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SURFACE FLOW MEASUREMENTS OF MICRO-SUPERSONIC IMPINGING JETS

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Impinging supersonic microjets have been studied experimentally where both surface measurements (pressure and shear stress) and flow-field visualizations have been obtained. Microjets are of interest because of their potential applications, such as in electronics cooling and surface cleaning. Microjets with diameters of 400 and 1000 microns have been investigated, operating at pressure ratios of 5 and 8 and impinging plate distances of 2 to 8 diameters. A specialized micro-Schlieren system is used to visualize the jet flow field, and oil-film interferometry is used to measure the skin friction on the impingement surface. This paper primarily concentrates on the application of oil-film interferometry to this flow. A detailed study of the various parameters affecting the interferograms obtained using oil-film interferometry is explored, and an approach for analyzing the interferograms in these high shear gradient flows is outlined. The results of this preliminary study indicate that high shear stress levels (50 Pa at 11 nozzle diameters from the impingement point for a pressure ratio of 5) exist over a significant region around the impingement point and that the shear stress gradients are very high. The shear stress distributions are compared with surface pressure distributions and to the limited computational results available for impinging jets. Although, a direct comparison is impossible due to lack of such data in literature, the trends observed in the present study appear to agree with those of larger supersonic impinging jets. The measurements indicate that oil-film interferometry provides repeatable, and reliable shear stress data in this complex flowfield - dominated by regions of high shear and large pressure gradients – which may not be amenable to other methods. Future improvements in the application of oil-film interferometry to this flow are also discussed.

Introduction

Supersonic impinging jets have been of interest to the fluid dynamic and the industrial community for a number of decades. From a fluid dynamics perspective, the flow-field is interesting due to its complex nature. This flow may typically consist of multiple shock-shock and shock-shear layer interactions, and regions of subsonic, supersonic and separated flows, which makes the study of this flow difficult (see Fig. 6). From a practical standpoint, the flow is of considerable interest due to either its presence or its potential use in a number of applications. High-speed impinging jets have been of particular interest to the aerospace/aerodynamic community because of their use in Short Take-off and Vertical Landing (STOVL) aircraft, such the Harrier/AV-8 family or the STOVL version of the proposed Joint Strike Fighter (JSF), during hover mode. The highly unsteady impinging jet flow-field in these aircraft can lead to a number of adverse effects, which degrade aircraft performance. A more detailed discussion of the supersonic impinging jet flows and their effects in the context of STOVL aircraft can be found in Krothapalli et al.[1], Alvi & Iyer[2] and Alvi et al.[3]

High-speed impinging jets have also found many applications including cooling and heating of devices, as discussed in Tawfek[4], to particle and dust removal (Smedley et al.[5]). In recent years, miniaturization of devices has led to considerable interest in supersonic microjets, specifically supersonic impinging microjets,

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