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AERODYNAMICS AND AEROACOUSTICS STUDY OF THE FLOW AROUND AN AUTOMOTIVE FAN AIRFOIL

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Several experimental and numerical studies were performed on the CD airfoil (shown in Fig. 1) in order to study the unsteady turbulent boundary layer and wake and the associated mechanism of noise generation. The reader is referred to [3] where most of studies are reported. Our numerical simulations in this study were performed via the in-house

Figure 1: The automotive cooling module, its 9-blades fan and the airfoil of the blade

SFELES solver which is a hybrid spectral/finite elements code capable of simulating 3D unsteady incompressible viscous flows over axisymmetric and planar geometries with a direction of periodicity. This work presents the results of these aerodynamic simulations for laminar and turbulent regimes. The results are compared with experimental results obtained by Moreau and Roger [1] and Moreau et al. [2] as well as other numerical results performed by J.Christophe [3] using OpenFoam. The simulations of the laminar regime were performed for Reynolds numbers equal to 1000, 3000 and 12000. The purpose is to gain insight into the characteristics of the laminar regime by visualizing the structure of the vortex street in the wake. Turbulent simulations were carried out for Re=160,000 in order to study the unsteady turbulent boundary layer and to calculate the wall pressure spectrum. Several turbulence models, such as the static Smagorinsky model (with Cs=0.17), the WALE model and the model proposed by G.Ghorbaniasl [4] were used and their results were compared to study the influence of the LES sub grid-scale on the results. In this study, the following observations were made:

- First concerning the laminar results, the flow was found to be 2D and steady for Re=1000, whereas it is 2D and unsteady for Re=3000 and Re=12000, with the development of Karman vortex street downstream of the trailing edge. The Strouhal number of the Karman street based on the trailing edge diameter increases with the Reynolds number as for the flow over a circular cylinder.
- Second, concerning the turbulent flow,
  - The intensity of vortex structures in the turbulent boundary layer is much more important for 64 Fourier modes than with 32 modes. Furthermore, the contribution of LES decreases when the number of Fourier modes increases. The laminar separation near the leading edge, which is called recirculation bubble, is characterized by a negative skin friction coefficient. Its size is found equal to 10%C (C stands for the chord) for the Smagorinsky model whereas it was found equal to 5.3%C in OpenFoam simulations with the dynamic Smagorinsky model.
  - The WALE model is more convenient than Smagorinsky for this type of problems. Indeed, it is remarked that the vorticity evolves and the solution converges faster than the Smagorinsky simulation. Computation time and accuracy are gained. The recirculation bubble size is found equal to 8%C.
  - The new SGS model proposed by G.Ghorbaniasl is implemented. It is found that the results are improved in general, especially near the leading edge, comparing with OpenFoam and experimental results. The recirculation bubble size is found equal to 3.5%C. Moreover, the wall pressure spectrum is closer to experiments especially for stations near the trailing edge and for high frequencies.
- Considering the aeroacousitcs results: Amiet′s theory is applied using the wall pressure spectrum for a station near the trailing edge. The sound pressure level is computed as well as its directivity. The predicted noise obtained using the wall-pressure spectrum of SFELES are in very good agreement with experimental results and closer than OpenFoam in particular for frequencies between 1000 and 2000 Hz regardless of the SGS model. The dipolar behaviour of the noise sources is found and the lobes multiply and orient towards the leading edge for high frequencies when the the acoustic pressure directivity is considered.

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