

Paper 8.5

The Laser-Doppler-Velocimeter (LDV) used in the ISL shock tunnel

for nozzle flow velocity diagnostics

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ABSTRACT

The ISL shock tubes, see Patz (1970, 1971), were used for several years with square nozzles as shock tunnels for expanding the shock tube flow to hypersonic flow speeds. For this purpose the circular shock tube cross section contour is transformed by means of a specially designed insert from circular to a rectangular nozzle shape, influencing the homogeneity of the circular shock tube flow at the beginning of the nozzle. Furthermore, the flow in this divergent duct is distorted by the boundary layers developing at the nozzle walls. At each of the four corners, formed by two nozzle walls, the wall boundary layers overlap, resulting in a corner boundary layer. The disadvantage of inhomogeneous flow development at the beginning of the square nozzle and the additional distortion by the edge boundary layers was overcome by using circular nozzles attached at the end of the shock tube facility. In this case the circular shock tube contour is continued into the inner of the nozzle. This conical nozzle is used in the non-reflected mode for accelerating directly the supersonic shock tube flow, see chapter 2. A principle sketch of the shock tunnel facility, operated with a non-reflected nozzle, is given in Fig. 1 with the high-pressure driver tube and the lower pressure driven tube containing the test gas.

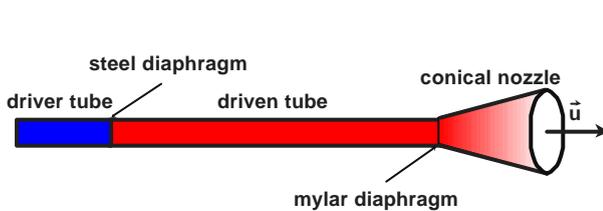


Fig. 1. Principle sketch of shock tunnel facility

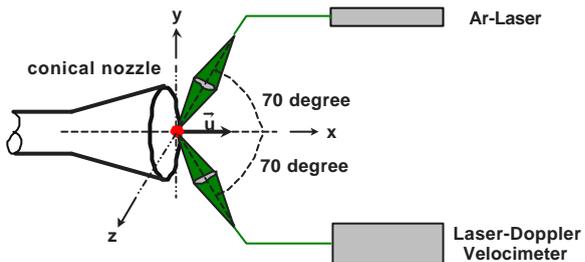


Fig. 2. Optical arrangement of LDV Measurement

In order to get information on the quality of the flow produced by flow expansion inside of the nozzle, velocity measurements have been performed at the nozzle exit using the Laser-Doppler-Velocimeter (LDV) developed by Smeets and George (1978) at ISL. With this device the velocity of tracer particles seeded into the flow was analysed by detecting the Doppler shift dv of the light scattered by the tracer particles passing the measuring volume while being illuminated by a laser light source, here an Ar^+ -laser, see Fig. 2. The LDV-System uses a Michelson-Interferometer for transforming the Doppler frequency shift dv into a varying light intensity output dI . This light intensity variation dI is continuous and proportional to the frequency shift dv . In coupling dv with the Doppler effect, the tracer velocity is obtained. The LDV is explained in detail in chapter 4 and the measurements and results are described in chapter 6. It came out that the flow profile at the nozzle exit is well shaped and the flow speed is in good agreement with the calculated flow Mach number M , i. e. $M = 3.5$, suitable for our future shock tunnel investigations.

For our shock tunnel operation it is desired to produce actual flow conditions around a projectile flying in earth atmosphere from ground level up to altitudes of more than 10 km with flight speeds up to 2000 m/s, i. e., Mach number $M \approx 6$. The Mach number $M = 3.5$ required in this study, was confirmed by the flow speed measurements using the ISL LDV system mentioned above. Additionally to the velocity measurements, the Pitot pressure, using a Pitot sensor, was registered and the required static gas pressure could also be confirmed.