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ACTIVE CONTROL OF HIGH TEMPERATURE SUPERSONIC IMPINGING JETS

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The Supersonic impinging jets such as those occurring in short takeoff and vertical landing (STOVL) aircraft, generate a highly oscillatory flow with high unsteady loads on the nearby structures and the landing surfaces. These high-pressure and acoustic loads are also accompanied by a dramatic loss in lift during hover, severe ground erosion of the landing surface and hot gas ingestion into the engine inlets. In the past we have examined impinging jets at cold conditions; the present study is a step toward examining this flowfield and assesses the effectiveness of microjet control at increasingly realistic conditions. An ideally expanded, Mach 1.5 primary jet was heated up to a total temperature of ~500K and issued from an axisymmetric nozzle. Temperature and pressure measurements were made on lift plate, representative of the undersurface of an aircraft and on the ground plane, over a range of nozzle-to-plate distances (representing aircraft hover conditions). In addition to temperature and pressure, near-field noise was measured using a microphone. Velocity field of impinging jets for both cold and hot conditions was mapped using particle image velocimetry. The results show that the temperature recovery factor is strongly dependent on the temperature ratio and nozzle to plate distance. The hover lift loss at high temperatures is significantly high, as large as 76% of the primary jet thrust at small nozzle to plate distances. The pressure fluctuations generated by hot impinging jets are substantially higher than cold jets and persist over a larger extent of nozzle to plate distances. The activation of microjet control shows a substantial reduction in pressure fluctuations both in terms of overall sound pressure levels and the attenuation of discrete, impinging tones. PIV results explain the increase in lift loss due to high entrainment velocities for hot impinging jets.

I. Introduction

Many examples of flow impingement of a jet on a solid surface can be found in engineering applications. To name a few: the launch of a rocket, takeoff and landing of a STOVL aircraft and the trust vector control of a solid rocket motor or an aircraft exhaust. For an efficient design of such systems, it is important to understand the flow field associated with impinging jets. In particular, STOVL aircraft during hover produce high temperature impinging jets on the landing surface. These lift producing jets results in the high temperature, turbulent and highly oscillatory flow. This leads to severe ground erosion of the landing surface, lift loss due to entrainment of high speed flow near the nozzle exit, very high unsteady loads on the nearby structures and hot gas ingestion into the engine inlets. High levels of overall sound pressure levels (OASPL) associated with high temperature supersonic impinging jets are a cause of concern due to sonic fatigue failure of the aircraft structure and a major source of noise pollution for the personnel in the aircraft vicinity.

Flow field properties of a supersonic impinging jet has been investigated by many researchers in the past, including, Donaldson and Snedeker[1], Lamont and Hunt[2], Powell[3], Tam and Ahuja[4], Messersmith[5], Alvi and Iyer[6], Krothapalli et al.[7] and more recently by Henderson et al.[8]. These studies clearly demonstrated the unsteady behavior of impinging jets and the presence of high amplitude discrete impinging tones. Krothapalli et al.[7] demonstrated that generation of large scale structures in the jet shear layer induce high entrainment velocity near the nozzle exit, and in turn significant lift loss during hover. It is now well known that the highly unsteady behavior of the impinging jets is due to a feedback loop between the fluid and acoustic fields, which leads to these adverse effects. There have been many attempts to suppress the feedback loop using passive as well as active control methods, for example, Karamcheti et al.[9] successfully suppressed edge tones by placing two plates normal to the jet centerline. Elavarsan et

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