Supersonic Flow Diagnostics using Optical Nozzles

Section: Interdisciplinary

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Optical flow diagnostic techniques have become critical to conduct complex flow diagnostics research. Some of these methods include Particle Image Velocimetry (PIV), both 2D and 3D, Schlieren, Shadowgraphs, and pressure sensitive paints (PSP). For supersonic and hypersonic research, data gathering typically involves using a high-speed wind-tunnel, but some of the issues with wind-tunnels are that they restrict optical access to be able to utilize these visual techniques. To tackle this an innovative glass blown supersonic Mach 2 nozzle is being used to test its ability for these flow diagnostic techniques. To conduct testing for this experiment, a Mach 2 blowdown to atmosphere wind-tunnel was used.

The PSP technique has developed into an important diagnostic tool. It has been shown to be a strong instrument to take measurements in a supersonic and hypersonic flow regime to view surface pressure on test objects, etc. In this investigation, for taking measurements in the wind-tunnel setup, a range of stagnation pressures have been used ranging from 30 PSI to 120 PSI, where 120 PSI would be the required stagnation pressure to isentropically expand to atmospheric conditions. A diamond wedge was used as a test vehicle, and a 3D printed insert was used to match the shape of the supersonic expansion section of the nozzle so inner wall pressures can be measured. Using the wedge shape at a range of up to 60 PSI, potential oblique shock wave pressure trends were able to be observed along with possible shock reflections on the surface at higher pressures. Using the insert compressible flow expansion pressure was seen, with a sudden high-pressure zone occurring at the end of the expansion, also a potential normal shock occurring with used testing conditions.

Some other preliminary results have also been taken using shadowgraphs and 2D PIV. PIV results were taken using 5 micron hollow spheres for seeding. Due to their large diameter particle lag is prevalent with these results, but still show flow trends in the wind-tunnel. Water condensation from air humidity was also observed and it can be used as flow seeding. At this low inlet pressure, the flow velocity was observed to be up to 400 m/s or a Mach number of 1.2 in our supersonic nozzle. Observable in some preliminary results are normal shock waves forming in the expansion of the nozzle due to low inlet pressure (20 PSI inlet testing conditions). Shadowgraph results seem to confirm this hypothesis as well.

Overall results show that it is possible to obtain results using a glass blown nozzle for optical diagnostics of high-speed test targets and of the inner walls. Compressible flow trends are observable using PSP testing along with some preliminary PIV and Shadowgraphs. Mainly PSP has been used with this investigation to generate pressure maps showing the change from subsonic to supersonic based on the inlet pressure. By investigating some of the preliminary results, it is possible to see the application of the glass blown nozzle for supersonic research in the future.