EXPERIMENTAL STUDY OF UNSTEADY CHARACTERISTICS OF TURBULENT MIXING LAYER FLOW OVER AN OPEN STEP AND A SQUARE-EDGED RIB

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ABSTRACT: Spatio-temporal characteristics of the wall-bounded turbulent mixing layer flow over an open step and a square-edged rib were extensively studied in a low-speed wind tunnel. Simultaneous measurements of wall-pressure fluctuations and velocity measurements were performed by using microphone array and X-wire/split film, respectively.

KEY WORDS: entrainment, turbulent flow, unsteady, wall pressure fluctuations, large-scale vortical structures

BRIEF INTRODUCTION: The time-mean, spectral and unsteady characteristics of a wall-bounded turbulent mixing layer flow over an open step and a square-edged rib were investigated experimentally. Extensive spatio-temporal measurements of the wall pressure fluctuations and velocity fluctuations were performed using a microphone array and an X-type gold-plated / split-film hotwire probe, respectively. The experimental data was analyzed in terms of conditional averaging, auto-spectra, cross-

correlation, coherence, wavenumber-frequency spectra, Continuous Wavelet Transform (CWT) and Multi-Resolution Analysis (MRA) based on Maximal Overlap Discrete Wavelet Transform (MODWT).

A two-dimensional subsonic open-circuit wind tunnel was set up. Three configurations, with step heights of $H/\delta = 0.67, 1.00$ and 1.67 were chosen for comparison. Inspection of the velocity fluctuations revealed a strong perturbation of the flow by the step of height $H/\delta = 1.67$, resulting in an intensification of the large-scale vortical structures. A wealth of information on the unsteady features of the scale-variant vortices superimposed in the turbulent mixing layer flow was demonstrated by using multi-resolution analysis based on the MODWT. The convective features of vortices at $St = 0.075$ and the higher harmonic frequencies $St = 0.15$ and 0.29 were delineated by examining the conditionally averaged velocity field and Reynolds stress field, the conditionally averaged wall pressure field, and the cross-correlation between the conditionally averaged wall pressure at $x/H = 15.0$ and the velocity field. For the separated and reattaching flow over the square-edged rib, the shedding large-scale vortical structures and the flapping separation bubble were clearly captured.

In general, this dissertation sheds lights on the unsteady characteristics of two classic wall-bounded turbulent mixing layer flows by using a wall-pressure and velocity joint measurement system.