Design of Maneuverable Ballistic Missile configuration Integrated with Liquid-Fueled Ramjet Engine by the assistance of CFD Simulation, FEA-Modal Analysis and Study State Thermal Analysis.

Mr. ABBU VENKATESH M.Tech¹, Mr. RAMPURAPU RAVISH M.Tech.²
¹Assistant Professor, Department of Mechanical Engineering, Dhanekula Institute Of Engineering And Technology, Vijayawada, venkateshawesome@gmail.com¹.
²Assistant Professor, Department of Mechanical Engineering, M.V.R College of Engineering and Technology, Paritala, Vijayawada, ravish.rampurapu@gmail.com²

Abstract: In which, Ballistic missile with high maneuverability model has been developed. An integrated liquid fuel ram jet engine which comprises of supersonic diffuser at inlet and convergent –Divergent nozzle at the rear end. A solid propellant rocket booster has been attached for initial launch purpose. Analyzed the simulation of Computational Fluid Dynamics at various Mach numbers, By Finite Element Analysis (FEA dynamic analysis) leads to resolve the impact of transient loads and identified the natural frequencies and Heat Transfer –Thermal analysis at the specified combustion chamber.

Key words: Ballistic missile, Computational Fluid Dynamics -Fluid flow (Fluent), Convergent –Divergent nozzle, FEA modal analysis, Liquid fuel ram jet engine, Study state thermal analysis, Solid propellant rocket booster.

I. INTRODUCTION

While missiles having prominent role to conquer in battlefield and contemporaneously to dilute the opponent. In this paper a special prominence given to indigenous development and shown my paramount interest on propulsion of Ramjet engine and tried to consolidate maneuverability of missile at a specified altitude. Missile structures are having diverse structural components by reinforce all these components to acquire cruise path of trajectory and precise guidance system.

Fig. 1 Missile Components
The typical missile components are

Fig. 2 Schematic representation of Canards, Wings and Tail fins.
Guidance system which accomplish the trace of path trajectory by the missile and improvise the accuracy of precision and optimize the scenario of reaching the target. Fuselage is peripheral surface of all the component ingredients. Missile shield with stiffeners have more durable compare than missile shield without stiffeners for vibrations analysis.

2. CLASSIFICATION OF MISSILE

Missiles are classified on the basis of their kind, launch criteria, span, propulsion, Guidance system and warheads.

Kind
- Ballistic Missile (Trajectory)
- Cruise Missile (Guided)

Launch criteria
- Surface to surface missile
- Surface to air missile
- Surface(coast) to sea missile
- Air to air missile
- Air to surface missile
- Anti tank missile.

2. CLASSIFICATION OF MISSILE

Missiles are classified on the basis of their kind, launch criteria, span, propulsion, Guidance system and warheads.

Kind
- Ballistic Missile (Trajectory)
- Cruise Missile (Guided)

Launch criteria
- Surface to surface missile
- Surface to air missile
- Surface(coast) to sea missile
- Air to air missile
- Air to surface missile
- Anti tank missile.

3. RAMJET ENGINE

It is a form of air breathing engine which is working on the principle of Brayton thermodynamic cycle. It accomplishes compression of suction air by forward motion of aircraft. At particular stagnation points all the kinetic energy converts in pressure energy through the ramming profile provided at the suction side. Fuel injected into the combustion chamber and got ignited. Hot flue gases are allowed to expand and passing through convergent & divergent nozzle. The induced thrust force will accelerate the body to move forward. The critical shock waves present in inlet implies on the performance loss of ramjet engine and indomitable for above Mach number of 5, in such cases facing difficulties while acquiring the positive pressures at combustion chamber rather than the nozzle pressure. For the above Mach number 5 scream jet will endorse the propulsion system for acquiring thrust. Even though both ramjet and scram jet do not produce thrust at zero velocity, they require additional assisted take-off at initial to get into their action.

4. TECHNICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Details</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>8500mm</td>
</tr>
<tr>
<td>Diameter</td>
<td>650mm</td>
</tr>
<tr>
<td>Engine first stage</td>
<td>Solid propellant booster</td>
</tr>
<tr>
<td>Second stage</td>
<td>Liquid fuel Ramjet engine</td>
</tr>
<tr>
<td>Wing span</td>
<td>2500mm</td>
</tr>
<tr>
<td>Range</td>
<td>200-400kms</td>
</tr>
<tr>
<td>Mach number</td>
<td>2-4</td>
</tr>
<tr>
<td>Material of Construction</td>
<td>Aluminum Alloy</td>
</tr>
</tbody>
</table>

5. DEVELOPMENT OF GEOMETRICAL MODEL

Missile configuration comprises of Fuselage, Aerodynamic war head, Flow Direction Stabilizer, liquid fuel ramjet engine, Wings, Fins, Solid propellant booster. All these models are developed in part drawings of CATIA V5 version And then later assembled as a single entity. This assembly model has imported into ANSYS software 16 version.
Fig. 7 Wireframe model of Direction Stabilizer

Fig. 8 Part Diagram of Ramjet engine

Fig. 9 Wireframe model of Ramjet engine

Fig. 10 Part diagram of aerodynamic Wing profile

Fig. 11 Part diagram of Fin

Fig. 12 Assembly drawing of Missile (Isometric View)

Fig. 13 Assembly Drawing Of Missile (Front view)

Fig. 14 Wireframe model assembly drawing of missile

6. ANALYSIS PROCESS

6.1 Computational Fluid Dynamics: - which is one of the stream of fluid mechanics that utilizes numerical analysis and data structures to analyze and solve problems that involve fluid flows with or without solid interactions. Computational fluid dynamics is completely based on the Navier-Stokes equations. These equations describe how the viscosity, velocity, pressure, temperature, and density of a moving fluid are related. CFD analysis which avoids the risk of preparing analytical and experimental methods for using prototypes in order to reduce the complexity and cost. In this paper fluid flow (fluent) analysis has been done and stream lines, pressure and velocity contours were observed.

Simulation diagrams of missile configuration
While missiles cruise in atmosphere it will be susceptible or easily influenced by wind which leads to induced vibrations. At particular frequencies if these vibrations are equals to Natural frequencies then which leads to Resonance, which is the most undesirable situation. Due to interaction between inertial and elastic properties of the materials within a structure will induced resonant vibration and which leads to vibration of the system at higher amplitude. As we know this phenomena is called as fatigue failure.
### COMPUTATIONAL NATURAL FREQUENCIES

<table>
<thead>
<tr>
<th>S. No</th>
<th>Frequency (Hz)</th>
<th>Max Deformation in metres</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.1248</td>
<td>1.0384e-003</td>
<td>Rigid body translation X-axis</td>
</tr>
<tr>
<td>2</td>
<td>9.5181</td>
<td>1.0111e-003</td>
<td>Rigid body translation Z-axis</td>
</tr>
<tr>
<td>3</td>
<td>17.988</td>
<td>1.7921e-003</td>
<td>Rigid body translation Y-axis</td>
</tr>
<tr>
<td>4</td>
<td>25.133</td>
<td>1.8561e-003</td>
<td>Rotation about Y-axis</td>
</tr>
<tr>
<td>5</td>
<td>33.46</td>
<td>4.3023e-003</td>
<td>Rotation about Z-axis</td>
</tr>
<tr>
<td>6</td>
<td>35.168</td>
<td>3.6248e-003</td>
<td>Rotation about X-axis</td>
</tr>
<tr>
<td>7</td>
<td>35.714</td>
<td>3.8684e-003</td>
<td>First elastic Bending</td>
</tr>
<tr>
<td>8</td>
<td>36.585</td>
<td>4.4215e-003</td>
<td>Second elastic Bending</td>
</tr>
<tr>
<td>9</td>
<td>40.459</td>
<td>1.5904e-003</td>
<td>Wing Body Bending</td>
</tr>
<tr>
<td>10</td>
<td>49.98</td>
<td>1.5692e-003</td>
<td>Wing Body Torsion</td>
</tr>
</tbody>
</table>

Simulation diagrams of missile configuration

1. **Fig. 20** Mode 1 - Rigid body translation X-axis
2. **Fig. 21** Mode 2 - Rigid body translation Z-axis
3. **Fig. 22** Mode 3 - Rigid body translation Y-axis
4. **Fig. 23** Mode 4 - Rotation about Y-axis
5. **Fig. 24** Mode 4 - Rotation about Y-axis
6. **Fig. 25** Mode 6 - Rotation about X-axis
6.3 Thermal – Heat transfer analysis

Usually ramjet engines utilize the ambient air as the oxidizer for combustion of fuel and which possess the unique ability to provide continuous thrust, sustained high supersonic speed and high specific impulse. This thermal simulation is useful for understanding the various important aspects of ramjet internal flows that include shockwave-boundary layer interactions, inlet-combustor coupling, flame holding and spreading, and combustion dynamics. Various processes were investigated systematically, including flame propagation, turbulent flame evolution, terminal shock train, modal analysis of the system. We are ensuring that in this ramjet engine only combustion flow analysis and temperature distributions have been discussed in this present study.

**TECHNICAL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Fuel description</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of injection</td>
<td>Droplet type</td>
</tr>
<tr>
<td>Self ignition temperature of fuel</td>
<td>500°C</td>
</tr>
<tr>
<td>Oxidizer</td>
<td>Ambient air</td>
</tr>
<tr>
<td>Tent of oxidizer</td>
<td>22°C</td>
</tr>
<tr>
<td>Mode of Heat Transfer</td>
<td>Convection</td>
</tr>
</tbody>
</table>

Simulation diagrams of missile configuration:

- **Fig. 26** Mode 7 - First elastic Bending
- **Fig. 27** Mode 8 - First elastic Bending
- **Fig. 28** Mode 9 - Wing Bending
- **Fig. 29** Mode 10 - Wing torsion
- **Fig. 30** Meshing Of Entire Assembly
- **Fig. 31** Temperature Distribution over the Combustion Chamber
7. RESULTS AND DISCUSSIONS

By scrutinizing all the above analysis’s we can ensure that this typical missile configuration has a unique behavior flow simulation under the various observations such as velocity and pressure distributions underneath of various mach numbers in CFD analysis. Observed the deformation of missile geometrical structure while over the its natural frequencies. After the detachment of solid propellant rocket booster data has been analyzed in case of temperature distributions and heat flow in ramjet engine where as liquid fuel injected into combustion chamber as a droplet form.

8. CONCLUSION AND FUTURE SCOPE

Generally missile technology has a solid research depth from the roots, and which required much more technology revolutions. It has a provision for so many design aspects as well as Structural material analysis in CFD simulation it has a scope of Crash analysis, Flow behavior of flow analysis of different contours with respect to various angle of attack, vibration analysis of stiffened missile shield, Aero dynamic warheads, advance research in grid fins, and virtual flight simulator.

In FEA dynamic analysis so many parameters has to be taken into consideration.

In thermal analysis, turbulent flow, velocity distribution in convergent divergent nozzle, thrust produced by ramjet engine, Shock wave propagation in combustion chamber and so on.

REFERENCES


2. CFD SIMULATION AND FEA ANALYSIS OF A BALLISTIC MISSILE by Sebastian Marian Zaharia, Rareș Ioan Ştefâneanu.

3. Modal Analysis of Typical Missile Configuration by Noble Sharma Aeronautical Department Institute of Aeronautical Engineering Dundigal, Hyderabad, Telangana 500043

4. COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF VARIABLE INLET AREA RAMJET ENGINE R.Silambarasan1, Dr.R.Vivekanandan2, P.Kesavan3 1PG Scholar, Department of Mechanical Engineering, Government College of Engineering, Salem, Tamilnadu, India.

5. DESIGN AND CFD ANALYSIS OF MISSILE AERODYNAMIC WARHEADS

6. Syed Azam Pasha Quadri, Ramavath Suman, Chandra Kumar, Akhil.A Department of Mechanical Engineering Lords Institute Of Engineering & Technology, Himayath Sagar, Hyderabad, India.

8. VIBRATION BEHAVIOR OF A STIFFENED AND UNSTIFFENED MISSILE SHIELD BY USING FEA

BOMMISETTY MANIKANTESH, H.PRADEEP REDDY, NIRANJANA.S. J

Mechanical Engineering (Machine Design), M.Tech Scholar, Faculty of Engineering Christ University,
PHD Scholar Assistant Professor, Department of Mechanical Engineering, Faculty of Engineering Christ University.