Triangular tabs for supersonic jet mixing enhancement

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Abstract

Jet control with tabs is an active research area, finding a lot of application. A concise compilation of the literature associated with jet control is recently compiled by Rathakrishnan [1]. From this survey it is evident that for an efficient mixing of the mass entrained by the large scale vortices, at the boundary of a free jet, an appropriate proportion of mixing promoting vortices need to be introduced into the jet flow, to ensure rapid mixing. Indeed, rapid mixing, resulting in the mixing of the jet issuing from the engine nozzle, with the cool air mass of the atmosphere to which the jet is discharged is essential to ensure that the length of the hot plume at the nozzle exit is reduced to as short as possible to minimize the infrared signature, resulting in high stealth capability for missiles. Also, this kind of rapid mixing of the hot gases with the cold ambient will result in the reduction of base heating, which is highly desirable for launch vehicles. Because of this kind of high-tech applications, large quantum of research has been done on jet mixing. However, until 2009 the school of thought was that the length of the tab should be within the boundary layer. This hypothesis is based on the vortex flow physics, namely that a vortex should have high vorticity and find large residential time to promote mixing efficiently. But in 2009, Rathakrishnan in his work on experimental studies on the limiting tab [2], demonstrated that the tabs need not be within the boundary layer and indeed, the tab length can extend upto the nozzle radius. Following this, Chiranjeevi and Rathakrishnan [3] showed that, corrugations introduced at the tab edges result is better mixing, owing to the generation of a mixing promoting vortices of mixed size. However, they studied only a rectangular tab with and without corrugation. Also, they studied only rectangular corrugation. Combining all the concepts, in 2011 Arun Kumar and Rathakrishnan [4, 5] studied triangular tabs and found that the triangular tabs shedding vortices of continuous variation in size is a better mixing promoter than rectangular geometry. But these investigations were with isosceles triangular tab. Even though this triangular tab sheds vortices of continuous variation in size, the vortices shed from the opposite edges at a given height are of identical size. To improve the mixing process by introducing vortices of continuously varying size, even from the opposite edges at a given height, right-angle triangular tabs are investigated in the present study. In addition to right-angle triangular tabs, with sharp and truncated vertex, rectangular tabs were also studied for comparison. Figure 1 shows the tabs studied.

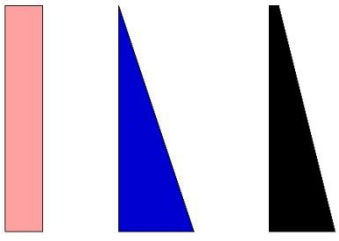

Figure 1 Schematic of triangular and rectangular tabs

Two tabs, of geometrical blockage, defined as the tab area normal to the flow to the nozzle exit area, of 2.5% each, located diametrically opposite at the exit of a Mach 2 circular nozzle, as shown in Figure 2, were studied, at different levels of expansion.

The centerline decay of the uncontrolled and controlled jets is shown in Figure 3, for nozzle pressure ratio 7. It is seen that, the strong waves prevailing in the long core of the uncontrolled jet is made weaker by all the tabs. Among the tabs, the truncated tab is found to be the best mixing promoter, resulting in the shortest core with weakest waves. This clearly demonstrates that the truncated right-angle triangular tab shedding mixing promoting vortices of continuous variation in

size, even at the identical opposite edges, is capable of promoting the mixing better than the identical tab with sharp vertex.

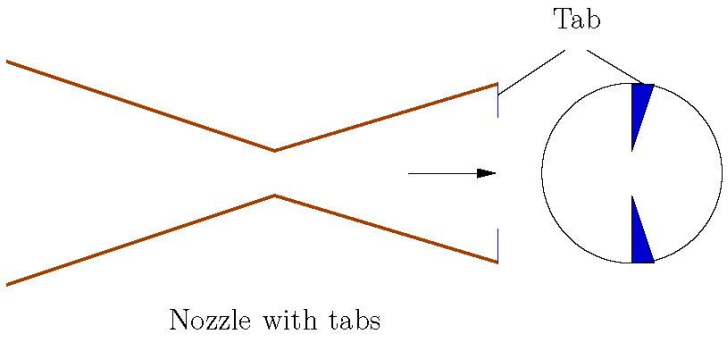

Figure 2 Schematic of triangular and rectangular tabs

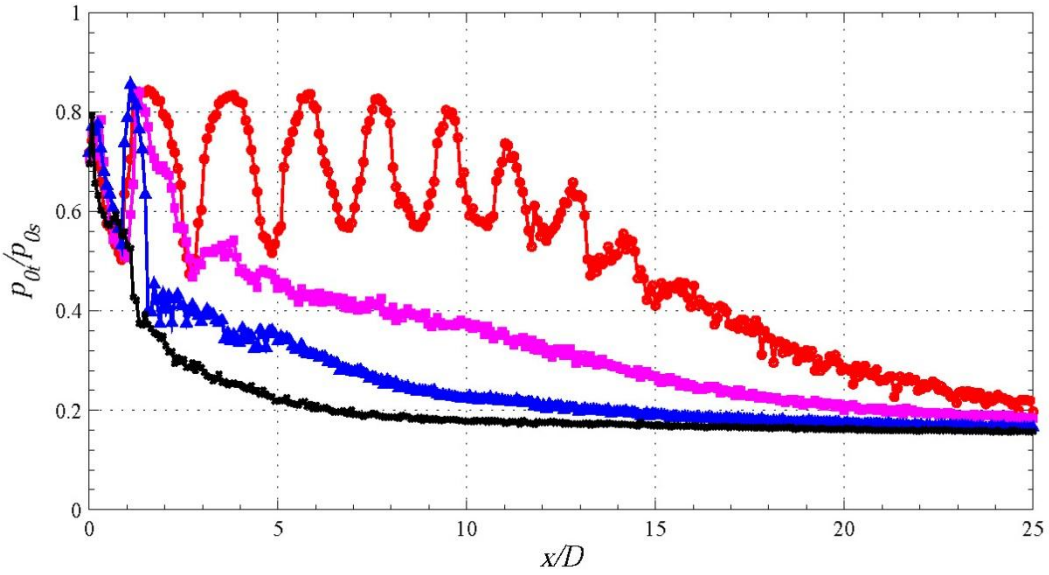

Figure 3 Centerline decay of Mach 2 jet at NPR 7

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