Numerical Analysis of Stage Separation System in Space Launch Vehicle

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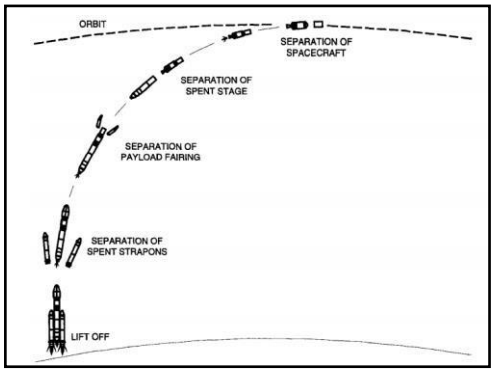
Abstract*— This project details the various Computational Fluid Dynamics (CFD) analysis performed on the stage separation of stage three and stage two in a four-stage median-lift launch vehicle. The analysis has been performed with the assistance of ANSYS Fluent 16.0. The analysis is conducted with density based solver and different parameters like mach numbers, velocity and pressures have been inputed for obtaining results in various conditions. These results are compiled and various respective graphs and contours have been obtained showcasing the flow characterisation during the separation process between stage two and stage three, where stage three is the spent stage and is to be jettisoned.

Index Terms— *CFD, ANSYS Fluent 16.0, Four-stage medium-lift launch vehicle, Jettisoned*

I.INTRODUCTION

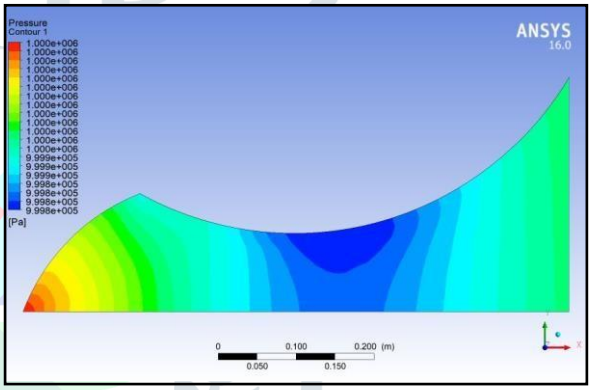
Launch vehicles are one of the most ingenious systems developed in order to transport various kinds of payload to earth orbit and beyond. Medium-lift rockets are highly used and are incorporated for various tasks, they are capable of reaching till the Low Earth Orbit (LEO) while carrying around 2,000 to 20,000 kilograms of payload. In any launch vehicle mission the most crucial process is the stage separation process in a multi-stage rocket, therefore proper analysis has to be carried out in order to assess the efficiency of the stage preparation process. There are various methods to carry out stage separation, like 'firing in the hole' and 'ullage rocket technique'. The selection of the technique is a very crucial decision and depends on various critical parameters, like ; drop in air pressure, reliability, production of low energy shocks, restriction of debris, the weight it adds and the cost. The technique incorporated should be able to obtain a separation without any collision between the spent stage and the upper stage, therefore ensuring a safe separation, it should also assure the structural integrity of the vehicle even under severe conditions and also ensuring that the stages are well connected and there is no loose ends. Every separation process has mainly three elements to function with ; "Actuator" in order to start the process, it is either electric or pyro based and depends from mission to mission, second is the "Releasing System" for the actual separation of the stage and the last is the system used for jettisoning so that the spent stage is given enough velocity for a safe separation.

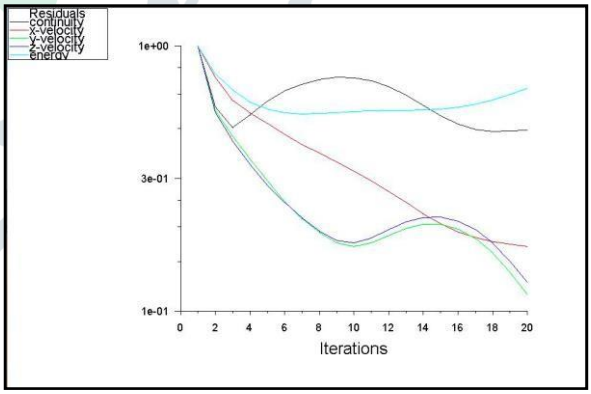


II. COMPUTATIONAL SETUP

1. Analysis of half C-D nozzle

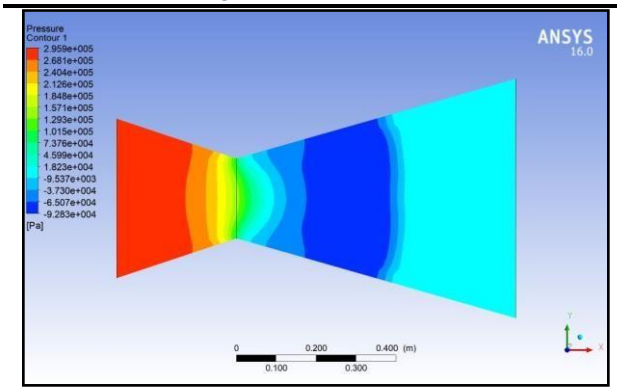
The analysis of half C-D nozzle is conducted using ANSYS Fluent 16.0.



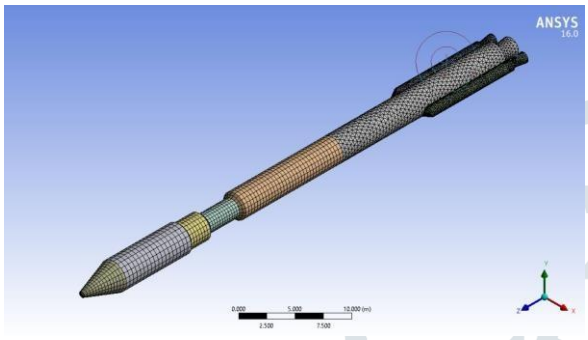


2. Analysis of Full C-D nozzle

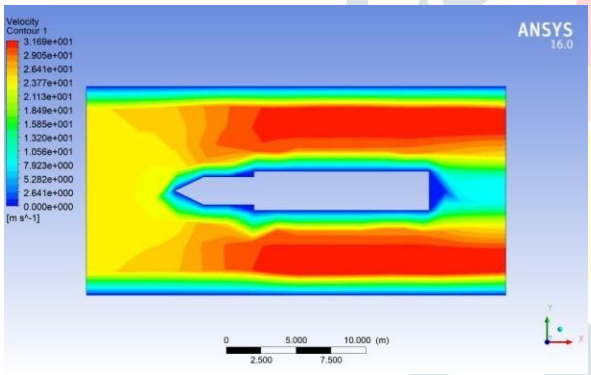
The analysis of C-D nozzle is conducted using ANSYS Fluent 16.0 whilst applying pressure of 3e+5, Temperature of 3000 K and velocity of 11 m/s. The same parameters were applied to the half C-D nozzle for the analysis.



C-D NOZZLE



Rocket Mesh

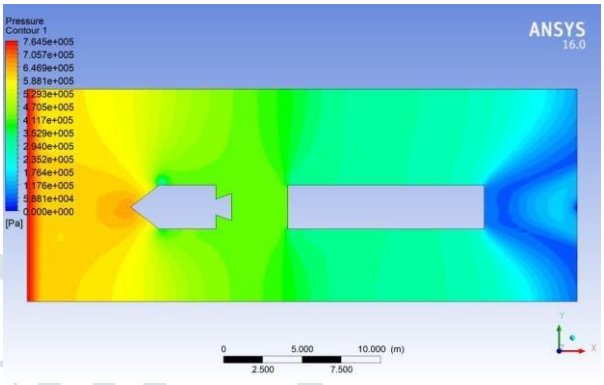


Two Stages of rocket

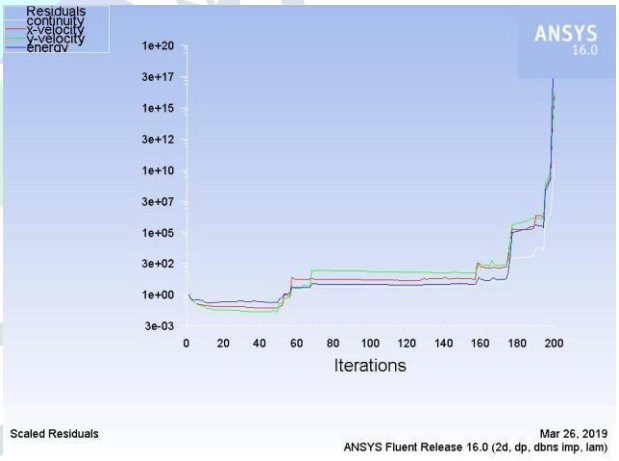
Here the analysis is done first for the C-D nozzle, then it was calculated for the the rocket mesh and its two different stages together.

III. PROBLEM STATEMENT

Since stage separation is a tedious and complicated process and we need to understand all aspects related to it properly. It demands proper analysis and proper calculations for more efficient and collision free separation. The jettisoning of the the spent stage should be given some velocity to ensure a smooth separation from the ongoing stage. Therefore, the aim of this project is to observe and analyse the flow characterisation and separation process under various conditions.



Two stage Separation



Graph Velocity

IV. CONCLUSION

The boosters of the launch vehicle are considered as a part of the rocket structure for a much more smoother flow around the vehicle. They use CFD tools for better analysis and simulation. They conclude that the air velocity over inclined boosters is much more than on normal boosters under various conditions and different parameters.

The Runga-Kutta method and various statistical methods have been used in this research to determine the separation time, velocity, as well as as longtidunal and lateral clearances between the two stages avoid any collision between them. They concluded that their research and calculations helps in adapting a suitable jettisoning procedure for a collision free stage separation in launch vehicle systems

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