IMAGING OF MICRO-RAMPS IN SUPERSONIC FLOW AND THE EFFECT ON FLOW OVER DOUBLE WEDGE

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Abstract Visualization of micro-ramps in supersonic flow and flow over a double ramp is performed using nano-tracer planar laser scattering (NPLS) technique in a Mach 3.0 low noise wind tunnel. Firstly, the wake flow features of Ashill micro-ramps are presented. Then, imaging of supersonic the double wedge is obtained and the coherent structures are investigated. Lastly, the effect of micro-ramps on supersonic flow over the double wedge is studied.

EXPERIMENTAL FACILITY

Micro-vortex generators (MVGs) have attracted widespread attention in recent years for their promising utility in delaying shock-induced turbulent boundary layer separation [1-2]. The experiments were performed in a Mach 3.0 low-noise wind tunnel. The total temperature and total pressure are 300 K and 101 kPa, respectively. The micro-ramp is one kind of MVFs. The micro-ramp in the present experiments has a height of h =4 mm (about 39% boundary layer thickness δ), with a wedge half angle α =14°and a chord length c =10.3 h . It is scale to Ashill's specification [1]. A single row of three micro-ramps are placed on a flat plate, with the spanwise space (the distance of two micro-ramps' center line) s = 7.5 h . The dimensions of the double wedge are 65mm in width, 90mm in length and 30 mm in length for the first ramp. The deflection angles of the model are (15°, 35°), belong to the domain 6 [3]. The schematic illustration of experimental arrangements is given in Figure 1. Nano-tracer planar laser scattering (NPLS) is a flow visualization technique with a high temporal-spatial resolution and can reveal fine structures of supersonic flow [2].

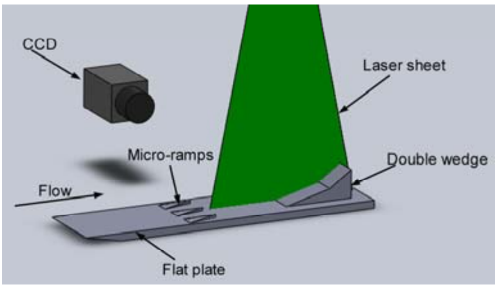

Figure 1. Sketch of the experimental setup.

RESULTS

An instantaneous image of Ma 3 flow over the micro-ramps is shown in Figure 2. The incoming boundary layer, the shock waves (labeled as S_1 and S_2) and structures of micro-ramps' wake flow can be identified clearly. As early studies, the wake exhibits a feature of low speed and low pressure, resulting in low tracer particles and low luminance [2]. After the micro-ramps, there is a relatively steady zone with a dark strip. This strip appears to have a trend of mounting up with an average elevation angle of 5.8° (almost equal to the lean angle of the micro−ramp's up surface 5.7°). It can be observed that the initial vortex structure could only survive for length of about 4 δ (about form 0 to 40 mm in Fig. 2) and subsequently it is replaced by a new large scale structure (after 40 mm in Fig. 2). The large scale structures exhibit obviously periodic and a trend of elevation and moreover these structures are hairpin-like vortices.

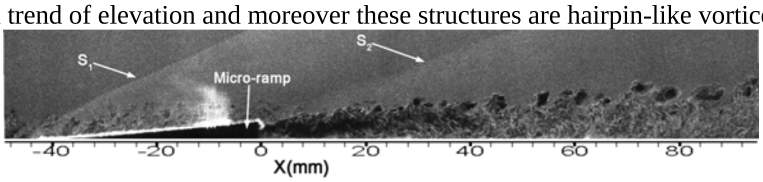

Figure 2. An instantaneous image of Ma 3 flow over the micro-ramps.

An instantaneous image of Ma 3 flow over the double wedge with and without the micro-ramps is presented in Figure 3. The origin is set at the leading edge of the model. In Fig. 3b, the distance between the leading edge of the micro-ramps and the leading edge of the model is 100 mm. In Fig. 3a, the shock waves marked as S_1 and S_2 are generated by the first and second ramp of the mode; in Fig. 3b, the shock waves labeled as C_1 and C_2 are originated from the micro-ramps, while the shock waves C_3 and C_4 are caused by the model. The shocks S_2 and C_4 are distorted due to the interaction with the boundary layer. Compared with Fig. 3a, the boundary layer is greatly altered due to the micro-ramps in Fig. 3b. The boundary layer thickness is increased and the large scale vortices exhibit different features resulting from the micro-ramps. The vortices (marked as A and B) at the second ramp display some different characteristics from that at the first ramp. Two typical high spatial resolution images of large scale vortex structures at the double wedge with the micro-ramps are shown in Figure 4. Moreover, the vortices structures are further investigated.

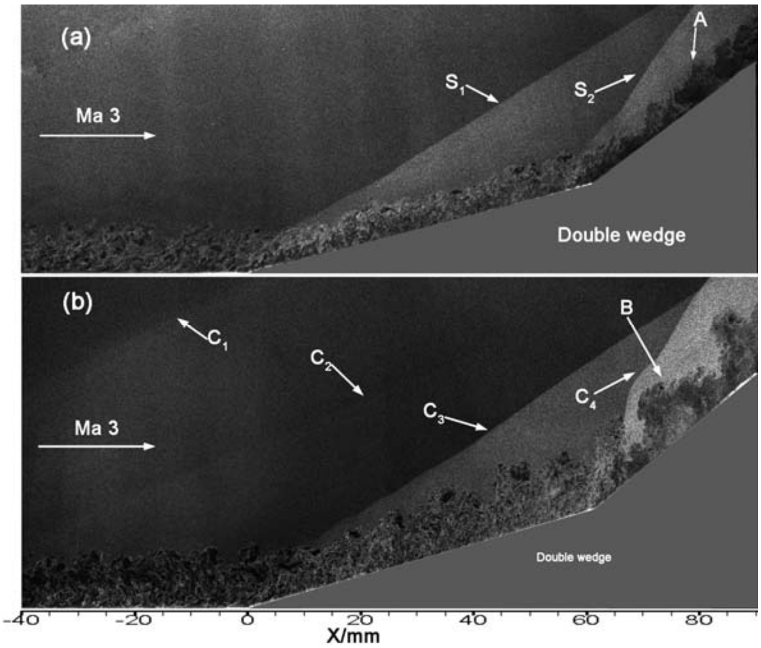

Figure 3. An instantaneous image of Ma 3 flow over the double wedge: (a) without the micro-ramps; (b) with the micro-ramps

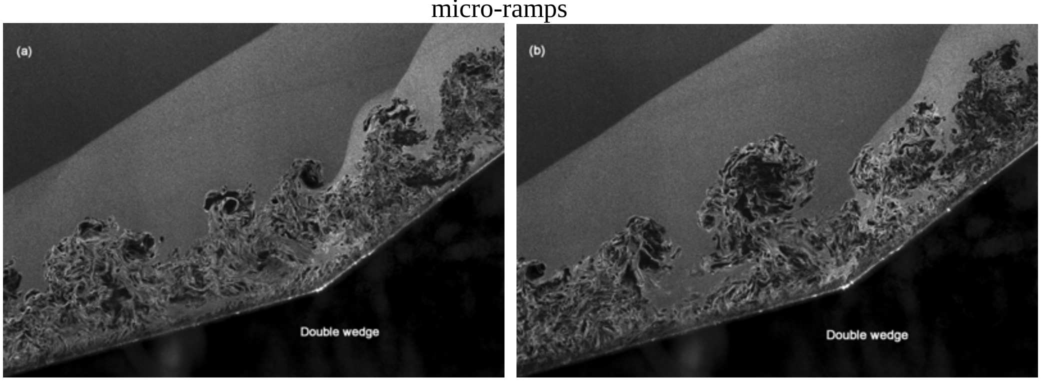

Figure 4. Two typical images of large scale vortex structures at the double wedge with the micro-ramps

References

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