Efficient Control of Separation Using Microjets

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Flow separation in engine inlets and ducts can significantly compromise the performance of aircraft propulsion systems. The study presented herein describes an experimental investigation carried out to study the feasibility of using microjets to control this boundary layer separation in an adverse pressure gradient. The geometry used for this study is a diverging "Stratford ramp" equipped with arrays of 400μm microjets. Detailed PIV investigations and Unsteady Pressure Measurements have been carried out to study the flow control over a wide parametric space. The results indicate that by activating these microjets, the flow becomes attached to the surface with minimal mass flux, less than 0.2% of the primary flow based on 30% Boundary Layer Ingesting duct.

1. Introduction

Flow separation and its control are of considerable interest both from fundamental fluid dynamics and practical perspectives. Flow separation can lead to significant reductions in performance for internal and external flows, such as lift loss, increase in drag, buffeting, and pressure recovery losses (in engine inlet/transmission ducts), among others. In particular, in the proposed Blended Wing Body (BWB)[1] configuration, shown in Fig. 1, flow distortion and separation is a major cause of concern. Serpentine inlet ducts[2](Fig. 2) used in these BWB are located on the aft end to reduce the size of aircraft and to diminish radar signatures from the engines. This placement of serpentine inlet ducts requires ingestion of a thick boundary layer developed over the aircraft surface. This thick degraded boundary layer is much more susceptible to separation when it encounters adverse pressure gradients in the inlet/diffuser ducts. 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[3,4]. Henceforth, it is highly desirable to avoid boundary layer separation as it can significantly compromise the performance of aircraft propulsion systems.

Numerous techniques[5-11] have been explored to control this flow separation in adverse pressure gradients. These range from the use of passive devices in form of vanes[11], bumps[11], Vortex Generators[10] (v.g's) etc. to the use of synthetic jets[6], acoustic excitation[7,8] as active control devices. However, to date, the performance of these techniques has been somewhat limited. For example, passive devices such as v.g.'s have been found to be effective in controlling separation. However, they need to be optimized for their location, size and other parameters for specific operating conditions and induce parasitic drag when not in use. As a result, active flow control devices have been suggested as an attractive control technique. Some of these active control devices, such as synthetic jets have also been explored by Amitay[6]. Their flow attachment was, however, limited to a certain region of the flow field and complete attachment was limited to few cases. Similar control devices (piezoelectric synthetic jets) were also employed by Jenkins *et al.*[12] over "Stratford ramp". Based on their results, Jenkins *et al*. concluded that synthetic jets did not have sufficient velocity/momentum to provide effective control. Acoustic excitation devices employed by Ahuja[8] and Zaman[7] showed some benefits. However, these studies were facility dependent[9] and as such are limited from a practical perspective.

A detailed investigation, examining the nature of separation and the means to control it, was initiated over the last few years at the Fluid Mechanics Research Laboratory (FMRL) located at the Florida State University (FSU). In this study, strategetically-located microjets were used to control the flow separation generated by adverse pressure gradients. Based on their success in other applications[13], their ability to produce relatively high-momentum streams

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