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Wavefront distortion of hypersonic plate boundary layer under two-dimensional strip

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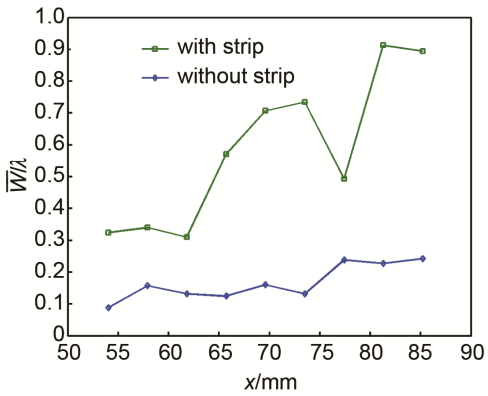

Comparison of wavefront distortion of plate surface with and without strip.

Abstract: Aero-optical effects caused by hypersonic boundary layer transition are always challenges in improving the accuracy of directed energy weapon. In order to avoid hypersonic boundary transition in the optical detection window, which can generate large scale structures and cause wavefront distortion, researchers have tried many flow control methods to accelerate or delay transition. We investigate the effects of 2D strip to the hypersonic boundary layer in the virtue of theoretical analysis and wind tunnel experiments. A radial shearing interference system is used to measure the wavefront distortion.

The experiment is conducted in FD-03 tunnel of China Academy of Aerospace Aerodynamics. Free stream total pressure is 1.05 MPa, total temperature is 350 K, Mach number is 5.01, Reynolds number is 2.45×10^7, and aerodynamic noise is 0.3%. We use plane model as an experimental model, the size of plane model is 250 mm×120 mm, the thickness of leading edge is 1 mm, and attack angle is 0. The plane is 30 mm above the bottom of the entrance of nozzle. The roughness is 0.8 μm~1.6 μm. The strip is attached on the plane 35 mm away from leading edge. The size of strip is 20 mm×120 mm×0.5 mm.

High-precision wavefront measurement system is used to measure the wavefront distortion of hypersonic boundary layer. This system based on the radial shearing interference system can measure the wavefront of flow filed precisely. We measure the wavefront of circular region with diameter of 0.9 mm and space of 3.9 mm, to reveal the development of hypersonic boundary flow and compare the distribution of wavefront induced by strip with the corresponding data without strip. After the calculation of data analysis program, we get the mean wavefront, root mean square and peak-valley value of wavefront, which are reflections of density distribution of hypersonic boundary flow.

The results prove that high-precision wavefront measurement system can present not only wavefront but also density distribution before the flow transition of boundary layer. In addition, the experimental results show that the wavefront distortion increases quickly when the flow is obviously unstable. Finally, comparing the distribution of wavefront induced by strip with the corresponding data without strip, we find that the mean wavefront, root mean square and peak-valley value of wavefront with strip are much larger than that without strip. It means the strip may accelerate the development of hypersonic boundary flow, and make the flow unstable earlier. The conclusions have some reference values to flow control of the guidance system on the hypersonic aircraft.

Keywords: wavefront; strip; hypersonic speed; plate boundary layer

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