Hydrodynamic Performances of KRISO Container Ship (KCS) Using CAD-CAE and CFD Techniques

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MASTER THESIS developed at "Dunarea de Jos" University of Galati in the frame of the "Emship" Erasmus Mundus Master Course in "Integrated Advanced Ship Design"

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Main objectives

To perform CAD-CAE computations of the hydrostatics and hydrodynamic characteristics using Tribon capabilties

To perform CFD potential and viscous compuataion in order to determine the characteristics of the flow around the hull, the topology of the free sureface, the own wave profile along the ship and the components of the KCS resistance

To perform model resistance tests in the small towing tank of Galati university and to compare the results with other obtained in a large towing tank to develop model test with this type of ship

To compare CAD-CAE, CFD and model experimental results, in order to verify the capabilities of the numerical systems to calculate and reproduce the physical reality.

Introduction

Hydrodynamic aspects play a significant role in the quality of the ship, dominant criteria in the hull form design are:

- **Resistance,;**
- **powring performance;**
- **Maneuvrability.**

CFD instruments used as a predictive tool for an accurate representation of reality
Ship flow has been applied directly to full scale in order to sudy the free surface potential flow and viscous flow around the KCS hull

C H A P T E R 1

General presentation of the KCS hull

The KCS container ship designed at the KRISO now MOERI, in order to be used as a benchmak model for CFD prediction

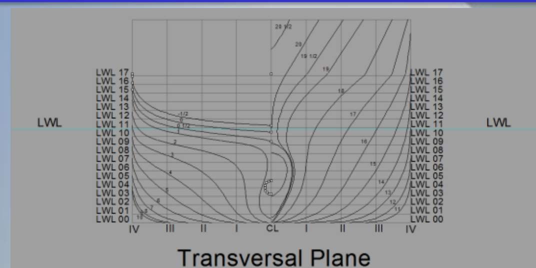
Figure 1.KRISO Container Ship KCS Hull.

Main characteristics	Full scale	Model scale 1/65.67
Length over all, *LOA* [m]	243.84	3.713
Length of waterline, *LW* [m]	232.5	3.54
Length between perpendiculars, *LBP* [m]	230.0	3.502
Beam, *B* [m]	32.2	0.49
Depth, *D* [m]	19.0	0.289
Draft, *T* [m]	10.8	0.164

Preliminary hydrodynamic performances

CHAPTER 2

RHINOCEROS.



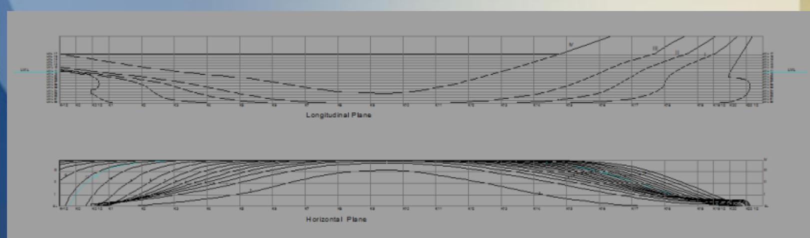


Figure 2.KRISO Container Ship Lines Plan

Geometry Preparation

CHAPTER 2

AVEVA Tribon-M3 Initial design.

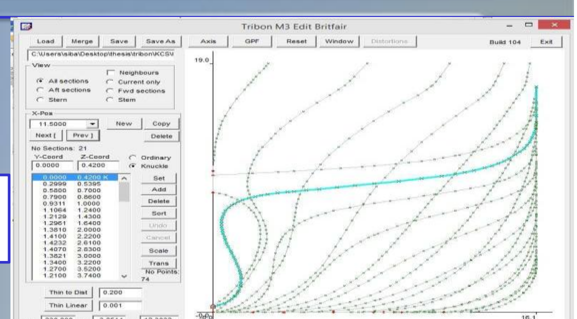


Figure 3. Britfair file generation.

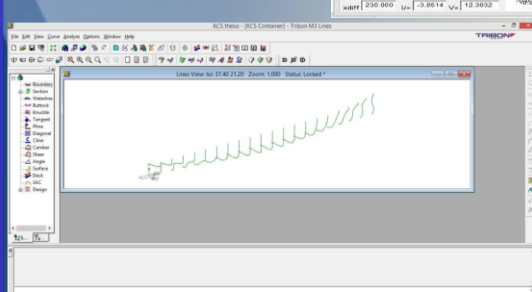


Figure 4. Lines fairing.

C H A P T E R 2

Hydrostatic calculaions

AVEVA Tribon-M3 Initial design.

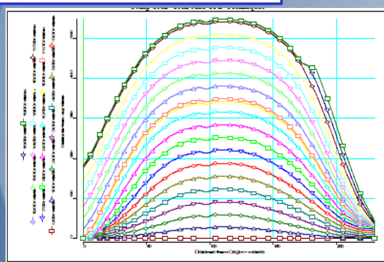


Figure 7. Bonjean curves.

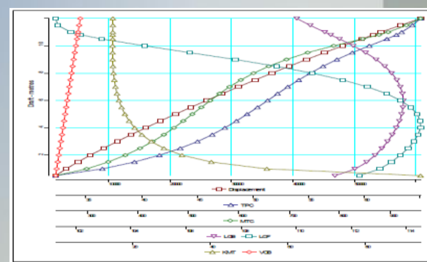


Figure 6. Hydrostatic curves.

- The form of the curves are typical
- The intercestion point between LCB and LCF is situated on the maximum of the LCB curve

C H A P T E R 2

Hydrostatic calculaions

main characteristics	Full scale KCS	KCS hull modelled in Tribon-M3	difference	
Volumetric displacement ∇ (m^3)	52030	51751,73659	0,5348134	%
hull wetted surface (m^2)	9424	9506,86	-0,879244	%
block coefficient C_B	0,6505	0,656	-0,845503	%
midship section coefficient C_M	0,985	0,9841	0,0913706	%
longitudinal prismatic coefficient C_P	0,66040	0,6665	-0,922752	%

- The comparison of the hydrostatics Tribon results with the KC S data suggest a very good accuracy of the CAD-CAE instrume nt, all the differences being less than 1%

C H A P I T R E 2

Resistance and propeller.

AVEVA Tribon-M3
Initial design.

V Knts	Rf*(1+k)	Rw	Ra	Rb	Rt
14	439,5754	17,18296	80,86097	3,643797	541,2631
15	500,1459	26,39714	92,82509	4,300412	623,6686
16	564,7528	40,59551	105,6143	4,904465	715,8671
17	632,6963	61,47728	119,2287	5,549722	818,9519
18	704,8655	91,06141	133,6681	6,0819	935,6769
19	780,3957	131,7124	148,9327	6,620524	1067,661
20	859,2045	186,1659	165,0224	7,163003	1217,556
21	941,8831	254,1435	181,9372	8,170116	1386,134
22	1027,807	336,3311	199,6771	8,642274	1572,457
23	1117,71	439,2122	218,2421	8,964976	1784,129
24	1210,855	577,0008	237,6322	9,980554	2035,469
25	1307,178	755,8154	257,8475	11,87307	2332,714
26	1407,647	963,0345	278,8878	12,06626	2661,636

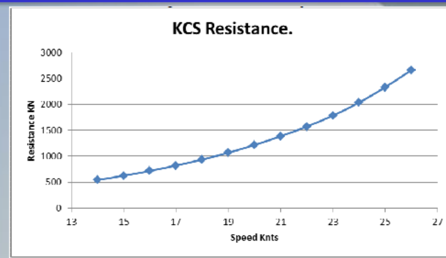


Figure 8. KCS Resistance.

- **We observe that the viscous resistance is the most important component, which represents about 60% from total resistance while the wave resistabce is about 28%**

C H A P I T R E 2

Resistance and propeller.

AVEVA Tribon-M3
Initial design.

J	Kt	Kq	eta0
0.326	0.391	0.0620	0.327
0.390	0.362	0.0580	0.388
0.455	0.332	0.0537	0.447
0.519	0.300	0.0493	0.503
0.584	0.268	0.0447	0.556
0.648	0.234	0.0400	0.605
0.713	0.200	0.0352	0.646
0.777	0.166	0.0303	0.677
0.842	0.131	0.0253	0.692
0.906	0.095	0.0203	0.678
0.971	0.060	0.0153	0.608
1.035	0.025	0.0103	0.397

Blade Area Ratio	0.917

Diameter	7.900	metres
Pitch ratio	1.035	
Effective BAR	0.917	(0.917 min)
Local Cavitation no	0.362	
Thrust load. coeff.	0.146	(0.146 max)
Kt/J^2	0.535	
Adv. coeff. J	0.656	
Thrust coeff. Kt	0.230	
Torque coeff. Kq	0.0395	
Open water eff.	0.610	

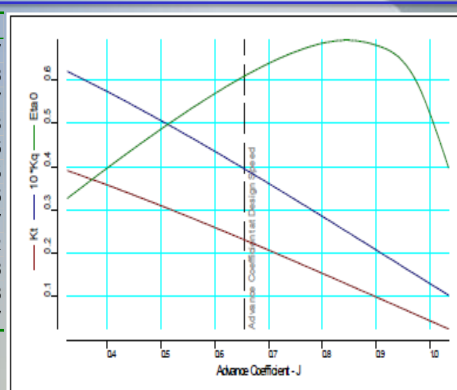


Figure 9. Open water characteristics of the propeller.

CHAPTER 2

Propeller rotation and Brake power

AVEVA Tribon-M3
Initial design.

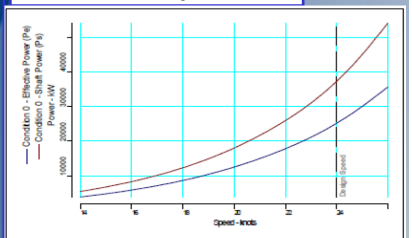


Figure 11. Brake power diagram.

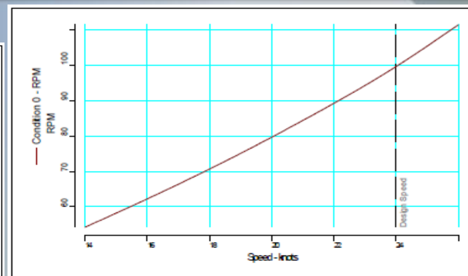


Figure 10. Propeller rotation speed diagram.

Speed kts	Pe (kW)	THDF	WFT	ETAR	ETA0	QPC	Ps (kW)	RPM
14.000	3899	0.195	0.306	0.988	0.638	0.732	5491	54.21
15.000	4814	0.195	0.306	0.988	0.638	0.731	6787	58.15
16.000	5892	0.195	0.306	0.988	0.637	0.730	8323	62.19
17.000	7164	0.195	0.305	0.988	0.636	0.728	10148	66.33
18.000	8664	0.195	0.305	0.988	0.634	0.725	12319	70.61
19.000	10435	0.195	0.305	0.988	0.631	0.722	14906	75.03
20.000	12528	0.195	0.305	0.988	0.628	0.718	17998	79.62
21.000	14975	0.195	0.304	0.988	0.624	0.713	21652	84.35
22.000	17801	0.195	0.304	0.988	0.620	0.708	25909	89.19
23.000	21116	0.195	0.304	0.988	0.615	0.703	30970	94.22
24.000	25135	0.195	0.304	0.988	0.610	0.696	37217	99.58
25.000	30003	0.195	0.304	0.988	0.603	0.688	44947	105.35
26.000	35604	0.195	0.303	0.988	0.595	0.680	54018	111.38

Pe – effective power;
THDF – thrust deduction fraction;
WFT – wake fraction;
ETAR – relative rotative efficiency;
ETA0 – open water efficiency;
QPC – quasi-propulsive coefficient;
Ps – brake power;
RPM – propeller revolution.

CHAPTER 2

Turning test characteristics

AVEVA Tribon-M3
Initial design.

ADVANCE/L	AT 90 DEG	3.35	
TRANSFER/L	AT 90 DEG	1.88	
SPEED/APR. SPEED	AT 90 DEG	0.71	
TIME	AT 90 DEG	122.00	SECS
MAX ADVANCE/L	AT 90 DEG	3.38	
MAX TRANSFER/L	AT 90 DEG	2.21	
TACTICAL DIAM/L		3.96	
ADVANCE/L	AT 180 DEGS	1.96	
SPEED/APR. SPEED	AT 180 DEGS	0.56	
TIME	AT 180 DEGS	234.00	SECS
MAX TACTICAL DIAM/L		3.99	
MAX ADVANCE/L	AT 180 DEGS	1.65	
TRANSFER/L	AT 270 DEGS	2.75	
ADVANCE/L	AT 270 DEGS	0.12	
SPEED/APR. SPEED	AT 270 DEGS	0.50	
TIME	AT 270 DEGS	348.00	SECS
STEADY TURNING DIAM/L		2.85	
STEADY TURNING RATE		0.76	DEG/S
NON DIM. TURNING RATE (L/R)		0.70	
TRANSFER/L	AT 360 DEGS	1.03	
ADVANCE/L	AT 360 DEGS	1.27	
STEADY DRIFT ANGLE		11.55	DEGS
SPEED/APR. SPEED	AT 360 DEGS	0.47	
TIME	AT 360 DEGS	466.00	SECS

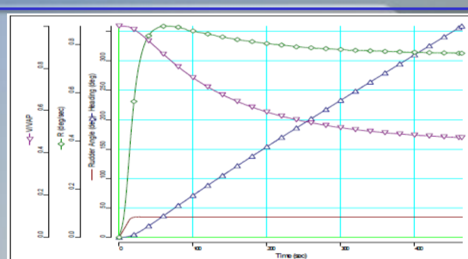


Figure 12. Turning characteristics of KCS.

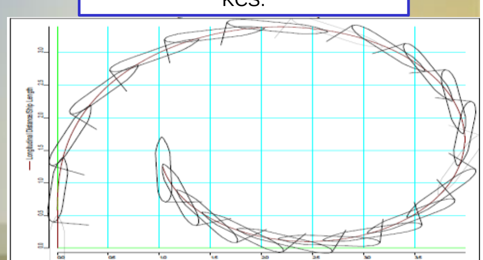


Figure 13. Turning trajectory of the ship in deep water.

CHAPTER 2

Zig-Zag and spiral maneuvre

AVEVA Tribon-M3
Initial design.

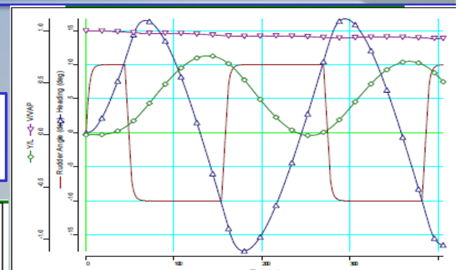


Figure 14. Zig-Zag characteristics of the ship.

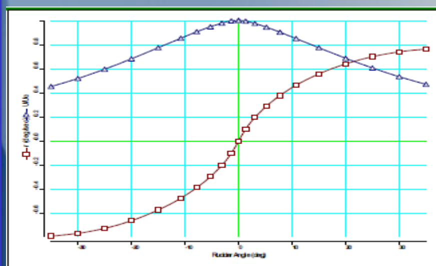


Figure 15. Dimentional reverse spiral maneuvre

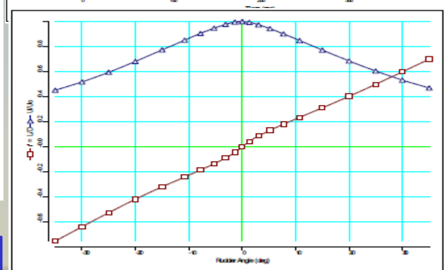


Figure 16. Non-Dimentional reverse spiral maneuvre

CHAPTER 2

Zig-Zag and spiral maneuvre

AVEVA Tribon-M3
Initial design.

1ST OVERSHOOT ANGLE	6.50	DEG
1ST OVERSWING ANGLE	4.14	DEG
2ND OVERSHOOT ANGLE	7.38	DEG
2ND OVERSWING ANGLE	4.91	DEG
3RD OVERSHOOT ANGLE	6.74	DEG
3RD OVERSWING ANGLE	4.22	DEG
4TH OVERSHOOT ANGLE	6.50	DEG
4TH OVERSWING ANGLE	4.43	DEG
PERIOD	226.00	SEC
INITIAL TURNING TIME	44.00	SEC
1ST TIME TO CHECK YAW	24.00	SEC
1ST LAG TIME	19.33	SEC
2ND TIME TO CHECK YAW	26.00	SEC
2ND LAG TIME	21.33	SEC
3RD TIME TO CHECK YAW	24.00	SEC
3RD LAG TIME	19.33	SEC
4TH TIME TO CHECK YAW	24.00	SEC
4TH LAG TIME	19.33	SEC
OVERSHOOT WIDTH OF PATH/LENGTH	0.69	

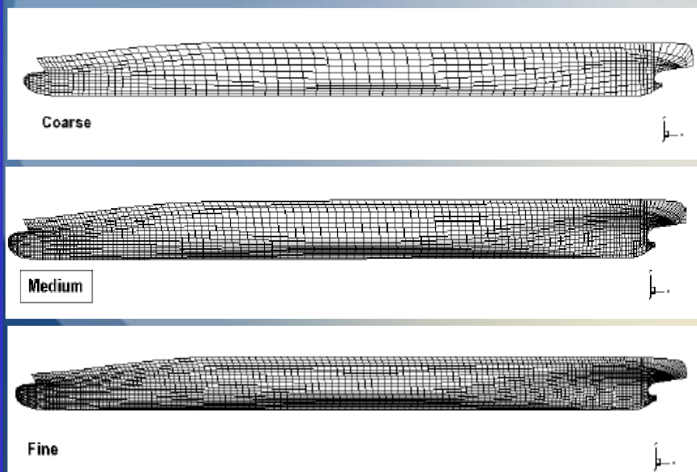
STANDARD MANOEUVRE		MAXIMUM VALUES	KCS values
TURNING CIRCLE	Advance (AD)	≤ 4,5 *L*	3.35
	Tactical diameter (TD)	≤ 5 *L*	3.96
	First overshoot angle (zigzag 10°/10°)	≤10° if *L/v*<10 sec.	6.5
		≤20° if *L/v*>30 sec.	
		≤ (5+0,5*L/v*) [degrees] if 10 sec.<*L/v*<30 sec.	
	Second overshoot angle (zig-zag 10°/10°)	Should not exceed the first overshoot angle by more than 15°	7.80
ZIG-ZAG MANOEUVRE	First overshoot angle (zigzag 20°/20°)	≤25°	
CRASH- STOP	The track reach	≤15 *L*	

- **The maneuvring performances of the KCS satisfy the IMO criteria**

C H A P T E R 3

CFD, Computational grids

The free surface flow of a modern container ship KCS without propeller was simulated with three sets of grid



N of panels 2608

N of panels 6568

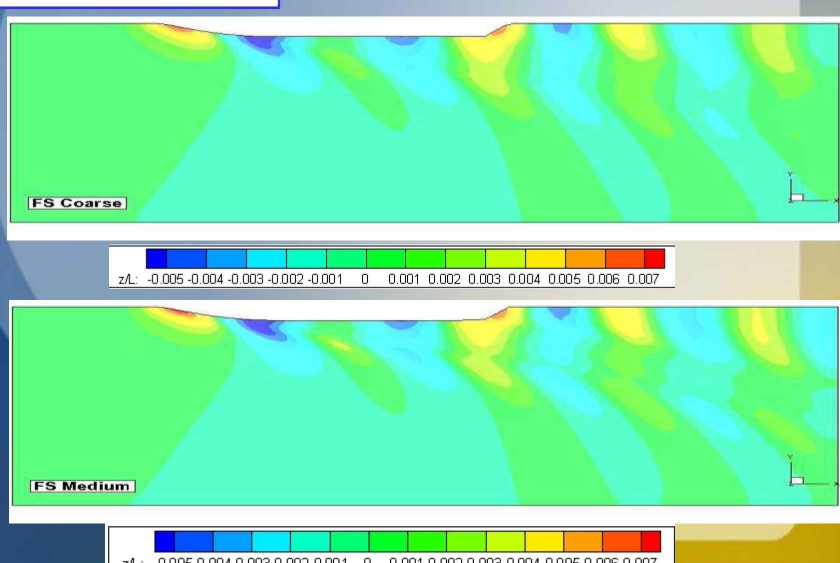
N of panels 10458

Figure 17. Three sets of grid.

C H A P T E R 3

Free surface potential flow around the hull

SHIPFLOW Code.



CHAPTER 3

Free surface potential flow around the hull

SHIPFLOW Code.

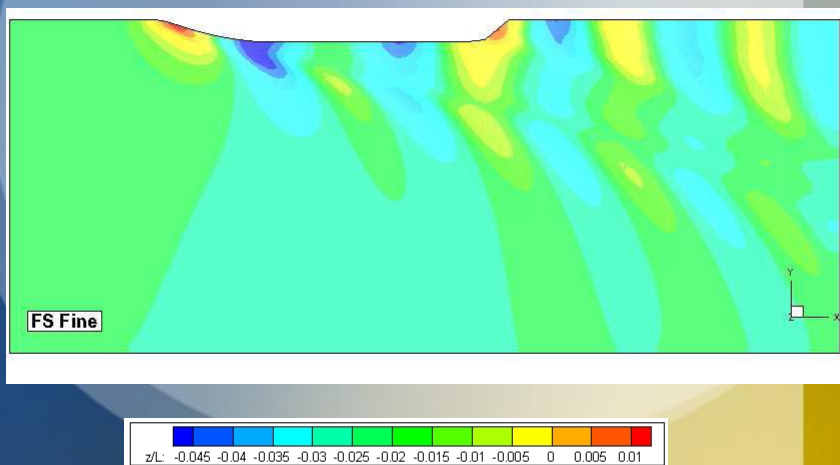


Figure 18. Free surface potential flow for three sets of grid

CHAPTER 3

Pressure distribution around the hull

SHIPFLOW Code.

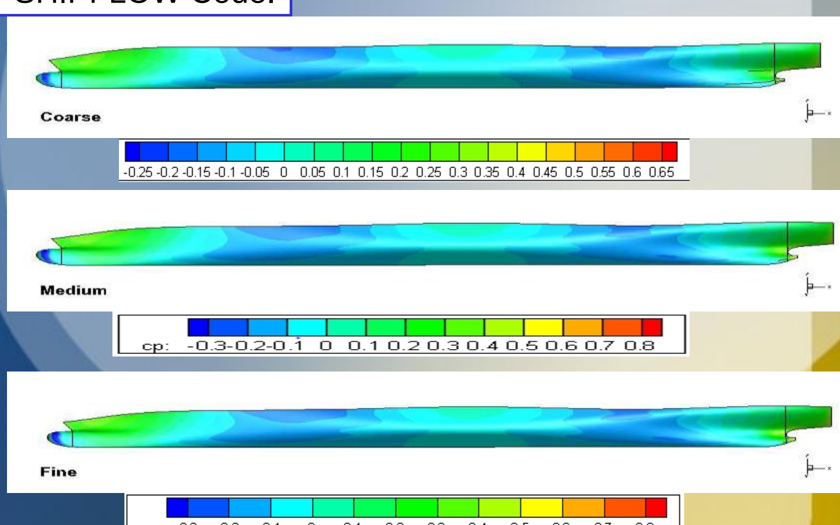


Figure 19. pressure around the hull for three sets of grid

CHAPTER 3

Wave cut elevation and resistance

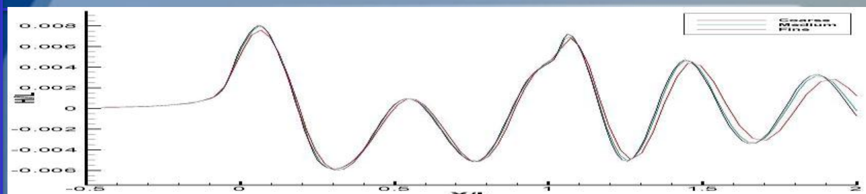


Figure 20. Wave profile for three sets of grids at 24 Knts speed.

- The wave elevation from the coarse mesh has less amplitude to the other meshes

- The difference between the medium and fine mesh are les than 2%, while the difference between fine and coarse mesh about 9.3%

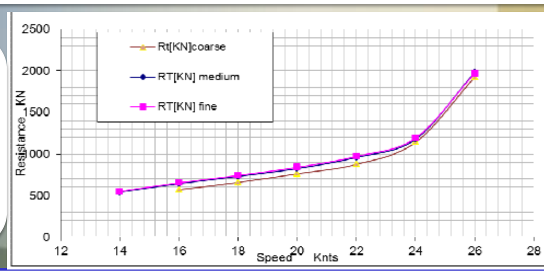


Figure 21. comparison of resistance for three sets of grid.

CHAPTER 4

Viscous flow mesh, Free surface

Viscous flow computaions for one set of grid

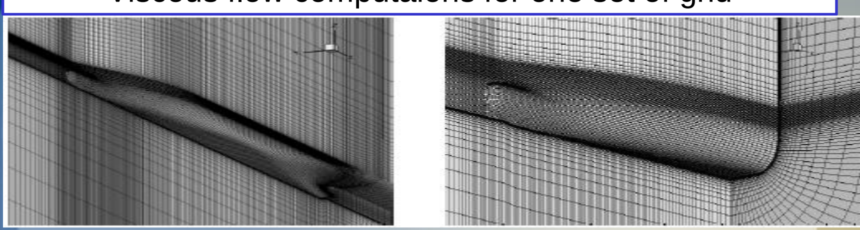


Figure 22. Coarse mesh for viscous flow

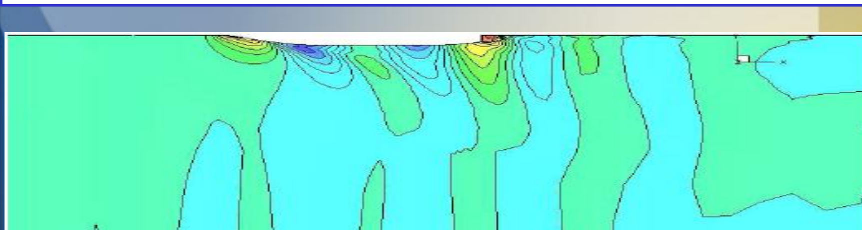


Figure 23. Free surface for viscous flow at design speed 24 Knts.

CHAPTER 4

Pressure distribution for viscous flow, resistance

SHIPFLOW Code.

Figure 24. Pressure distribution for viscous flow at design speed.

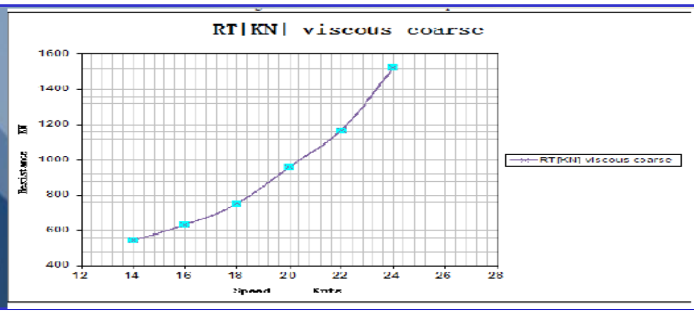


Figure 25. Ship resistance for Viscous flow.

CHAPTER 5

Resistance test

Towing tank test.

Size: 45 x 4 x 3

Figure 26. University of Galati Towing Tank.

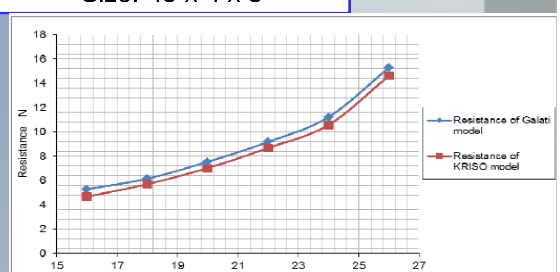


Figure 27. Comparison results for KCS model resistance from Galati with KRISO results.

- The medium difference between the KRISO and Galati model experimental results are about 7.5%. As a consequence, in the case of this type of ship. Seems to be rational to use the small towing tank of Galati university only for educational point of view.

CHAPTER 5

Resistance test full scale comparison

Figure 27. Comparison results for KCS full scale test with Tribon and viscous flow results.

The Comparison of CAD-CAE, CFD (viscous) and experimental r esults (transpose to the full scale) suggest the following remakrs:

- The CFD numerical results underestimates the experimental r esults with about 27%.
- The ITTC1957 method used to transpose the model experime ntal results to the full scale don't perform the form factor deter mination, as a consequence is an optimistic method
- A very good correlation was established between the tribon re sults obtained on the basis of Holtrop-Mennen method and ex perimental results, the medium difference being less than 1%.

CHAPTER 6

Conclusions

The Holtrop and Mennen method from the Tribon initial design has been used for resistance calculations. And a B-Series Wageningen for the optimum propeller.

The KCS KRISO container ship has good maneuvering properties referring to the IMO criteria.

Potential flow analysis free surface around the KCS hull has been performed fusing SHIPFLOW Code or different sets of grids and for a range of speed [14 Knts – 26 Knts]

Viscous flow analysis free surface around the KCS hull has been performed for coarse grid and for a range of speed [14 Knts – 24 Knts]

The accuracy of the resistance test results in small towing tanks as the one of the UGAL, which allow a model not exceeding 4m, should be verified, in this thesis it was verified referring to the results from the KRISO towing tank results and the numerical results.

C H A P T E R 6

Future recommandations

- Seakeeping calculations
- Hydrodynamic derivatives calculations
- Study of the viscous flow for different sets of grids

Thank you for attention

شكرا على انتباهكم

Hassiba OUARGLI