Exp Fluids
DOI 10.1007/s00348-007-0438-4

RESEARCH ARTICLE

Experiments on free and impinging supersonic microjets

K. A. Phalnikar · R. Kumar · F. S. Alvi

Received: 26 January 2007 / Revised: 19 July 2007 / Accepted: 20 July 2007

Abstract The fluid dynamics of microflows has recently commanded considerable attention because of their potential applications. Until now, with a few exceptions, most of the studies have been limited to low speed flows. This experimental study examines supersonic microjets of 100–1,000 μm in size with exit velocities in the range of 300–500 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, cavity flows, and flow separation. Flow properties of free as well as impinging supersonic microjets have been experimentally investigated over a range of geometric and flow parameters. The flowfield is visualized using a micro-schlieren system with a high magnification. These schlieren images clearly show the characteristic shock cell structure typically observed in larger supersonic jets. Quantitative measurements of the jet decay and spreading rates as well as shock cell spacing are obtained using micro-pitot probe surveys. In general, the mean flow features of free microjets are similar to larger supersonic jets operating at higher Reynolds numbers. However, some differences are also observed, most likely due to pronounced viscous effects associated with jets at these small scales. Limited studies of impinging microjets were also conducted. They reveal that, similar to the behavior of free microjets, the flow structure of impinging microjets strongly resembles that of larger supersonic impinging jets.

K. A. Phalnikar · R. Kumar (✉) · F. S. Alvi
Department of Mechanical Engineering,
Florida A & M University and Florida State University,
Tallahassee, FL 32310, USA
e-mail: drrajank@gmail.com

1 Introduction

Recent years have seen a rise in interest in the study of the fluid dynamics of high-speed microjets due to their potential use in applications such as micropropulsion, cooling of MEMS (micro-electro mechanical systems) components, and fine particle deposition and removal such as in inkjet printer heads, among others. Supersonic microjets provide several advantages over subsonic jets in a number of applications. For example, in jet impingement cooling, supersonic microjets offer a concentrated source of cooling fluid due to the lower jet spreading rates associated with compressible jets and the rapid heat removal due to high heat transfer rates in the impingement region (Phares et al. 2000; Smedley et al. 1999; Love et al. 1994; Goldstein et al. 1986; Kim et al. 2003). Microjets are also used as actuators to control the ground effect created by large supersonic impinging jets, which typically occur in STOVL (short take-off and vertical landing) aircraft during hover. The feedback loop associated with these large-scale supersonic impinging jets is substantially attenuated by the use of microjets and results in a significant reduction in the overall sound pressure levels thus minimizing the adverse effects on the aircraft performance (Alvi et al. 2003; Lou et al. 2006). More recently, microjet-based actuators have also been used for the control of flow separation (Kumar et al. 2006), cavity flows (Zhuang et al. 2006), and for jet noise control (Arakeri et al. 2003; Alkislar et al. 2007). In addition to their practical applications, this flowfield is also of interest from a fundamental fluid dynamics perspective, in part because the combination of highly compressible flow at low-to-moderate Reynolds number is not very common, and in part due to the complex nature of the flow itself. It consists of multiple shock–shock and shock–shear layer