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# EFFECT OF AERO DISC ON DRAG AND HEAT FLUX ON SUPERSONIC VEHICLE USING COMPUTATIONAL METHOD

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***Abstract***

***A forward facing aero-spike attached to a blunt body of a missile and re-entry model changes its flow field and has the potential in drag reduction and wall heat flux. An aero-spike replaces the strong bow shock wave into weaker oblique shock waves and reduces the dynamic pressure in the recirculation region which created upstream of blunt body. In this paper, a blunt body re-entry model represented by hemisphere cylinder placed axis-symmetrically with an aero-disk aero-spike at the stagnation point of blunt body was numerically simulated for different shapes of spikes. The spike consist of 4mm diameter with different aero-disk (hemispherical, flat, flat triangular and inverted flat triangular disk) of varying positions of inner disc(0.2L,0.4L,0.6L and 0.8L) which were numerically simulated. The scaled down geometry has hemisphere cylinder of Diameter (D) 40mm, an overall length 50mm.Numerical simulation has been carried out for single and double aerodisk spike by varying the aero-disk positions.***

## 1. INTRODUCTION

In today's advanced world, time is everything. Space travelers travelling deep into space face biggest challenge of high aero thermal environment. Most Hypersonic vehicles are made to overcome time. Hypersonic vehicles are those man-made devices which move five times more than the speed of sound (Mach number>5). These kinds of aircrafts are generally used in Defense or space related projects in vehicles like missiles, space shuttle and aero planes. Among the variety of design requirements, reducing the drag and aero heating on hypersonic vehicles is the most crucial one. Drag is an aerodynamic force that opposes aircraft motion through air. Unfortunately these two objectives are often conflicting. On one hand, sharp slender fore-bodies design reduces the drag and ensures longer ranges and more economic flights. However, they are more vulnerable to aerodynamic heating which can cause the melting of nose cone. Most of the sensors like accelerometer, balance sensor, payload, communication system and GPS are placed at the front of the vehicle means very near to the nose point. These sensors can melt because of high temperature of nose during flight. On the other hand, blunt bodies produce more drag. However, they are preferred as far as overheating is concerned. In hypersonic vehicles blunt bodies are preferred over slender ones for practical implications such as higher volumetric efficiency.

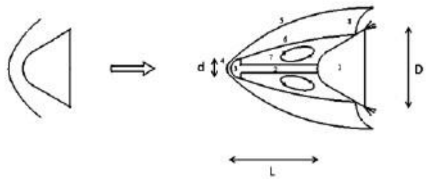



***Fig. 1. Flow features around the blunt cone without spike and with spike***

## 2. Literature Review

The use of aerospikes was first suggested by Alexander in 1947[1] at the Langley pilotless aircraft division for the reduction of drag on blunt bodies at supersonic speeds. Subsequently, a large number of investigations were carried out to understand the physics of high speed flows past a blunt body with protruding aerospace at the tip. Most of the investigations conducted for spiked blunt bodies have shown that the use of aero spikes can substantially reduce the aerodynamic drag at supersonic and hypersonic speeds for a certain ratios of length of aerospace to the diameter of the base body (l/*D*).The studies conducted by Motoyama[12]*et al*, Milicev and Pavlovic,
Milicev*et al*, Menezes*et al*, Gopalan*etal*andKalimuthu[13]*et al*have shown that the effectiveness of theaerospikes can further be improved by the use of flat faced or hemispherical faced spikes called the aero disks

On the heat transfer front, the first study on the effect of aero spikes on the aerothermodynamics of a blunt body was done by Stadler and Neilsonin 1954[15]. In the experimental investigations



conducted at Mach numbers in the range of 0·12 to 5·04 and the Reynolds number of 1·55 x 105 to 9·85 x 105, with the *l*/*D* ratio of the aerospace between 0·5 and 2·0, it was found that regardless of the length of the spike and the spike configuration, the addition of spikes at the nose of a hemispherical blunt body approximately doubles the heat transfer rates to the blunt nose as compared to the blunt nose without spike. In another experimental investigation conducted by Bogdonoff and Vason[2] a flat faced and hemispherical cylinder with an aerospike with *l*/*D* ratios between 0 and 8 in a Mach 14 flow of helium, it was found that the heat transfer to a spiked blunt body is significantly reduced if the separated shear layer remains laminar until reattachment. Yet another exhaustive study to investigate the effect of aero spikes on the aerodynamic heating was done by Crawford [3] in 1959 wherein it was concluded that the heat transfer to a spiked nosed cylinder was greatly influenced by the nature of flow field over the separated boundary layer. It was again found that the heat transfer rates are reduced as compared to the un-spiked body only if the Reynolds number is low enough for the existence of laminar flow at the reattachment point.

The investigation conducted by Holden [10]on spiked blunt bodies at Mach numbers of 10 and 15 with *l*/*D* ratio of the spike varying from 0 to 4 suggested that the heat transfer rates at the reattachment point is directly proportional to the reattachment angle which is dictated by both the spike length and the cone vertex angle. The investigation conducted by Khlevnikovon [11] a spherical model equipped with conical and pyramidal aero disk of *l*/*D* ratio varying between 0·283 and 1·78 showed that the value of peak heat flux varies inversely with its distance from the spike base.

## 3. PROBLEM DESCRIPTION

Design of a blunt body with double disc (both flat and flat triangular geometry) aero spike using ANSYS workbench and analyze the blunt body using ANSYS fluent software. To study the temperature and pressure distribution of the blunt body under atmospheric conditions and to determine the coefficient of drag, lift coefficient and temperature (K) under atmospheric conditions.

## COMPUTATIONA MODEL

### 3.2.1. PRE-PROCESSING

The following are the steps followed in creating the geometry:

Fluid flow (fluent) is opened.

#### 3.2.1.1. CREATING GEOMETRY

Fluid flow (fluent) is opened and the geometry is created by going to new geometry. The basic body of the required geometry is created using tools in sketching toolboxes like circles, lines, rectangles. The unwanted edges are removed using trim option.

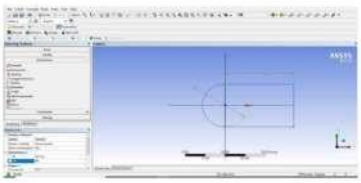


***Fig.3.1.To create the geometry***

The spike is created using a rectangle. The double discs according to the required geometry (flat and flat triangle) are created using lines according to the dimensions given in the table.

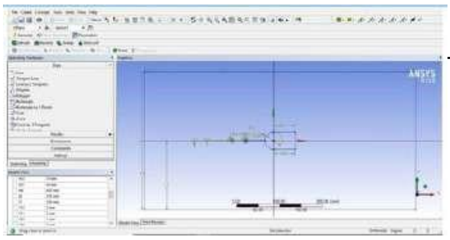


**Fig.3.2.To create the spike using rectangles**

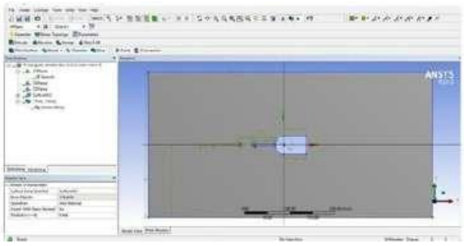


***Fig.3.3.To create the boundary***

The dimensions of the required geometry are as follows

**Table 3.1. Dimensions of the blunt body**

| | |
|---|---|
| Diameter of the base body | D = 40mm |
| Length of the base body | L = 70mm |
| Diameter of the spike | d = 4mm |
| Length of the spike | l = 80mm |
| Radius of aero disc | r = 6, 8mm |

## 4. TEMPERATURE DISTRIBUTION OF FLAT AND FLAT TRIANGULAR DISCS

The temperature distribution of a flat disc aero spike when the intermediate disc is positioned at 0.2L, 0.4L, 0.6L & 0.8L from the nose is shown below. Here, the mach number is 8.

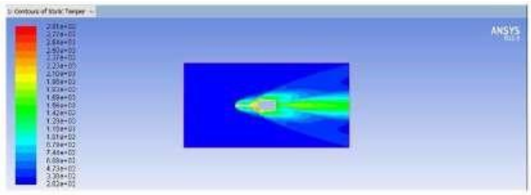


***Fig.4.9. Temperature Distribution of the Flat Disc at Mach number 8 when Intermediate Disc is at 0.2L distant from the nose***

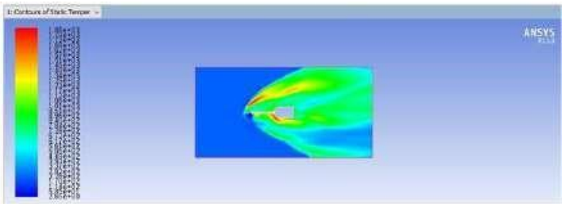


***Fig.4.10. Temperature Distribution of the Flat Disc at Mach number 8 when Intermediate Disc is at 0.4L distant from the nose***

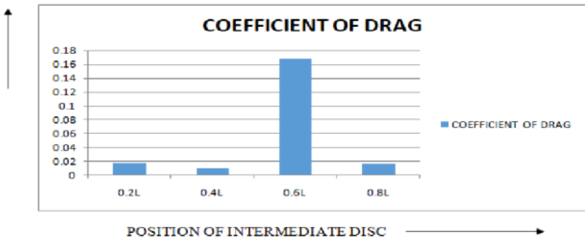
## 5. RESULTS AND DISCUSSION

For various geometries of the disc the coefficient of drag, lift coefficient and temperature (K) varies depending on the geometries. This is shown in the below graphs clearly for the flat plate disc and triangular disc geometry. The temperature is taken in Kelvin.

### 5.1.1 FLAT PLATE DISC GRAPHS

#### 5.1.1.1. COEFFICIENT OF DRAG

*Fig.5.1 Coefficient of drag of flat plate disc*




The coefficient of drag is less when the intermediate disc is placed at 0.6L position when compared to 0.2L, 0.4L, 0.8L positions. Therefore there will be more drag reduction when the intermediate disc is placed at 0.6L position.

The temperature distribution for the flat triangular disc is plotted below for various disc positions. The value of temperature is low at the position 0.4L and is high at position

0.8L.

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### 4.1.1.2. TEMPERATURE (K)

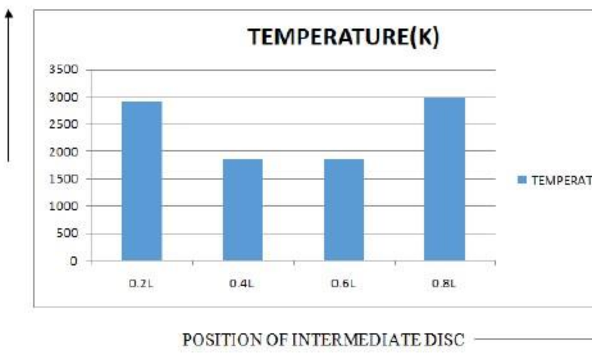
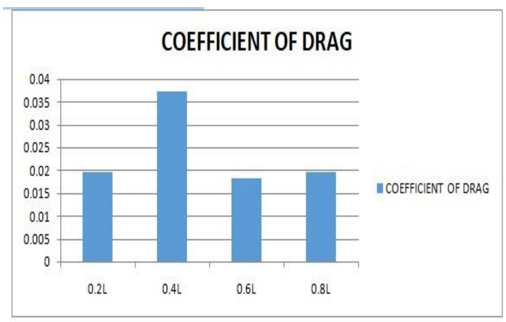



*Fig4.2 Temperature of flat plate disc*




### 5.2. TABLE

### 5.2.1FLAT PLATE DISC

| MACH NO. 08 | $C_d$ | TEMP. (K) |
|---|---|---|
| 0.2L | 0.0197 | 2909.769 |
| 0.4L | 0.0373 | 1862.799 |
| 0.6L | 0.0182 | 1860.769 |
| 0.8L | 0.0197 | 2980.079 |

**Table 5.1. Parameters of the blunt body when**

**the intermediate flat disc is placed at different**

Generally drag coefficient and temperature effect are inter depended. So, the position at which the value of drag is less at the same position the value of temperature is also less. Therefore the optimum position for flat plate disc is 0.6L.

➢ **5.1.2 TRIANGULAR DISC GRAPHS**

➢

**5.1.2.1. COEFFICIENT OF DRAG**

➢

*Fig.5.3 Coefficient of drag for triangular disc*

The coefficient of drag is less when the **positions**

The following table displays that in a flat plate disc the drag reduction when the intermediate disc is placed at a distance of 0.2L, 0.4L, 0.6L and 0.8L from the blunt body are 0.0197, 0.0373, 0.0182 and 0.0197 respectively.

intermediate disc is placed at 0.4L position when compared to 0.2L, 0.6L, 0.8L positions. Therefore there will be more drag reduction when the intermediate disc is placed at 0.4L position.

- On comparing there is more drag reduction when the intermediate disc is at a position 0.6L.

The temperatures obtained when the intermediate disc is placed at a distance of 0.2L, 0.4L, 0.6L and 0.8L are 2909.769, 1862.799, 1860.769 and 2980.079 respectively.

On comparing the least temperature is obtained when the intermediate disc is placed at distance of 0.6L from the blunt body.

Therefore, the position of the intermediate disc when it is placed at a distance of 0.6L from the blunt body is the optimum position when considering flat plate disc geometry.

### 5.2.2. TRIANGULAR DISC

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| MACH NO. 8 | $C_d$ | TEMP. (K) |
|---|---|---|
| 0.2L | 0.0173 | 2842.5 |
| 0.4L | 0.0102 | 2787.473 |
| 0.6L | 0.168 | 2850.59 |
| 0.8L | 0.01679 | 2900.064 |

**Table 6.2.Parameters of the blunt body when the intermediate flat triangular disc is placed at different positions**

- The following table displays that in a flat plate disc the drag reduction when the intermediate disc is placed at a distance of 0.2L, 0.4L, 0.6L and 0.8L from the blunt body are 0.0173, 0.0102, 0.168 and 0.01679 respectively.
- On comparing there is more drag reduction when the intermediate disc is at a position 0.4L.
- The temperatures obtained when the intermediate disc is placed at a distance of 0.2L, 0.4L, 0.6L and 0.8L are 2842.5, 2787.473, 2850.59 and 2900.064 respectively.
- Therefore, the position of the intermediate disc when it is placed at a distance of 0.4L from the blunt body is the optimum position when considering flat plate disc geometry.

## 6. CONCLUSION

It is clear from the results that the triangular disc with the pointed edge facing away from the nose gives more drag reduction when the intermediate disc is placed at an approximate position of 0.4L. The coefficient of drag at this position is 0.0102. The temperature of the blunt body at this position is 2787.743K. The coefficient of drag and the temperature at 0.4L position when the Mach number is 10 are 0.02299 and 4140.29K respectively. Hence, it is the most suitable geometry.

**6.2 FUTURE SCOPE**

The more the speed of jet, the better the benefits. The jet moving at a high speed has the problem of drag reduction and heat. The usage of spikes along with double discs has an advantage in drag reduction but the temperature around the nose body is still a problem. The enhancement of thermal protection system for the manipulation of temperatures around the body has a scope for future work.

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