Experimental Investigation of a Tandem Nozzle Supersonic Wind Tunnel

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Abstract

The flow characteristics of a new tandem nozzle supersonic wind tunnel at the Institute of Fluid Mechanics, Technische Universität Braunschweig, is investigated. This tandem nozzle supersonic wind tunnel was designed based on the infrastructure of the existing Hypersonic Ludwieg Tube Braunschweig(HLB), which produces a Ma= 6 flow for 80 ms and reaches unit Reynolds numbers up to 20 million. The new design successfully alters the original Ma=6 flow to a Ma=3 flow using two nozzles and an additional settling chamber, according to Figure 1 while it retains the test section size and the tunnel running time. The flow in the first nozzle exhibits a system of strong shocks which induces flow separation due to boundary layer interactions. The flow re-establishes into an organized state in the settling chamber. Using several devices to damp flow disturbance, the flow eventually obtains a good uniformity. Finally, the flow accelerates along the second nozzle and achieves the desired supersonic state in the test section. CFD-simulations of the tunnel design were reported in Ref. 1. Compared to the normal configuration of Ludwieg tubes, this tunnel has a more complex structure, which gives rise to intricate flow conditions. Therefore, it is crucial to make an overall assessment of the flow quality in the wind tunnel.

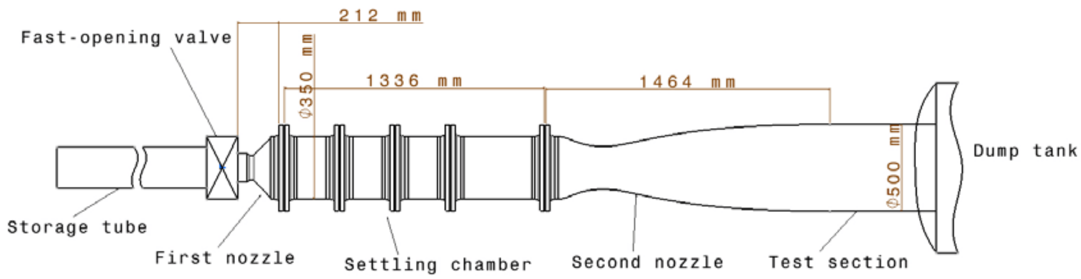

Figure 1: Sketch of tandem nozzle supersonic wind tunnel of the TU Braunschweig

The current assessment of the tandem nozzle tunnel with dedicated measurements is the subject of the present paper. Conventional measurement techniques are utilized in this experiment. The static pressure of storage tube and settling chamber was measured by pressure sensors, which were installed around and along the tunnel wall. These measurements provide a rough impression of how the flow reconstructs before reaching the second nozzle. In order to evaluate the temperature distribution, three thermocouples were placed around the central valve body ahead of the first nozzle with an angular offset of 120° (central axis) and four thermocouples were installed at the rear part of the settling chamber with an angular offset of 90° (central axis) around the wall. Also a 30° wedge model is placed in the test section, which can generate an oblique shock-wave. Schlieren pictures of the flow field are used for visual inspection of test section flow and its homogeneity. Quantitative data of the flow field in the test section are obtained using a 6-probe Pitot rake, that is traversed both in streamwise and traverse directions Through the Pitot rake measurements, the flow uniformity of the entire test section is evaluated. The rhombus area, namely the region of best flow quality, will be outlined as well. In addition, the cross-section flow is measured by rotating Pitot rake by 45° angular offset along central axis, thus the axisymmetric property of tunnel can be checked. Further more, the quantitative influence of the settling chamber inserts, these are perforated plates and screens, on the flow quality will given in the full paper. As a consequence, an optimum combination of perforated plate and screen will be obtained. Figure 2 is one sample of pressure variation for different numbers of perforated plates in the settling chamber.

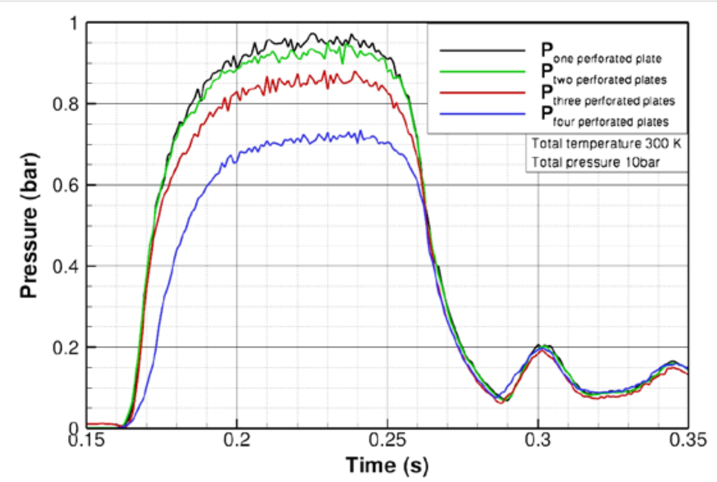

Figure 2: Pressure variation for different numbers of perforated plate in the settling chamber

Finally, the full paper will compare measurements to corresponding numerical flow simulation carried out with the DLR TAU-Code. The results show that the pressure drop in the settling chamber obtained from the experimental measurements is in good agreement with the numerical simulation. The Mach number distribution of the test section also agrees with the numerical simulation, which confirms the CFD-based design of nozzle and settling chamber.

A preliminary assessment of unsteady freestream flow disturbances is provided by investigating boundary layer transition on a 7° cone model with fast response pressure sensors, aiming to measure the dominating instability modes of the laminar boundary layer. The results are used to analyse flow quality of the new tunnel relative to existing blow-down facilities. In conclusion the paper will demonstrate the potentials and feasibility to extend the operation range of high-speed wind tunnels by using the tandem nozzle concept.

[1] WU, J.; RADESPIEL, R.: Tandem Nozzle Supersonic Wind Tunnel Design. Proceedings 47th International Symposium of Applied Aerodynamics, Paris, 26-28 March 2012, 2012.

Keywords: wind tunnel experiment, numerical simulation, tandem nozzle, supersonic flow