Assessment of turbulence models on transverse jet in cross-flow.

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Abstract:

High speed jets in crossflows are central to fuel injection in supersonic combustion ramjet engines. In supersonic combustion ramjet engines, the sonic under-expanded transverse jet of fuel is injected into a supersonic cross flow of air, where efficient mixing of fuel and air is one of the major critical issue. Due to the limited flow residence time inside combustion chamber, the enhancement of supersonic turbulent mixing of jet fuel and crossflow air is a critical issue in developing supersonic air-breathing engines. The Accurate estimation and detailed physical understanding of the turbulent mixing mechanisms play important roles in combustor design of these engines. The detailed physical analysis of high speed jet interaction with a supersonic crossflow for different gases depending on parameters of the flow field as the Mach numbers of the air stream, parameters of turbulence, pressure ratio should be performed. Such an analysis can improve understanding of the flow structures responsible for the generation of the pressure field and for the mixing of the injected fuel jet with the cross flow. These type of analysis will contribute to understanding of scramjet fuel injection systems. In the current study the flow field resulting from a transverse injection through a slot into crossflows is numerically simulated. Numerical simulations are used to study an under-expanded jet injected into a supersonic and subsonic cross flow and also the effect of slot width on the transverse slot injection flow field has been investigated. This study examines the flow structure, separation topology and performance characteristics of an under expanded transverse jet issuing normally into subsonic and supersonic free streams as shown in figure 1. The influence of the compressibility effect on the shock wave structure and on the vortex system ahead and behind of the jet are studied in the context of the SST $k - \omega$ and LES models of turbulence. The influence of the jet Mach number and the ratio of the jet and flow pressure on shock wave structure of the flow and jet penetration depth is studied. The numerical results are compared with the previous study done by [1-10] and also with available experimental data. Series of mesh refinement study is done for more accurate results. It is found out that wall pressure profile of the transverse slot injection for the high jet-to- crossflow pressure ratio is predicted more accurately by the SST k- ω turbulence model. High jet-to-crossflow pressure ratio can increase the jet penetration depth in supersonic flows. Jet penetration depth found out to be increasing with the increase of slot width.

Keywords: supersonic flows, CFD, Shock wave

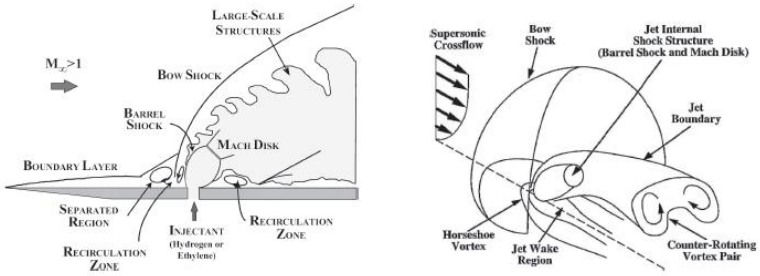

Figure 1. Flow structure during transverse injection of an under-expanded jet into a supersonic crossflow (2D-Ben-Yakar et al, 3D-Gruber et al)

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