EFFECT OF PRESSURE COEFFICIENT ON MISSIEL STABILITY

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Abstract— In Defence system, we are designing the more accurate design for missile and rockets for increasing their efficiencies. In this paper, the flow variation computed on a missile with the help of computational fluid dynamics by using software ANSYS202R1 which is analysis software. The aerodynamic flow over a missile body tells many important aerodynamic parameter like drag, drag coefficient, moment and moment coefficient value and also predict the behaviour of the flow over the design. They are two types of flow, laminar & turbulent. We know that, the flow over a high speed object should be in laminar because in laminar flow the darg value is less as compared to turbulent flow and turbulent flow also increase the instability. When we talk about the longitudinal static stability, for missile design the moment coefficient value always less than & equal to zero it's means the moment coefficient should be negative, if moment coefficient is negative then we can say that our missile design is statically stable at cruise stage. The object moving at high speed induced the drag which decelerate the velocity and affect the efficiencies of design .The Designing field give the ability to make more efficient body design for missile and rockets .we can develop prototype missile design with accurate aerodynamics with the help of analysis software which save our time and we can change the design shape as according to our results. In this paper I also check my design in open rocket software which tell the location of centre of gravity and centre of pressure, for stable missile design the centre of pressure location always backward from the centre of gravity.

Keywords— Missile, Drag, Drag Coefficient, moment, moment coefficient, AOA (Angle of Attack), pressure coefficient, centre of gravity.

I. INTRODUCTION

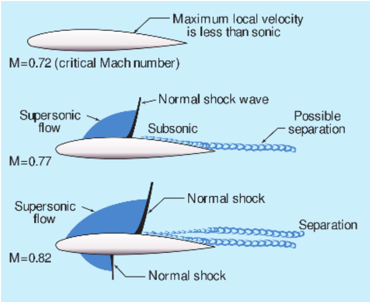
The U.S. Air Force Missile DATCOM Ver. 97 software1) is used widely in stability and aerodynamic analyses for wing-bodies and tails.2) Basically, Missile DATCOM is an engineering level computer code that predicts the aerodynamic forces, moments, and stability derivatives of axisymmetric and non-axisymmetric missile configurations for a wide range of attack angles and Mach numbers. The capabilities of missile DATCOM are comprehensive in computing a wide range of flight conditions from subsonic to hypersonic speeds But in India we are using **ANSYS2020R1**, **Open Rocket Software Space Cad, Solid Works Simulation Software** which are all analysis software available in India. When we study about the flow over a body, the study is called aerodynamic and if flow is greater than Mach1.0 then study is called high speed aerodynamic. Flow over a body decide the drag value and also tells, the flow is laminar or turbulent. In laminar flow the flow is streamline but in turbulent the flow is more disturb for missile design the flow should be streamline. The stability of missile based on some parameter like centre of pressure, moment coefficient, moment, drag and which talk about in body design then canard, wing, tail fins and fuselage design like what type of nose we are using for example blunt, conic, elliptical etc.

In high-speed flight, the assumptions of incompressibility of the air used in low speed aerodynamic no longer apply. In subsonic Aerodynamic, the theory of lift (for missile lift is zero at cruise stage) is based upon the forces generated on a body and a moving gas (air) in which it is immersed, At air speed below130 m/s; air can be considered incompressible in regards to an aircraft, in that, at a fixed altitude, its density remains nearly constant while its pressure varies. Under this assumption, air acts the same as water and is classified as a fluid.

Subsonic aerodynamic theory also assumes the effects of viscosity (the property of a fluid that tends to prevent motion of one part of the fluid with respect to another) are negligible, and classifies air as an ideal fluid, conforming to the principles of ideal-fluid aerodynamics such as continuity, Bernoulli's equation, and circulation. In reality, air is compressible and viscous. While the effects of these properties are negligible at low speeds, compressibility effects in particular become increasingly important as airspeed increases.

Compressibility (and to a lesser extent viscosity) is of paramount importance at speeds approaching the **speed of sound**. In these **transonic speed** ranges, compressibility causes a change in the density of the air around an airplane.

During flight, a missile produces lift negligible near to zero. This accelerated air can, and does, reach supersonic speeds, even though the airplane itself may be flying at a subsonic airspeed (Mach number < 1.0). At some extreme **angles of attack,** in some airplanes, the speed of the air over the top surface of the wing may be double the airplane's airspeed. It is, therefore, entirely possible to have both supersonic and subsonic airflows on an airplane at the same time. When flow velocities reach sonic speeds at some locations on an airplane (such as the area of maximum camber on the wing), further acceleration will result in the onset of compressibility effects such as shock wave formation, drag increase, buffeting, stability, and control difficulties. Subsonic flow principles are invalid at all speeds above this point.



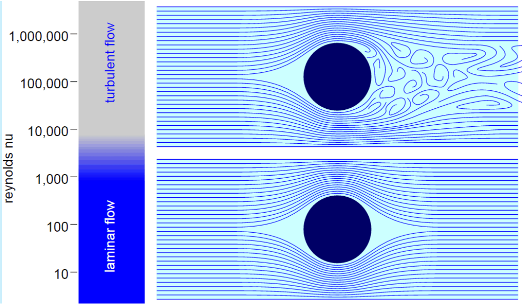


Figure1 transonic region Figure 1 difference in laminar flow or turbulent flow

II. PROBLEM STATEMENT

The objective of this paper is to show the variation in drag force on entire missile and how the aerodynamic coefficient change with change in Mach number at standard sea level. To increase overall efficiency, we need to give an optimum shape to missile design shape which can reduce drag force and provide a streamline structure & flow and analyse the stability of missile design with help of open rocket software. Open rocket is tells the location of pressure coefficient of any missile design. Condition for stability is, the pressure coefficient always backward from the centre of gravity.

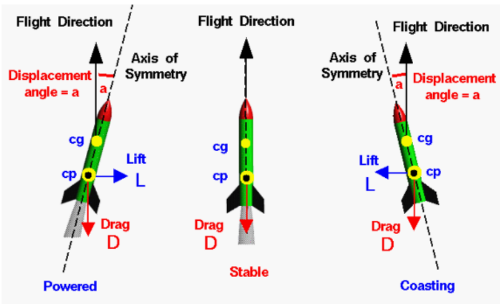


Figure 2 stability condition

III. MATERIAL SELECTION

In open rocket software, we can select the material's for missile design. Material also effect on the stability, like different material give different value of centre of gravity and centre of pressure values. For this missile, I choose the steel for nose, carbon fibre use for slender body of missile, for fin and wing I use the aluminium, because of some reason I use this material. They are given below here:

(1st) Steel have high capacity to resist the heat, for nose design it is good material because nose/ tip of the missile is the first surface which interact with the air, air pressure generate high temperature on the nose / tip of the missile and can't melt easily at high temperature because high speed create the temperature. SpaceX company also use the steel material for making in body and nose shape manufacturing.

(2nd) Carbon fibre is very lite weight material and very high strength capacity material which can handle the shear force, stress and air pressure of the atmosphere. Now days, carbon fibre are using in many industry like in automobile, aircraft company, spaceX and many more company who prefer the carbon fibre.

(3rd) Aluminium is very ductile material and lite weight material, for fins and wing we want lite weight material.

IV. METHODOLOGY

In this paper missile is designed by using PTC Creo parametric 4.0 software. The first step is to create a 2D Slender body with nose shape and revolve with respect to the central axis, for fin and wing design we use extrude command and Last step, convert into 3D model for CFD testing. The commonly used tools in designing to create a model in Creo 4.0 parametric are- Extrude, extrude cut, Revolve, revolve cut Sweep, Swept cut, Fillet, Chamfer, Mirror. CFD Analysis is carried out in three steps i.e.

1)Pre-processing, geometry, – Designing, meshing, boundary conditions and numerical method.

2) Processing – Solving fluid flow governing equations by numerical method till the convergence is reached.

3) Post processing – extracting results in terms of graphs, contours which explains the physics of flow and required results. The above three steps are carried out in ANSYS using fluid fluent CFD for designing and meshing with Hybrid grid that is prismatic layer around missile design and unstructured grid. Simulations are carried out using ANSYS fluent a finite volume solver at with inlet conditions. In this analysis we use the automatic mesh generation method because of the complexity of structure.

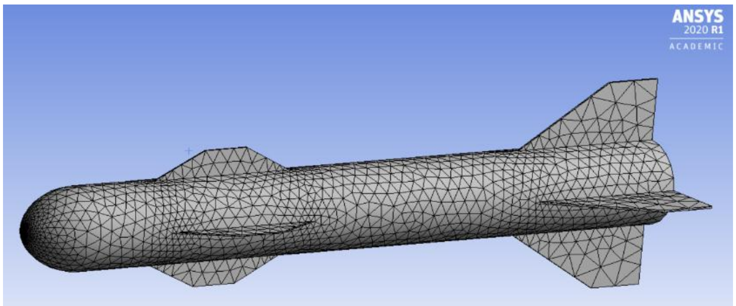


Figure 3 Mesh generation

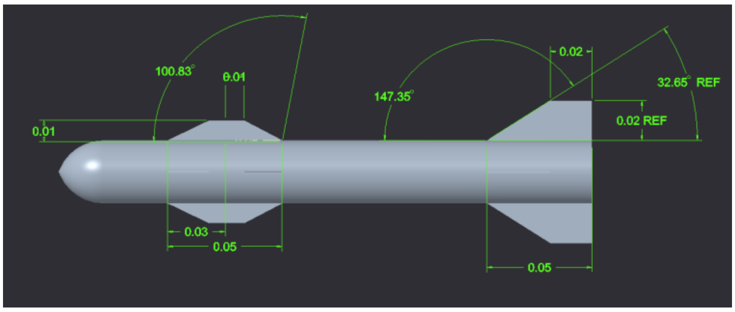


Figure 4 Fins and wing dimension.

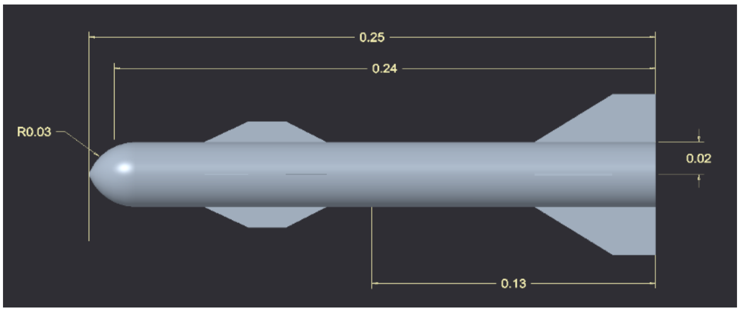


Figure 5 Slender body and blunt nose shape dimension.

V. INLET CONDITION AND BOUNDARY CONDITION

Table 1: Inlet and boundary condition

SL.NO	Parameter	Value
1	Flow Medium	Air
2	Mach Number	0.3,1.0,1.2,2.0
3	Density	1.225Kg/m^3
4	Length	0.25m
5	Turbulent Model	K-omega
6	Kinematic Viscosity	1.7894e-05kgs/m^2
7	Altitude condition	Standard sea level

VI. RESULT AND DISCUSSION

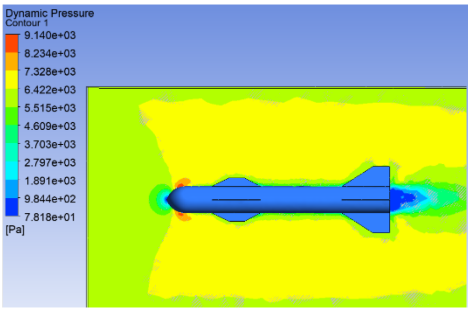
The effect of Mach Number on the drag & aerodynamic coefficient has been found by the analysis of design for various conditions of Mach number and it is tabulated as follows. Some of the tabulated results are shown here under. We can see that with increase in the Mach number, the drag and the moment increase. When this two factor's increase than it reduced the efficiency of design and create structural vibration on the missile design. High speed also effect the location of centre of pressure due to the shifted location of pressure coefficient make moment, by the moment at high speed, the design become more unstable so the location pressure coefficient always backward the location of centre of gravity for he stabilize design.

ANSYS2020R1 COMPUTATIONAL DATA:

Table 2: Aerodynamic Characteristic with different Mach number.

Mach Number	Drag	Drag coefficient	Moment	Moment coefficient
0.3	2.1	3.5	-0.017	-0.028
1.0	22.9	37.5	-0.15	-0.25
1.2	32.2	52.6	-0.20	-0.33
2.0	87.6	143.0	-0.51	-0.84

DYNAMIC PRESSUSE DISTRIBUTION



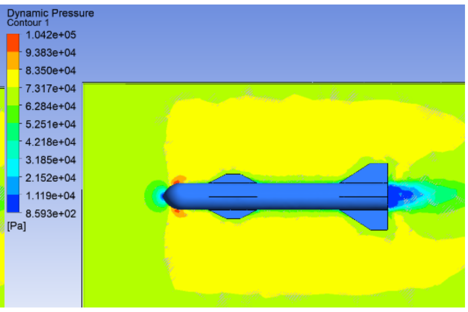
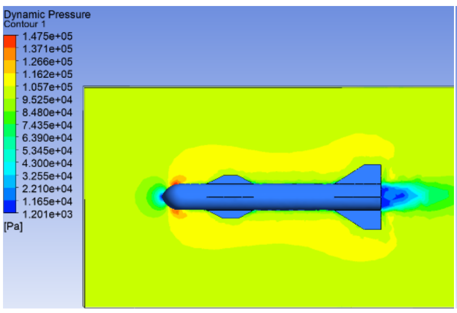


Figure 7: At Mach 0.3 Figure 8: At Mach 1.0



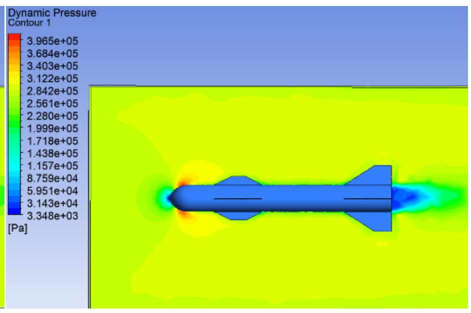
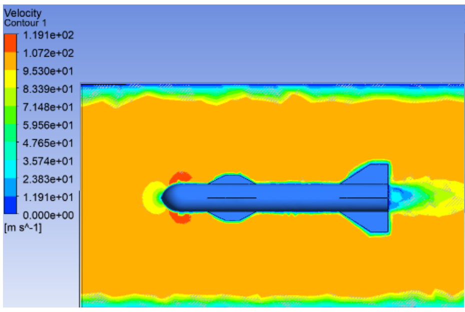


Figure 9: At Mach 1.2 Figure 10: At Mach 2.0

VELOCITY VARIATION



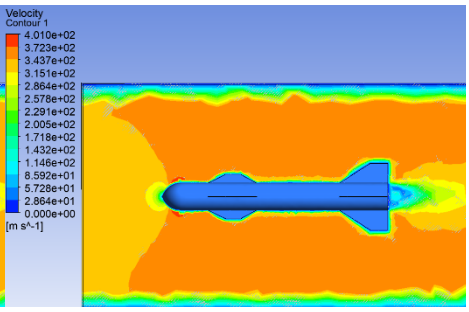
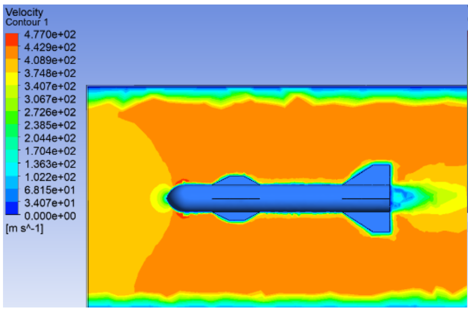


Figure 11: At Mach 0.3 Figure 12: At Mach 1.0



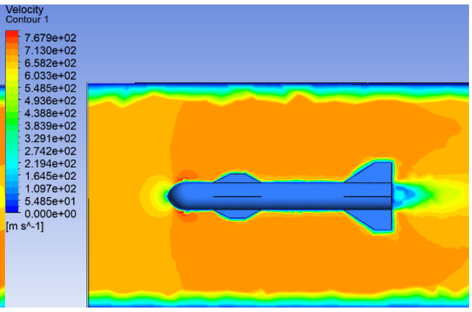


Figure 13: At Mach 1.2 Figure 14: At Mach 2.0

OPEN ROCKET SOFTWARE COMPUTATIONAL DATA ANALYSIS:

TABLE 3: Location of Centre of pressure and Centre of gravity

Mach number	Centre of pressure (Cp)	Centre of gravity (Cg)
0.3	**0.134**	**0.127**
1.0	**0.14**	**0.127**
1.2	**0.141**	**0.127**
2.0	**0.117**	**0.127**

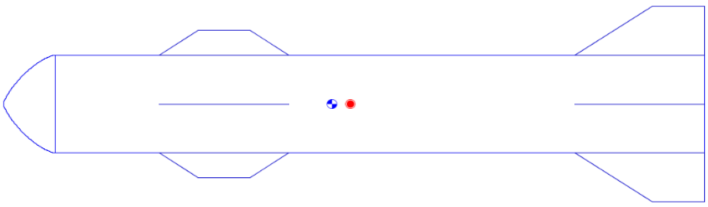


Figure 15: At Mach 0.3

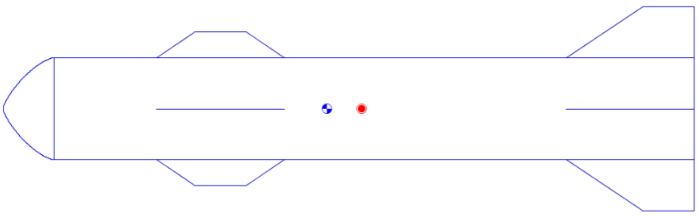


Figure16: At Mach 1.0

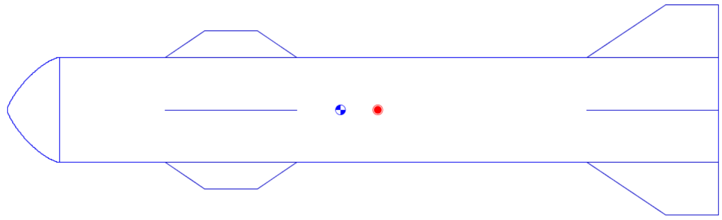


Figure 17: At Mach 1.2

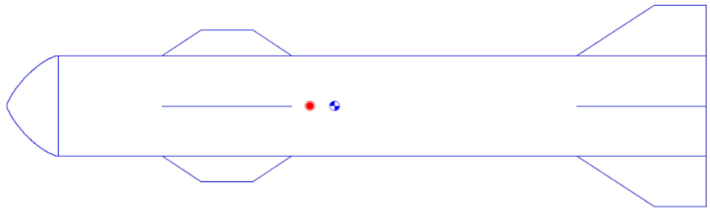


Figure 18: At Mach 2.0

VII. CONCLUSION

From results, we conclude that the Drag values are increasing with Mach Number which results in formation of induced drag over the body surface which increases as well. and we also see that Increase in Mach number the boundary layer thickness also induced on missile body surface at Mach 1.0 which make the turbulence and which will effect' on the darg value and structure of missile because turbulence make vibration on a missile body. In this paper we find that, up to the Mach Number 1.2 the location of pressure coefficient **(red point)** shifted backward from the centre of gravity but at Mach number 2.0 the location of centre of pressure suddenly change and forward to the centre of gravity, which is not acceptable condition for stable missile design. Now we can think that most of the missile design at a high speed are more unstable because of the centre of pressure shifted toward the nose which create moment but we can also control the location of pressure coefficient by using thrust vector control.

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