EXPERIMENTAL STUDY ON THE EFFECT OF LEADING EDGE BLUNTNESS ON AN OSCULATING WAVERIDER IN HYPERSONIC FLOW

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1 INTRODUCTION

The modern demands of missions requiring long-range, maneuverable hypersonic vehicles across space exploration, military applications, and transportation sectors underscore the need for innovative designs. Nonweiler[4] proposed a hypersonic vehicle concept featuring a waverider design characterized by a high lift-to-drag (L/D) ratio in hypersonic conditions. He developed the caret-based waverider by suggesting a 2D planar flow around a wedge as the generating flowfield. Some researchers have explored utilizing a conical flowfield[6], which notably enhances the volumetric aspect of waveriders. In recent years ,waveriders developed from the osculating cone theory[1] have garnered attention due to their potential to significantly expand the design space for the waveriders . Essentially in a waverider, the forebody shock remains fully attached to the leading edge, resulting in elevated pressure along the lower surface and consequently yielding a substantially higher L/D ratio.

The prevailing literature on osculating cone waveriders predominantly concentrates on their design intricacies and performance evaluations[3] across different on/off-design scenarios utilizing CFD or analytical methods. Conducting experimental tests on waveriders presents significant challenges, primarily stemming from the intricate geometry of the body and the lack of straightforward manufacturing techniques for producing such complex shapes[5]. The performance of a waverider hinges greatly on its shape, especially the configuration of its leading edge. Additionally, the intricate nature of a waverider's shape presents considerable challenges in manufacturing through traditional machining methods. 3D printing emerges as a promising solution to address these challenges. In this article, an osculating cone waverider shape is developed using an in-house code[2] and has been fabricated using a 3D printer. The high-speed schlieren imaging technique is employed to capture the shock shape at various angles of attack and different planes, providing insights into the three-dimensional shock envelope present.

2 EXPERIMENTAL FACILITY AND TECHNIQUES

The experiments detailed in this paper were conducted using the Hypersonic Shock Tunnel 2 (HST 2) facility located at LHSR, Indian Institute of Science, Bengaluru. It is a general conventional shock tube and tunnel facility which has been transformed into a Ludwieg tube setup by joining the driver and driven sections and using a solenoid actuated quick acting valve. High pressure gas is filled in the long tube and the dump tank is evacuated to a pressure of about 10^{-5} mbar. The facility produces a Mach 6.5 flow with varying Reynolds numbers from 9-33 million/m. A steady flow of about 35 ms can be acquired using this facility.

The flow conditions for the experiments conducted in the ludwieg tunnel are as follows

Fill Pressure (bar)	Mach Number	P_∞	T_∞ (K)	ρ_∞	U_∞	Reynolds Numbers (million/m)
40	6.58	725	30.5	0.083	740.90	33.53

Table 1 : Free Stream Conditions

A Mach 6, 180 x 120 mm, bluntness 3mm , waverider model was fabricated using Bambu Labs X-1 Carbon 3D printer with PLA (Poly Lactic Acid) polymer as the material .

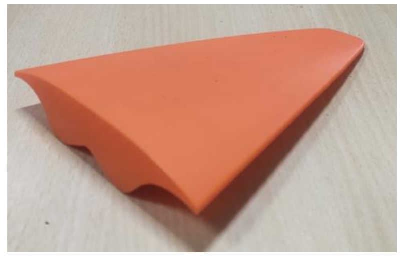

Figure 1 : 3D printed Waverider model

A Z-type schlieren imaging technique was carried out using concave mirrors of 200 mm diameter and a focal length of 2m , the images were captured using a Photron FASTCAM SA4 camera with 320 x 320 pixels resolution at a frame rate of 30000 Hz and an exposure time of 1.87 µs.

3 RESULTS

Schlieren images were captured from various model configurations, including planview and sideview perspectives, at both 0^0 and 4^0 degrees Angle of Attack. This comprehensive approach aimed to enhance our understanding of the shock shape surrounding the leading edge of the waverider geometry.

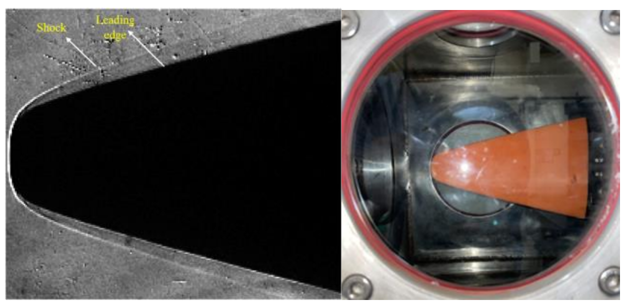

Figure 2: On the right is the plan view of the mounted waverider model, with its corresponding schlieren image displayed on the left at 0^0 Angle of Attack.

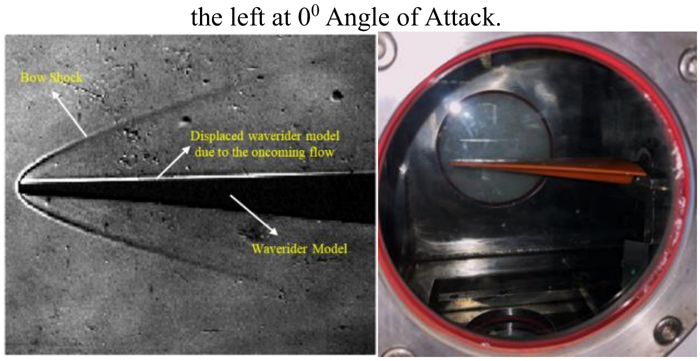

Figure 3: On the right is the side view of the mounted waverider model, with its corresponding schlieren image displayed on the left at 0^0 Angle of Attack.

In the side view, a bowshock is observed, positioned closely to the leading edge, with its deviation attributed to the model's bluntness. Additional experimental details, demonstrating the response of the flow topology to variations in leading edge bluntness, will be elaborated upon in the complete paper.

4 REFERENCES

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