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A PIV Study of Supersonic Impinging Jet

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An experimental investigation of the flow and acoustic properties of an axisymmetric impinging jet, with and without microjet control, has been performed. The near-field acoustic measurements clearly show that the use of microjet control eliminates or significantly suppresses the impinging tones, and reduces broadband spectral amplitudes. To understand the physical mechanism responsible for the control effectiveness, the flowfields with and without control are examined using Particle Image Velocimetry Technique (PIV). The detailed PIV measurements reveal that the activation of microjets introduces strong streamwise vorticity in the form of well-organized, counter-rotating vortex pairs. The generation of these streamwise structures is speculated as the result of the tilting and stretching of the shear layer vortices when the microjets interact with primary jet flow. Due to this redistribution, the peak value of azimuthal vorticity is significantly reduced leading to a subsequent weakening of the primary jet instabilities. On the other hand, near the nozzle exit, the use of Microjets control increases the thickness of the shear layer further limiting the number of the unstable modes. The combined effect of an increase in thickness of the shear layer and a decrease of the peak azimuthal vorticity suppresses the instabilities in the primary shear layer. This sequence of events leads to the weakening of the feedback loop and the subsequent reduction in the flow unsteadiness of the supersonic impinging jet flow.

Introduction

The study of acoustic and flow fields generated by high-speed impinging jet has been a popular subject for many years, not only because of its practical importance in aerodynamic applications, but also its fundamental importance in the study of free shear flows. The acoustic properties of single high-speed impinging jet usually are dominated by discrete, high-amplitude tones, referred to as "impinging tones". The presence of such discrete tones usually is undesirable in most operational conditions. For example, they lead to problems such as high overall noise, substantial lift loss, and acoustic fatigue of nearby structures, among other challenging issues if the jet is a part of the aircraft propulsion system. These problems become increasingly serious for supersonic impinging jets, the operating regime of the STOVL version of the future Joint Strike Fighter (JSF). The ability to control the impinging noises and accompanied adverse effects is critical for the successful development of the program.

A host of studies on the aeroacoustics of impinging jets by Neuwarth[1], Powell[2], Tam and Ahuja[3], and more recently Krothapalli *et al.*[4] have clearly established that the self-sustained, highly unsteady behavior of the jet and the resulting impinging tones are governed by a feedback mechanism, between the instability waves in the jet that originate at the nozzle and grow as they propagate downstream towards the impingement surface, and the acoustic waves that are produced upon impingement which then travel upstream and excite the nascent shear layer near the nozzle exit. For further details of the feedback loop, the reader is directed to the above articles.

Though one of the important components in the feedback loops mechanism, the large-scale structure in supersonic jets, has been studied by various techniques[4-6], the connection between the large-scale structures and noise generation of these jets has been a subject of intense debate. Preisser & Block[7]

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