INVESTIGATIONS OF SUPERSONIC FLOW PAST MICRO RAMP AND VANES

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Summary: The supersonic flow past micro ramp and vanes has been investigated numerically with Large Eddy Simulation and 3rd-order WENO scheme. Efforts have been made to characteristics the similitude and the difference of flow details. It is found that the vanes are more effective than the ramp in the boundary layer control.

In supersonic/hypersonic flight, shock wave/boundary layer interaction (SWBLI) is a typical fluid dynamic phenomenon. As we know, the SWBLI can significantly reduce the quality of the flow field and cause unsteady separation of the boundary layer, and lead to the increased aerodynamic drag, heat-fluxes and fluctuating pressure loads etc.[1]. Vortex generator (VG) is a hopeful device to overcome these problems [2]. More recent work has found that micro vortex generators (MVGs) with the height less than the boundary layer thickness can be effective at flow separation control. Actually, there are more than one kind of MVGs, like the micro ramp and micro vane, etc, and their theoretical guidance and the mechanism of the flow control is still in investigating. In this study, we try to get further understanding of the control mechanism of both micro ramp and vanes

The three-dimensional compressible LES equations are solved using the finite volume method. A third-order WENO scheme is used to discretize the convective term. The immersed boundary methods are used to mesh complicated boundary, and the blockstructured adaptive mesh refinement algorithm utilized to supply the required temporal and spatial resolution locally based on the hydrodynamic refinement criteria.

The computational model and domain for the supersonic flow past ramp and vanes is shown in Fig.1. The physical models are based on the previous experiments[2]. The geometric parameters of the vane are, h=2mm, a=7.5mm, b=1.25mm, c=13.05mm. As for the ramp, h=2mm, w=7.5mm, c=9.246mm. The inflow is laminar flow with Mach number Ma=2.5, and Re≈1.7×10^5. The computational boundaries are all outflow condition except for the bottom boundaries, and the wall is adiabatic.

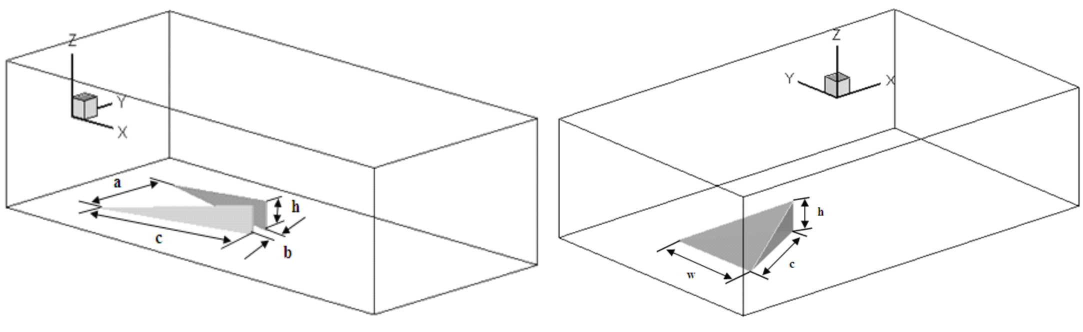

Fig. 1 Computational model of both micro vane (left) and ramp (right)

Surface skin friction lines of both the micro vane (left) and ramp (right) on the flat are shown in Fig.2. There is a separation line in front of the ramp, and similar to other blunt bodies, horseshoe vortexes form in front of the ramp and spread downstream from both sides of the ramp. Secondary separation lines beside and after the ramp are also visible. Different with that, there is a pair of counter rotating vortices between the two vanes and two separation lines extend to downstream which become outspread after the vanes.

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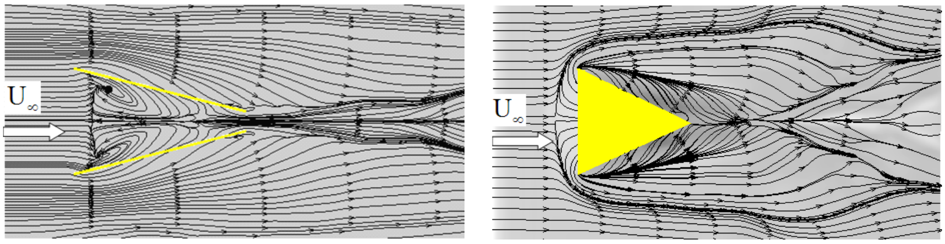

Fig. 2 Surface topology of both vane (left) and ramp (right) at *t=0.0005s*

Fig. 3 describes pressure contours and streamlines on different slices vertical to the inflow. High pressure area locates at the middle of two vanes and low pressure area is behind them. But the very high pressure area locates near the upper surface of the ramp which indicates that there is a shock wave in this area. It is clear that the pressure variation caused by the vanes is smaller than the ramp, which suggests that the ramp causes a larger parasitic drag. Streamlines on slice x1 (left), indicate that there is a pair of vortices which is formed by the flow near the bottom wall, and also a pair of secondary vortices is under them. Meanwhile, a pair of vortices forms as the upper flow moves past the vane surface. When travel to the downstream, the two upper pairs of vortices merge together to form two larger circles as described in x2 plane. As for the ramp, we can only see a pair of vortices in x1(right) plane, and the pair of secondary vortices does not generate until the flow travels behind the ramp.

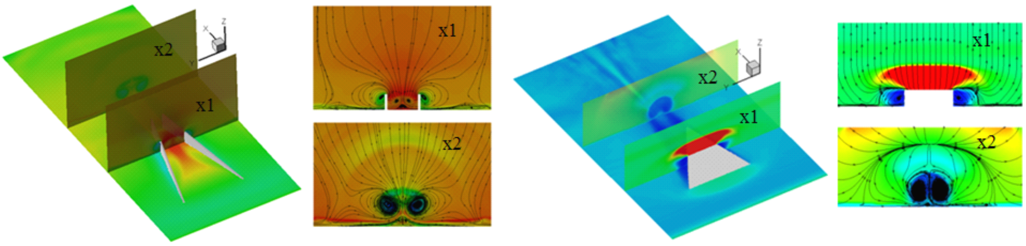

Fig.3 Pressure contours of both micro vane (left) and ramp (right)

CONCLUSIONS

The supersonic flow past micro ramp and vanes has been investigated numerically. The numerical results characteristic the pressure distribution and vortex structure of the ramp and vanes. The pressure variation caused by the vanes is far less than the ramp, which suggests that the ramp causes a larger parasitic drag. Meanwhile the vortices generated by the vanes which can make the energy change between the boundary layer flow and outer high energy flow are more and stronger than the ramp. Although both the ramp and vanes have the effect to control the boundary layer, it is obvious that the vanes are more effective in the boundary layer control.

References

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