# EXPERIMENTAL INVESTIGATION OF MACH 3.0 SUPERSONIC DOUBLE CONE FLOW AND COMPARISONS BETWEEN EXPERIMENTAL AND NUMERICAL RESULTS

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*Abstract* Fine structures of Mach 3.0 supersonic flow over various double cone geometries are clearly observed with nano-tracer planar laser scattering (NPLS) technique. And comparisons are made between experimental and numerical results, which show good agreement in general, however, in the vicinity of the separation region there's great departure

## INTRODUCTION

Double cone geometries are typical models in supersonic and hypersonic flow. However, the flow field is so complicated that few techniques could realize the fine structures which include the shock wave interaction, shock wave boundary layer interaction and separation [1]. In the past twenty years, a great amount of work was dedicated to hypersonic double cone flow especially at Mach>8 for CFD validation and pressure and heat transfer distribution were measured [2-4]. Little attention was paid to supersonic flow over double cone geometries. With NPLS technique, fine structures of the flow field in the symmetry plane could be detected, which is of great value to CFD validation and engineering. NPLS technique was developed by YI and ZHAO et al, and it has been successfully applied in the measurement of density field, velocity field and aero-optics [5-7].

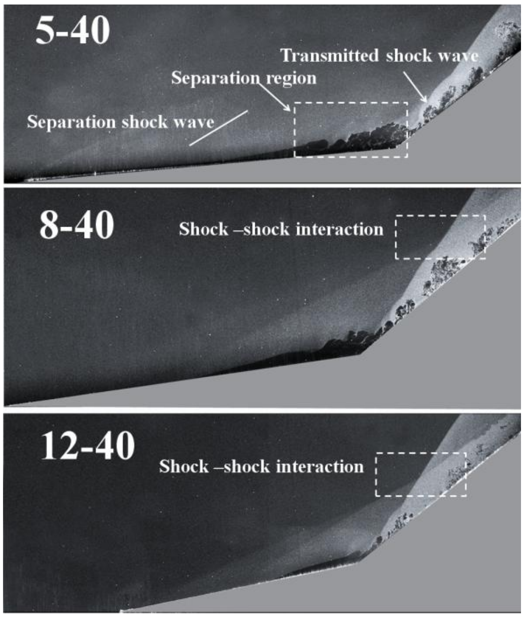


**Figure 1.** NPLS image of flow structures in double cone configurations.

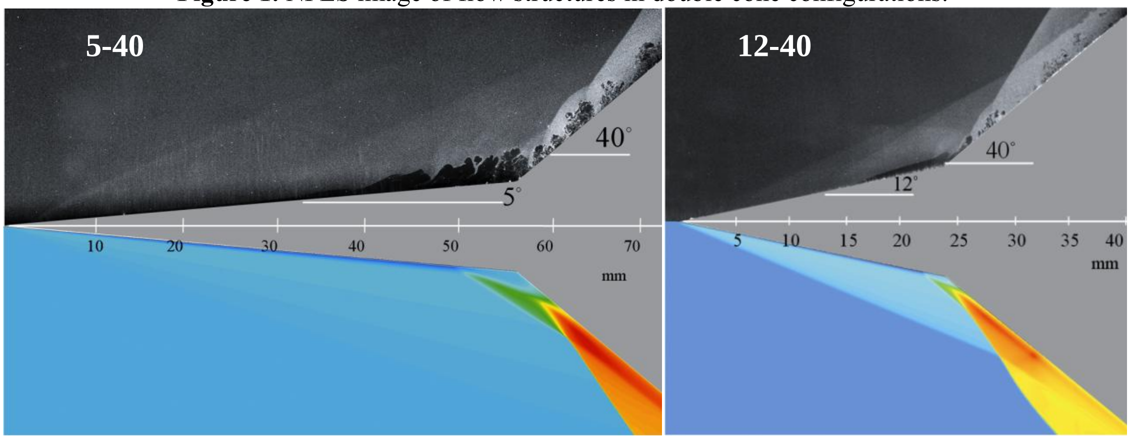


**Figure 2.** Comparisons of numerical and experimental results of 5-40 and 12-40 configurations.

## EXPERIMENTAL RESULTS AND COMPARISONS

Three double cone geometries of various parameters are investigated in a low-noise supersonic wind tunnel whose nozzle is designed by B-spline technique and could ensure harmonious supersonic flow in the exit plane. The first cone angles are 5, 8 and 12 degree, while the second cone angle is 40 degree. The first cone length is very short and in fact the thickness of the boundary layer of the single cone configuration is much thinner than the flat-plate as it is three-dimensional compression [9], however due to the strong adverse pressure gradient induced by the second cone, the boundary layer of the first cone occurs and grows in an incredible speed as shown in Figure 1. To the 5-40, 8-40 and 12-40 double cones separation region and the separation shock wave near the corner could be distinguished. Around the second cone there's shock wave interaction and transmitted shock waves. The boundary layers on the second cone have all developed into turbulent flow. 5-40 and 8-40 configurations have relatively fiercer separation even though the 12-40 configuration also has a separation shock wave, for its boundary layer keeps laminar flow state to the end of the first cone. It could be analyzed that the lager first cone angle works as a transition section and when coming to the second cone the flow will have a smaller turn angle. More large scale vortices could be observed in the NPLS figure of the double cones with a smaller first cone angle.

Numerical computations are done on the 5-40 and 12-40 configurations using the k-epsilon turbulent model and second order upwind scheme and comparisons are made between numerical and experimental results as shown in Figure 2. Numerical results are shown in the form of density contour for the grayscale grades of NPLS figures rely on the intensity of nano-particles and thus rely on the density [6]. As it is shown in Figure 2, the numerical results in general agree well with experimental results, however the separation region sizes are both much smaller and the separation shock waves are closer to the corner than the experimental results. This difference might be caused by the unchanging viscosity considered during the simulations while the actual one changes with the variation of temperature. Fine structures of vortices could not be viewed using ordinary numerical methods.

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