Reader's Forum

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Comment on "Turbulence Model for Rotating Flows"

G. D. Stubley* and G. Riopelle†
University of Waterloo
Waterloo, Ontario N2L 3G1, Canada

IN their recent article, Galperin and Kantha[1] present a turbulence model that has been successfully applied to the prediction of atmospheric boundary-layer flows and propose that the model is suitable for the prediction of rotating flows in turbomachinery. The model proposed by Galperin and Kantha is an algebraic Reynolds stress model derived from the quasiequilibrium form of the exact Reynolds stress transport equations. Because the model is derived from the Reynolds stress transport equations, the direct effect of rotation on the Reynolds stresses is accounted for without approximation. This is one of the major strengths of the proposed turbulence model.

However, rotation does not only affect the Reynolds stresses directly through the mechanism included in the Reynolds stress transport equations. It also directly affects the dissipation rate of turbulent kinetic energy and therefore affects the turbulence time and length scales. The decay of homogeneous turbulence in solid-body rotation has been definitively studied in the experimental work reported by Wigeland and Nagib.[2] Their results indicate that rotation acts to decrease the dissipation rate of turbulent kinetic energy in homogeneous turbulence. The large-eddy simulations of Bardina et al.[3] confirm the findings of Wigeland and Nagib.

The effects of rotation on homogeneous turbulence indicate that the dissipation equation (or corresponding length scale equation of Galperin and Kantha) must include a term accounting for rotation. Bardina et al. present a correction term that accounts for rotation in the dissipation equation. Their correction term indicates that rotation has a significant effect on the dissipation rate when the ratio of the turbulence time scale to the period of rotation is significantly greater than 1. Stubley and Riopelle[4] show that for flows in the atmospheric boundary layer, the period of the Earth's rotation is sufficiently long so that rotation has no significant effect on the dissipation rate. However, in high-speed turbomachinery it is possible that the ratio of the turbulence time scale to the period of rotation can become large enough that the dissipation rate is significantly affected by the rotation.

The lack of a universal theory or model for turbulence requires that care be taken when applying a turbulence model developed for atmospheric flows to turbomachinery flows. Until the effect of rotation on the dissipation of turbulent kinetic energy and its prognostic equation is quantified for turbomachinery flows, the model presented by Galperin and Kantha should be used with caution when predicting turbomachinery flows.

References

[1]Galperin, B., and Kantha, L. H., "Turbulence Model for Rotating Flows," *AIAA Journal*, Vol. 27, No. 6, 1989, pp. 750–757.

[2]Wigeland, R. A., and Nagib, H. M., "Effects of Rotation on Decay of Turbulence," *Bulletin of the American Physical Society*, Vol. 23, 1978, p. 998.

[3]Bardina, J., Ferziger, J. H., and Reynolds, W. C., "Improved Turbulence Models Based on Large Eddy Simulation of Homogeneous, Incompressible, Turbulent Flow," Thermosciences Div., Dept. of Mechanical Engineering, Stanford Univ., Rept. TF-19, 1983.

[4]Stubley, G. D., and Riopelle, G., "The Influence of the Earth's Rotation on Planetary Boundary-Layer Turbulence," *Boundary-Layer Meteorology*, Vol. 45, 1988, pp. 307–324.