Application of Partially-Averaged Navier Stokes Simulations for Bluff Body Aerodynamics

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ABSTRACT

The paper discusses the Partially-Averaged Navier-Stokes (PANS) model [1] in the framework of engineering applications of bluff body flows. PANS was previously used for flows such as the flow around a rudimentary landing gear [2] and the flow around a cuboid. In this paper we are exploring the usefullnes of this technique for application in vehicle aerodynamics. Furthermore, we are making the critical evaluation of the PANS technique for bluff body flows in comparison with other unsteady techniques. Comparisons with the resolving LES technique and URANS of a three dimensional bluff body flow are made for a better understanding of the behavior of PANS model in these flows. Several implementation issues of PANS such as fk variable in space and time, the influence of the inlet boundary conditions and discretization scheme are discussed. The reference comparison with LES and URANS displays the differences between the methods in the complex interaction between the resolved and the modeled coherent flow scales. The PANS model is compared with competing techniques of LES, DES and RANS for flows around a surface mounted cube, flow around one generic vehicle body at yaw and the flow around an Ahmed body.

To bring more insight into what happens when we run PANS we study the flow around a surface mounted cube that is a standard test case for bluff body simulations and has previously been predicted using LES, DES, URANS and steady RANS. The test case contains regions of massively separated unsteady flow that cannot be predicted using traditional turbulence modeling in a RANS framework. There is also a sufficient amount of experimental data that can be used for validation of the predictions. In this study, we performed LES, URANS and PANS using identical computational grid. All calculations were performed twice on two different computational grids for the purpose of studying the behavior of the method when the resolution was improved/worsened. URANS and PANS simulations used the same underlying RANS model, called the z-f turbulence model. LES simulations used the Smagorinsky-type subgrid-scale model. The second bluff body that was studied is that of a generic car geometry at yaw. This flow was previously simulated with RANS approach and explicit algebraic stress model (EASM), DES and LES. The existence of these RANS, DES and LES simulations together with well documented experimental data makes this flow ideal for evaluation of the capabilities of the present PANS

The flow predicted with PANS of the vehicle body at yaw was found to be in better agreement with the experimental data than predictions of previous LES, DES, RANS or URANS simulations. PANS simulation of the flow around the Ahmed body predicted the flow in good agreement with the experimental data using much corser computational grid from the one used in the LES. The PANS method was found to adjust to the computational grid by adding or removing turbulence modelling. The paper will present detailed analysis of both time-averaged and instantaneous PANS results and their comparison with experimental data and results of other numerical simulations. Issues such as adequacy of the computational grid, deficiency of the variable fk and influence of the numerical scheme on PANS results of bluff body flows will be discussed.

REFERENCES

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