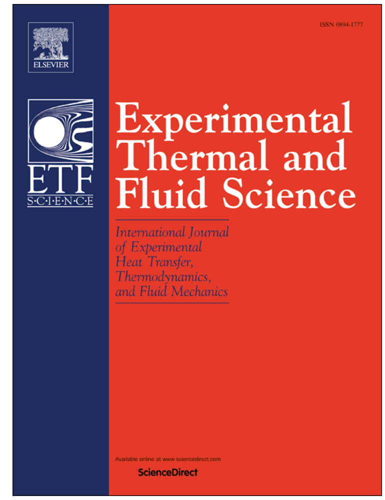
Accepted Manuscript

Effects of recess depth and opening diameter on pressure measurement by recess mounted transducers in a hypersonic boundary layer

Shiyong Yao, Changwan Min, Shaofei Xie, Haiyan Li, Jian Lin, Pan Yang, Yi Duan



PII: S0894-1777(18)30129-8
DOI: https://doi.org/10.1016/j.expthermflusci.2018.04.027
Reference: ETF 9462

To appear in: *Experimental Thermal and Fluid Science*

Received Date: 2 February 2018
Revised Date: 28 April 2018
Accepted Date: 28 April 2018

Please cite this article as: S. Yao, C. Min, S. Xie, H. Li, J. Lin, P. Yang, Y. Duan, Effects of recess depth and opening diameter on pressure measurement by recess mounted transducers in a hypersonic boundary layer, *Experimental Thermal and Fluid Science* (2018), doi: https://doi.org/10.1016/j.expthermflusci.2018.04.027

Effects of recess depth and opening diameter on pressure measurement by recess mounted transducers in a hypersonic boundary layer

Shiyong Yao [a,*], Changwan Min [a], Shaofei Xie [b], Haiyan Li [b], Jian Lin [b], Pan Yang [a], Yi Duan [a]

[a] Science and Technology on Space Physics Laboratory, China Academy of Launch Vehicle Technology, 100076 Beijing, China
[b] China Academy of Aerospace Aerodynamics, 100074 Beijing, China

Abstract Experimental measurements of pressure fluctuations in a hypersonic boundary layer were conducted based on recess mounted transducers and the effects of recess depth and opening diameter on fluctuating pressure characteristics were studied. The results showed that as the recess depth increased, the bulk of counter flow in the cavity enlarged with the decreased energy of large scale structures, and more small scale structures with relatively higher frequency were generated which contributed to the multiscale structures with broadband frequency spectrum. Similarly, as the opening diameter increased, the low-frequency large scale structures inside the cavity had larger energy due to the shear flow entering the cavity having more mass and carrying larger energy, and the small scale structures with higher frequency exhibited stronger dissipation intensity. The symmetric and stable flow filed was more likely to cause the cavity resonance, and the asymmetry and instability of the flow field for smaller recess depth as well as larger opening diameter could inhibit the cavity resonance phenomenon. Compared to surface mounted, nonlinear phase coupling occurred between the flow structures caused by recess mounting which transfers the energy from high frequency structures to low frequency structures. Overall, smaller recess depth and larger opening diameter are optimized in the hypersonic flight test on the premise of pressure sensors not destroyed by the harsh aerothermodynamic environment.
Keywords: Hypersonic; Recess mounted; Pressure fluctuation; Recess depth; Opening diameter

Nomenclature

f	frequency
f_s	sampling frequency
Δf	frequency resolution
p_{rms}	root mean square of pressure fluctuation
t	time
Δt	time spacing
D	opening diameter
H	recess depth
K	kurtosis of pressure fluctuation
M	Mach number
M_{cp}	Mean Mach number of uniform flow field
ΔM	Mach number difference
P_0	total pressure
R_{DD}	cross correlation
Re_{unit}	unit Reynolds number
S	skewness of pressure fluctuation
T_0	total temperature

1. Introduction

The intensity and frequency of pressure fluctuations significantly affect the structural dynamic loading characteristics of flight vehicles. It is of particular importance for the fatigue load determination of vehicle skin when the frequency of local fluctuating pressure loads couples with the structural natural frequency that can cause the internal components vibration and lead to the structural fatigue even failure. Additionally, pressure fluctuations are the main source of the aerodynamic noise, which also have a remarkable impact on the heat shield of vehicles. Therefore, prediction of fluctuating levels and characteristic frequency is required from the view point of aerodynamic and structural design of vehicles.

Direct drilling method with surface mounting is commonly used for the pressure distribution measurements [1–8], that is holes are drilled directly into the model where, pressure transducers are inserted in and mounted flush with the object