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Experimental Investigation Of Pressure Distribution Of Sharp Conical Nose of Missile At Subsonic Speed

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Abstract

In this research efforts were put to understand the aerodynamic characteristics of medium-range Air-to-Air missiles and surface-to-air missiles. The major characteristics of a missile are its range and maneuverability. The different methods were available to understand the aerodynamic coefficients of the missile model using theoretical methods, wind tunnel testing, and computationalfluid dynamics. In our study, low-speed wind tunnel testing is considered to experiment on the scale down sharp cone missile models. The experiments were conducted on the sharp conical nose at different velocity range 5 m/s to 25 m/s and various angles of attack0° to 25° with the step of 5°in the wind tunnel test section. Pressure distribution over the sharp cone model was investigated at two different locations x/D =1 & 2 and results were plotted for different subsonic velocities and various angles of attack. All the experimental investigation has been performed at subsonic speed. Experimental results revealed that the coefficient of pressure distribution is uniformly varying at x/D=2 with an increase in velocity at different angles of attack and Pressure distribution decreases with an increase in the angle of attack and increase in velocity..

Keywords: Aerodynamics,Missile, Co-efficient of Pressure, Sharpe Cone, AOA.

1. Introduction

Aerodynamics characteristics of the Missile body are very important for designing the vehicle body. Generally, various approaches are used to get the aerodynamics characteristics: Theoretical analysis, Computational Fluid Mechanics (CFD), and Wind tunnel test. Recent experimental research in advanced missiles has shown that missiles with circular bodies have definite aerodynamic performance and stability advantages over the conventional body shape. Commonly, maneuvering has been done by the deflection of a set of control surfaces attached to the body and nose configurations, the most common ones are canard control, wing control, and tail controls. Theapplication of state-of-the-art missile aerodynamic predictioncodes to elliptic body missile configurations has shownrelatively poor force estimates on the missile body, whichis in contrast to previous results on circular-body configurations. As a result of these findings, an experimentalprogram was initiated to obtain detailed surface pressure on the nose of the sharp conical missile configurations.

Stephen *et.al* [1] An experimental investigation of modified nose cone configurations to improve the properties for flight control at subsonic speed. For the Mach 0.3 case with 20° nose deflections, it is observed that the strakes were more effective with the +tail configurations and uncommanded side forces are generated at angles of attackgreater than 10°. Also, It leads to being provided valuable information for further development of the subsonic, articulating nose cone missile.Strakes appear to be necessary but keeping them small will optimize side force stability. Sharma et.al [2] the quantitative and qualitative investigations have carried out using experiments and computations for flow field around the missile with the different deflected nose at a different angle of attack at the subsonic speed of 17m/s. It is observed that the normal force generated in the positive deflections and negative deflection leads to less pitching moment which is important for the stability at a high angle of attack. Further computations indicate the deflection of the nose tip modifies the flow in positive deflection at a high angle of attack and increase the normal force of the body. Allen et.al [3] studied the surface pressure distributions of two elliptic Missile bodies, body vortices, and leeside pressure was calculated using nonlinear full-potential flow methods at Mach 2.5.

Balaji et.al [4] experimental investigation of the cylindrical tower with different downstream locations is studied in the wind tunnel to understand the wake characteristics of the flow. Peng et.al [5] numerical study of aerodynamics characteristics of guided rocket projectiles was investigated in actual flight conditions. It is found that the angle of canard deflection has a significant influence on the flow field near the tail fins. Coyle et.al [6] and Balaji et.al [7] numerical investigation of aerodynamics characterization of high maneuverability of canard-controlled guided projectile was studied. It is found that canards and fins produce the tip and root trailing edge vortices on the airframe. Honkanen et.al [8] CFD and Experimental of split canard air-to-air missile at high angles of attack in the turbulent subsonic flow wind tunnel, It is observed that longitudinal aerodynamics force coefficient and center of pressure at several angles of attack studied. Rajendran et.al [9] numerically investigated the over speeding of the wind turbine rotor is effectively controlled without affecting the power generation and chordwise slot were optimized both approach.

In this research work, Pressure distribution at two different locations x/D = 1 & 2 of Sharp Conical Nose missile is experimentally investigated in the subsonic wind tunnel test facility. The main aim of the research work is to study the pressure co-efficient of Sharp Conical nose missile at five different velocities 5 m/s, 10m/s, 15 m/s, 20 m/s, and 25 m/s and at different angles attache 0° to 25° with the step of 5° as shown in Fig 1.

Fig.1 Experimental Model of Sharp Conical Nose

2. Experimantal Procedure

In any wind tunnel testing, the accuracy of the wind tunnel estimate strongly depends on the exactness of the model, precise mounting to simulate test conditions, and of course calibration of the acquisition system. A scaled-down model was tested in the wind tunnel to measure the pressure distribution around the Sharpe cone missile and the surface of the model was polished and made smooth. The model was tested in the low-speed wind tunnel with a test section of the cross-section of 600 mm x 600mm and length 1.2m at Hindustan Institute of Technology and Science, Chennai as shown in Fig.2.

Fig 2 Suction types Low-Speed wind Tunnel

Wind tunnel designed for the velocity of air at test section of 45 m/s maximum conditions and turbulencelevel of less than 0.1%.Scale down model tested inthe wind tunnel for pressure distribution of the over the sharp conical nose missile at various angles of attack (0°to +25°and 0° to -25°) and scale down model of the sharpconical nose missile configuration was testedat very low Reynolds number as shown in Fig.3. The tunnel wasoperated at a wind speed of 5m/s, 10m/s, 15 m/s, 20 m/s, and 25 m/s to conduct the experiments and multitube manometer used for static pressure distributions over the model at different positions x/D = 1 and 2 each position provided with16 and 20 pressure taping respectively around the nose and surface pressure was measured using a manometer and pitot-static tube is used for total and static pressure measurement.

Fig. 3 Fabrication of Sharp Conical Nose Model

The subsonic wind tunnel is calibrated by different speeds of the rotor by the various operating condition of RPM. The blockage ratio of the model in the wind tunnel test section is estimated at less than 3%. The Pressure coefficient is of the body can be calculated as

$$\text{Co-efficient of Pressure } C_p = \frac{P_S - P_\infty}{P_O - p_\infty}$$

3. Result And Discussion

The experimental study of pressure distribution of Sharp conical nose has been investigated in the subsonic wind tunnel section at a different angle of attack and various velocity conditions as shown in Fig.4.

(a) AOA – 0° (b) AOA – 5°

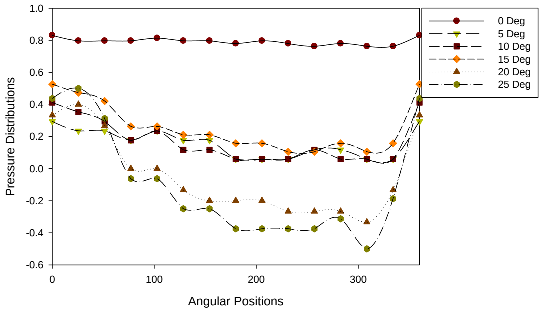
(c) AOA – 10° (d) AOA – 15°

(e) AOA – 20° (f) AOA – 25°

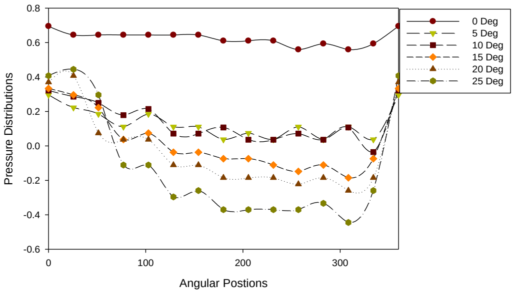
Fig.4 Different position of Sharp Conical Nose in Test Sections

3.1 Effect of Pressure distribution at x/D =1

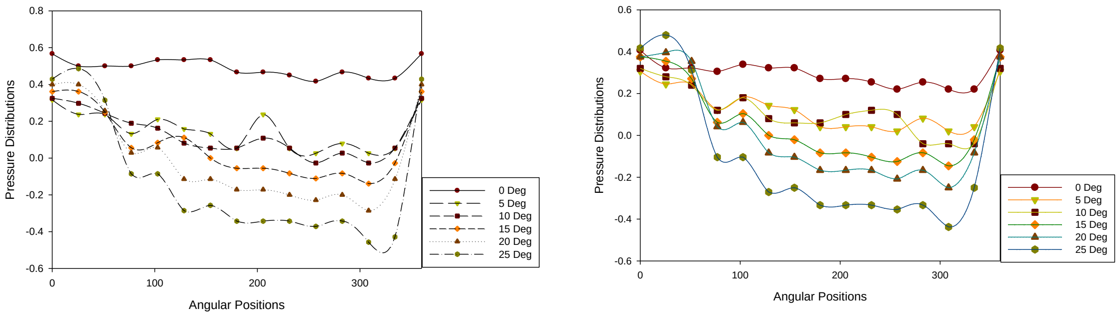
The Pressure distribution over the sharp conical nose missile model is tested in the wind tunnel for the different freestream velocity range from 5 m/s to 25 m/s and different angle of attack as 0°,5°,10°,15°,20° and 25° as shown in Fig.5.(a-e). It is found that pressure distribution gradually decreases in an increase in the angle of attack which can be seen in Fig.5 (a-e). Further, it is observed that pressure distribution become more complex at 70° to 90° at all the angle of attack and the entire range of freestream velocity as clearly depicted in Fig 5 (a-e)



(a) Pressure distribution at x/D =1 and Velocity 5 m/s

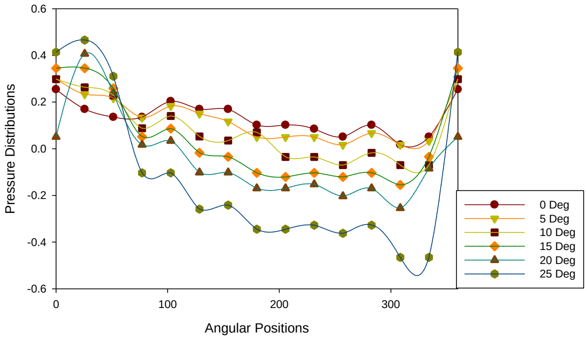


(b) Pressure distribution at x/D =1 and Velocity 10 m/s



(c) Pressure distribution at x/D =1 and Velocity 15 m/s

(d) Pressure distribution at x/D =1 and Velocity 20 m/s

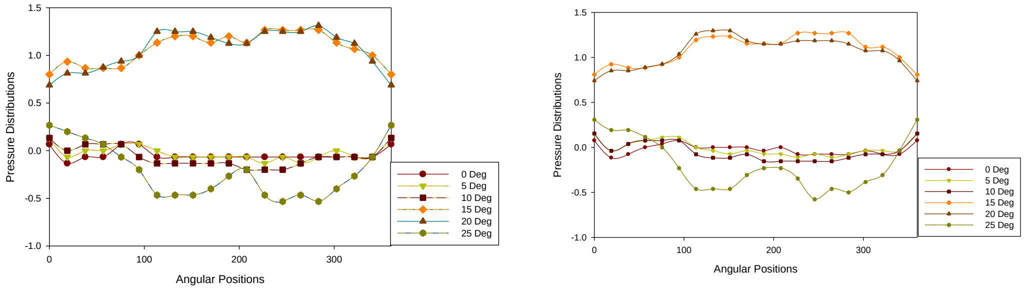


(e) Sharp Nose Cone Pressure distribution at x/D =1 and Velocity 25 m/s

Fig . 5 Pressure distribution of Sharp conical Nose different freestream velocity at x/D =1

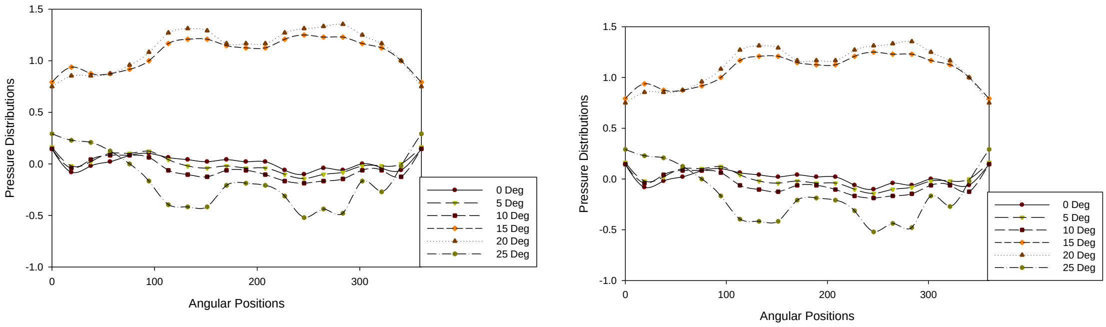
3.2 Effect of Pressure distribution at x/D =2

The Pressure distribution over the sharp conical nose missile model is tested in the wind tunnel for the different freestream velocity range from 5 m/s to 25 m/s and different angle of attack as 0°,5°,10°,15°,20° and 25° as shown in Fig.6.(a-e). It is found that pressure distribution uniformly varying around the surface of the at x/D=2. Further, it is observed that freestream is accelerated at the one of the surfaces of the missile at an angle of attack and similarly pressure co-efficient increase in the other side of the sharp nose cone can be seen in the figure Fig.6 (a-e)



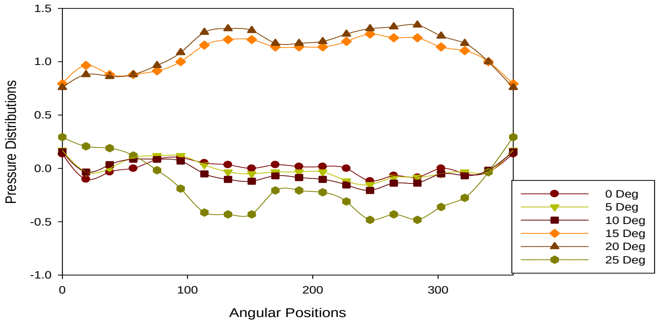
A) Pressure distribution at x/D =2 and Velocity 5 m/s

B) Pressure distribution at x/D =2 and Velocity 10 m/s



C) Pressure distribution at x/D =1 and Velocity 15 m/s

D) Pressure distribution at x/D = 2 and Velocity 20 m/s



e) Pressure distribution at x/D =2 and AOA = 25 Deg

Fig . 6 Pressure distribution of Sharp conical Nose different freestream velocity at x/D =2

4. Conclusion

In this research study, an Experimental investigation of pressure distribution of Sharp Conical Missile has been carried out for different x/D locations and different angles of attack at the subsonic speed of 5- 25 m/s.

The following observation has been made in the current research.

1. It is observed that pressure distributions over the sharp conical nose at x/D =1 decrease with an increase in the angle of attack as well as a decrease in freestream velocity.

2. At x/D = 2, Pressure distributions is uniformly varying along with the angular position of the cone surface and also pressure co-efficient is maximum than x/D=1.

5. Future Scope

For further understanding and appreciation of aerodynamicflow past the missile of the varying angle of attack and deflectionangle. Flow visualization tests are planned shortly exhaustive wind tunnel testing for different angles of attack attransonic and supersonic speed should be carried out for fine-tuning. Theoretical methods need to be updated to capture theeffects of shedding vortices and the lifting characteristics ofthe missile.

References

[1] Stephen, Eric J., Thomas E. McLaughlin, Brett Bixler, Benjamin Dickinson, and Joshua Turner. "Investigation of Nose Cone Enhancement to Improve the Effectiveness of an Articulating Nose Cone on a Subsonic Missile." In AIAA Aviation 2019 Forum, p. 3165. 2019.

[2] Sharma, Gagan, Gaurav Sharma, and Gaurav Chopra. "Computational and experimental study of the deflected nose of missile at subsonic speed." In 2015 IEEE Aerospace Conference, pp. 1-10. IEEE, 2015.

[3] Allen, Jerry M., and James L. Pittman. "Analysis of surface pressure distributions on two elliptic missile bodies." Journal of Spacecraft and Rockets 21, no. 6 (1984): 528-533.

[4] Balaji, G., S. Nadaraja Pillai, and C. Senthil Kumar. "``Wind tunnel investigation of downstream wake characteristics on a circular cylinder with various taper ratios,"." Journal of Applied Fluid Mechanics 10, no. 3 (2017): 69-77.

[5] Peng, Jiazhong, Liangyu Zhao, and Longyin Jiao. "Numerical Simulations on Aerodynamic Characteristics of a Guided Rocket Projectile." In 2016 3rd International Conference on Materials Engineering, Manufacturing Technology and Control, pp. 1004-1007. Atlantis Press, 2016.

[6] Coyle, Craig J., and Sidra I. Silton. "CFD aerodynamic characterization of a high maneuverability airframe." In 33rd AIAA Applied Aerodynamics Conference, p. 3015. 2015.

[7] Balaji, G., B. Navin Kumar, J. Vijayarangam, A. Vasudevan, and R. Pandiyarajan. "Numerical investigation of expansion Fan optimization of truncated annular aerospike nozzle." Materials Today: Proceedings (2021).

[8] Honkanen, Tomi, Tuomas Tuisku, and Antti Pankkonen. "CFD simulations and wind tunnel experiments of a generic split-canard air-to-air missile at high angles of attack in turbulent subsonic flow." In AIAA Atmospheric Flight Mechanics Conference, p. 6335. 2011.

[9] Rajendran, S., A. Vasudevan, and G. Balaji. "Aerodynamic braking system analysis of horizontal axis wind turbine using slotted airfoil." Materials Today: Proceedings 33 (2020): 3970-3979.