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The Effect of SGS Models on the Large Eddy Simulation of a Corrugated Channel Flow

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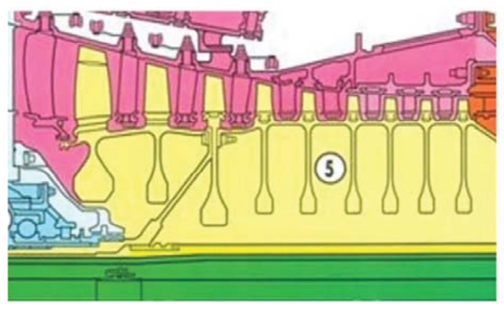
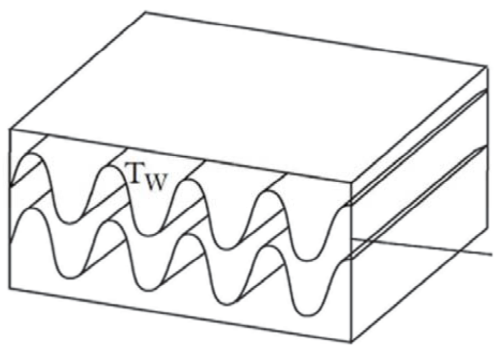
GOAL:

Analyse the effect of different Sub-grid Scale (SGS) models on the Large Eddy Simulation (LES) of the realistic corrugated channel flow.

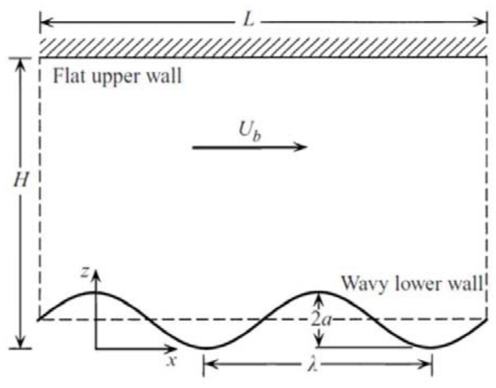
Realistic

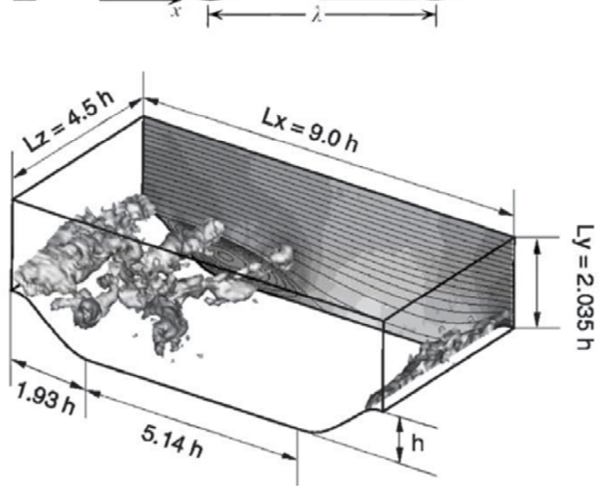




VS

Academia

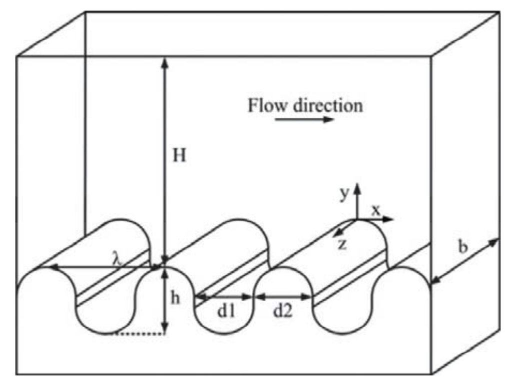




MOTIVATION:

The existing researches in academia on multiple cavities or corrugated wall are focusing on simplified/idealised geometry. Although reports show many SGS models perform well on these idealised geometries, their accuracy of prediction on more realistic corrugated geometry has not been systematically evaluated.

Current Research



Variables	Description	Value (mm)
H	channel height	15.85
h	corrugation height	4.15
λ	wavelength of the corrugation	6.6
d_1	diameter of the groove	3.0
d_2	corrugation diameter	3.6
b	channel width	20

CASE INTRODUCTION:

The geometry is a 2D representation of a widely used commercial stainless steel flex pipe (heat exchanger) with a circular cross-section. the bottom wall has a wavy shape with periodic grooves, whereas top wall and two sidewalls are both flat plates.

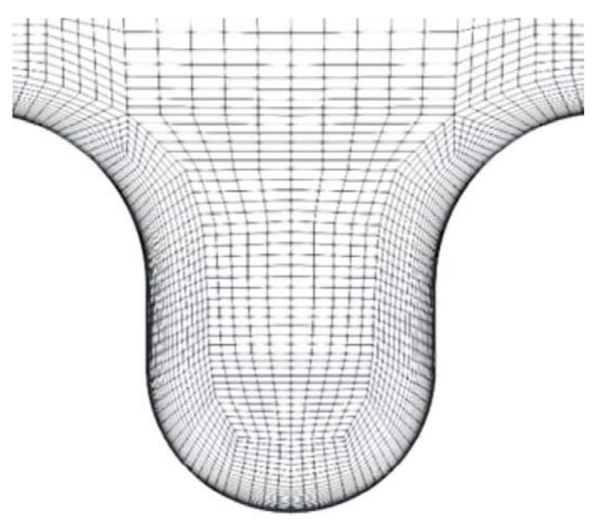
NUMERICAL SETUPS:

$Re_b = 5300 \quad U_b = 0.3m/s \quad \rho = 998.2kg/m^3 \quad \mu = 0.001\ Pa\cdot s \quad \Delta t = 5\times10^{-5}s$

Periodic Boundary Condition (BC) is applied to both inlet and outlet. Spatial interpolation of convection and diffusion terms is based on 2nd order central differencing scheme. Time marching is approximated by 2nd order backwards differencing implicit scheme. The decoupling of velocity and pressure in the equation is obtained by PISO algorithm, i.e. velocity components are calculated by one momentum predictor step (using smooth solvers with symmetric Gauss-Seidel smoother) and pressure field is corrected twice (by generalised geometric-algebraic multi-grid (GAMG) solver) with Gauss-Seidel smoother for the first corrector step and diagonal incomplete-Cholesky/LU with Gauss-Seidel (DICGaussSeidel) for the second one.

MESH DETAILS:

The structured hexahedral mesh is used in current study. The mesh density increases as approaching the wall. The first layer distance on the corrugated wall is less than 0.005 mm, on top wall is less than 0.006 mm and on sidewalls is less than 0.06 mm. A posterior analysis shows that y+ value for the corrugated wall is less than 0.25 with a mean value of 0.04, for top wall it is less than 0.16 with a mean value of 0.11, for sidewalls it is less than 2.4 with a mean value of 0.72, justifying the use of no-slip wall boundary condition. The total number of mesh cells for each corrugation is 0.9 million.



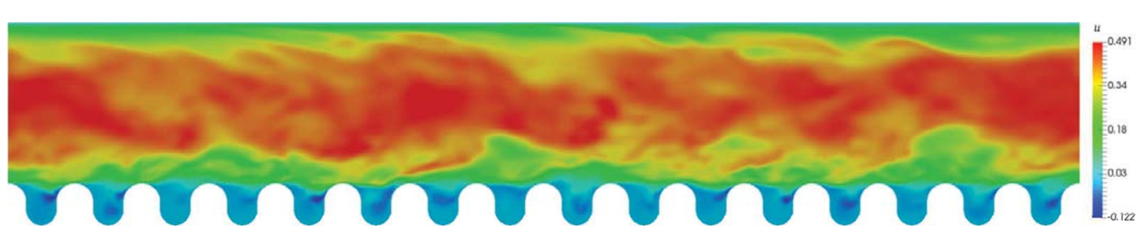
CALCULATION PROCEDURE:

A fully developed flow field with SMAG+VD is used as initial condition for all cases with other SGS models. All cases are allowed for a further 1s simulation to ensure the fluctuation induced by the change of SGS model to be settled, followed by an averaging window of 8s. Flow field became statistically steady before data processing.

RESULTS AND FUTURE STUDIES:

All SGS models tested in the current study can predict a chaotic, 3-dimensional and unstable flow field (Fig. a). Vortex Evolution and hydrodynamics observed in the experiment can be reproduced by all SGS models in LES (Fig. b). The suitable channel length is 16 corrugations (Fig. c) and the current grid is adequately fine (Fig. d). The results suggest that the simulation is insensitive to the selected SGS models for both mean velocity profile (Fig. e) and turbulence intensity (Fig. f-h). In next stage, different inlet turbulence BCs will be tested.

(a)



(b)