DETERMINATION OF MINIMUM DESCENT DISTANCE FOR POWER LANDING OF RE-ENTRY VEHICLE IN EARTH ATMOSPHERE

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Abstract *:* All space missions must have different parameters to achieve mission objectives. Cost of building expendable launch vehicle is higher than building a re-entry vehicle for multiple mission. In this paper we use powered re-entry vehicle using retro engines. The re-entry vehicle gravity force acting toward earth centre and both drag & thrust force acting opposite to the gravity force. To slow down the re-entry vehicle opposite forces will be equal. This paper determines minimum decent distance(altitude) by calculating drag force, gravity force and thrust force through computational fluid dynamics.

Keywords: -re-entry vehicle, Powered re-entry, Re-entry Motion, Minimum decent distance, Drag Force.

I. INTRODUCTION

Atmospheric inrush is the motion of an object in outer space. Atmospheric re-entry guidance and control is an ongoing subject of research in aerospace. It almost shows the power of solving theories and techniques through their re-entry function and is becoming a classic example for engineers, mathematicians and scientists. Also, manned atmosphere re-entry is a common denominator between human space exploration and space station operation. Modern requirements make the problem of re-entry more difficult, and finding a solution to it is not enough. Best of all, it's a pre-related final landing point error. A re-entry passage is a small area of space that a re-entry vehicle must pass through. You can skip when the vehicle is off the aisle. If you move away from the bottom, you may get lost.

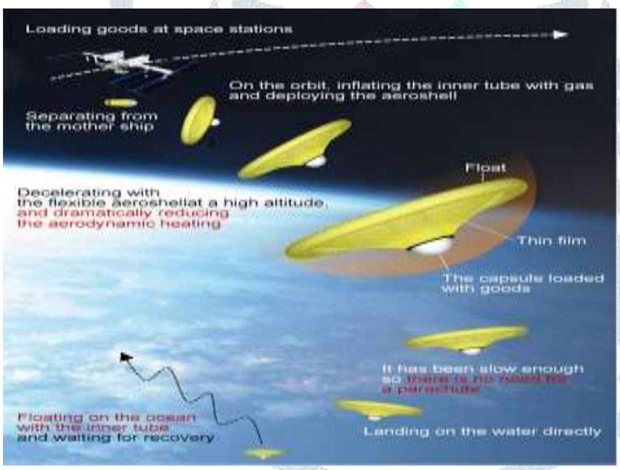


Fig1

a) Re-entry vehicle

A re-entry vehicle is a part of rocket that is designed to return earth atmosphere, by surviving from extreme heat and pressure with high velocity. It protects crew and instruments.

We have two types in re-entry process

1. powered reentry
2. unpowered reentry

b) **Powered re-entry**

Re-entry of vehicle into atmosphere which use power (thrust using engines) to decrease the velocity of vehicle to land the vehicle safely is powered re-entry.

c) Unpowered re-entry

Re-entry of vehicle into atmosphere without any power to decrease velocity is unpowered re-entry Parachute using for capsule landing.

d) Re-entry motion

Atmospheric re-entry guidance and control (G&C) has been a significant and all the space – mission planning. We have to balance three requirements. The structure and load of the vehicle must be able to withstand the maximum deceleration G. Where g is the gravitational force. Humans can cope with a speed drop of up to 12g, but this is short-term. Currently, the problem of re-entry is not limited to g. Even a slight deceleration can cause serious problems. Another complication is warming up. The string of a meteorite in the night sky suggests that the three-faculty season can end up hot. The intensive warmth is the result of friction. We have to assume about the relevant power to be conscious that warm, can go if it returns to school. We apprehend that kinetic force is totally dependent on energy. To discover the entire potential.

We have

- E = 3.3*10^12 joules
- E = 3.66*10^9 Btu

All space missions must have different parameters to achieve mission objectives. Powered re-entry of vehicle into the earth atmosphere is more reliable. Most of the meteors burn up completely before reaching earth's surface. The velocity of the meteors stays constant for the first 10sec, when meteor is still above the atmosphere. Things change swiftly after the 10sec. we must keep the vehicle intact. The vehicle's centre of mass must be at the starting of the re-entry, after that we have to analyse the motion with the fixed centre. To understand the motion of re-entry shuttle we have to know how forces might affect it.

We have few predominant force's as following

a. The gravity forces
b. The drag forces
c. The lift forces

Engineers commenced to analyse the trajectories of cannon balls; this had a one of a kind significance in describing how an object strikes via the atmosphere. Engineers transpose this time period and call it as ballistic co-efficient.

BC = m/Cd A
Where
BC = vehicle's ballistic coefficient (kg/m^2)
m = vehicle's mass(kg)
Cd = vehicle's drag coefficient (unit less)
A = vehicle's cross-sectional area (m^2)

In this relationship, it can represent the amount of deceleration the object experiences as it moves around. This is inversely proportional to the object's trajectory coefficient. The theory of inverse relativity between two substances means "one goes up, the other goes down". For example, on a seesaw, the peaks of two children are connected in reverse due to the fact that one rises and the other falls. In deceleration and BC,the same is true for it.

Suppose the ballistic coefficient is simply expressed. Suppose a 50 kg skydiver and a 60 kg potato bag fly out and fall at the same initial velocity (eg, the same mass) at the same time. Drag coefficient when the weight of the umbrella and potato bag is the same as (m) cross-sectional area (A)

II. VEHICLE SHAPE

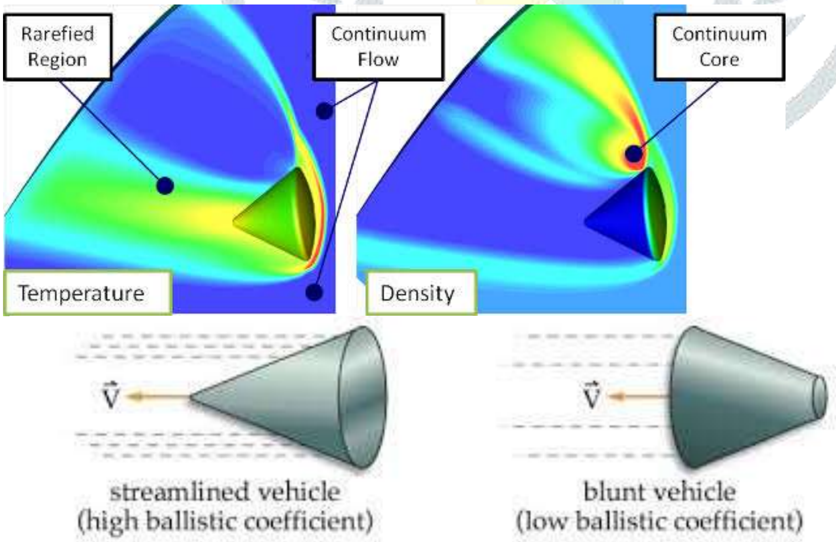


fig 2

III. Future scope of Powered re entry

Future Scope of the project:

1. Use of CFD in further study of space re-entry vehicle.
2. Change in parameters to find more results and using it as modification criteria in design of space vehicle.
3. Owing to limited time and resources for the project basic analysis was only done. Further exploration of lift and drag values can be done in addition.
4. Apart from velocity and pressure change, change in atmospheric conditions can also be considered as scope of research.

5. The change in altitude can also be included in the analysis.

IV. DESIGN METHODOLOGY

When designing a model, it must be as aerodynamic as possible and when choosing materials, it is also necessary to choose materials that can withstand these atmospheric conditions. The weight of the material should be as light as possible. Here by produce great lift.

Plenty of other parameters need to be considered when we are designing the vehicle, some of them are structural strength, Material thermal resistance, Ergonomics etc.

V. MATERIAL DETAILS

One of the important aspects that we have to keep in our mind while designing is the material selection, which would determine our safety, reliability, weight reduction and performance. The parameters for comparison were strength, density, ultimate tensile strength, yield tensile strength, modulus of elasticity, weight, cost, ease of manufacturability of the material etc.

Aluminium Properties

S NO	Properties	Value
01	Density	2.8
02	Young's Modules	70
03	Tensile Strength	150-680
04	Specific Strength	54-243
05	Specific Stiffness	25.0

VI. CAD MODEL

We have designed our CAD model in SOLIDWORKS software, At the time of designing we have considered all the parameters that was mentioned above.

Let's have a look at different views of the model

Isometric view

Fig 3

Front view

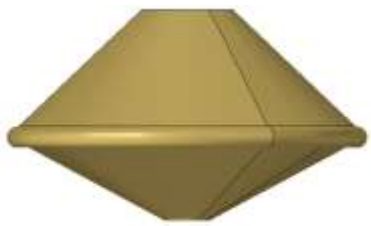


Fig 4

Top view

Fig 5

PRESSURE CHAMBER VIEW

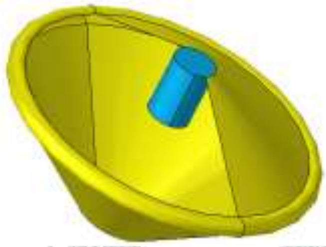


Fig 6

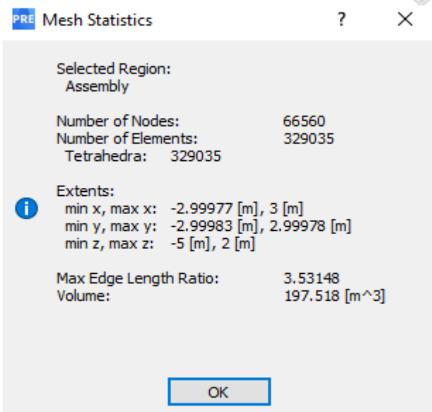
VII. CAE ANALYSIS OF THE VEHICLE

Computer aided engineering analysis should be performed to evaluate the amount of force acting. We have performed computational fluid dynamic analysis in ANSYS FLUENT.

We have DESIGNED two one of a kind cad models, one with pressure chamber in which vary one of a kind strain values, different one is besides pressure chamber in which we exchange velocity.

MESHING DETAILS

Meshing details of Model01 and 02



We have done tetrahedral meshing for both models. Number of elements and nodes are same in both the cases.

S No	Type	Value
01	Nodes	66560
02	Elements	329035

VIII. BOUNDARY CONDITIONS

a) Boundary condition of Mode 01 (with Varying Pressure)

Ambient Conditions

S No	Boundary condition Type	Values
01	Relative Pressure	26436 [p]
02	Opening Temperature	223[F]
03	Flow Regime	Subsonic

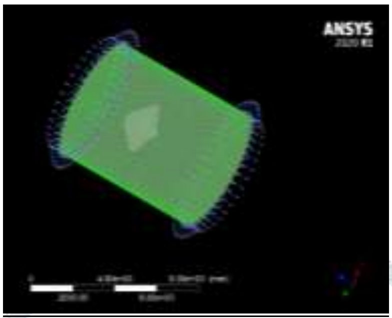


Fig 7

Pressure Chamber Inlet Condition

S No	Boundary condition Type	Values
01	Relative Pressure (Total Pressure)	10[bar]
02	Opening Temperature (Static Temperature)	450[K]
03	Flow Regime	Subsonic

Pressure Chamber outlet Conditions

S No	Boundary condition Type	Values
01	Relative Pressure (Average static Pressure)	0.007[P]
02	Flow Regime	Subsonic

In the abovementioned Boundary Conditions, we can clearly observe that the pressure at inlet was taken as 10[bar]. This pressure is variable, we are going to perform different iterations by changing the pressure value.

b) Boundary condition of Model_02 (with varying velocity)

Inlet Conditions

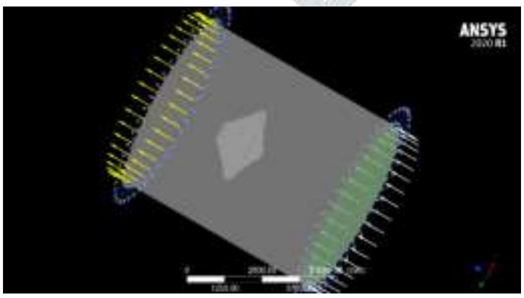


Fig 8

S No	Boundary condition Type	Values
01	Normal Speed	1000[m/s]
02	Opening Temperature (Static Temperature)	223[K]
03	Flow Regime	Subsonic

Outlet Conditions

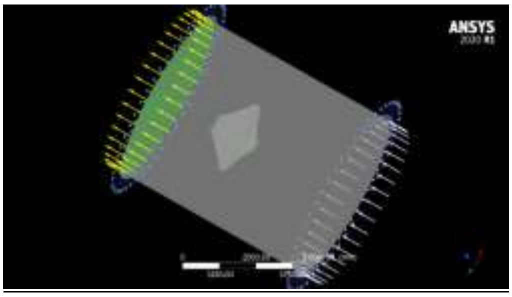


Fig 9

S No	**Boundary condition Type**	**Values**
01	Relative Pressure	0[bar]
02	Flow Regime	Subsonic

Opening Conditions

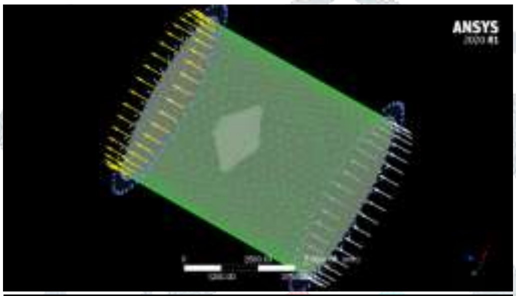


Fig10

S No	**Boundary condition Type**	**Values**
01	Relative pressure	26436[p]
02	Opening Temperature (Static Temperature)	223[F]
03	Flow Regime	Subsonic

In the above-mentioned Boundary Conditions, we can clearly observe that the velocity at inlet was taken as 1000[m/s]. This velocity is inconsistent, we are going to perform different iterations by changing the velocity value.

IX. RESULTS

In the first analysis, we obtained the value of the force at the exit, while in the second analysis we obtained the value of the force at the capsule. Our purpose is to get the same force value in both models. A total of 16 iterations were run in the first analysis and 7 iterations in the second analysis to obtain the same force value.

The table mentioned below shows different force values at different pressures

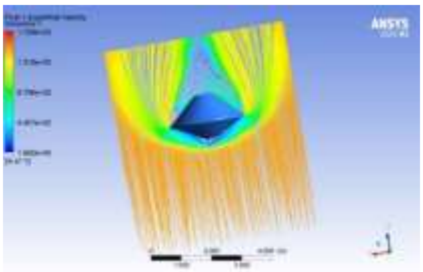


Fig 11

S No	Pressure values [bar]	Force[N]
01	40	-846723 [N]
02	30	-653815 [N]
03	20	-391979 [N]
04	15	-352799 [N]
05	10	-246161 [N]
06	18	-365185 [N]
07	21	-414184 [N]
08	20.1	-393914 [N]
09	20.2	-396077 [N]
10	20.4	-400282 [N]
11	20.45	-401385 [N]
12	20.448	-401413 [N]
13	20.447	-401389 [N]
14	20.444	-401318 [N]
15	20.431	-401012 [N]
16	20.434	-401083 [N]

The table mentioned below shows different force values at different Velocity

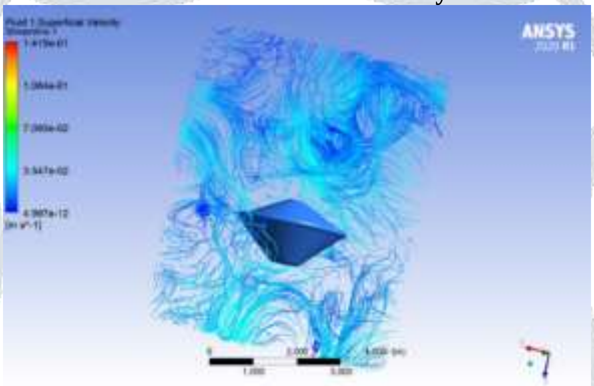


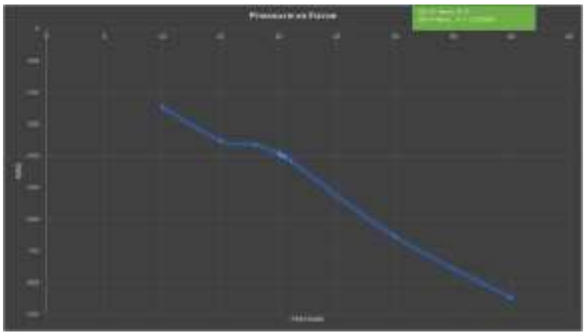
Fig 12

S no	Velocity value[m/s]	Force[N]
01	1000	170673 [N]
02	1500	335988 [N]
03	500	37578.4 [N]
04	750	92514.3 [N]
05	1350	265521 [N]
06	1600	406655 [N]
07	1510	401077 [N]

In the above two tables, we can clearly see that the two forces have the same value at one point. At a speed of 1510 m/ s, we get a force of 401077 [N], while at a pressure of 20.434 [bar], we get a force value of -401083 [N]. We can only display a force difference of 6 [N] between both models. Therefore, we can clearly recognize that the following pressures must be applied to achieve the equilibrium position.

Plotting of Pressure vs Force Curve

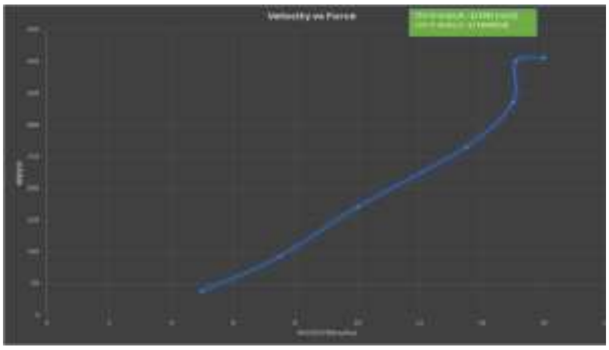
In the graph mentioned below we can observe that how force is varying when we switch the pressure value. As the pressure value increases force also increases



Graph_01

Plotting of Velocity vs Force Curve

In the graph mentioned below we can observe that how force is varying when we switch the Velocity value. When we increase Velocity force also increases.



Graph_02

Plotting of Force-01 vs Force-02 Curve

In the graph mentioned below forces of both models are plotted, we can clearly observe that the value of force is getting “Equal” in one point. At this point weattain equilibrium.

Graph_03

X. High Pressure Gas Bottle

We have considered cylinder-shaped high-pressure gas bottle with the height of 0.5m and diameter of 0.4 m. The obtained area value was 0.1256.

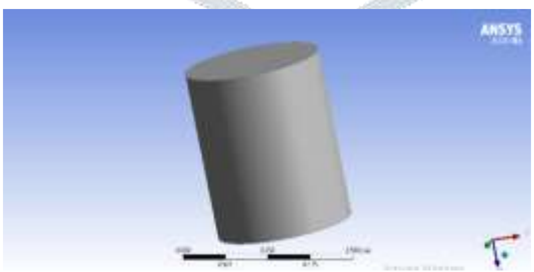


Fig 13

XI. Minimum Distance Calculation

The formula mentioned below, will be used for calculation of mass flow rate value, from which we will calculate the time required to apply the pressure, once we get the value of time we will multiply with the velocity, then we will get the minimum distance value.

$$\frac{\dot{m}}{A} = \sqrt{\frac{2\gamma}{\gamma-1}\left(\frac{p_0^2}{RT_0}\right)\left[1-\left(\frac{p_a}{p_0}\right)^{(\gamma-1)/\gamma}\right]}\left(\frac{p_a}{p_0}\right)^{1/\gamma}$$

We have consideredvalue of argon gas, the properties we have considered for calculating are mentioned below.
We have considered the γ value of argon gas as 1.667

i) Density value as 0.2593 kg/m3
ii) Par value is 26436[P]
iii) Po is equal to 20.434[bar]
iv) A= 0.156 m2
v) R = 200.848
vi) To =450[K]

Our aim is to find Mo value, once we get Mo value, we will divide it by M. then we will get the amount of time required to produce that 20.434 [bar] pressure. After getting the value of time required to apply 20.434[bar] pressure, we will multiply it with velocity to get the value of minimum distance.

XII. CALCULATION PART

$$\frac{\dot{M}}{A} = \sqrt{\frac{2y}{r_{-1}} \frac{P_a^2}{RT} o_{\{(1-\frac{P_a}{P_0})} \frac{r_{-1}}{r}\}} \left(\frac{P_a}{P_0}\right)^{\frac{1}{\gamma}}$$

P= $\boldsymbol{\delta}$RT

$\gamma = 1.667$

R=P\$\delta$T T=450K δ=0.2593Kg/m^3

P=20.434 bar

R=200.848 J/Kg. k P_a =23436 Pa

D=0.4m P_0=2043400 pa

A=πr^2

A=0.1256

$$\frac{\dot{M}}{0.1256} = 19946.508$$

$$\dot{M} = 19946.508 * 0.1256$$

$$\dot{M} = 2505028$$

$$\boldsymbol{M = \delta V}$$

Velocity (v)=1510m/sec

M=0.2593*1510

M=391.54 kg/m s

$$\frac{\dot{\boldsymbol{M}}}{\boldsymbol{M}} = \boldsymbol{t}(\boldsymbol{time})$$

t =391.54/2505.28

t= 0.156 sec

Distance (D)

D=VELOCITY*TIME

D=1510*0.156

D=235.56m

Minimum descent distance for power landing of re-entry vehicle in earth atmosphere is 235.56m

XIII. CONCLUSION

This study presents the minimum descent distance for landing on earth to the best landing aim point can be efficiently obtained .Based on the good initial value guess provided by the sensitivity analysis.We used powered re-entry vehicle using retro engines. By using ANSYS FLUENT software we have calculated force values by applying different boundary conditions.
We got 2 equal force values at a pressure of 20.434[bar] and velocity of 1510m/s. by using this simulation result we have calculated minimum distance as mentioned above. In the above-mentioned calculation, we have got the value of of minimum distance as 235.56m. This is nothing but the height at which we need to switch on the retro engines so that by the time it reaches ground our velocity becomes zero.

XIV. ACKNOWLEDGMENT

We would like to express our gratitude to Mr. Manikandan S , assistant professor lovely professional university who guided us throughout this project. We would also like to thank our friends and family who supported me and offered deep insight into the study. Also for providing us financial and emotional support to complete this project during this pandemic. Our special thanks to editor and anonymous reviewers for their comments that help us to improve the work.

We wish to acknowledge the help provided by the technical and support staff in the school of mechanical engineering, lovely professional university. We would also like to show our deep appreciation to our supervisors who helped us finalize our project

XV. REFERENCE

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