DESIGN AND NUMERICAL ANALYSIS OVER A REUSABLE LAUNCH VEHICLE

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Abstract— Reusable launch vehicle (RLV) continuous to be a growing field with on-going research into unsteady flow condition. The design of a Reusable launch vehicle by three dimensional simulations to mainly investigate the re-entry characteristics like re-entry temperature fluctuations, pressure variations at Supersonic velocities. The computational approach strike a reasonable balance to handle the competing aspects of complicated physical second order accurate discretization, tetra grid iterative solution procedure. Numerical simulations based on computational fluid dynamics (CFD) demonstrate a guideline for selecting parameters during re-entry of RLV and help to find out the best materials for the construction of RLV. Accordingly in present study an attempt has been made to design a reusable launch vehicle [space shuttle] using CATIA V5 and analyse it through CFD approach using ANSYS CFX 14.5 to analyse the flow pattern, temperature fluctuations and other re-entry characteristics of RLV or space shuttle (a reusable launch vehicle) at supersonic velocities. In addition to this an attempt has been made to study the effect of using Ultra High Temperature Ceramic materials like Silicon di boride and Zirconium di Boride commonly used as heat shields in Intercontinental Ballistic Missiles, as Thermal shielding of RLV/Space shuttle, instead of conventionally used Silicon based Thermal protection systems.

Keywords: Ceramic materials, computational fluid dynamics, Reusable launch vehicle, supersonic velocities.

I. INTRODUCTION

A reusable launch vehicle is a launching system which is capable of launching a launch vehicle into space more than one or two times. This contrasts with expandable launch systems, where each launch vehicle are launched once and then discarded. No true orbital reusable launch system is currently in use. The closet example was the partially reusable space shuttle. The orbiter, which included the main engine and the solid boosters were reused after several months of refitting work for each launch. The external fuel drop tank was discarded, but it would have been possible for it to be reused in space various applications.

Table 1. Present RLVs.

Level Of Reusability	**Examples**
Full reusability	Venture Star, Original Space Shuttle designs
Full reusability of one stage, partially reusability of Another stage	Space Shuttle fleet, Buran/Energia
Full reusability of one stage, expendable other stages	Pegasus, HOPE space plane, Ariane 5 with Crew Transfer Vehicle
Partially reusability of one stage	ALS
No reusability	ELVs

II. DESIGN TOOL

Aerodynamic analysis of theoretical calculation of shock wave angle and interaction of shock wave are considered because the shock wave interaction between isolator inlets gives more separation and flow disturbance and shock wave creates more temperature. The positions of cowl and ramp length and ramp angle are determined and sketched. This sketch was made 3D model by using CATIA V5.

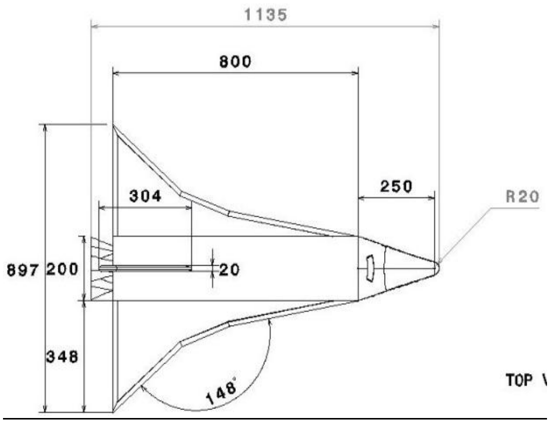

Figure 1. Top View of the RLV

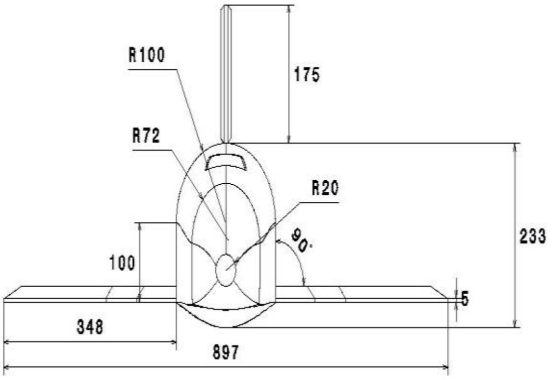

Figure 2. Front View of the RLV

III. COMPUTATIONAL FLUID DYNAMICS (CFD) SETUP

Computational Fluid Dynamics (CFD) is an integral part of aerodynamic design process along with wind tunnel testing and engineering methods. But, CFD decrease the dependence on the expensive, time consuming wind tunnel testing. The use of CFD methods accelerates the design process, reduce preliminary development testing, and help create reliable designs of space launch vehicles and their components. Presently the simulation capability and reliability of CFD simulation increased due to availability of advanced models and computer hardware.

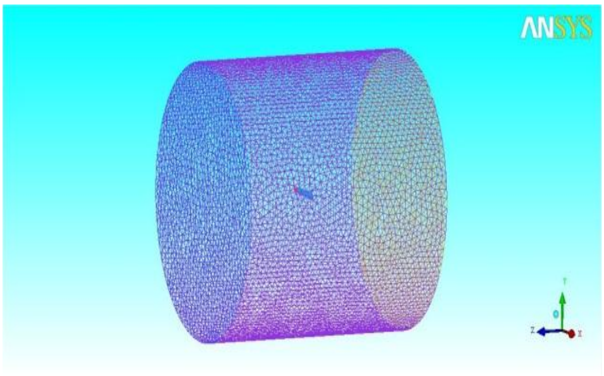

Figure 3. Mesh Generation of RLV

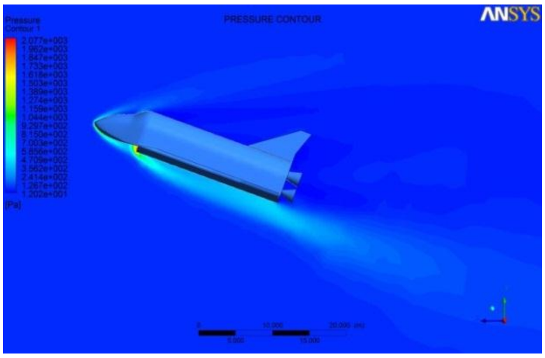

Figure 4. Pressure contour For Silicon carbide at Mach 1.5

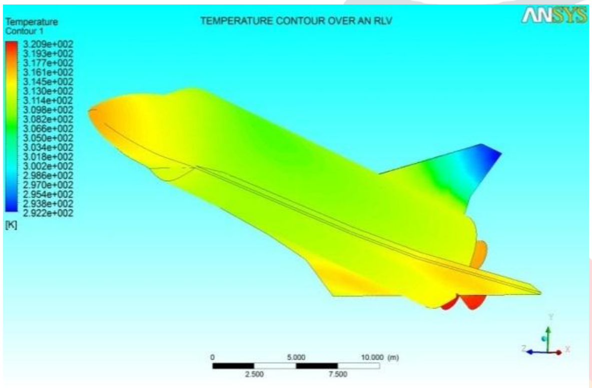

Figure5. Temperature contour over RLV

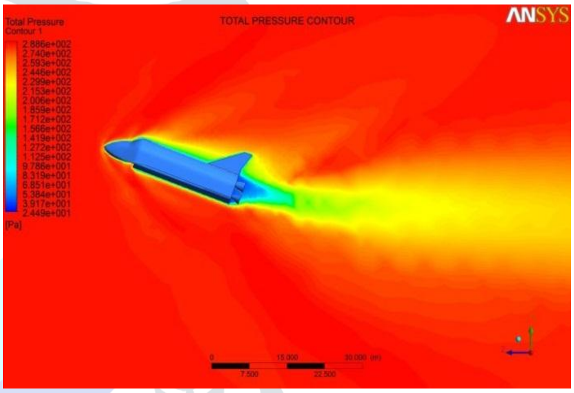

Figure 6. Total Pressure For Silicon carbide at Silicon carbide at Mach 1.5 for Mach 1.5

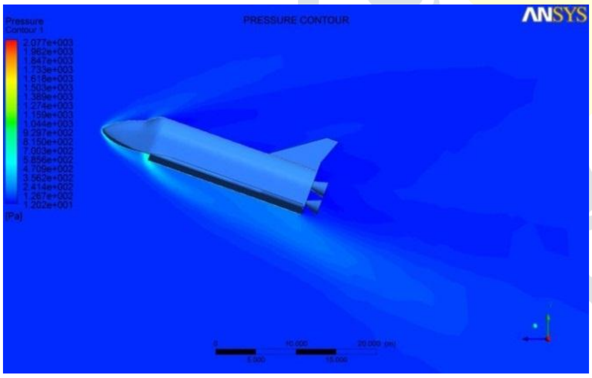

Figure 7. Pressure contour For Silicon carbide at Mach 3

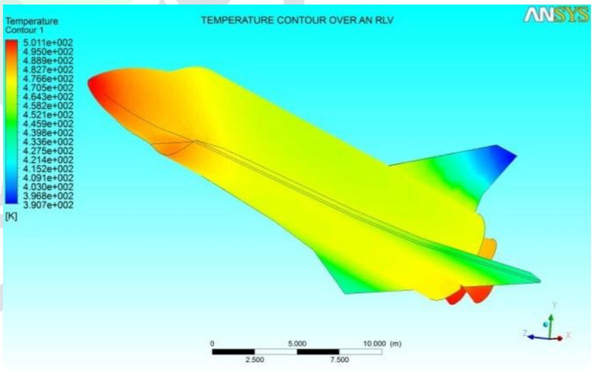

Figure 8. Temperature contour over RLV For Silicon carbide at Mach 3

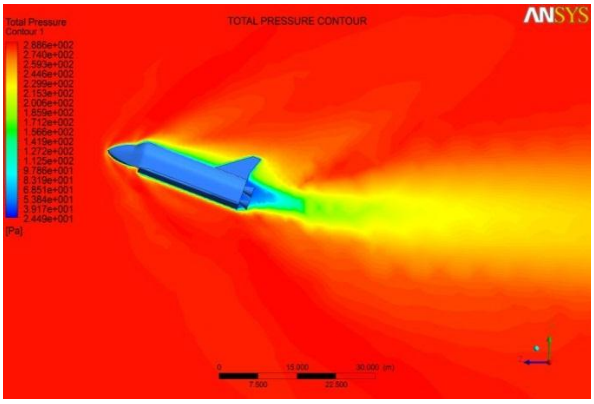

Figure 9. Total Temperature contour For Silicon carbide at Mach 3

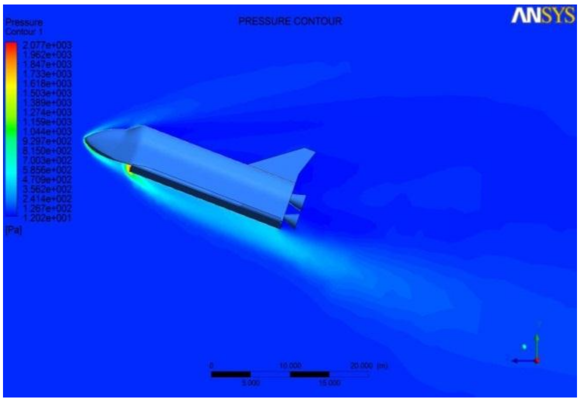

Figure 10. Pressure contour For Silicon carbide at Mach 5

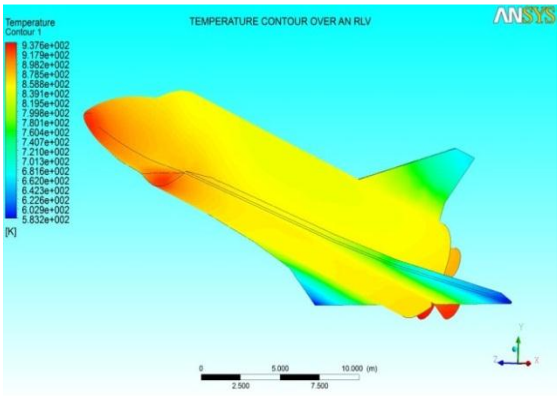

Figure 11.Temperature contour over RLV For Silicon carbide at Mach 5

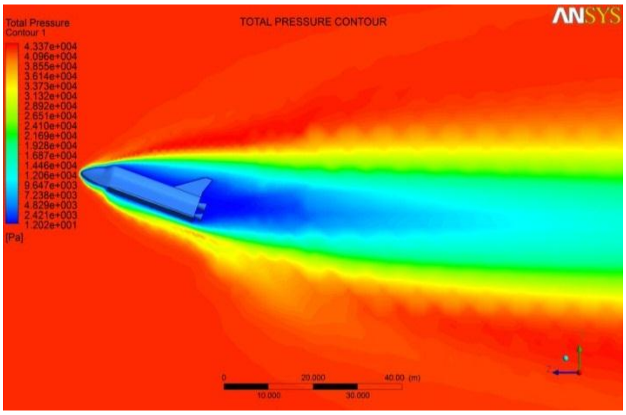

Figure 12. Total pressure contour For Silicon carbide at Mach 5

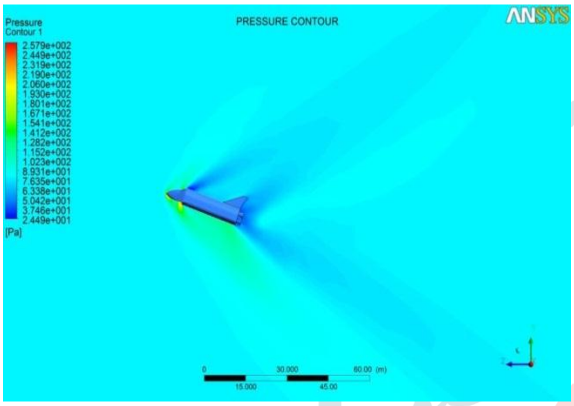

Fig.11 Pressure contour For Zirconium diboride at Mach 1.5

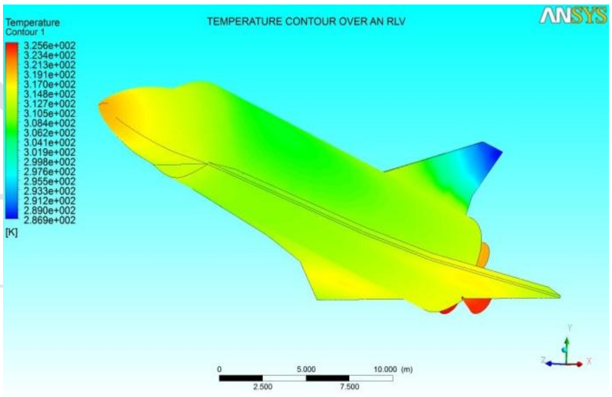

Figure 13. Temperature contour over RLV for Zirconium diboride at Mach 1.5

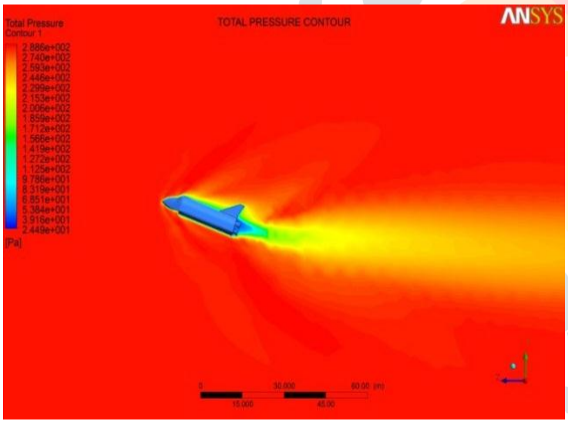

Figure 14. Total temperature contour For Zirconium diboride at Mach 1.5

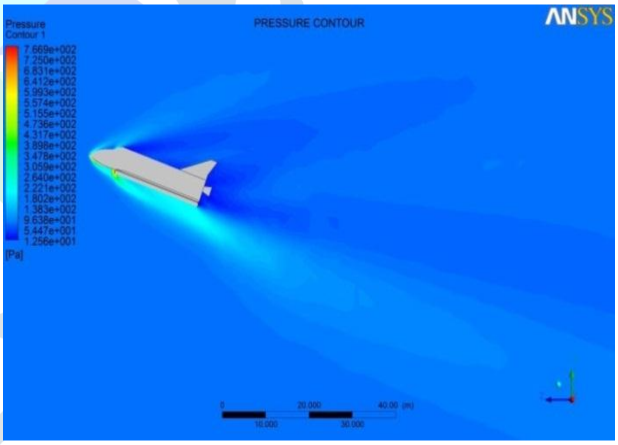

Figure 15. Pressure contour For Zirconium diboride at Mach 3

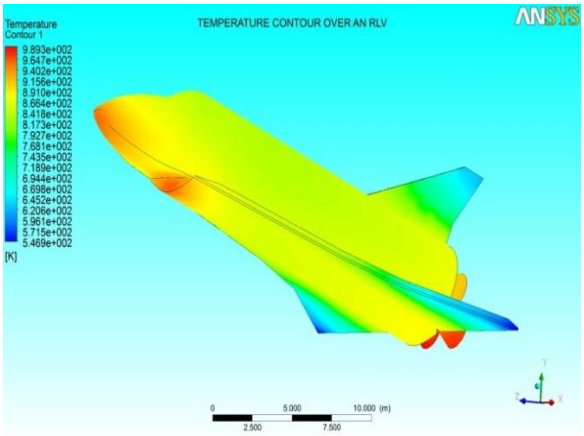

Figure 19. Temperature contour over RLV For Zirconium diboride at Mach 5

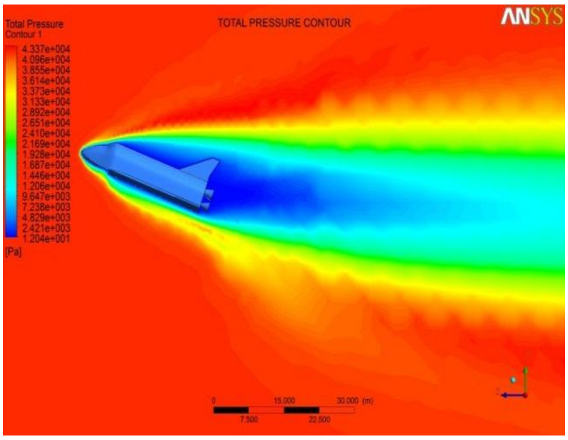

Figure 20. Total pressure contour For Zirconium diboride at Mach 5

Table 2. Mach number vs Temperature at Silicon carbide

Mach no	Nose	Wing bottom	Fuselage
1.5	371.54	298.05	319.325
3	537.533	420.307	457.57
5	838.36	441.49	794.3

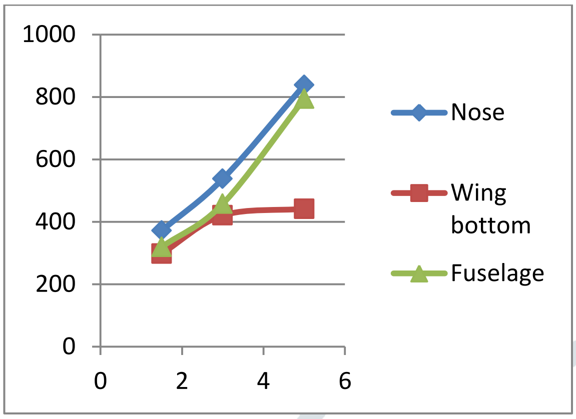

Figure 21. Variation of temperature at different Mach numbers for SiC

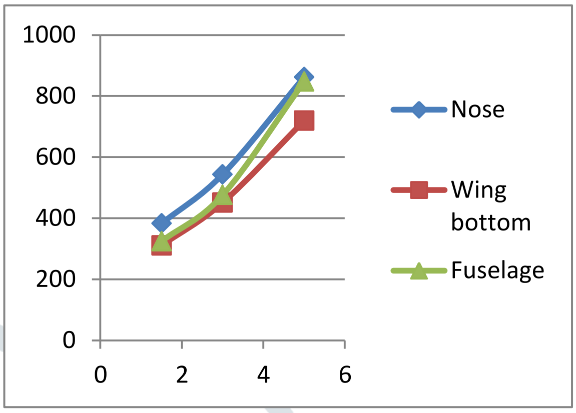

Figure 22. Variation of temperature at different Mach numbers for ZrB2

IV. CONCLUSION

The two different materials used (silicon carbide & zirconium diboride) to analyze at different Mach numbers which are at supersonic velocities. After comparing with the results we have concluded that silicon carbide is best suited for nose, wing bottom and fuselage sections, as it have lower temperature effects than zirconium diboride. At high Mach number of vehicle, velocity of flow increased and the pressure of the vehicle decreases drastically. The temperature increases with increase in Mach number. In future, separate materials for each section will be discussed and analyzed. Experimental and computational studies have been made to obtain the flow field over a typical RLV configuration. Computations made using FLUENT shows reasonably good comparison with experimental results and capture most of the features of flow field. The re-entry vehicle behaves differently at different Mach numbers.

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