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Keio University

Thesis Abstract

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Thesis Title

On the Improvement of Algebraic Model for Prediction of Turbulent Flows

Thesis Summary

There continues to be considerable interest in the development of turbulence models within the framework of the Reynolds-averaged Navier-Stokes (RANS) approach in order to meet the increasing demands in industrial applications. Among various RANS approaches, the eddy viscosity model (EVM) has received the most consideration and has been applied to many problems, due to its simple form and affordable computation cost. However, an EVM eventually fails to represent many complex features of turbulent flows. The differential Reynolds stress models (DRSM) include significantly more flow physics, and its application to complex flows is an active area of research. In parallel with such efforts, there is a considerable renewed interest in developing the algebraic approximations for transport equations of anisotropy tensor, as well as for the heat fluxes.

The present research aims at developing algebraic Reynolds stress model (ARSM), which is feasible and accurate to simulate engineering turbulent flows. The study has been focused on the assessment and modification of the diffusive transport assumption, which is necessary and crucial to derive ARSM. By using the budget analysis and asymptotic analysis, it has been shown that the current diffusive transport assumption tends to fail in the near-wall region. Furthermore, based on above analyses, an alternative form of diffusive transport constraint is proposed by using the redistribution term to represent the diffusive transport term in the near-wall region. The a priori test suggests that the proposed form has the potential to improve the predictive ability of resultant ARSM.

The similar methodology has also been applied to the algebraic heat flux model (AHFM). As a result, an alternative diffusive transport constraint has been proposed. Preliminary evaluations result has shown that the improvement of consequently resulted model can also be expected by employing the proposed constraint. In addition, the frame invariant concept is invoked in this study to extend the original advection assumption for flows associated with rotation and curvature effects. Moreover, the frame invariant form of AHFM is derived by using the extended weak-equilibrium condition. It is also proven that the transport equation of normalized heat flux can be written in a Euclidean invariant way by introducing the Jaumann- Noll derivative.

To this end, some key issues concerning the basic performance of RANS models have been recognized, such as the modeling of pressure-strain rate, modeling of pressure transport term. With further study, the improvement of such models can advance the RANS modeling fundamentally, which also naturally applies to the algebraic models. It is also note that, although the a priori tests have proved the proposed alternative constraints can improve the resultant algebraic models potentially, the more detailed tests should be performed to validate the proposed alternative constraints.