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EVALUATION OF A DIFFERENTIAL REYNOLDS STRESS MODEL INCORPORATING NEAR-WALL EFFECTS IN A COMPRESSOR CASCADE TIP-LEAKAGE FLOW

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The flow in axial compressor rotors is highly complex due to, amongst other phenomena, the tip-gap vortex. Industrial CFD applications in this kind of flow often rely on highly tuned linear eddy viscosity models (LEVM) although the turbulence field is anisotropic. Hence, in a RANS context, it is sensible to compute such flows with an anisotropy-resolving turbulence model, as demonstrated by Borello et al. [1]. The results obtained were superior to predictions by a LEVM. Despite the obvious advantages of differential Reynolds stress models (DRSM), they are not yet routinely applied in industry.

In a previous paper, the present authors applied the SSG/LRR-ω DRSM to a compressor cascade flow and compared the results to those obtained with a LEVM and an explicit algebraic Reynolds stress model [2]. It could be shown that the prediction of secondary velocities in the tip-gap flow and the shape of the tip-gap vortex could be improved by the DRSM. However, there was still potential for improvement in the representation of the mean velocities and especially of the Reynolds stresses near the wall. This motivated the present investigation.

The DRSM of Jakirlić and Hanjalić (JH-ϵ^h) was specifically designed to incorporate near-wall effects [3]. In the DLR's in-house flow solver for turbomachinery applications TRACE, the JH model was implemented using the homogeneous specific dissipation rate ω^h as scale determining equation (JH-ω^h) [4]. The implementation was validated using a series of building block flows. Not only showed the predicted the boundary layer velocity profile very good agreement with DNS data, but also is the model able to reproduce Reynolds stress anisotropy close to the wall. This holds true for the whole range of DNS data available ($Re_\tau = 180$ to 2003).

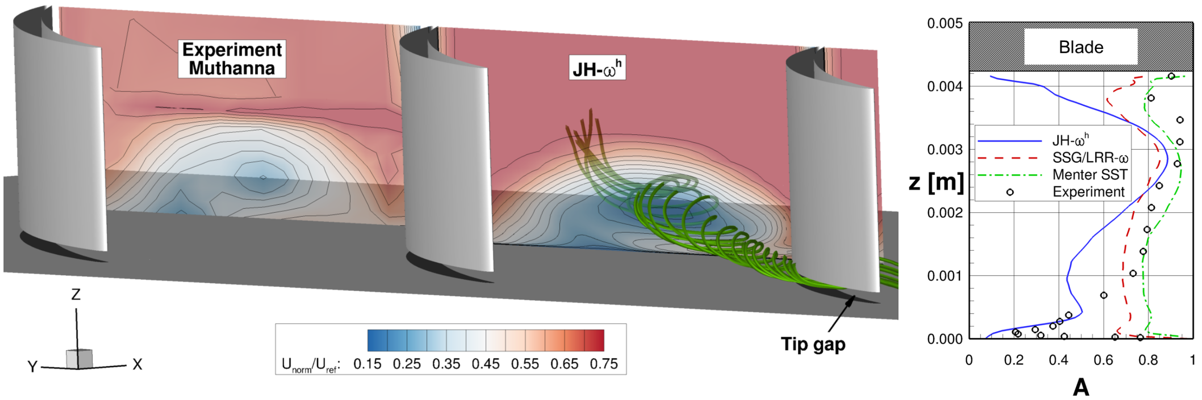

Figure 1: Left: Illustration of tip-leakage flow in Virginia Tech compressor cascade. Measured mean velocity in blade passage is compared to prediction by JH-ω^h DRSM. Right: Reynolds stress anisotropy two-component parameter A in tip-gap.

The turbulence transport equations are solved with a second-order accurate, conservative and segregated solution method. The source terms for the Reynolds stresses and dissipation rate are linearised and treated implicitly. The stability of the solution algorithm was significantly improved by the introduction of explicit realisability constraints for all six Reynolds stress tensor components.

In this paper, the tip-leakage flow of the Virginia Tech compressor cascade (Fig. 1 left) was simulated employing the JH-ω^h model and results are presented. The predictions are compared with those obtained using the SSG/LRR-ω DRSM and the Menter SST k-ω LEVM and their quality is assessed. In addition to the mean flow quantities, the focus is on the Reynolds stresses and their anisotropy (Fig. 1 right). Both DRSMs show significant improvements compared the the LEVM and have their own advantages in different regions of the flow depending on the modeling strategy.

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