

# Sarod 2009

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## Experimental Investigation of Isolated Hypersonic Inlet

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### ABSTRACT

Wind tunnel tests were conducted in the 340 mm diameter supersonic enclosed free jet wind tunnel on hypersonic air intake model to study the intake starting characteristics. The intake with five different cowl plates was tested. Different cowl plates were used to change the contraction ratio of intake. These tests were carried out at Mach numbers 3.5 and 4.0. Internal pressure distribution on four walls of the intake along its length was measured. Unsteady pressure near cowl entry was also measured. Analysis of intake internal pressure data, cowl unsteady pressure data and flow visualization through color Schlieren clearly show the starting and un-starting of intake with differentiate clearly the starting and un-starting of intake. The measured total pressure recovery is higher than the normal shock pressure recovery for started intake. Contraction ratio required for intake starting is found to be much lower than the theoretical value (normal shock theory).

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Key Words: Contraction ratio, pre-compression shock, started and un-started intake

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### NOMENCLATURE

$A_{intake}$  = Cross-sectional area of intake at entry plane

$A_{exit}$  = Cross-sectional area of combustor, 23mm from exit

CR = Contraction Ratio, ratio of throat area to entry area of intake

$M_{exit}$  = Mach number in the combustor, 23 mm from exit

$M_{\infty}$  = Free stream Mach number

$P$  = Internal wall static pressure

$P_0$  = Tunnel stagnation pressure

$P_{0^*}$  = pitot pressure at combustor, 23 mm from exit

$X$  = Horizontal distance from the leading edge of the air intake bottom wall, mm

$f$  = Frequency of oscillations of pre-compression

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shock wave

$m_{intake}$  = mass flow rate through intake

$m_{\infty}$  = mass flow rate entering the intake at free stream conditions

$\theta$  = Angle between cowl internal surface and free stream, degrees

### 1. INTRODUCTION

Scramjet engines are efficient at hypersonic Mach numbers above 6.0. If the hypersonic flow is decelerated to subsonic speed, which is the case for ramjet combustion, the static temperature rise is very high and addition of heat to the flow is not possible. Also pressure losses as well as wave drag are high due to large deceleration of the flow. Hence scramjet engines are preferred worldwide to power the atmospheric hypersonic vehicles.

Hypersonic air-intake is located on bottom surface of the body of the vehicle, down stream of fore-body ramps and employs a one-step one-time variable cowl to collect and compress free stream air for feeding into the scramjet combustor. Schematic of typical hypersonic vehicle is shown in Figure 1.

### 2. MODEL MEASUREMENTS

Internal wall static pressures were measured on four walls of the intake. Pressure ports were located along the length at the centerline of the intake. A three-probe pitot rake was used to measure the total pressure near combustor exit (23 mm from exit). Unsteady pressure measurement was made at cowl entry. The pressure port locations are shown in Figure 2. Colour Schlieren pictures were recorded

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with video camera at shutter speed of 1/2000 second to capture the un-steady shock.

### 3. DISCUSSION OF TEST RESULTS

Internal wall static pressures were measured on four walls of the intake. Pressure ports were located along the length at the centerline of the intake. A three-probe pitot rake was used to measure the total pressure near combustor exit (23 mm from exit).

#### 3.1 Effect of opening of air-intake

Internal wall static pressures were measured on four walls of the intake. Pressure ports were located along the length at the centerline of the intake. A three-probe pitot rake was used to measure the total pressure near combustor exit (23 mm from exit).

### 4. CONCLUSION

#### Acknowledgment

#### REFERENCES

1. Lawrence D. Huebner, Kenneth E. Rock, Edward G. Ruf, and David W. Witte, "Hyper - X Flight Engine Ground Testing for Flight Risk Reduction," Journal of Spacecraft and Rockets, vol.38, No.6, November - December 2001.

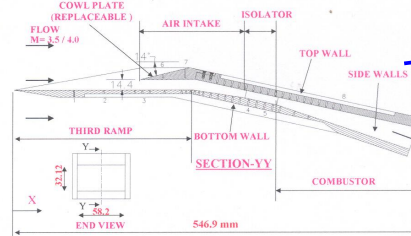


Figure 2 Pressure port locations

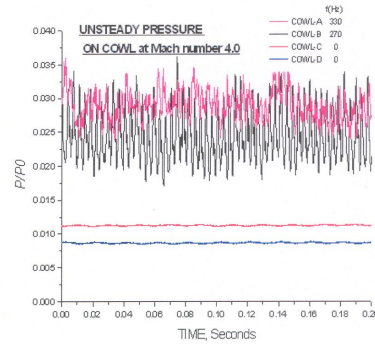


Figure 3 Unsteady pressure measurements

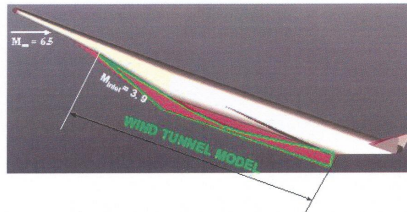


Figure 1 Geometry of hypersonic vehicle

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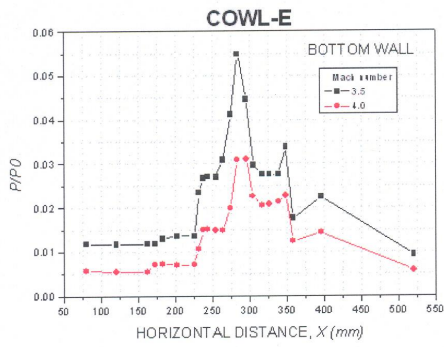


Figure 4 Comparison of bottom plate pressure at  $M=3.5$  & 4