USE OF SUPERSONIC MICROJETS FOR ACTIVE SEPARATION CONTROL IN DIFFUSERS

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Inlets to aircraft propulsion systems must supply flow to the compressor with minimal pressure loss, distortion or unsteadiness. Flow separation in inlets and ducts can reduce the overall system performance. The present paper describes an experimental investigation carried out to study the feasibility of using supersonic microjets to control boundary layer separation in an adverse pressure gradient. The geometry used for this study is a simple diverging "Stratford ramp" equipped with arrays of 400μm supersonic microjets. Measurements include detailed surface flow visualizations, surface pressure distributions, flow visualizations and velocity field measurements using Particle Image Velocimetry. The results clearly indicate that by activating these microjets, the separated flow was eliminated. This was achieved with minimal mass flux, lower than 1.5 % of the primary flow. The activation of microjets and the resulting elimination of separated flow led to a significant increase in the momentum of the flow near the surface. The increase in momentum was at least an order of magnitude higher than the momentum injected by the microjets. As such, supersonic microjets appear to be very effective actuators for separation control.

1. Introduction

Flow separation is generally accepted to be the breakaway or detachment of fluid from a solid surface. Whether caused by a severe adverse pressure gradient, a geometrical aberration or by any other means, separation is usually accompanied by significant thickening of the rotational flow region adjacent to the surface with a marked increase in the velocity component normal to the surface. This separation is almost always associated with losses of some kind, including loss of lift, drag increase, pressure recovery losses and in some cases, it is also the cause for aerodynamic stall[10,11]. While the inlet length required to avoid separation and its associated losses may not be a significant design driver for some vehicles (such as uninhabited air vehicles), the inlet may drive the size of the overall vehicle[1]. For many military applications, the inlet design is also constrained by low observability requirements. To reduce the radar signature from the compressor face, a serpentine inlet is typically used (Fig. 1) to block the line of sight[2,3]. Similar buried propulsion system installation has also been considered for Blended Wing Body (BWB) design. In case of BWB[4], engines are located at the aft end of the aircraft that requires the ingestion of a thick boundary layer developed over the aircraft surface.

The degraded condition of this thick boundary layer makes it much more susceptible to separate when it encounters the pressure gradients of a diffusing inlet duct. The pressure loss due to this separation reduces the overall system efficiency. Moreover, flow distortion and unsteadiness created due to this separation can result in aerodynamic stall and surge of the compressor and the fan blades[5,6]. Henceforth, it is highly desirable to avoid boundary layer separation as it can significantly diminish the engine performance.

Not surprisingly, there has been a tremendous amount of research and development to control this boundary layer separation[7,8]. Traditionally, beyond tripping a laminar boundary layer, four major approaches were used for separation control: 1. Tangential blowing (in various forms including slotted flaps, and moving wall) to directly energize the low momentum region near the wall, 2. Wall suction to remove the low momentum region, 3. Vortex generators (v.g's) in form of vanes, bumps, 4. Forced excitation devices e.g. synthetic jets. Tangential blowing and suction are very effective in controlling the separation. However, they have the parasitic cost of very high-pressure requirement involved and are infrequently used. Vortex generators are among the most widely examined flow control methods, where v.g.'s of various shapes and sizes have been used to control the boundary layer separation[9]. Although the mechanism is still not understood very well, it has

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