Numerical Simulations of a Subsonic/Supersonic Coaxial Jet for an Efficient Design of Experimental Setup

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Introduction: At the von Karman Institute, a jet rig will be realized, in an anechoic chamber, to investigate the shock-cells flow field and associated noise, generated by a cold subsonic/supersonic coaxial jet. We used COMSOL Multiphysics® to verify the nozzle geometry and to have an insight of the flow field at various test conditions. This will help us in the definition of the experimental techniques that will be applied in the facility.

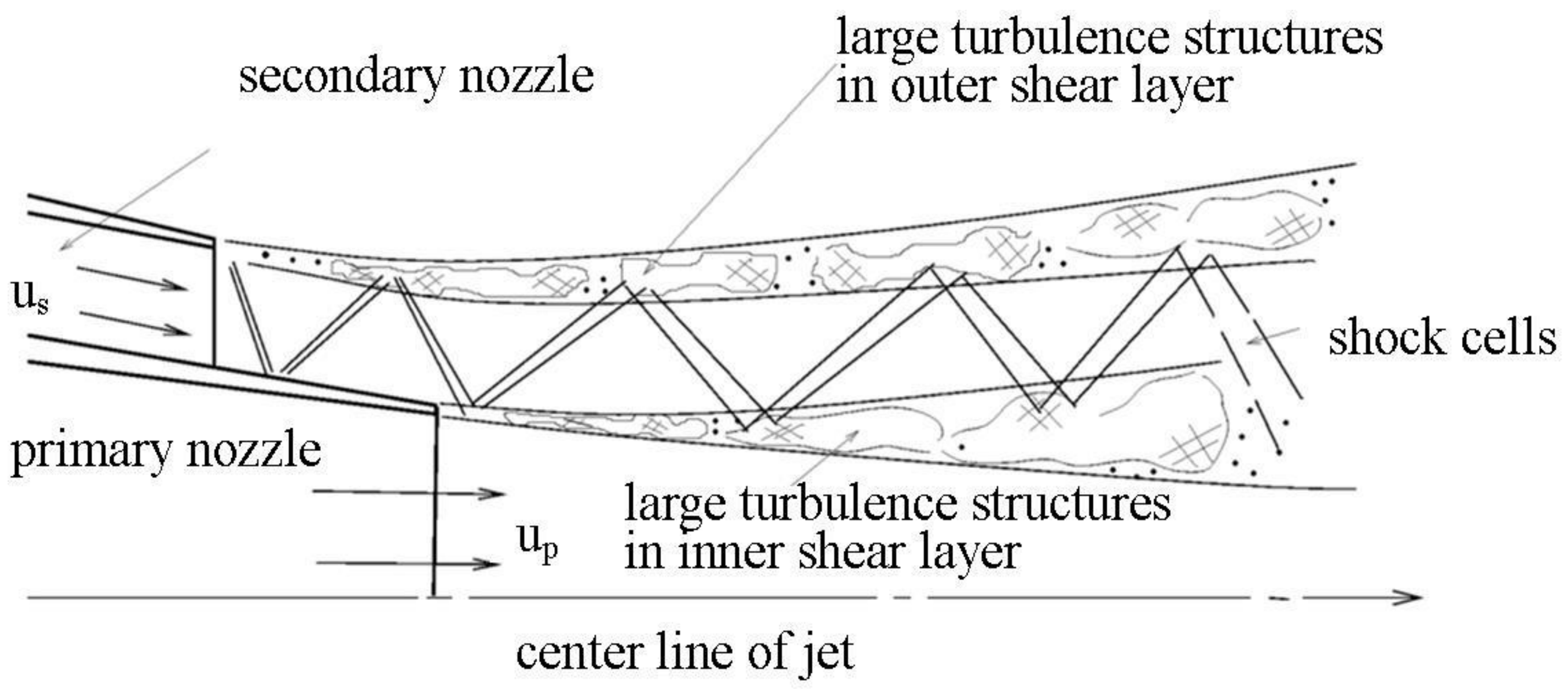

Figure 1. Sketch of shock-cells formation on a coaxial jet [4].

Computational Methods: We used the **CFD module** to have reliable prediction on the topology of the flow. Geometry and test conditions are shown in Fig.2.

We coupled the fluid dynamic problem with the **Heat Transfer in Solids,** with the aim to verify possible influences of the heat transfer through the nozzle walls on the boundary layer development, which is an important factor in the shock-cells noise formation. Finally, we used of the **Solid Mechanics interface** to compute stresses and deformation in the material.

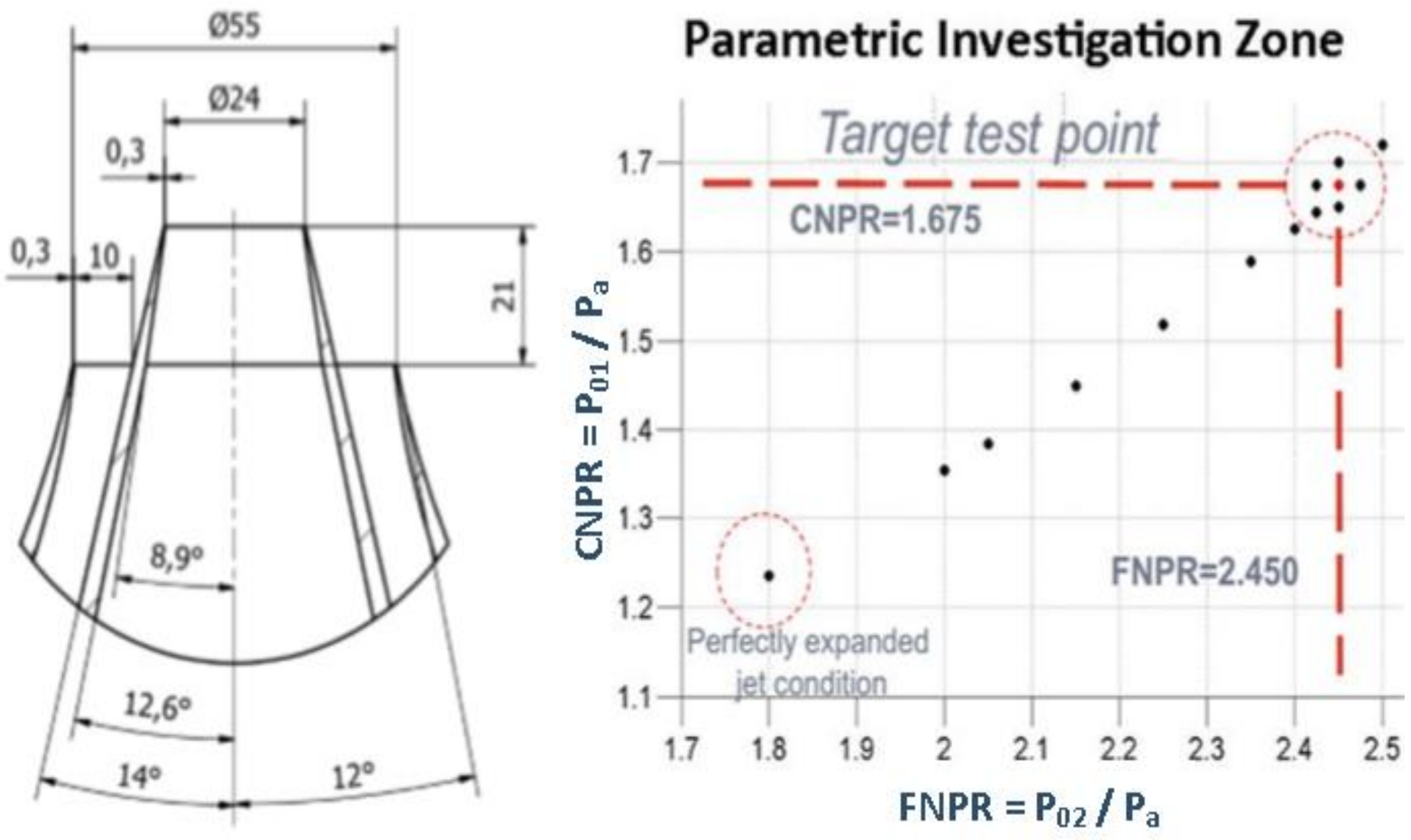

Figure 2. Nozzle geometry and test cases. $T_{02} = T_{01} = T_a$

Results: We found three different flow regimes. At higher pressure, we can observe the formation of a first supersonic cell, which is interrupted by an oblique strong shock wave starting at the lip of the internal nozzle (Fig.3). After that, the external flow became again supersonic and have the formation of shock-cells in the wake between the internal shear layer and the external shear layer.

Lowering the pressure, we have the formation of shock-cells both in the wake and at the exit of the external nozzle (Fig.4). Further lowering the pressure we can find shock-cells only at the exit of the external nozzle.

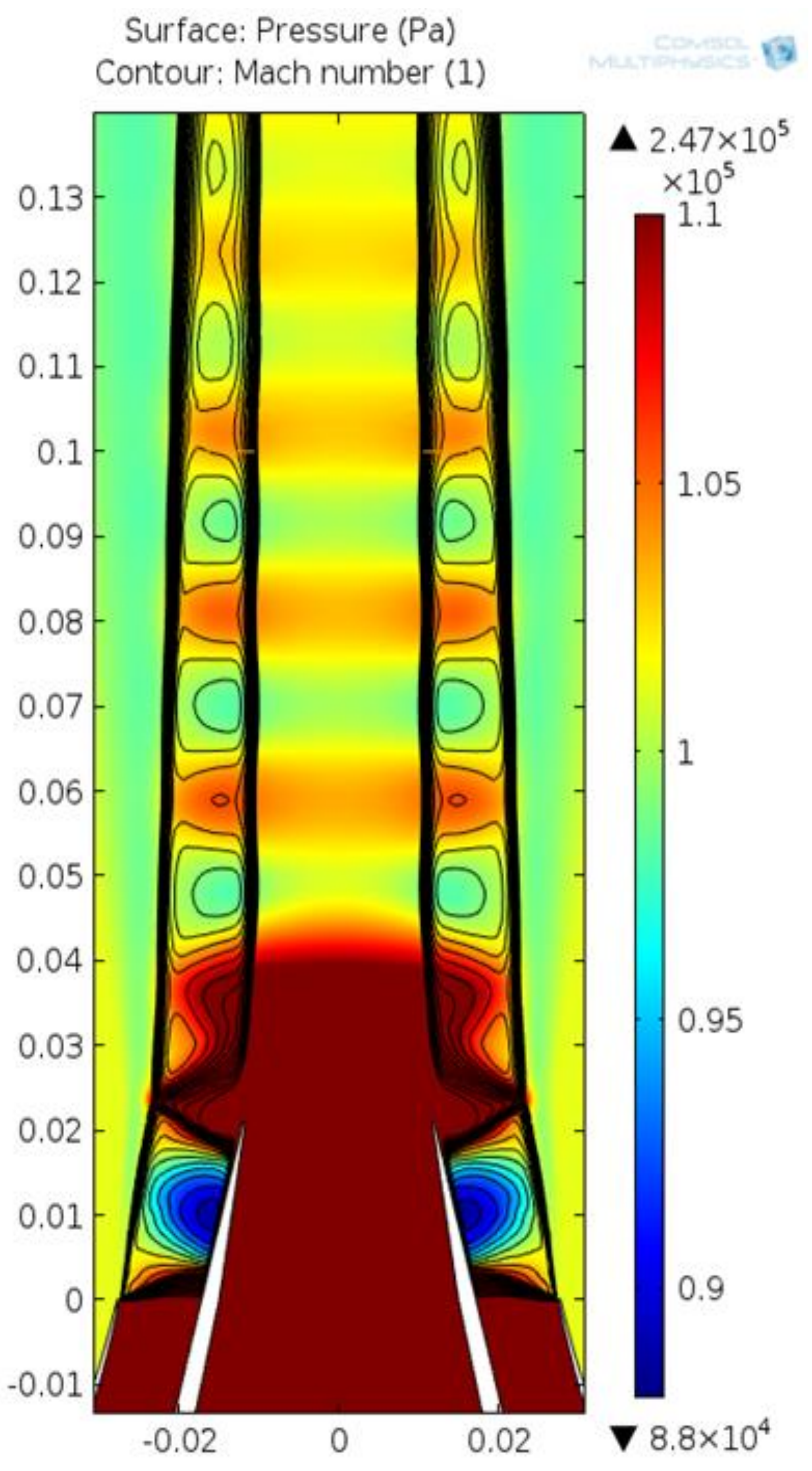

Figure 3. Flow field at FNPR=2.45, CNPR=1.675

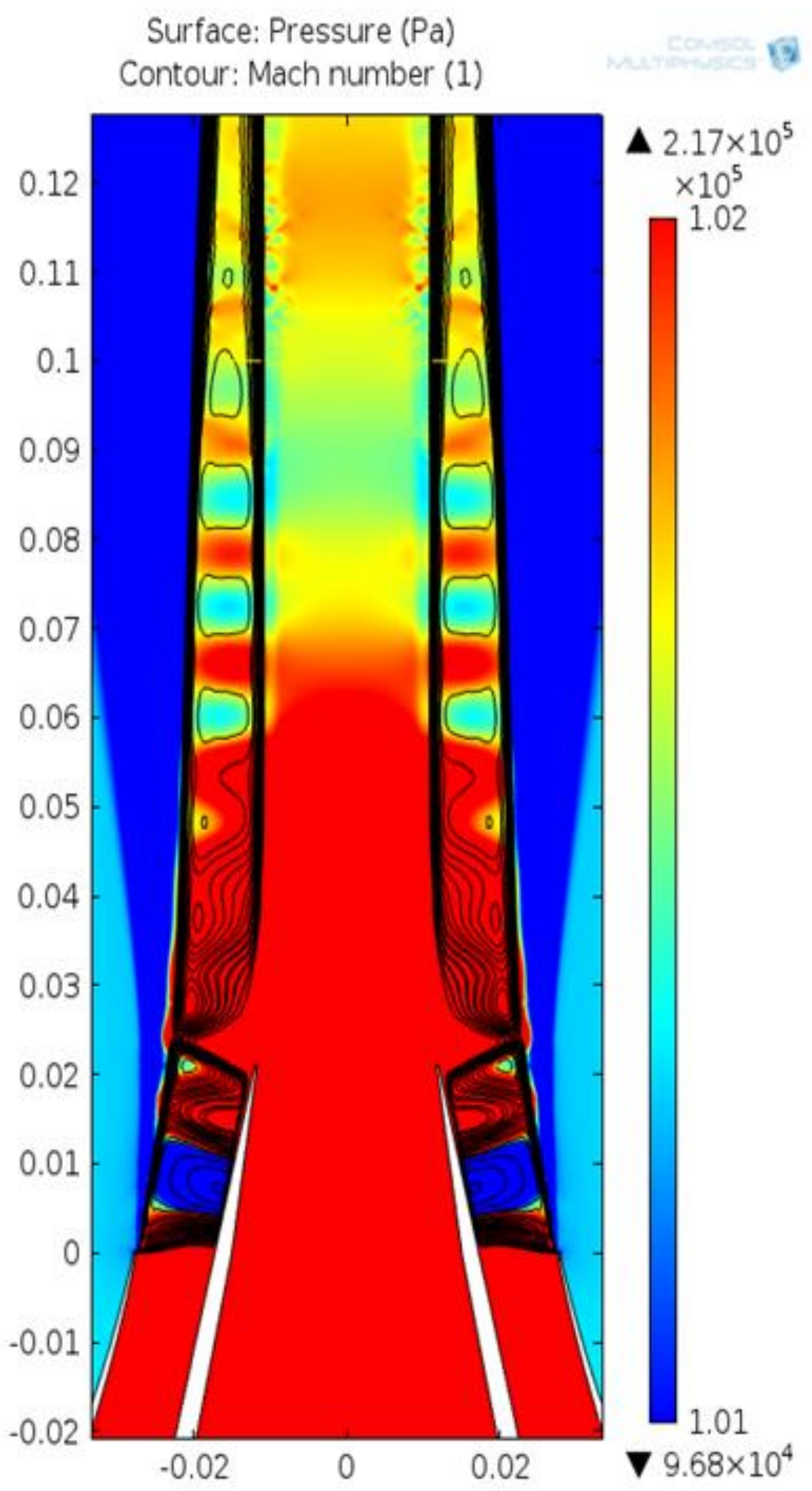

Figure 4. Flow field at FNPR=2.15, CNPR=1.45

We extracted the Mach profiles along a streamline (Fig.5), and based on this, we estimated the range of frequencies that we should expect in the experiments based on the fluid particle travel time (Fig.6).

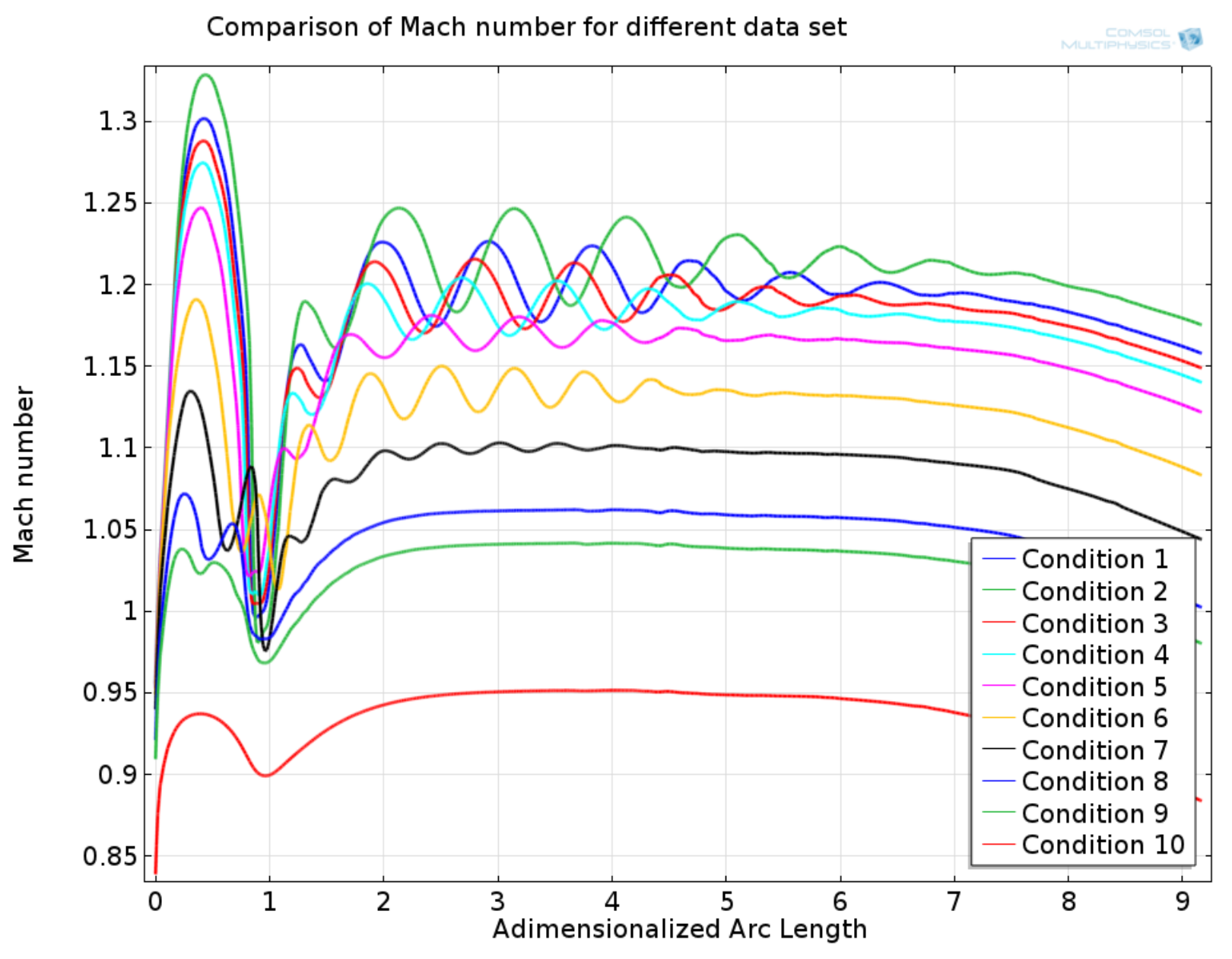

Figure 5. Mach number profiles along a streamline passing the shock-cells for different test conditions.

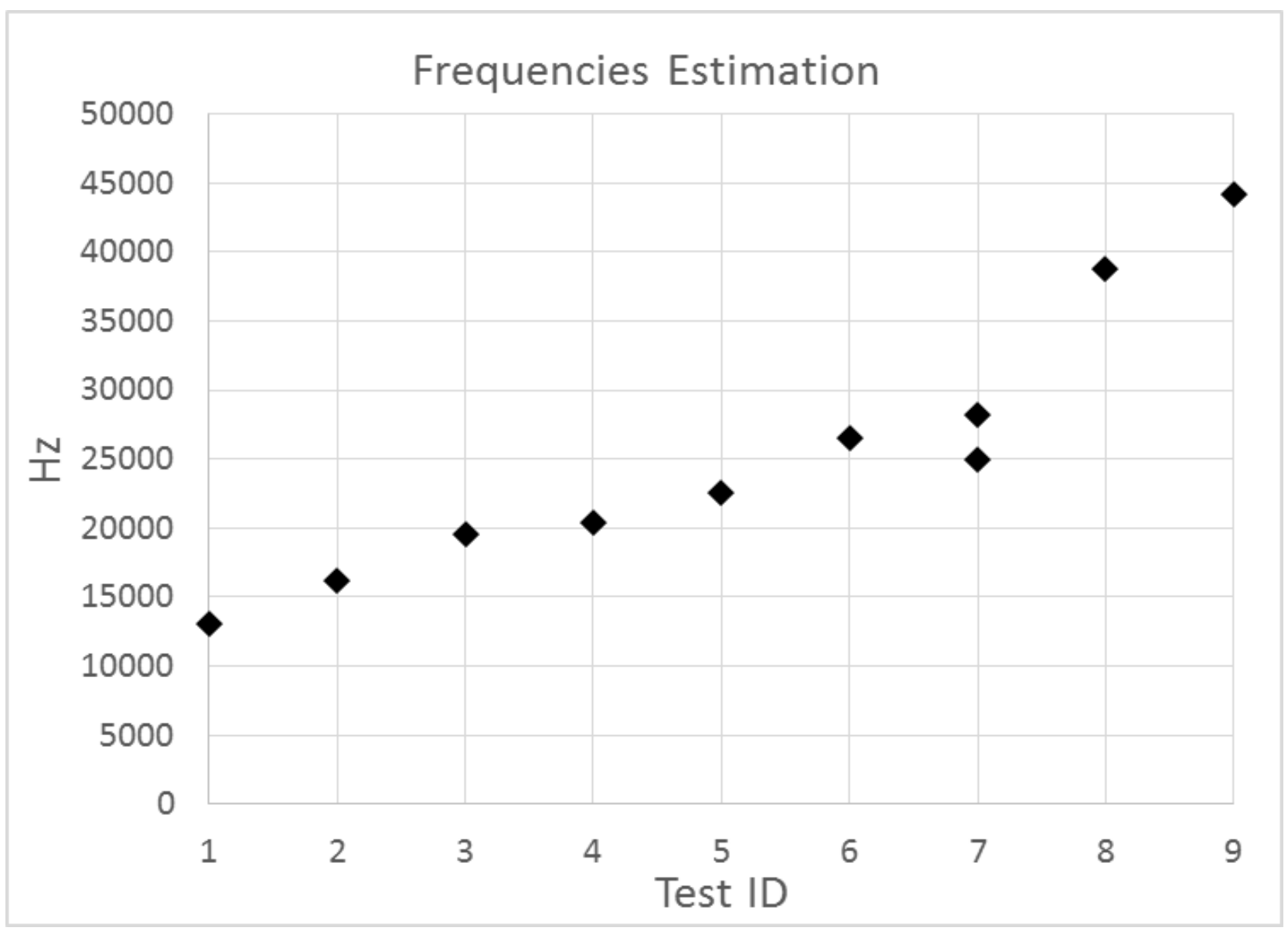

Figure 6. Frequency estimation based on a fluid particle travel time along a streamline passing through a shock-cell.

Conclusions: We validated the nozzle geometry through CFD and mechanical computations, and we predicted the flow field for different conditions. The best setup for flow and aeroacoustic measurements will be chosen accordingly.

References:

1. Tam, C. K. W., Pastouchenko, N. and Viswanathan K., “Broadband Shock-Cell Noise from Dual Stream Jets” 14th AIAA/CEAS Aeroacoustics Conference (29th AIAA Aeroacoustics Conference). May 2008
2. André, B., Castelain, T., and Bailly, C., "Broadband Shock-Associated Noise in Screeching and Non-Screeching Underexpanded Supersonic Jets", AIAA Journal, Vol. 51, No. 3 2013,

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