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INVESTIGATION OF THE EFFECTS OF TURBULENCE MODELS ON A 2-D RIB ROUGHENED PIPE

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ABSTRACT
In this paper, one-equation turbulence model (Spalart-Almaras), two-equation turbulence models (Standard k-ε, RNG k-ε, Realizable k-,ε, Standard k-ω and SST k-ω) and five-equation turbulence model (Reynolds Stress Turbulence Model) performances are tested on 2-Dimensional rib-roughened surface. Results obtained from the present CFD study is compared with an experimental data which was obtained by a 2-D Laser Doppler Anemometer (LDA) and it is seen that RNG-k-ε and Standard k-ε turbulence models give the best results than the others.
Keywords: rib, groove, heat transfer, CFD

1. INTRODUCTION
Turbulence along a rough wall is of keen concern in engineering, since all walls are rough. Rough wall turbulence arises in many applications, such as turbo-machinery, electronics cooling and vegetation canopies. Use of a rib-roughened channel is one of the basic and effective tools for the enhancement of internal flow convective heat transfer. The flow field characteristics are strongly dependent on the length-to-depth (L/D) ratio of the cavity, the freestream conditions, the approach boundary layer, and the characteristics of cavity components, etc. Navier-Stokes equations that govern the flow are non-linear partial differential equations and in most cases cannot be solved analytically so direct numerical simulation (DNS) and large eddy simulation (LES) are used for numerical studies because they are the most accurate but unfortunately they require large computational resources than the other models. RANS solvers although they are affected by numerical and physical approximations perform reasonably accurately and less computational resources and they are widely used for industrial applications. Some experimental studies are reported by Ref. 1-Ref. 3. Comparing with the experimental studies there are a lot of numerical studies such as Ref. 4-Ref. 7.

In this study, the turbulence model performances are tested by using RANS solver on a 2-D rib-roughened pipe. For comparisons one-equation turbulence model; Spalart-Almaras (SA), two-equation turbulence models; Standard k-ε (SKE), Renormalized Group k-ε (RNG-KE), Realizable k-ε (RKE), Standard k-ω (SKO), Shear Stress Transport k-ω (SST-KO) and Reynolds Stress turbulence model; RSM are tested. Results are compared with an experimental data obtained from open literature and it is seen that RNG k-ε and Standard k-ε turbulence models are in good agreement than the others. The main goal of this study is to show advantages and disadvantages of these turbulence models on a 2-D rib roughened pipe.

2. COMPUTATIONAL MODEL

The configuration of the rough surfaces examined is presented previously in Ref. [1], so it is not repeated here. The mesh structure and coordinate system is shown in Fig. 1. This figure shows only the vicinity of the computational ribs and grooves for clarity. Totally 700×120 mesh elements for the whole domain are used in x, y-directions, respectively. y^+ which is dimensionless wall distance from the first cell was set unity so all turbulence models tested here are used with enhanced wall treatment. The flow is considered from left to the right sides and velocity inlet and pressure outlet are specified as boundary condition for inlet and outlet region, respectively.

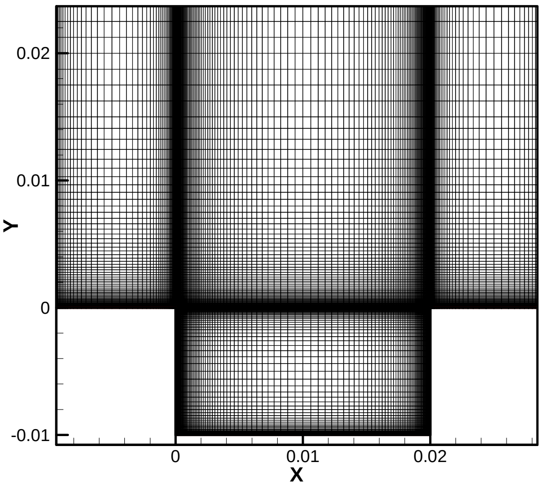

Figure 1. Grid structure and coordinate system.

The governing equations are discretized by finite volume method with second order upwind scheme and the solution procedure is based on SIMPLEC algorithm which is preferred for structured mesh. At All abovementioned turbulence models are tested and compared with an experimental data of Ref. [1] which was obtained by using Laser Doppler Anemometry (LDA).Information about turbulence model is not given here because of limitation but reader can obtained detailed knowledge from Ref. [8]

3. RESULTS AND DISCUSSION

Streamlines for ribbed pipe are shown in Fig. 2. In this figures an experimental result obtained by LDA (Fig2a) is compared with CFD solution (Fig.2b) for P=3.

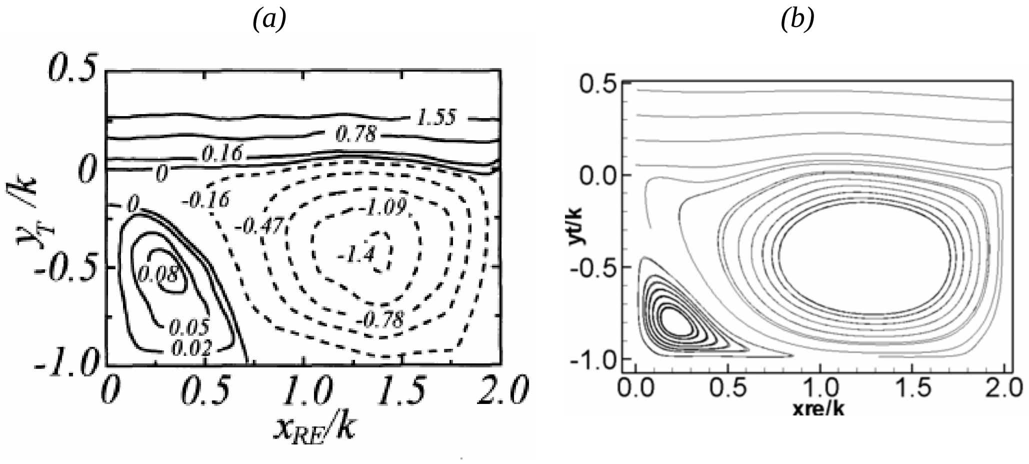

Figure 2. Streamlines obtained from, a) LDA data [1] and b) CFD results.

Flow after the rib goes directly to the next one while the flow between two ribs makes two recirculation regions. Although the main characteristics of these regions are the same the size and location of the big and small regions is not identical. The small recirculation region which seen just after the rib in the streamwise direction is smaller than the LDA result.

Fig. 3 compares the normalized streamwise velocity with freestream velocity versus dimensionless height (y/δ) and it is seen that none of these models compare well with the experimental data. Velocity variation comparisons at the surface between the boundary layer and the groove are shown in Fig. 4 and Fig. 5. In these figures it can be seen that the trend by one-equation and two-equation turbulence models and RSM is correct partly except SKO. For the vertical velocity component these two turbulence models are in good agreement with the experiment as well. After $x_{RE}/k=6$ there are keen variations in both velocity components.

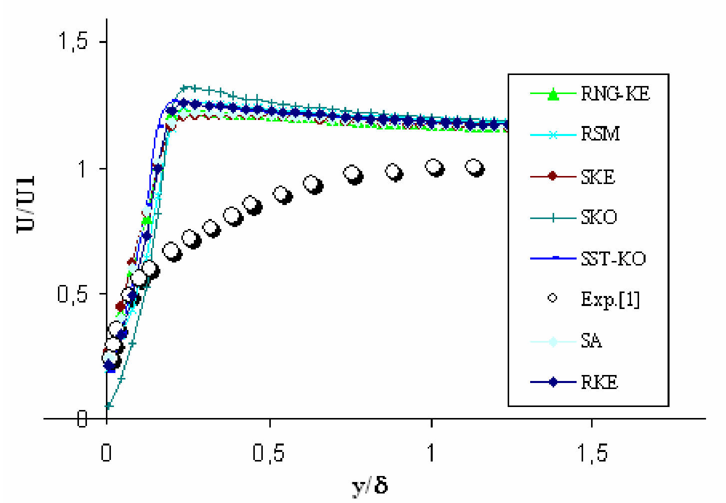

Figure 3. Streamwise velocity profiles for different turbulence models with comparison with [1].

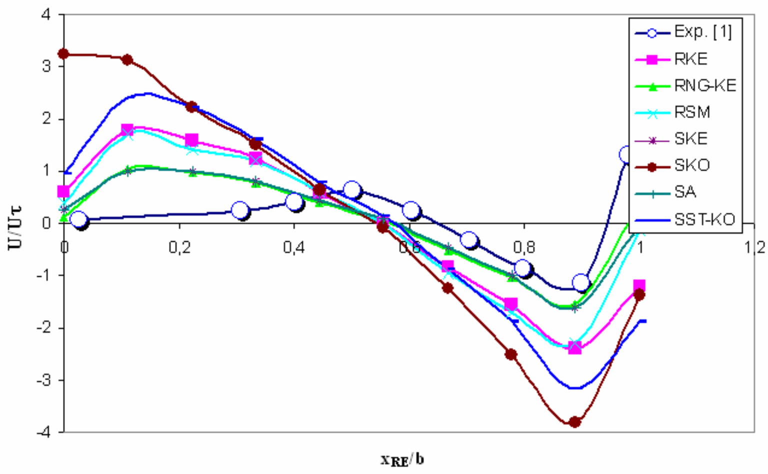

Figure 4. Streamwise velocity comparison with [1].and CFD at the surface between the boundary layer and the groove.

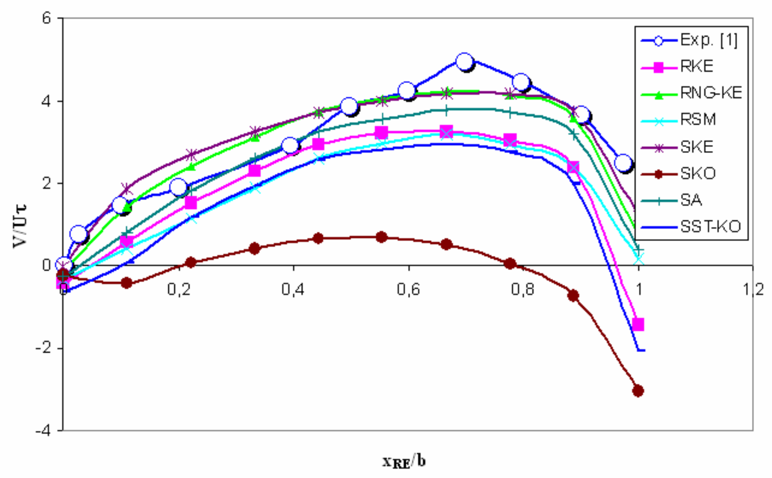

Figure 5. Vertical velocity comparison with [1].and CFD at the surface between the boundary layer and the groove.

4. CONCLUSION

In this study a short comparison of one–equation, two-equation and Reynolds Stress turbulence models (RSM) is made for a rib-roughened pipe for P=3 so k-epsilon and its variants, standard k-omega and shear-stress transport k-omega and one-equation turbulence model of Spalart-Almaras are tested by comparing with 2-D Laser Doppler anemometer results of Ref [1] and it is seen that RNG k-epsilon and Standard k-epsilon give the best results among others. The same conclusion is reported by Ref.[8].

5. REFERENCES

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