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REYNOLDS STRESS MODELING OF SEPARATED FLOWS OVER CURVED SURFACES

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1. Introduction

Reynolds Stress Models (RSMs), are sensitive to streamline curvature and should mimic the turbulent behaviour more accurately than eddy viscosity models, EVMs, when the flow is heavily curved.
This work is focused on flows including separation. Two testcases are regarded and these are the flow over a 2D hill and the flow over a backward facing step. Comparisons are made between simulations and experiments or direct numerical simulations, DNS, respectively.

2. Turbulence models

All RSMs used in this work models the turbulent diffusion by the generalized gradient hypothesis by Daly & Harlow. Furthermore High-Re models assumes $\varepsilon_{ij} = \frac{2}{3}\varepsilon\delta_{ij}$ and low-Re models assumes an anisotropic dissipation rate model according to Hanjalić & Launder[1]. Thus the models differ mainly in the modeling of the pressure strain interaction term ϕ_{ij}. The simple isotropization of production model by Naot *et al.* 1970, (IP), is used and the model of Gibson and Launder, (GL), has been added on to IP. In addition to this model a nonlinear quadratic model by Speziale, Sarkar and

[1]HANJALIĆ K. and LAUNDER B.E., Contribution towards a Reynolds-stress closure for low-Reynolds-number turbulence., *J. Fluid Mech.*, 74:593–610, 1976.

Gatski[2] (SSG), and a cubic proposal by Launder and Li[3] (LLI) has been tested. Wall-functions are used for high-Re models. The low-Re RSM used was proposed by Hanjalić and Launder, (HL). This model was also tested when replacing its pressure strain model for the more elaborate cubic realizable model by Launder & Li, (LLIHL).

3. Results and concluding remarks

2D hill flows includes separation at a curved boundary. The results for the U velocity compared with experiments by Almeida[4] *et al.* can be seen in fig 1. High Reynolds number models completely fails in the prediction of the separation point which occurs too late.
In the flow over a backward facing step, comparisons are made between simulations and DNS, by Le & Moin[5] . All high-Re models reattach too fast and the k-ε-model reattached faster than any RSM. All these models had an erroneous flow angle over the step corner. The LLIHL reattached somewhat too late which is because of an underprediction of the shear stress, $\overline{uv}$, in the shear region, see fig 2.

It is shown that it is hazardous to use wall functions in any flow where separation occurs. Low-Re models is necessary in order to capture the features of the separation region properly.

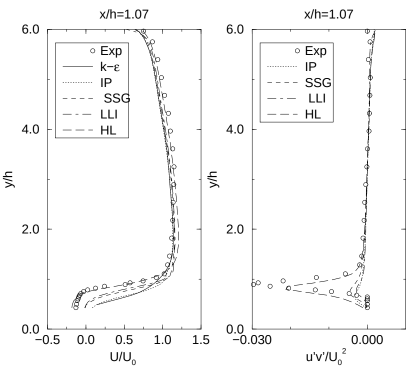

Figure 1 *U-velocity and shear stress profiles for the 2D hill flow at* $x/h = 1.07$.

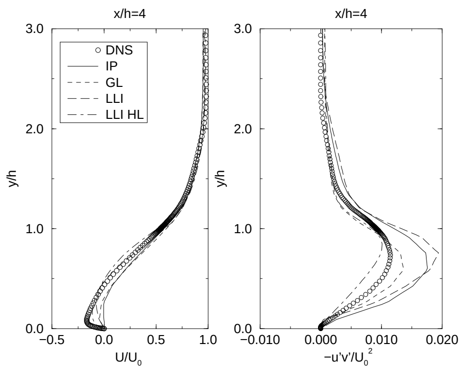

Figure 2 *U-velocity and shear stress profiles for the backward facing step flow at* $x/h = 4$.

[2]SPEZIALE C.G., SARKAR S. and GATSKI T.B. , Modeling the pressure-strain correlation of turbulence. , *J. Fluid Mech.*, 227:245–272, 1991.

[3]LAUNDER B.E. and LI S.-P. , On the elimination of wall-topography parameters from second-moment closure. , *Phys. Fluids*, 6(2):999–1006, 1994.

[4]ALMEIDA M.V., DURAU D.F.G. and HEITOR M.V., Wake flows behind two-dimensional hills., *Exp. Thermal and Fluid Science*, 7:87–101, 1993.

[5]LE H. and MOIN P. , Direct numerical simulation of turbulent flow over a backward facing step. , Report no. tf-58, Stanford University, Dept. Mech. Eng., 1994.