A two-dimensional model for three-dimensional symmetric flows

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Abstract

A two-dimensional model for three-dimensional symmetric laminar flows is described. This model is derived from the incompressible Navier-Stokes equations using the velocity-pressure formulation. By locating the origin of the three-dimensional structures on the symmetry plane and applying an appropriate treatment of the three-dimensional term remaining in the derived equations an accurate solution of the three-dimensional flow at the symmetry plane can be achieved.

The backward-facing step numerical test case is used to test the performance and accuracy of the derived model. Above $Re = 400$, three-dimensional structures arise [1] leading to different primary reattachment lengths for the two-dimensional and the three-dimensional cases. These structures are located close to the separation point. We show that using a two-dimensional transport equation for the responsible three-dimensional term would result into a reattachment length close to the three-dimensional solution. The direct benefit of this work is a significant reduction of the computational time required to achieve the three-dimensional solution of symmetric laminar flows. As a future work, a two-dimensional model of three-dimensional terms will be explored in the field of turbulence for spatially periodic flows.

References

[1] B.F. Armaly, F. Durst, J.C.F. Pereira and B. Schönung, *Experimental and theoretical investigation of backward-facing step flow*, Journal of Fluid Mechanics, vol. 127, pp. 473–496, 1983.