University of Nottingham

Department of Mechanical, Materials and Manufacturing Engineering

MMME3086 (Computer Modelling Techniques)

MMME3086 Coursework Assignment (CFD)

2022/23

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Module:	Computer Modelling Techniques
Coursework:	CFD

Part A

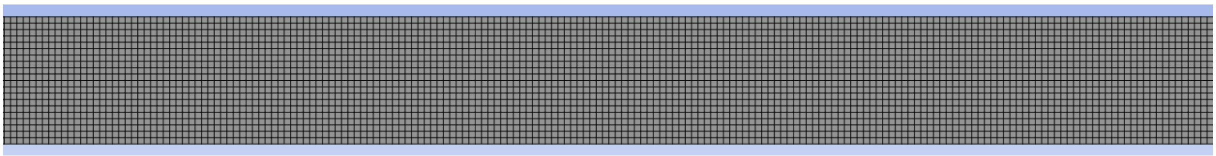

Figure 1: mesh of a duct with 6mm rectangular cells

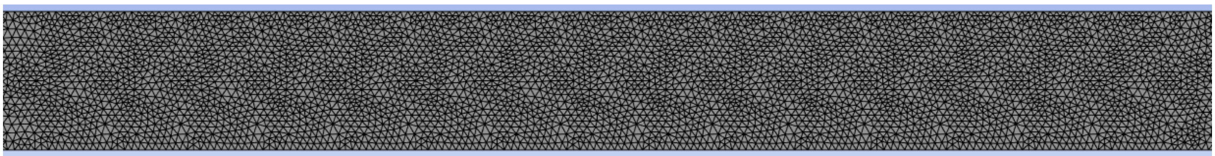

Figure 2: mesh of a duct with 6mm triangular cells

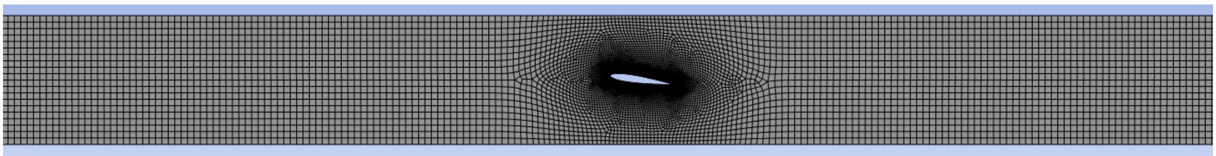

Figure 3: mesh of an aerofoil with 5mm global sizing on a rectangular element mesh

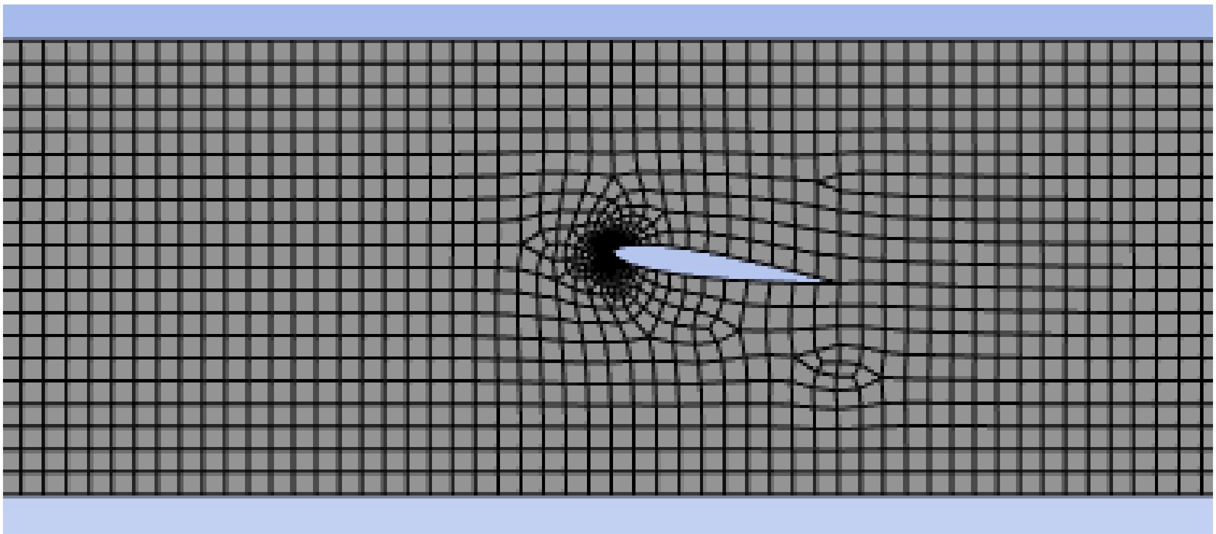

Figure 4: mesh of an aerofoil with 5 mm rectangular cells , 0.5mm cell length on aerofoil surfaces and a 1.05 growth rate

Part B

Density of air	1.225 Kgm^{-3}
Viscosity of air	1.7894×10^{-5} $Kgm^{-1}s^{-1}$
Turbulence intensity at inlet	5%
Velocity at inlet	45 ms^{-1}
Re based on chord	1.54×10^{5}

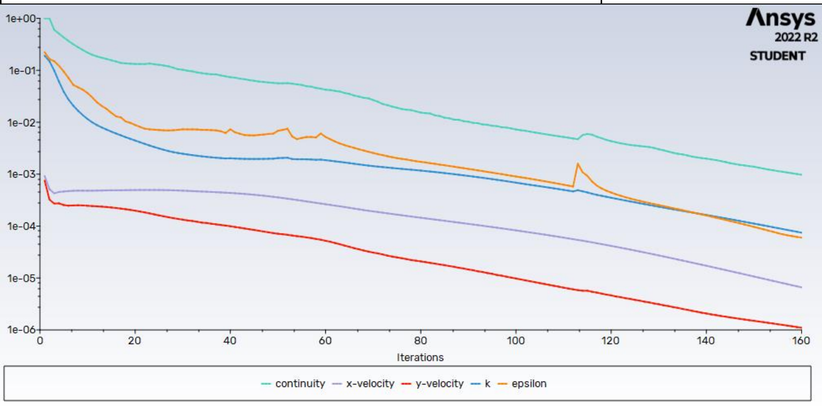

Figure 5: residual plot

For the k epsilon models the number of iterations to convergence was 160 whereas for the Reynolds stress model the number of iterations to convergence was 200. As you can see the difference in the number of iterations to convergence between the two models is 40. This could be because Reynolds stress model is more complexed than the k epsilon model as it includes more equations for stress components unlike the k epsilon model which relies on the kinetic energy and dissipation rate of kinetic energy.

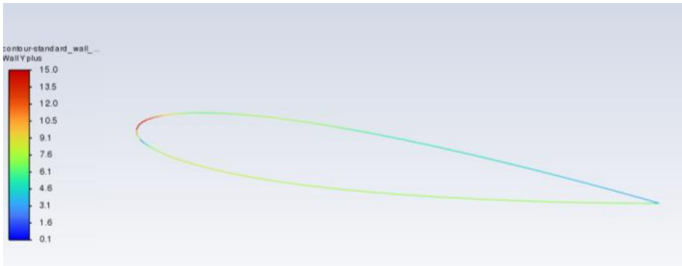

Figure 6: Contours of y+ on aerofoil for standard wall function; where the lift force is 50.52N and the drag force is 2.618N

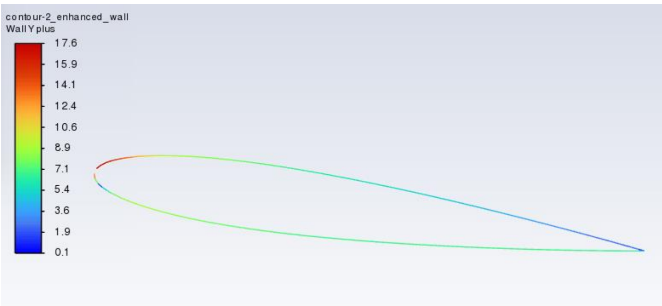

Figure 7: Contours of y+ on aerofoil for enhanced wall function; where the lift force is 53.09N and the drag force is 2.598N

Part C

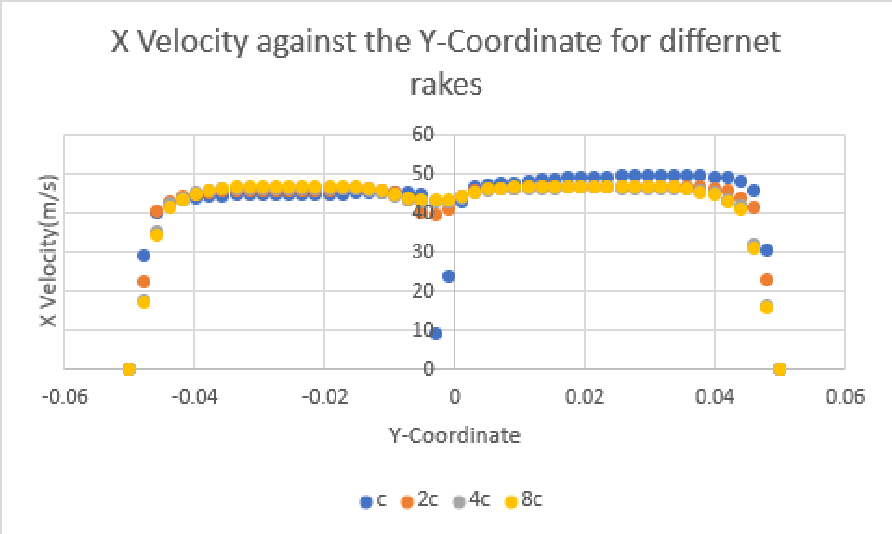

Figure 8: graph showing streamwise velocity vs. width position on duct at c, 2c, 4c and 8c

The lift for the enhanced wall was 2.57N greater than the lift for the standard wall because using the enhanced wall allows for more precise predictions for the flow near the wall. Therefore, allowing for more precise predictions for the lift force due to the lift force being related to the behaviour of the flow within the boundary layer. Furthermore, with the enhanced wall other factors that may influence the lift force are also precisely predicted for example viscous forces and slip boundary conditions, in return giving a more precise prediction for the lift force.

The drag for the enhanced wall was 0.02N less than the drag for the standard wall because when using the standard wall, it does not have attributes that decrease the separation at the boundary layer and increase the laminar flow like smooth surfaces at the wall. As a result, the drag for the standard wall would be higher.

Enhanced wall Lift coefficient (CL):

$$CL = \frac{(Lift\ Force)}{(0.5 \times fluid\ density \times inlet\ velocity^2 * planform\ area)} = \frac{53.089624}{(0.5 \times 1.225 \times (45)^2 \times (0.05))} = 0.856$$

Enhanced wall Drag coefficient (DC):

$$DC = \frac{(Drag\ force)}{(0.5 \times fluid\ density \times inlet\ velocity^2 * planform\ area)} = \frac{2.5975513}{(0.5 \times 1.225 \times (45)^2 \times (0.05))} = 0.042$$

Standard wall CL = $\frac{50.530095}{(0.5 \times 1.225 \times (45)^2 \times (0.05))} = 0.815$ Standard wall DC = $\frac{2.6178376}{(0.5 \times 1.225 \times (45)^2 \times (0.05))} = 0.042$

Based on the Reynolds number calculated in B the graph I shall be using to interpret the data will be when Re=1.1.33 $\times 10^5$. Therefore, the corresponding drag and lift coefficient for an angle of attack of 8 degrees is 0.07 and 0.38 respectively. From this you can see the drag coefficient interpolated by the graph is significantly higher than the drag coefficient calculated above. Furthermore, the lift coefficient interpolated from the graph is significantly lower than the lift coefficient calculated.

$$lift\ force = CL \times (0.5 \times fluid\ density \times inlet\ velocity^2 * planform\ area)$$
$$= 0.38 \times 0.5 \times 1.225 \times 20^2 \times 0.05 = 4.655\ N$$

$$Drag\ force = DC \times\ (0.5 \times fluid\ density \times inlet\ velocity^2 * planform\ area)$$
$$= 0.07 \times \left(0.5 \times 1.225 \times (20)^2 \times (0.05)\right) = 0.8575\ N$$

Hence the net force is the lift force minus drag force which is 3.798 N. From the Sheldahl's results when the Reynolds number was at 3.6 $\times 10^5$ the value of the lift and drag coefficient were 0.75 and 0.03. Even though the Reynolds number is significantly greater the value of these coefficients is like the ones generated. Therefore, the Sheldahl's test compare well to the boundary conditions of the 2D CFD model.