and supersonic conditions has been demonstrated.

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A Brief Author Biography

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