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SUITABILITY OF DIFFERENT RANS MODELS IN THE DESCRIPTION OF TURBULENT PLANE AND ROUND IMPINGING JETS

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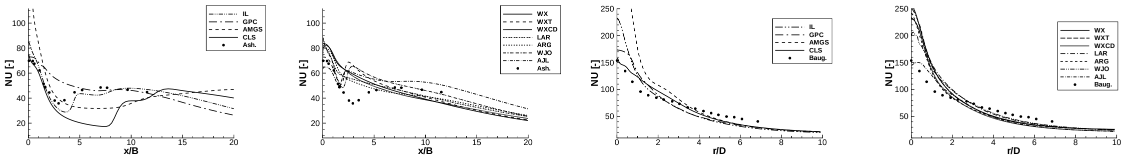
ABSTRACT

Due to the highly localized mass, momentum and heat transfer, impinging jets are used in heating, cooling or drying processes for the production of paper, textiles, glass, annealing of metal sheets, cooling of turbine blades and electronic components, air curtains, etc. Thus, a correct prediction of flow structure and heat transfer in this kind of flows is of great importance in many industrial applications.
Predictive inaccuracies of linear eddy-viscosity models have motivated that a great deal of effort has gone into the elaboration of constitutive expressions that relate Reynolds-stress tensor non-linearly, assuming a higher-order tensor representation, to the strain-rate and vorticity tensors. This kind of models are capable of resolving Reynolds-stress anisotropy and streamlines curvature. Also, they are thought to preserve computational economy and numerical robustness of linear models [1].

The main goal of this work is to study the suitability, in terms of accuracy and numerical performance, of different RANS models in the description of both plane and round impinging jets. The analysis of the models in these flows is atractive because of the presence of complex phenomena: strong curvature of the streamlines, stagnation, recirculation, adverse pressure regions, etc.
Within RANS technique, two-equation Linear Eddy-Viscosity Models (LEVM) [1], Non-Linear Eddy Viscosity Models (NLEVM) [2], and Explicit Algebraic Reynolds Stress Models (EARSM) [3], are taken into account in this paper. Moreover, a comparison in the use of different variables, such as ε or ω, for the turbulence length scale calculation is carried out.
The set of differential equations (mass, momentum, energy and turbulent quantities) are transformed to algebraic equations using fully implicit finite-volume techniques over structured and staggered grids. The SIMPLE algorithm [4] is utilized for solving, in a segregated manner, the

velocity-pressure fields coupling. First and higher order schemes are used to approximate the convective terms.
Two chosen configurations of single turbulent impinging jets are numerically studied in this paper. They involve plane and round nozzle geometries at different Reynolds numbers and nozzle-to-impingement surface distances. Results obtained with the models under consideration are carefully verified applying a post-processing procedure based on the generalized Richardson extrapolation [5], and validated with experimental data from the technical literature [6], [7]. Furthermore, a detailed analysis of mean velocities, turbulent stresses and global parameters such as the local Nusselt number is presented.
Illustrative results for the local Nusselt number at the impingement plate are presented together with experimental data in Figure 1 for the plane and round impinging jet configurations.



(a) $k-\epsilon$ models. (b) $k-\omega$ models. (c) $k-\epsilon$ models. (d) $k-\omega$ models.

Figure 1: Local Nusselt at the impingement plate. Left, plane jet $Re = 20000$ and $H/B = 4$. Right, round jet $Re = 23000$ and $H/D = 6$. Lines numerical results and symbols experiments by Ashforth-Frost et al.[6] and Baughn and Shimizu [8].

REFERENCES

[1] S.B. Pope. *Turbulent Flows*. Cambridge University Press, 2000.

[2] T.J. Craft, H. Iacovides, and J.H. Yoon. Progress in the Use of Non-linear Two-Equation Models in the Computation of Convective eat-Transfer in Impinging and Separated Flows. *Flow, Turbulence and Combustion*, 63(1):59–81, 1999.

[3] R. Abid, J.H. Morrison, T.B. Gatski, and C.G. Speziale. Prediction of Aerodynamic FLows with a New Explicit Algebraic Stress Model. *AIAA Journal*, 34(12):2632–2635, 1996.

[4] J.P. Van Doormal and G.D. Raithby. Enhancements of the simple method for predicting incompressible fluid flows. *Numerical Heat Transfer*, 7:147–163, 1984.

[5] J. Cadafalch, C. D. Pérez-Segarra, R. Cònsul, and A. Oliva. Verification of finite volume computations on steady state fluid flow and heat transfer. *Journal of Fluids Engineering*, 124(11):11–21, 2002.

[6] S. Ashforth-Frost, K. Jambunathan, and C. F. Whitney. Velocity and Turbulence Characteristics of a Semiconfined Orthogonally Impinging Slot Jet. *Exp. Thermal and Fluid Science*, 14(1):60–67, 1997.

[7] D. Cooper, D.C. Jackson, B.E. Launder, and G.X. Liao. Impingement Jet Studies for Turbulence Model Assessment–I. Flow-field Experiments. *International Journal of Heat and Mass Transfer*, 36(10):2675–2684, 1993.

[8] J. W. Baughn and S. Shimizu. Heat Transfer Measurements From a Surface with Uniform Heat Flux and an Impinging Jet. *ASME J. Heat Transfer*, 111:1096–1098, 1989.