RANS SIMULATIONS OF THE MULTIPHASE FLOW AROUND THE KCS HULLFORM

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SUBMISSION EXPLANATION

Test cases: Kriso Container Ship (KCS) - Case 2.1 (wave pattern, Fn=0.26), 2.2b (resistance sinkage and trim), 2.3a (self propulsion at ship point)
Name of the Code: ANSYS CFX v12
Institution: FSI Research Group, University of Southampton, UK & QinetiQ Ltd, UK

MODELING

Governing Equation: Two-phase Volume of Fluid (VOF) Unsteady Reynolds Averaged Navier-Stokes (URANS) equations.
Turbulence Modeling: Sheer Stress Transport (Isotropic two equation blended k-ω/k-ε model (Menter 1994)) & Baseline Reynolds Stress (Anisotropic blend of ω & ε Reynolds Stress models).
Propeller Model: Axial and tangential body force propeller model (Phillips *et al.* 2009).

NUMERICAL METHOD

Discretization: Finite volume method on collocated (nonstaggered) grids.
Advection Scheme: High resolution (bounded second order).
Temporal discretization: Second order backward Euler.
Velocity-pressure coupling : Fully coupled solver.
Mesh movement: Mesh deformation.

HIGH PERFORMANCE COMPUTING

Iridis 3 Linux Cluster (University of Southampton) :
24 Partitions run on 3, 8 processor nodes, each node has 23 Gb RAM.
Linux cluster (QinetiQ Haslar):
up to 64 Partitions run on 8, 8 processor nodes, each node has 8 Gb RAM.

GRIDS, DOMAINS, BOUNDARY AND FLOW CONDITIONS

Grids: (Case2.1 and 2.3a (Southampton)) Systematically √2 refined structured grids (10,4.5 and 1.5M) $y^+=1$, (Case 2.2b (QinetiQ)) Structured grids (680K, 1M, 1.7M, 3M, 5M and 9M)) $y^+=10$.
Domain: the domain size matches towing tank dimensions in [Y,Z] and extends +-2.0L from the hull in X. Half the ship is modeled fro Case 2.1 and 2.2b full ship for Case 2.3a.
Boundary Conditions: Hull has a no-slip wall, X-min (upstream) is uniform velocity (U_0) inlet, X-max (downstream) and Z-max (top) is an opening with entrainment, Y-max (side) and Z-min (bottom) use free-slip walls, a longitudinal symmetry plane at Y=0, is used for cases without the propeller.

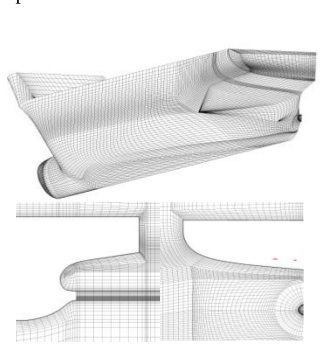
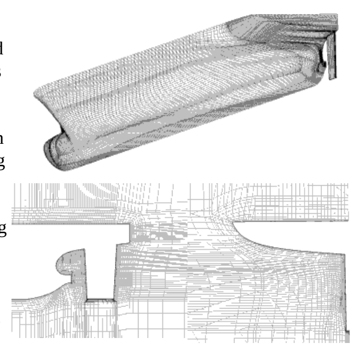


Figure 1: Hull surface mesh and surrounding O-grid structure for Cases 2.1&2.3(left) and 2.2 (right). Note a comparison of the two meshing strategies, Soton and QinetiQ, was made by conducting the case 2.1 simulations using both meshes (without a rudder).



VERIFICATION AND VALIDATION

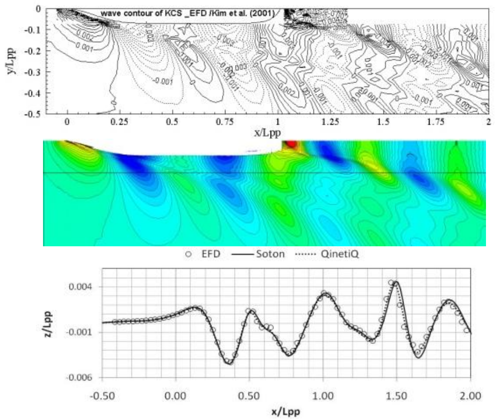


Figure 2 - Case 2.1: Free surface contour plots for EFD (top), Soton CFD (middle) and comparison of a wave cut at y/L=0.15 for both Soton and QinetiQ meshes with EFD data (bottom).

Parameters	EFD	Coarse (1.5M)	Medium (3.4M)	Fine (9M)
$CT\times10^3$	4.162	4.344	4.321	4.287
$CF\times10^3$		2.903	2.959	2.988
$CP\times10^3$		1.441	1.362	1.300
K_T	0.170	0.200	0.199	0.202
K_Q	0.0288	0.034	0.033	0.034
w_T	0.208	0.281	0.279	0.296
n (rps) (for given SFC)	9.5	9.463	9.464	9.358

Table 2 - Case 2.3a: Table of propeller model characteristics.

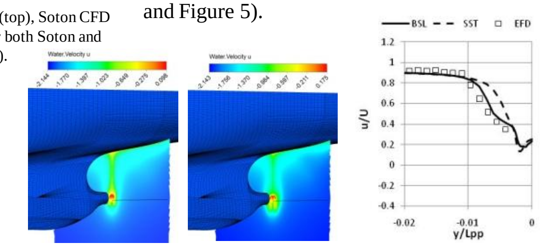


Figure 3 - Case 2.1: Comparison of axial velocity at prop plane with SST (left), BSL (middle) and both plotted against EFD data (right).

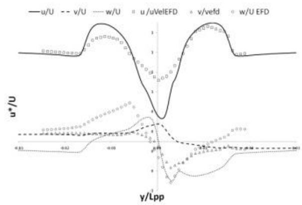


Figure 5 – Case 2.3a: velocity components at the propeller plane.

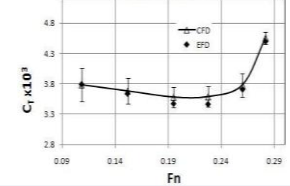


Figure 4 - Case 2.2b: Total simulated resistance, plotted with uncertainty, compared to EFD data.

The free surface simulations for Case 2.1 (Figure 2) shows good correlation between the numerical results and the EFD data for both contour plots and wave cuts. The BSL turbulence model was found to be significantly better at capturing the prop plane velocities (Figure 3).

The resistance components for a towed hull free to sink and trim closely agreed with the experimental data (Figure 4) and were validated using the least squares approach of Eca & Hoeksra, 2008 (Table 1).

The body force propeller model in Case 2.3a simulated the action of the propeller well, but due to the inaccuracies in the nominal wake failed to correctly simulate the experimental data (Table 2 and Figure 5).

$Re = 1.1\times10^7$, $Fr = 0.2274$.

Parameters	EFD (D)	V&V Study						r_G	$\varepsilon_{12}\%S_1$	U_I/ε_{12}	$p_G/p_{G,th}$	$U_G\%S_1$	$U_D\%D$	$U_v\%$
		Grid#N (S_N)		Grid # …	Grid#3 (S_3)	Grid#2 (S_2)	Grid#1 (S_1)							
$C_T\times10^3$	3.467	3.895	3.793	3.724	3.664	3.621	3.591	1.2	0.835	0.033	0.772	4.631	1.0	4.74
$\sigma\times10^2$(m)	-0.944	-0.967	-0.964	-0.965	-0.966	-0.968	-0.968	1.2	0.035	0.006	0.015	8.107	2.78	8.57
$\tau°$	-0.127	-0.121	-0.124	-0.126	-0.128	-0.129	-0.130	1.2	0.354	0.068	0.803	3.679	3.26	4.92

Table 1 – Case 2.2b: Example uncertainty analysis.

REFERENCES

Eca, L., Hoekstra, M., (2008) Testing Uncertainty Estimation and Validation Procedures in the Flow Around a Backward Facing Step, 3rd Workshop on CFD Uncertainty Analysis, Lisbon.

Menter, F.R., (1994) Two Equation Eddy Viscosity Turbulence Models for Engineering Applications, *AIAA Journal*, **32(**8), 1598-1605.

Phillips, A.B., Turnock, S.R. and Furlong, M.E. (2009) Evaluation of manoeuvring coefficients of a self-propelled ship using a blade element momentum propeller model coupled to a Reynolds averaged Navier Stokes flow solver. Ocean Engineering, Vol 36, Issues 15-16, pp1217-1225.