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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 $_{\text{MTech}}$[1], Mr. RAMPURAPU RAVISH $_{\text{M.Tech,.}}$[2]
[1]Assistant Professor, Department of Mechanical Engineering, Dhanekula Institute Of Engineering And Technology, Vijayawada, venkateshawesome@gmail.com[1].
[2]Assistant Professor, Department of Mechanical Engineering, M.V.R College of Engineering and Technology, Paritala,Vijayawada, ravish.rampurapu@gmail.com[2]

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.

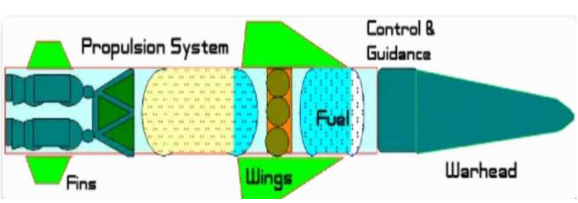

Fig. 1 Missile Components

The typical missile components are

- Aerodynamic control surfaces such as wings, fins and canards.
- Control and Guidance system.
- Fuselage or outer shell.
- Propulsion system.
- Warhead.
- Solid propellant booster.

Mostly missile configuration has minimum one set of aerodynamic surfaces such as Wings, canard, and fins. Basically a wing has relatively large surfaces mostly those are located at near the Centre of gravity. In which Angle of attack plays a major role in flow pattern distributions and it might be impact on drag to lift ratio. From the observations Short wing span more chord length will give the better performance. And then tail fins are direction stability purpose and canards are for better maneuverability with respect of altitude. Aerodynamic wing profile designed such a way of lift force will be generated by the differential pressure acts over the profile of aero foil wing.

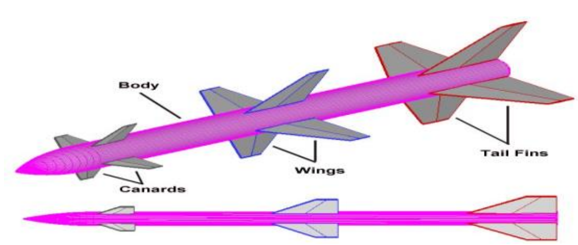

Fig.2 Schematic representation of Canards, Wings and Tail fins.

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.

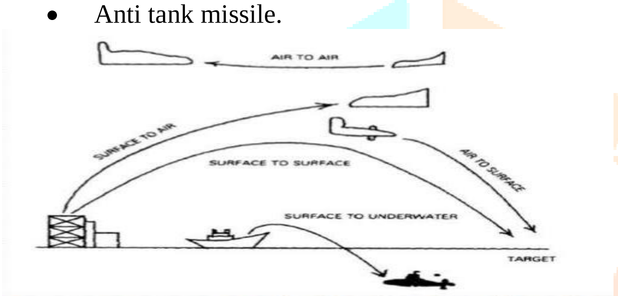

Fig.3 Diagram to enunciate the classification of missiles.

Span

- Short range missile
- Medium range missile
- Intermediate range ballistic missile
- Intercontinental ballistic missile

Propulsion

- Solid propulsion
- Liquid propulsion
- Hybrid propulsion
- Ramjet
- Scramjet (supersonic combustion ramjet)
- Cryogenic (liquefied gases mostly hydrogen and oxygen)

Warhead

- Conventional (High energy explosives)
- Strategic (Radio active materials)

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

Details	Dimensions
Length	8500mm
Diameter	650mm
Engine first stage	Solid propellant booster
Second stage	Liquid fuel Ramjet engine
Wing span	2500mm
Range	200 -400kms
Mach number	2-4
Material of Construction	Aluminum Alloy

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.

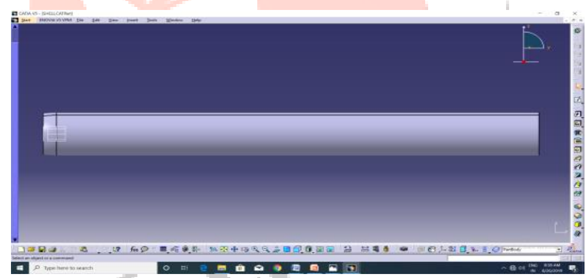

Fig.4Part Diagram of Fuselage.

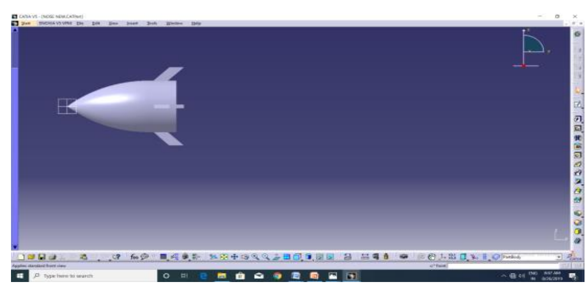

Fig.5Part Diagram of Aerodynamic Warhead

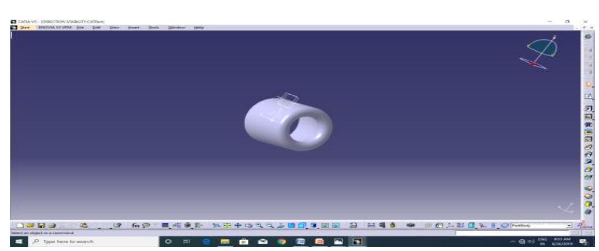

Fig.6Part Diagram of Direction Stabilizer

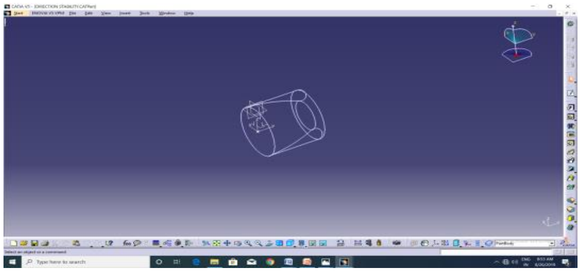

Fig.7Wireframe model of Direction Stabilizer

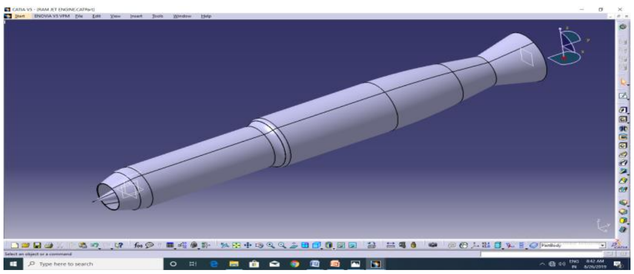

Fig.8Part Diagram of Ramjet engine

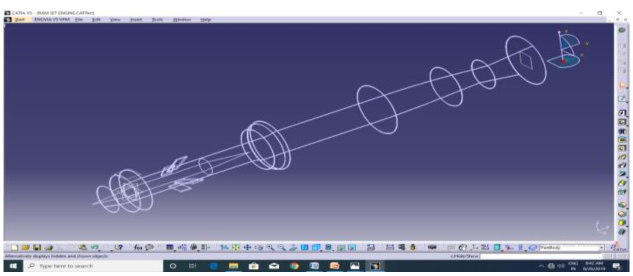

Fig.9Wireframe model of Ramjet engine

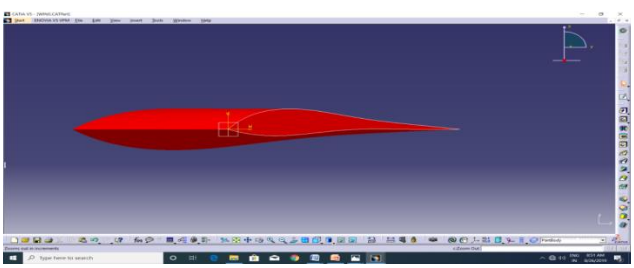

Fig.10Part diagram of aerodynamic Wing profile

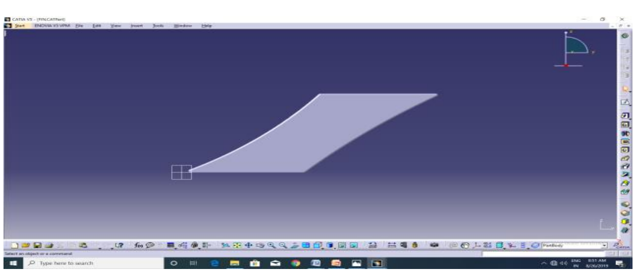

Fig.11Part diagram of Fin

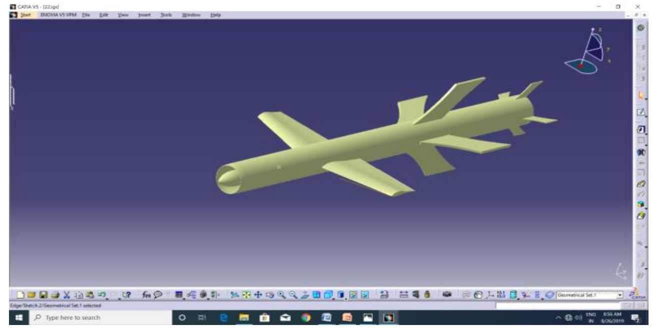

Fig.12Assembly drawing of Missile (Isometric View)

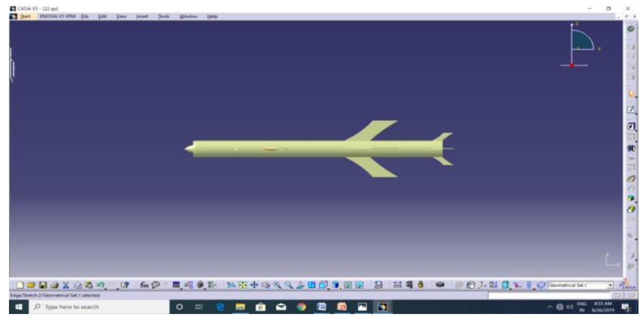

Fig.13 Assembly Drawing Of Missile (Front view)

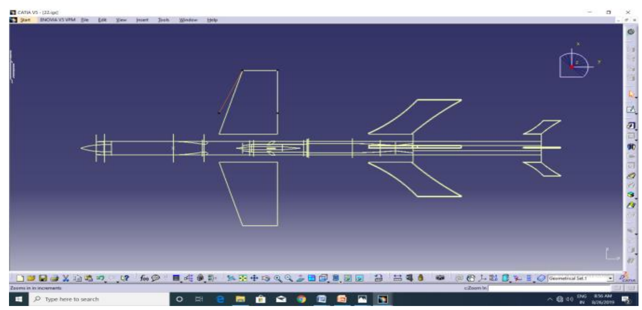

Fig.14Wireframe model assembly drawing of missile

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 problem 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

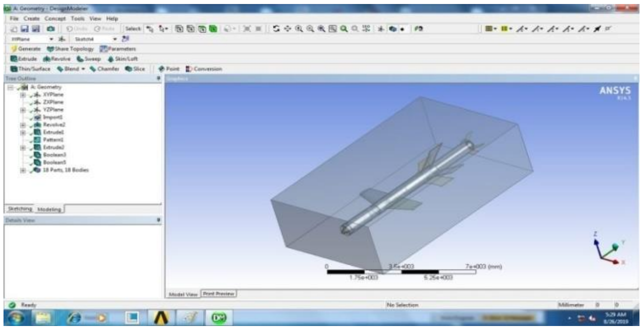

Fig. 15 Enclosure of entire missile configuration

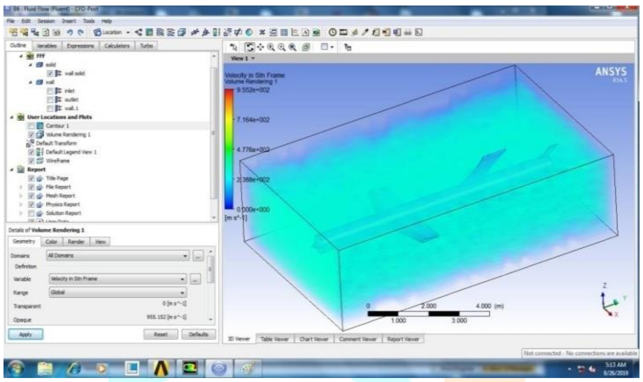

Fig.16Velocity Profile Over The Missile Configuration

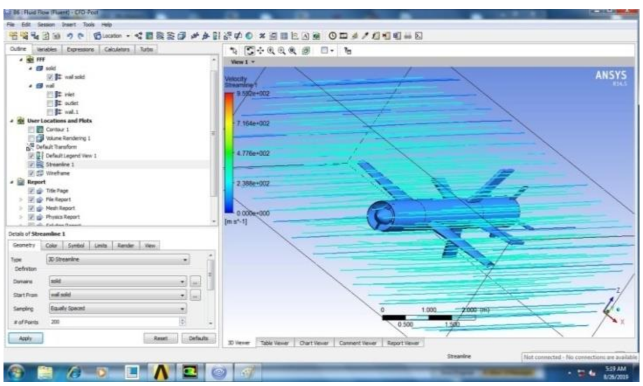

Fig.17 Stream Line View Of Velocity Over The Missile Configuration

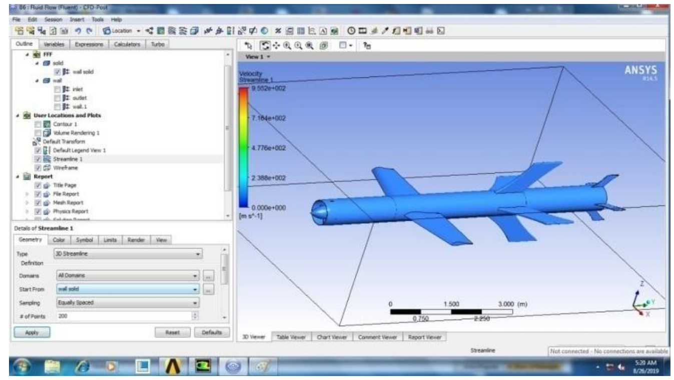

Fig. 18 Overview Of Missile Gradient

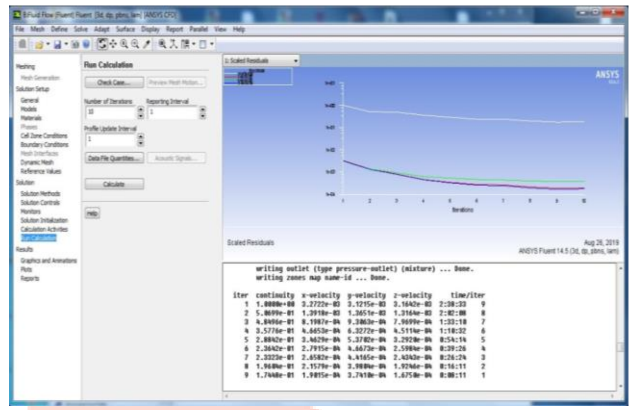

Fig.19Graph Represents the Pressure Distribution over the Missile Configuration

6.2 FEA-Computational Modal Analysis:-

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

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

Simulation diagrams of missile configuration

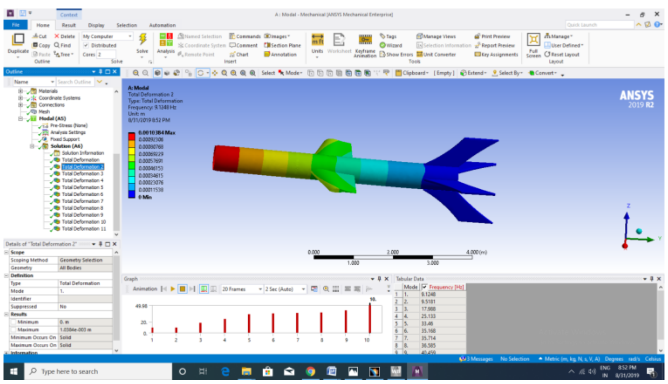

Fig.20 Mode 1- Rigid body translation X-axis

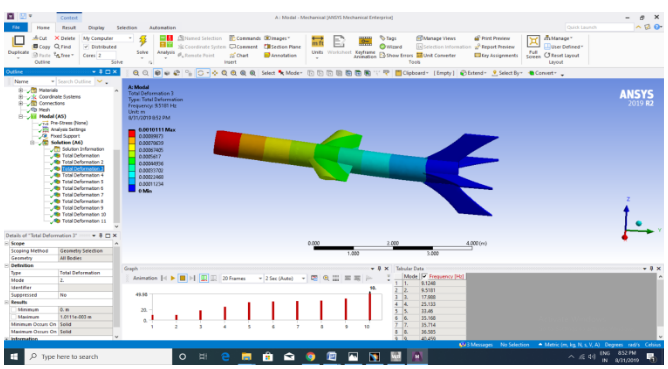

Fig.21Mode 2- Rigid body translation Z-axis

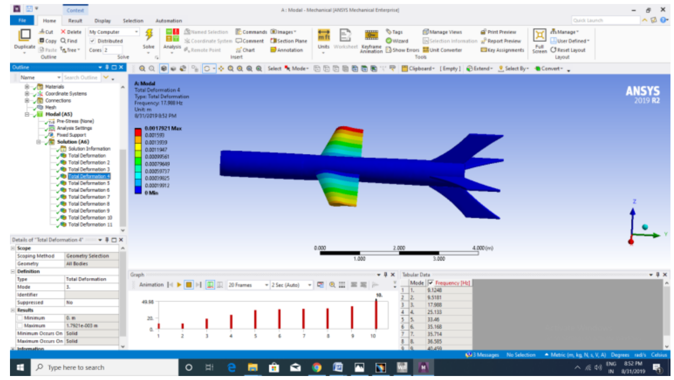

Fig.22Mode 3- Rigid body translation y-axis

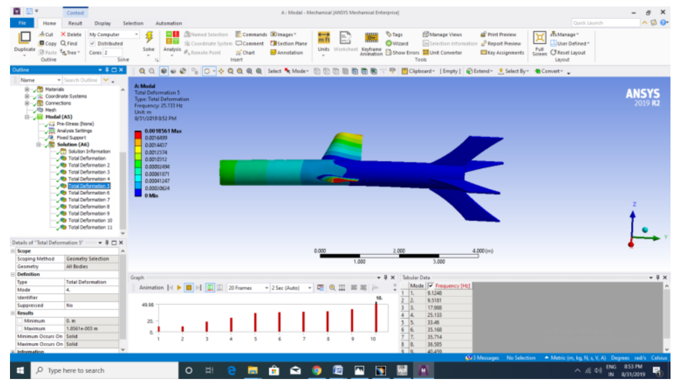

Fig.23Mode 4- Rotation about Y-axis

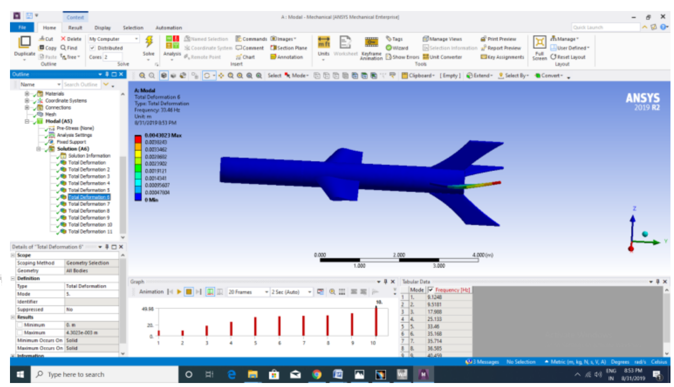

Fig.24 Mode 4- Rotation about Y-axis

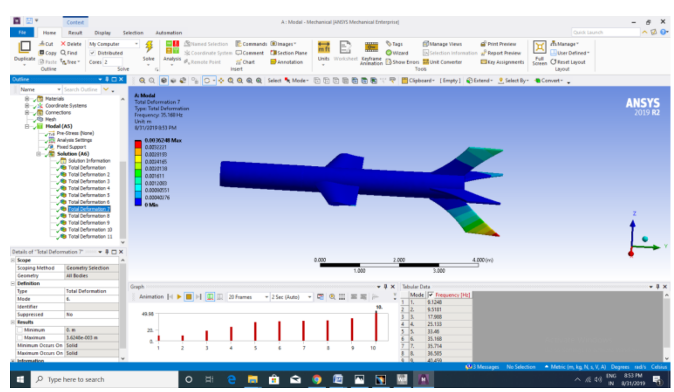

Fig.25Mode 6- Rotation about X-axis

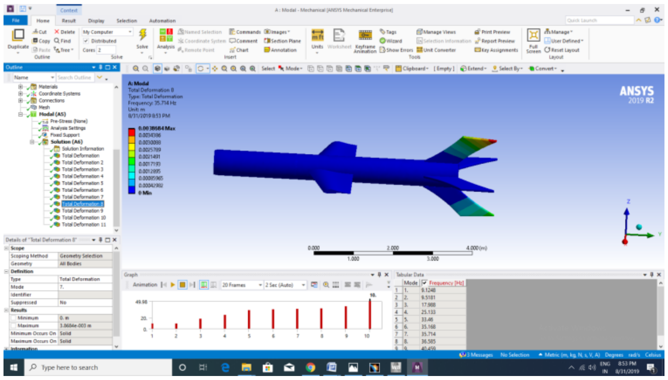

Fig.26Mode 7- First elastic Bending

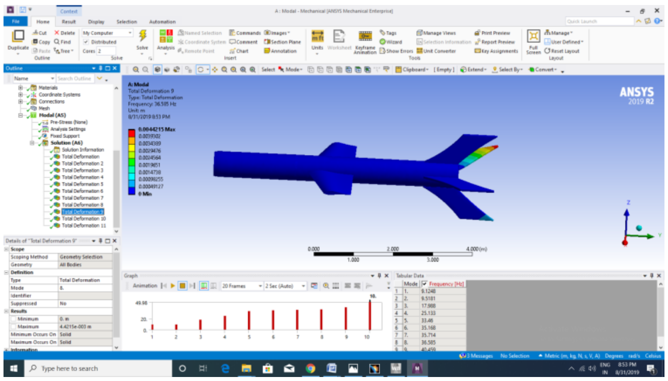

Fig.27Mode 8- First elastic Bending

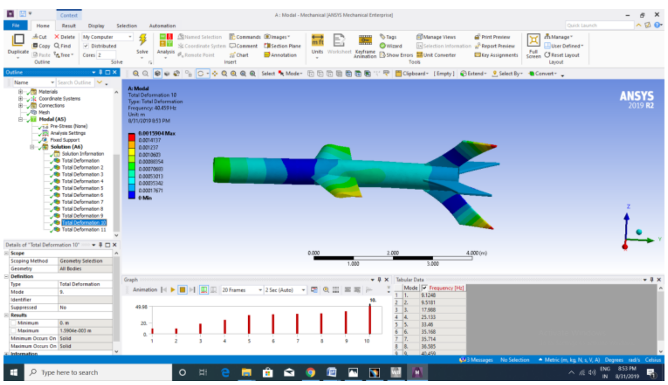

Fig.28Mode 9- Wing Bending

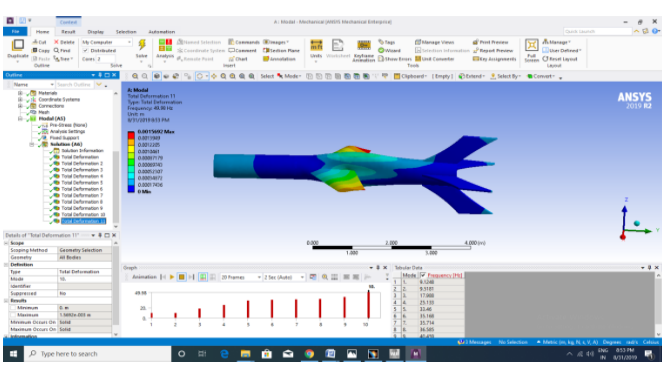

Fig.29 Mode 10- Wing torsion

6.3 Thermal –Heat transfer analysis

Usually ramjet engines utilizes 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

Fuel description	Hydrogen
Type of injection	Droplet type
Self ignition temperature of fuel	500^0 c
Oxidizer	Ambient air
Tempt of oxidizer	22^0 c
Mode of Heat Transfer	Convection

Simulation diagrams of missile configuration

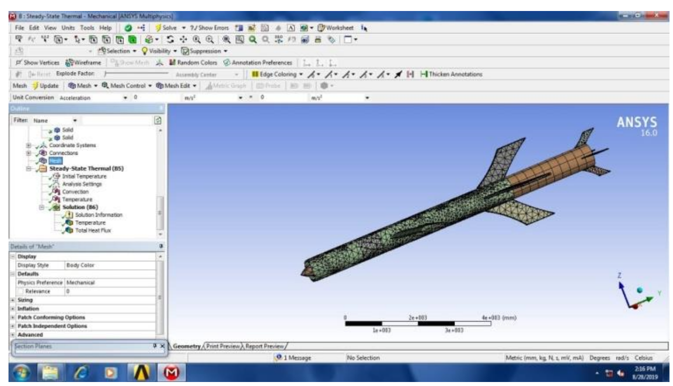

Fig. 30 Meshing Of Entire Assembly

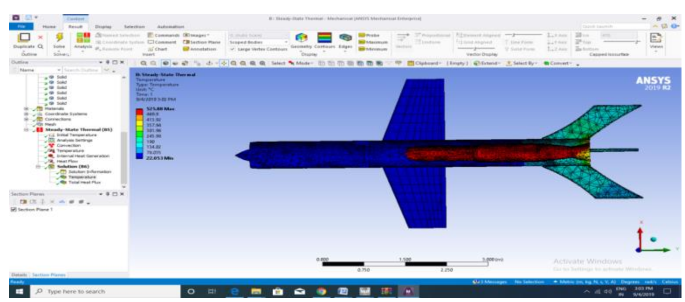

Fig. 31 Temperature Distribution over the Combustion Chamber

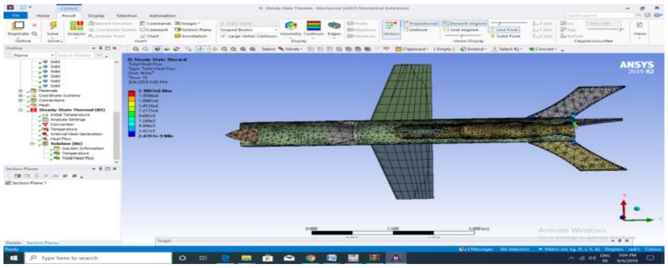

Fig. 32 Total Heat Flux Distribution

Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	1.	22.053	525.88	252.82
2	2.	22.053	525.88	252.82
3	3.	22.053	525.88	252.82
4	4.	22.053	525.88	252.82
5	5.	22.053	525.88	252.82
6	6.	22.053	525.88	252.82
7	7.	22.053	525.88	252.82
8	8.	22.053	525.88	252.82
9	9.	22.053	525.88	252.82
10	10.	22.053	525.88	252.82
11	11.	22.053	525.88	252.82
12	12.	22.053	525.88	252.82
13	13.	22.053	525.88	252.82
14	14.	22.053	525.88	252.82
15	15.	22.053	525.88	252.82

Fig. 33 Tabular Data Of Temperature Distribution

Tabular Data

	Time [s]	Minimum [W/m²]	Maximum [W/m²]	Average [W/m²]
1	1.	2.2559e-009	2.1807e+006	10791
2	2.	2.2546e-009	2.1807e+006	10791
3	3.	2.4712e-009	2.1807e+006	10791
4	4.	2.2719e-009	2.1807e+006	10791
5	5.	2.3676e-009	2.1807e+006	10791
6	6.	2.432e-009	2.1807e+006	10791
7	7.	2.3104e-009	2.1807e+006	10791
8	8.	2.2546e-009	2.1807e+006	10791
9	9.	2.4712e-009	2.1807e+006	10791
10	10.	2.2719e-009	2.1807e+006	10791
11	11.	2.3586e-009	2.1807e+006	10791
12	12.	2.4302e-009	2.1807e+006	10791
13	13.	2.3102e-009	2.1807e+006	10791
14	14.	2.2537e-009	2.1807e+006	10791
15	15.	2.4707e-009	2.1807e+006	10791

Fig. 34 Tabular Data Heat Flux Distribution.

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.

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8. VIBRATION BEHAVIOR OF A STIFFENED AND UNSTIFFENNED MISSILE SHIELD BY USING FEA [1]BOMMISETTY MANIKANTESH, [2]H.PRADEEP REDDY, [3]NIRANJANA.S.J [1]Mechanical Engineering (Machine Design), M.Tech Scholar, Faculty of Engineering Christ University, [2]PHD Scholar [3]Assistant Professor, Department of Mechanical Engineering, Faculty of Engineering Christ University.