Numerical simulation of turbulence induced aeroacoustics in a simplified HVAC duct

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1. Abstract:

This work involves calculating the sound generated by fluid flow inside a simplified HVAC duct using a CFD solver. The noise that is generated by the flow is computed using ANSYS Fluent© and is to be compared with both experimental and simulation data from acoustic solvers. The main goal of the work is to estimate the efficiency of using only the CFD code in obtaining the acoustic field results compared to the general method where the acoustic field is calculated using a specialized acoustic solver as a follow-up step to the fluid flow simulation.

2. Model Description

The model used for this study is a square tube (80*80mm) with a 90° bend with a throttle flap attached at an angle of 30° in the flow direction after the bend. The geometrical dimensions of the model are shown below in Figure 1 .

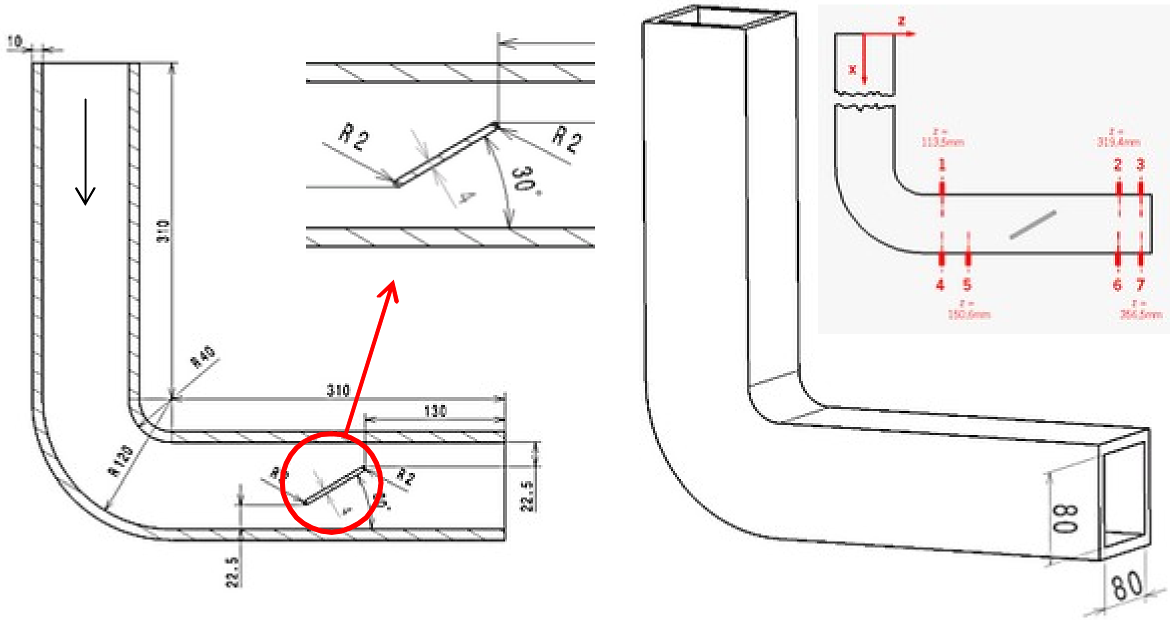

Figure 1 : Geometry of the simplified HVAC duct; left: section cut, right: perspective view

The unsteady wall pressure fluctuations were measured at 7 positions within the HVAC duct. For the acoustic measurements in the far-field region a microphone array at the orifice of the duct was used. For a detailed description of the geometry, measurement technique and specifications used refer [1].

3. CFD-Methodology

The computational domain is presented in Figure 2. A non-reflective boundary condition is set at the outflow to prevent the unphysical reflections into the acoustic domain. Since the model is symmetrical, in order to reduce the simulation time and computational requirement only half of the model (15 million cells) was used.

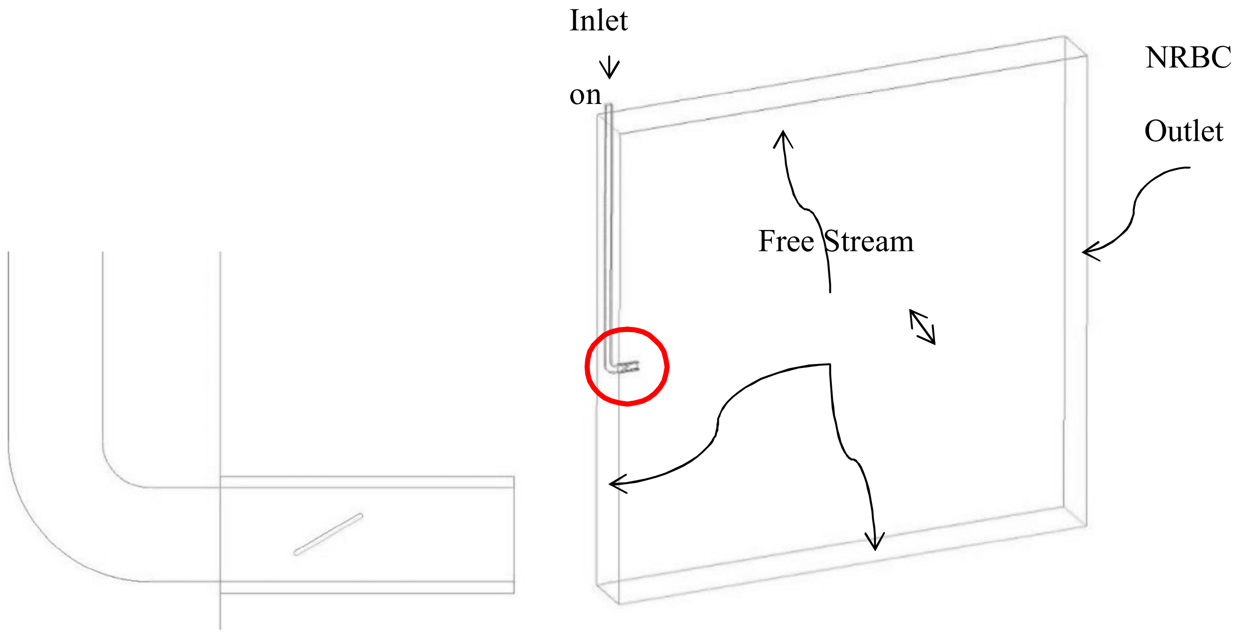

Figure 2: Geometry of the computational domain

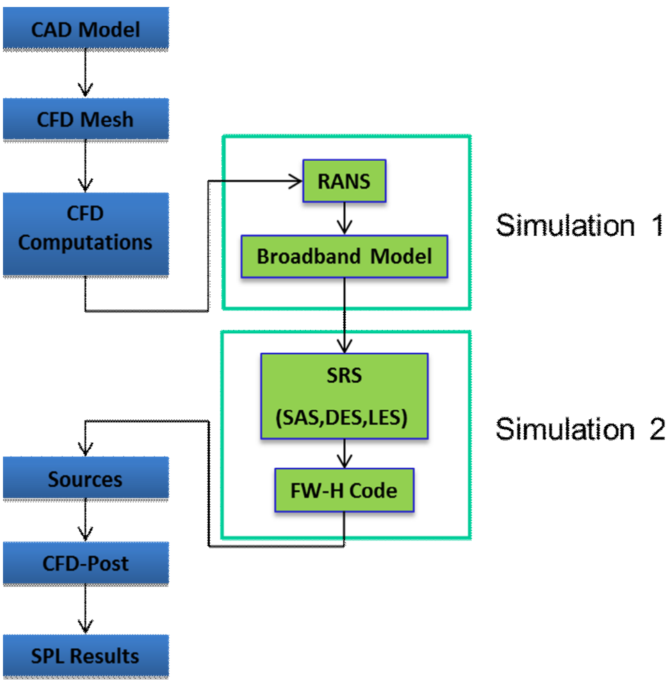

Figure 3: Scheme of aeroacoustic simulation with Fluent

Figure 3 shows the steps involved in the (DDES) acoustic simulation through fluent. After the CAD model is imported into the preprocessor a mesh of sufficient quality is used in the fluid flow computations. The sources estimated from the fluid simulations are then imported into the CFD-Post program and using a FW-H (Ffwocs Williams and Hawkings) model which is based on the acoustic analogy of Lighthill; the SPL values are estimated. In this methodology of acoustic simulation the acoustic field is decoupled from the flow field and can be calculated for a free field. This approach also allows extrapolating the acoustics in an area that is not in the computational domain. For the near field (area around the flap) the above method is not feasible due to the limitation of the FW-H model that it requires a free field to estimate the SPL values. Here the acoustics are evaluated using a direct simulation method. This hybrid method of using free field and direct simulation will be compared to the values acquired through experimental methods [1] and from other acoustic solvers [2, 3, and 4].

4. Results

The Figure 4 shows the velocity and the turbulent kinetic energy field of the flow at a cross-section through the middle of the geometry. The figure shows the flow separation after the bend and behind the flap (i.e. higher turbulence).

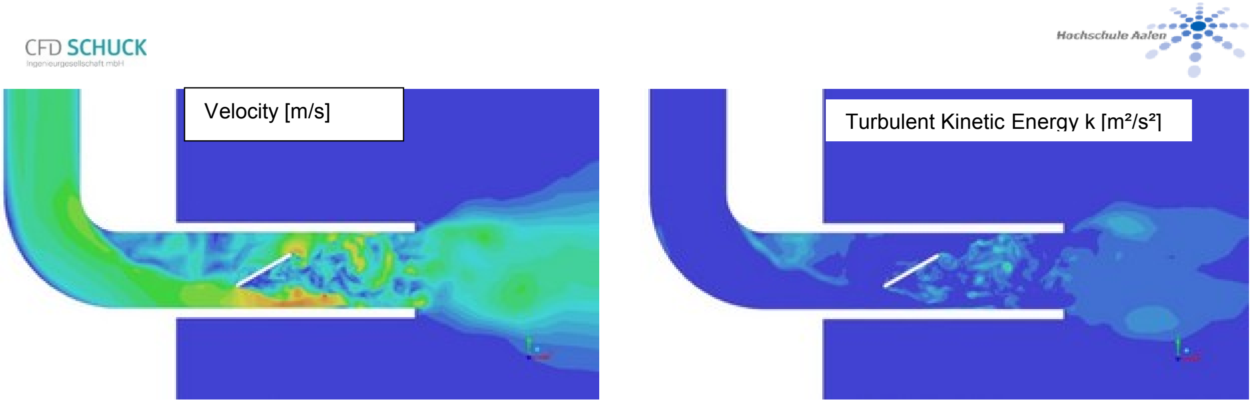

Figure 4: Velocity and Turbulent kinetic energy

4.1. Sound pressure level near-field region

The figures 5, 6 and 7 show the sound pressure levels (SPL) from the measurement points M1, M2 and M6 (see figure 1) at the time level t=0.78s from the CFD simulation. The DDES turbulence model together with the FW-H model (acoustic simulation) was used for the simulation. The results from the CFD simulation were compared with those from experimental data (shown in red). The results show good correlation between simulation and experimental data for the high frequency region, especially for measurement points M1 and M6. In the low frequency region the peak at 80Hz in the experimental data is not seen in the CFD results. The reason being coarser mesh around the throttle flap together with the transport region and a short simulation time.

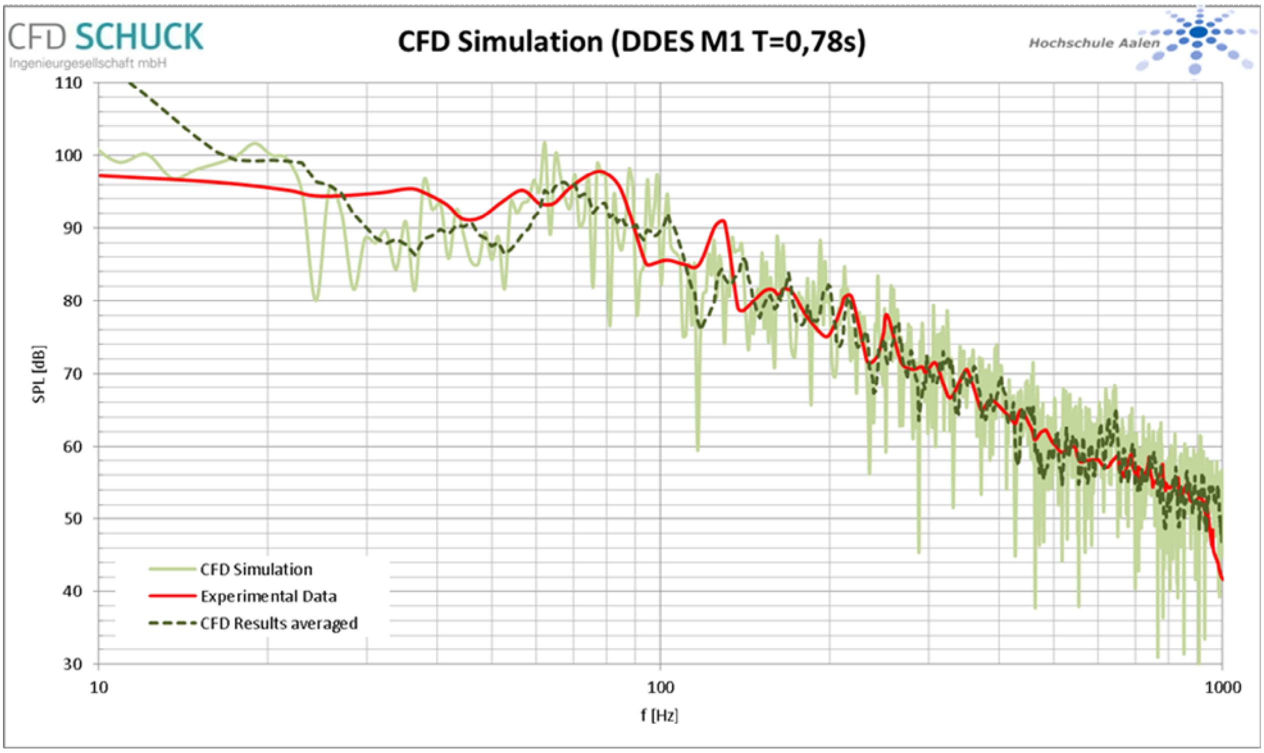

Figure 5: Sound Pressure Level at M1

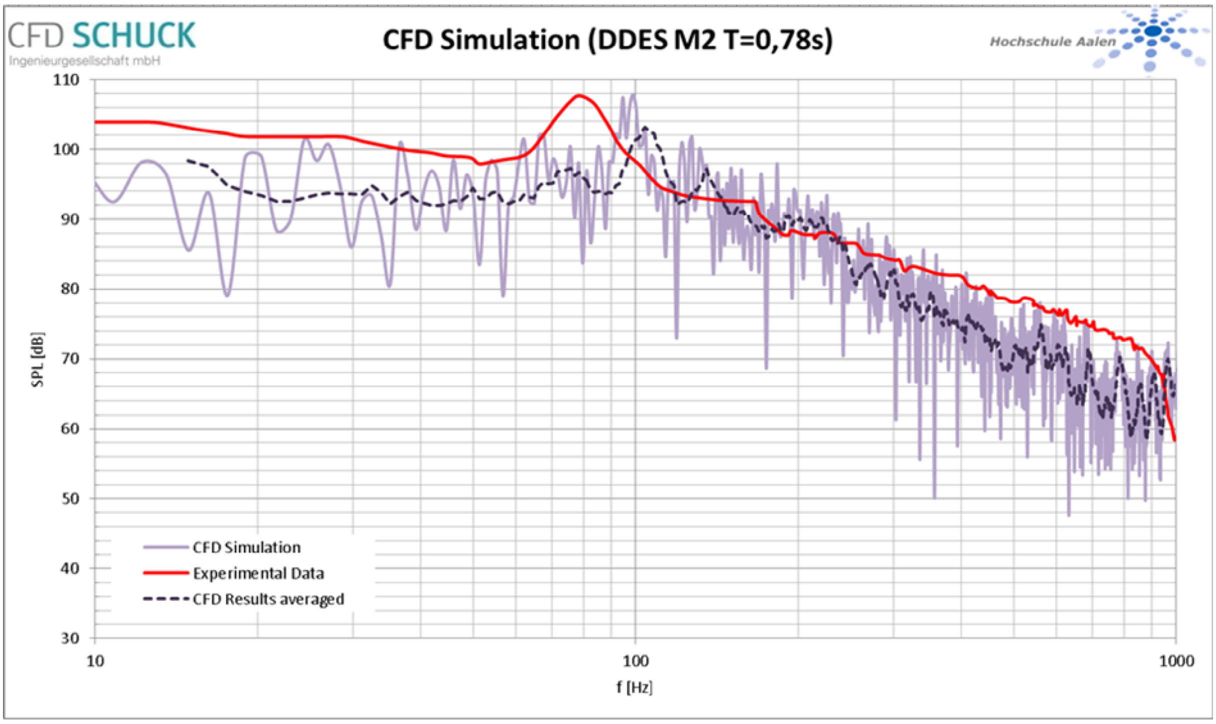

Figure 6: Sound Pressure Level at M2

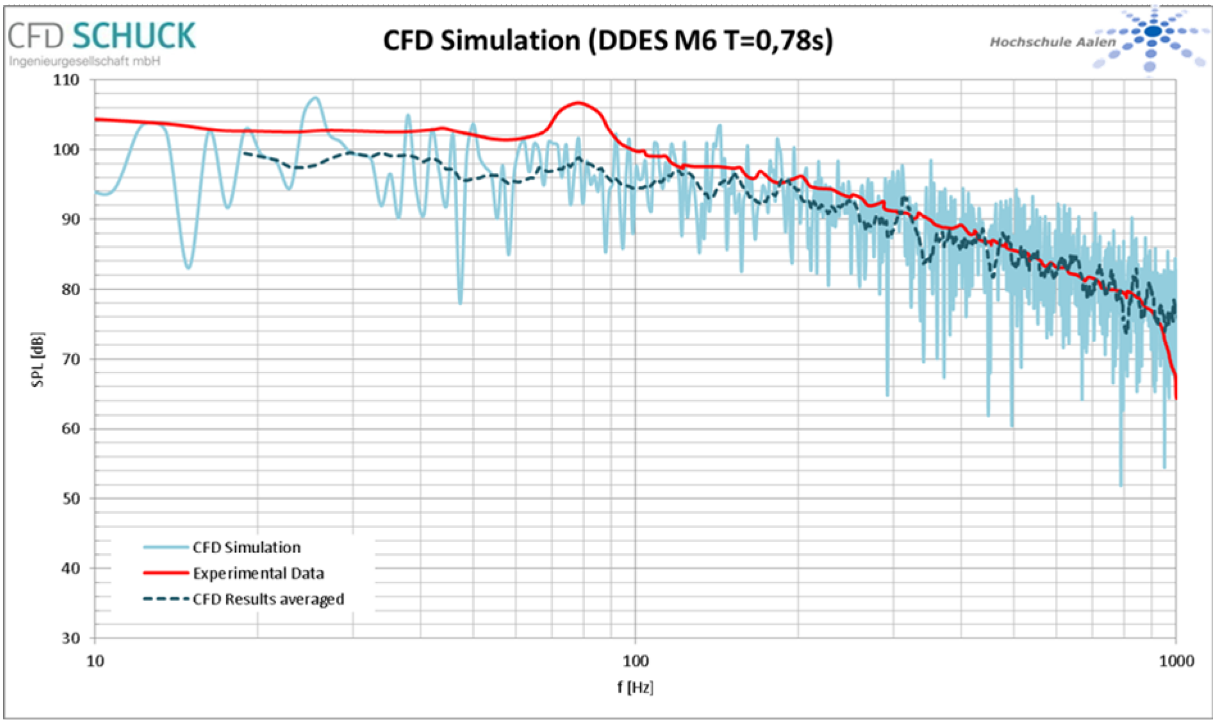

Figure 7: Sound Pressure Level at M6

4.2. Sound pressure level far-field region

In the far field region (figure 8) the results from the CFD simulation show a good correlation with that of the experimental data in the high frequency region. The peaks in the low frequency region from the experimental data are not seen in the CFD results.

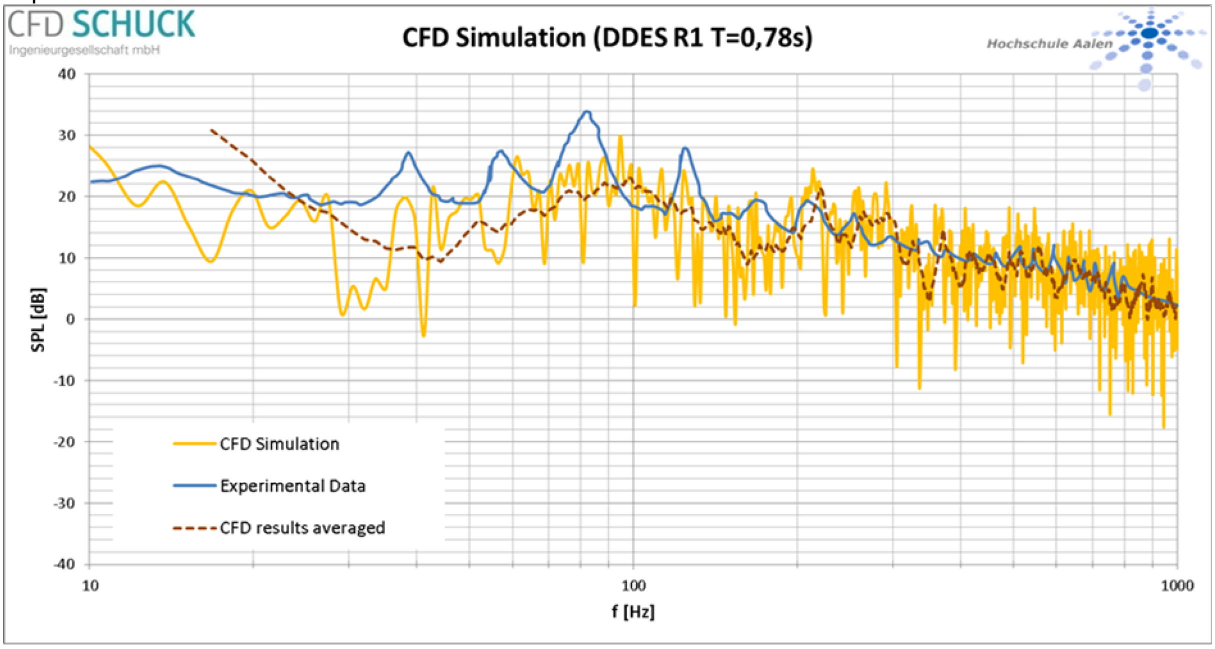

Figure 8: Sound pressure level in the far-field-region

5. Summary and outlook

From this study it can be seen that an Aeroacoustic simulation could be carried out only using a CFD solver with DDES-turbulence model. Though the results show a similar trend between the experimental and CFD data for higher frequencies, an improved resolution of the tonal components is necessary. The far field acoustics under the use of FW-H code show a good correspondence between the experimental and simulation data from 200Hz.

Further investigations will be performed using hexahedral meshes to improve the accuracy of the results especially for frequencies below 100Hz.

6. Acknowledgements

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7. References:

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