Applicability of the SNGR-Model to compute Trailing Edge Noise

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Introduction

Trailing edge noise plays a very important role in road traffic, rail traffic and air traffic. Its direct computation, however, can hardly be accomplished with present computers and therefore is not suitable for the industrial design of quiter means of transportation. Computational efforts may be reduced by splitting the computation into a computation of the flow field and a succeeding acoustic computation (hybrid methods).

The SNGR-Model, which has been used to compute the noise of a jet and a duct flow [1], belongs to those hybrid methods.

The aim of the investigations was to find out if and how, respectively, the SNGR-Model can also be used to compute trailing edge noise.

SNGR-Model

Figure 1 gives an overview of the SNGR-Model [1].

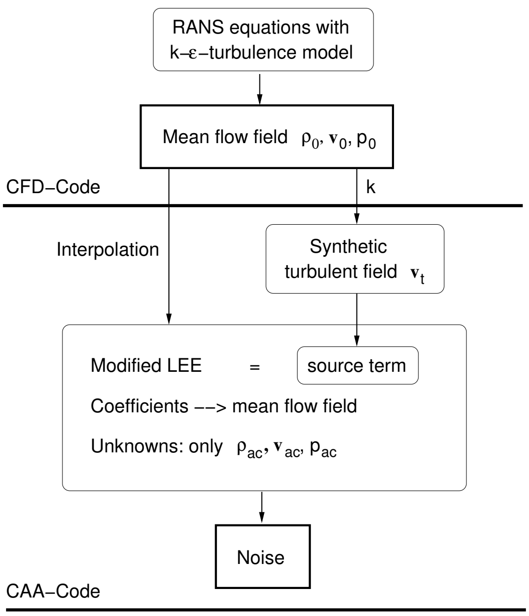

Figure 1: Overview of the SNGR-Model [1]

The variables density ρ, velocity vector $\boldsymbol{v}$ and pressure p are split into a time averaged part (subscript '0'), a turbulent part (subscript 't') and an acoustic part (subscript 'ac'). In the first step the time averaged mean flow field $(\rho_0, \boldsymbol{v}_0, p_0)$ is computed with a CFD-Code as a solution of the Reynolds Averaged Navier Stokes (RANS) equations. In the second step a modified form of the Linearized Euler Equations (LEE) with a source term is solved with a CAA-Code to obtain the time-dependent noise $(\rho_{ac}, \boldsymbol{v}_{ac}, p_{ac})$. The source term is driven by an incompressible, stochastically synthesized turbulent field $\boldsymbol{v}_t$.

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Analysis of the SNGR-Model

In the first place the noise production of the SNGR-Model depends on the gradient of the weighting function W. No noise was observed when W had little gradients, see figure 2. W is normally muliplied with the source term to reproduce the spatial distribution of the turbulent kinetic energy k obtained from the RANS-solution.

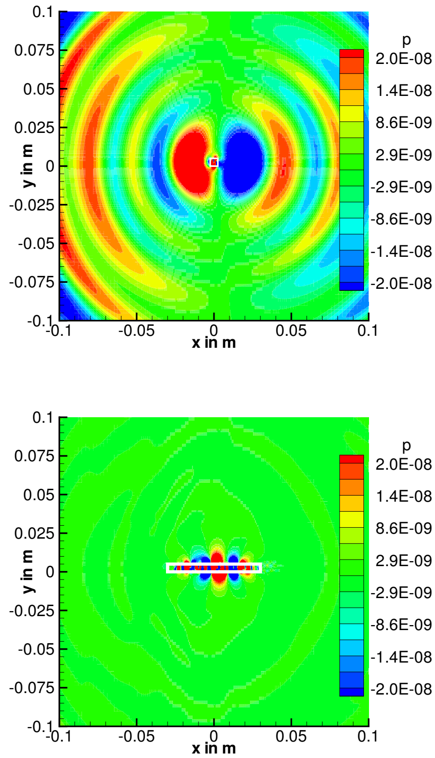

Figure 2: Noise is generated due to a large gradient of W in the x-direction (top). In spite of a larger source area no noise is visible as the source term is faded in/out smoothly by W in the x-direction (bottom). Only the x-component of the source term was calculated.

Secondly the unknowns $\rho_{ac}, \boldsymbol{v}_{ac}, p_{ac}$ contain turbulent fluctuations in the source area, see figure 2 (bottom). These fluctuations are also convected out of the source area in case of a non-zero mean flow field, figure 4. The reason for this behaviour is that the *structure* of the left hand side (LHS) of the governing equations of the SNGR-

Model is equal to that of the LEE, which are known to have an acoustic *and* a turbulent mode (next to an entropy mode). The unknowns of the SNGR-Model, however, are purely acoustic, because numerous (turbulent) terms are neglected in the derivation.

Exceptional usage of the SNGR-Model

Regarding the aforementioned items the source term was not used to excite noise directly, but to introduce turbulent fluctuations into the CAA-domain. Trailing edge noise was computed by the interaction of these fluctuations with a trailing edge in the vicinity of the source area, figure 3. To ensure a good performance of this procedure

- no noise should be generated by the source mechanism directly, i.e. if there is no trailing edge in the CAA-domain. This was achieved by a certain combination of source term and weighting function;
- the right turbulent fluctuations $\boldsymbol{v}'_{\mathrm{turb}}$ should be generated in the CAA-domain. In order to verify $\boldsymbol{v}'_{\mathrm{turb}}$ one may attempt to achieve $\boldsymbol{v}'_{\mathrm{turb}} = \boldsymbol{v}_t \cdot W$.

To account for $\boldsymbol{v}'_{\mathrm{turb}}$ more appropriate governing equations are proposed where the unknowns imply acoustic *and* turbulent fluctuations $(\rho', \boldsymbol{v}', p')$. Now the LHS is equal to the LEE and the same source term as proposed in the SNGR-Model was derived for the RHS. As the *structure* of the LHS of the SNGR-Equations resembles the LEE, the programme code had not to be changed at all, although formally different unknowns are calculated.

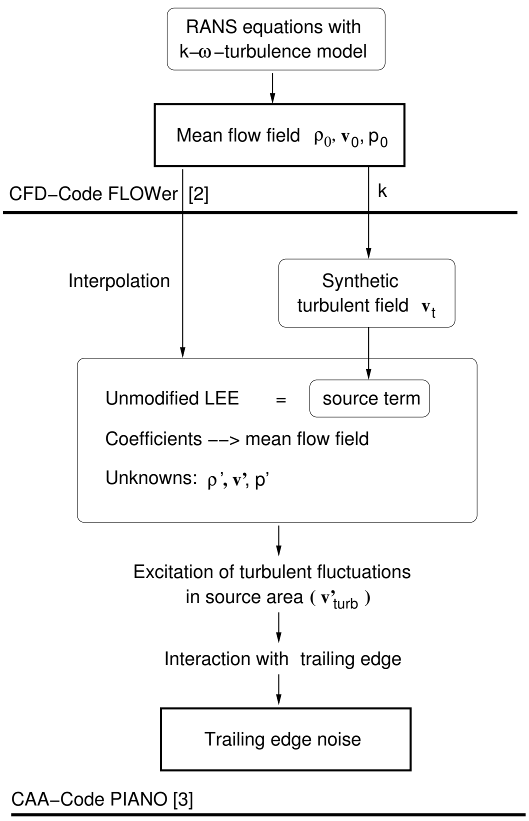

Figure 3: Overview of the employed approach

Simulated trailing edge sound field

Figure 4 shows the computed two-dimensional pressure field in the trailing edge region of a thin flat plate.

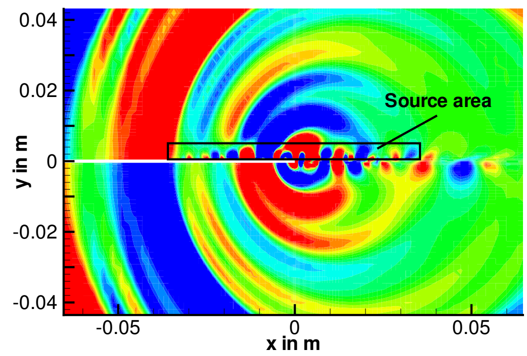

Figure 4: Snapshot of the pressure field obtained from CAA. The thin flat plate is marked with a white line. Just for the sake of clarity only one source area (located above the trailing edge) was used.

The source mechanism generates small scale turbulent fluctuations in the source area. They are convected out of the source area by the mean flow. The sound waves are perfectly antisymmetric along $y = 0$. This indicates that no noise is generated by the source mechanism directly, which would result in an unsymmetric sound field using a source area only on one side of the flat plate. The sound waves are generated right at the trailing edge and cancel each other in the wake region. This shows that the generated noise is trailing edge noise.

Conclusion

It seems to be possible to compute trailing edge noise by an exceptional use of the SNGR-Model. A reliable prediction of the absolute value of the generated sound pressure level and its spectral distribution, however, is not possible at present, because $\boldsymbol{v}'_{\mathrm{turb}}$ is not sufficiently under control yet. Thus a further investigation of the source mechanism is neccessary.

Acknowledgement

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References

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