Behavior of Free and Impinging Supersonic Microjets

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The fluid dynamics of microflows has recently commanded considerable attention because of their potential applications. To date, most of this work has been limited to low velocity flows. The present study examines supersonic microjets in the range of 100 - 400 microns with exit velocities in the range of 400-500 m/s. Such microjets are presently being used to actively control larger supersonic impinging jets, which occur in STOVL (Short Takeoff and Vertical Landing) aircraft. The flow field is visualized using a Micro-schlieren system with effective magnifications greater than 100x. Schlieren images, which to the best of our knowledge have never before been obtained at this scale, clearly show the characteristic shock cell structure observed in large-scale jets. Based on these images, the jet is clearly supersonic as far as 10-12 diameters downstream. Quantitative measurements providing jet decay and spreading rates as well as shock cell spacing are also obtained via pressure surveys using micro-pitot probes. Overall, the microjet properties are similar to larger supersonic jets, especially those operating at similar Reynolds number. However, pronounced viscous effects in the present microjets do lead to some differences. The impingement of these supersonic microjets on flat surfaces is also examined in this study. A comparison reveals that the flow structure of impinging microjets strongly resembles that of larger, macro supersonic impinging jets.

1. INTRODUCTION

Recent years have seen considerable research in the fluid dynamics of high-speed microjets due to their potential use in applications such as micro-propulsion, cooling of MEMS (Micro-Electro Mechanical Systems) components, fine particle deposition and removal as well as in inkjet printer heads. Supersonic microjets present several advantages over subsonic jets. For example, in cooling applications by jet impingement, supersonic microjets offer a concentrated source of cooling fluid because of lower jet spreading rates, as well as rapid heat removal due to high heat transfer rates in the jet impingement region and inherently high velocities. Microjets are also presently being used as actuators to control the ground effects created by large-scale supersonic impinging jets which typically occur in STOVL (Short Take-Off and Vertical Landing) aircraft.[1]

To-date studies have mainly focused on internal flows in micro-channels and nozzles. Meinhart et al [2] describe a MicroPIV investigation of flow through an inkjet printer. Breuer and Bayt [3] carried out a detailed computational and experimental study examining the flowfield inside silicon-etched converging–diverging (c-d) micronozzles with throat heights ranging from 10-50 μm. Their study emphasized the behavior and influence of the nozzle boundary layer on the thrust performance of these micronozzles. No measurements of the external flow were made in their work, the presence of supersonic flow was estimated via mass flow and thrust measurements. A comprehensive analysis of MEMS based Microthruster system has been conducted by Bayt [4]. Scroggs and Settles [5] obtained schlieren images as well as pitot pressure surveys for supersonic jets issuing from c-d nozzles ranging in size from 1200

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