

PERFORMANCE OF DOUBLE ACTING TANKER DURING ASTERN IN ICE
CONDITION

MUHAMAD RIDZUAN BIN ARIFIN

A project report submitted in partial fulfilment of the
requirement for the award of the degree of
Master of Science (Ship and Offshore Engineering)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JUNE 2016

Dedicated to...

My beloved mother Zabidah binti Zainudin,

My beloved father Arifin bin Yatim,

My beloved wife Miftahul Jannah binti Mohamad,

My beloved son Muhamad Ar Rayyan bin Muhamad Ridzuan,

Universiti Teknologi Mara,

Marine Technology Center.

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many peoples, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my supervisor, Dr. Eng. Jaswar Koto, for encouragement, guidance, critics and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Teknologi Mara (UiTM) for funding my master study. And also thanks to librarians at Universiti Teknologi Malaysia (UTM) for their assistance in supplying the relevant literatures.

My fellow postgraduate students should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

ABSTRAK

Tujuan kajian ini adalah untuk menyiasat prestasi kapal tangki dual-tindakan (DAT) semasa bergerak mengundur dalam keadaan lautan diselaputi ais. Reka bentuk kapal adalah berdasarkan reka bentuk yang sedia ada dikenali sebagai Kapal-A yang merupakan kapal tangki yang sudah digunakan di pasaran. Prestasi kapal telah dinilai untuk bergerak mengundur dalam keadaan ketinggian ais yang berbeza. Reka bentuk kapal baru yang dikenali sebagai Kapal-B telah dibangunkan dengan berpandukan reka bentuk pada Kapal-A dengan pengubahsuaian tertentu pada bahagian belakang kapal. Kesan geometri rekabentuk kapal telah dikaji dan rintangan kapal telah dianalisa. Hasil kajian diantara data Kapal-A dan Kapal-B telah dibandingkan dengan perbincangan mengenai hubungan rekabentuk geometri bahagian belakang kapal dengan rintangan terhadap kapal.

ABSTRACT

The purpose of this study is to investigate the performance double acting tanker (DAT) during astern in ice condition. The design of ship is based on the existing design known as Ship-A which is the tanker that already used in the market. The performance of ship has been evaluated for moving astern in different ice level condition. The design of ship is designed using SolidWorks and Maxsurf. The design from SolidWorks format is used in CFD simulations by ANSYS to evaluate the performance of ship. New ship design known as Ship-B has been developed based on design on Ship-A with certain modification at stern hull. The effect of ship geometry was studied and resistance of ship were highlighted. Results were compared between data of Ship-A and Ship-B come out with discussion about the relationship of stern hull geometry with resistance of ship.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRAK	v
	ABSTRACT	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF SYMBOLS	xiv
	LIST OF APPENDICES	xv
1	INTRODUCTION	1
	1.1 Background of study	1
	1.2 Problem Statement	2
	1.3 Objective	2
	1.4 Scopes of Study	3
2	LITERATURE REVIEW	4
	2.1 Introduction	4
	2.2 Past researcher	4
3	METHODOLOGY	10
	3.1 Introduction	10

4	DOUBLE ACTING TANKER (DAT) CONCEPT	12
	4.1 Introduction	12
	4.2 Double Acting Tanker concept	12
	4.3 Power of DAT using Azipod.	15
	4.4 Design of the stern hull for DAT	17
5	FUNDAMENTAL THEORY	22
	5.1 Introduction	22
	5.2 Deadweight carrier hull	22
	5.3 Hull resistance in open water	24
	5.4 Hull resistance in ice condition	25
	5.5 Viscous Flow	29
	5.6 Turbulence Model	33
	5.6.1 The k- ω model	34
	5.6.2 The k- ω Shear Stress Transport (SST) Model	36
	5.7 Boundary Layers	38
	5.8 Fluid Structure Interaction	39
	5.9 Rigid Body Motion	39
	5.10 Non dimensional coefficients	41
	5.11 Design of Hull Tanker	41
6	NUMERICAL METHODS	43
	6.1 Introduction	43
	6.2 The Finite Volume Method	43
	6.2.1 Mesh Quality	46
	6.3 Pressure Velocity Coupling	48
7	CFD SIMULATIONS	50
	7.1 Introduction	50
	7.2 Computational domain definition	50
	7.3 Mesh generation	51

7.4	Boundary conditions	53
7.5	Solution	53
8	RESULTS AND DISCUSSION	55
8.1	Introduction	55
8.2	Ship Design using SolidWorks	55
8.3	Ship Design using Maxsurf	57
8.4	Mesh sequences	60
8.5	Fluid flow through hull surface	61
8.6	Wave pattern	64
8.7	Ship resistance	67
8.8	Stern hull modification	69
9	CONCLUSION AND RECOMMENDATION	71
9.1	Conclusion	71
9.2	Recommendation	72
	REFERENCES	73
	Appendices A - B	77-78

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Ship parameter of MT Uikku ⁷	7
2.2	Maximum ship speed attainable at full power in astern mode ⁷ .	8
2.3	Hull resistance augmentation in 18mm level ice in astern mode ⁷ .	8
2.4	Hull resistance augmentation in 29mm level ice in astern mode ⁷ .	8
2.5	Average value of the model ice properties ⁷ .	9
4.1	List of double acting tanker (DAT) power by Azipod ¹⁰	16
6.1	Fluid properties used in the simulations.	54
6.2	ANSYS Fluent setups for k- ω SST transition model.	54
8.1	Comparison resistance by meshing type.	60
8.2	Ship resistance in ice level with different speed while moving astern.	67
8.3	Resistance coefficient for different speed in different ice level.	68
8.4	Comparison data for Ship-A and Ship-B	70

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Location of ice actions ¹	1
2.1	MT Uikku in level ice ² .	5
2.2	Ice breaking capability of DAT ² .	5
2.3	Speed of vessel against ice thickness for MT Mastera ³ .	6
2.4	Thick ice against speed curve ⁷ .	9
3.1	Flow chart for thesis methodology	11
4.1	Bulbous bow for common tanker ² .	13
4.2	Ice breaking bow ² .	14
4.3	Stern hull design of Vasily Dinkov tanker ⁵ .	14
4.4	Propeller milling the ice level.	15
4.5	MT Uikku ³ .	17
4.6	Stern design for model vessel ² .	18
4.7	General arrangement of double acting tanker Tempera ³ .	19
4.8	General Arrangement of MT Vasily Dinkov ⁵ .	19
4.9	MT Mikhail Ulyanov ⁶ .	20
4.10	Common design with pod hanger	21
5.1	Characteristic and properties parts of a hull.	23
5.2	Hull and ice interaction ¹³	26

5.3	The h-v curves determined from the full scales tests of four vessels ⁷ .	27
5.4	Kelvin wake pattern behind a moving object ¹⁶ .	29
5.5	Schematic illustration of a boundary layer at a flat plate ¹⁹ .	38
5.6	Coordinate system showing the 6 degrees of freedom of a rigid body ¹² .	40
5.7	Stern part modification	42
6.1	Cell centered, a) Vertex centered, b) Control volumes.	44
6.2	Geometries of mesh element.	45
6.3	Wrong edge association in mesh generation ²¹ .	46
6.4	a) Good quality and b) Poor quality boundary layer meshes ²¹ .	46
6.5	a) Positive and b) Negative Hexahedral cell ²¹ .	47
6.6	a) Gradual and b) Abrupt node distribution ²¹ .	47
6.7	a) Low and b) High aspect ratio hexahedral cells ²¹ .	47
6.8	a) Normal and b) Skewed hexahedral cells ²¹ .	48
6.9	a) Normal positive and b) Deformed by small angles hexahedral cells ²¹ .	48
7.1	Dimensions of computational domain.	51
7.2	Mesh application interface.	52
7.3	Schematic illustration of the FLUENT mesh structure.	52
7.4	Boundaries of the computational domain.	53
8.1	Isometric view of Ship-A.	55
8.2	Hull top view of Ship-A.	56
8.3	Front view of Ship-A	56
8.4	Back view of Ship-A	57
8.5	Size surface for ship design.	57

8.6	Perspective view of ship.	58
8.7	Profile view of ship.	58
8.8	Plan view of ship.	59
8.9	Body plan view of ship.	59
8.10	Plot of comparison resistance for different mesh.	60
8.11	Contour plot of pressure distribution while moving astern.	61
8.12	Contour plot of pressure distribution at side view.	61
8.13	Velocity vector through the hull surface.	62
8.14	Velocity vector through the hull surface at side view.	62
8.15	Contour plot of pressure distribution at ship speed, $V_s = 1.0$ m/s.	63
8.16	Contour plot of pressure distribution at ship speed, $V_s = 2.0$ m/s.	63
8.17	Contour plot of pressure distribution at ship speed, $V_s = 3.0$ m/s.	64
8.18	Contour plot of pressure distribution at ship speed, $V_s = 4.0$ m/s.	64
8.19	Contour wave pattern at speed, $V_s = 1.0$ m/s.	65
8.20	Contour wave pattern at speed, $V_s = 2.0$ m/s.	65
8.21	Contour wave pattern at speed, $V_s = 3.0$ m/s.	66
8.22	Contour wave pattern at speed, $V_s = 4.0$ m/s	66
8.23	Plot ship speed against ship resistance.	67
8.24	Plot of resistance coefficient against speed.	69

LIST OF SYMBOLS

d	-	Diameter
F	-	Force
g	-	Gravity = 9.81 m/s
T	-	Thrust
R	-	Resistance
ν	-	Kinematic viscosity
σ	-	Ice flexural strength
h	-	Ice thickness
μ	-	Viscosity
A	-	Area
ρ	-	Density
L	-	Length
L_{OA}	-	Length overall
L_{PP}	-	Length between perpendiculars
L_{WL}	-	Wetted length
Ω	-	Angular velocity
P	-	Pressure
V	-	Velocity
T	-	Draught
B	-	Beam
D	-	Depth
ε	-	Dissipation

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Hydrostatics Data at DWL from Maxsurf	77
B	Curves of Ship Area from Maxsurf	78

CHAPTER 1

INTRODUCTION

1.1 Background of study

The increasing of shipping activities through the Northern Sea Route (NSR) and growth of oil and gas activities in Arctic and Sub-Arctic regions required suitable design of ice-going ships and planning operations in ice. The characteristic of ice should be noted depends on locations of ice, form of ice level, ice ridges and icebergs. Figure 1.1 shows the typical geographical regions where the ice actions are of current concern¹.

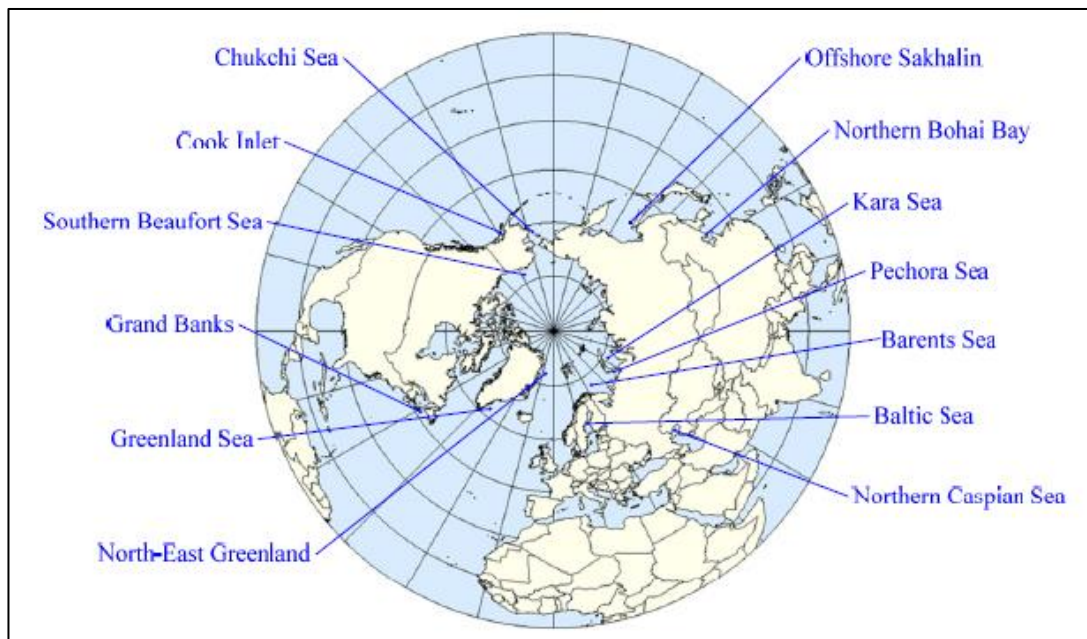


Figure 1.1: Location of ice actions¹

Design of ice-going ships requires considering the performance, adequate hull and strength of machinery and good functioning of the ship in ice condition and open water condition. Nowadays, the ice-going ships has been develop that called as Double Acting Tanker (DAT) which is can run astern more efficiency than ahead in ice condition².

There is a lot of research finding the optimum design of hull for best performance of double acting tanker in ice condition during astern. In addition, the lacks of research about DAT in ice condition during astern also motivate us to do the case study for performance of DAT. The existing research has been doing the analysis of performance of DAT with different angle of stern design. Hence, to finding better design of stern hull and optimum performance of tanker, this thesis has been doing

1.2 Problem Statement

The running in astern mode of DAT in ice condition will give effect to thrust, wake and ice cutting performance. Beside that the design of stern hull will gives impact to the performance of DAT

1.3 Objective

The objectives of this research are:

- i. To evaluate hull performance of double acting tanker during astern operation.
- ii. To analyse the performance of double acting tanker during astern in ice condition using different ice level.

REFERENCES

- [1] Gürtner, A. *Experimental and Numerical Investigations of Ice-Structure Interaction*. Ph.D Thesis. Norwegian University of Science and Technology; 2009.
- [2] Juurma, K., Mattson, T., Sasaki, N., Wilkman. G. The development of the Double Acting Tanker for Ice Operation. *Okhotsk Sea & Sea Ice*. February 24-28, 2012. Mombetsu, Japan. 2012.
- [3] Wilkman. G., Arpiainen. M., Niini. M, Mattson, T. Experience of Azipod Vessels in Ice. Aker Arctic Technology Inc. Helsinki, Finland. 2005
- [4] Jaswar. Determination of Optimum Hull of Ice Ship Going. *Proceeding of the 5th Osaka Colloquium-on advanced Research on Ship Viscous Flow and Hull Form Design by EFD and CFD Approaches*. Osaka, Japan. 2005
- [5] Aker Arctic Technology Inc. *Arctic Shuttle Tanker MT "Vasily Dinkov"*. Helsinki, Finland:Brochure. 2007.
- [6] Aker Arctic Technology Inc. *70.000 tdw Arctic Shuttle Tanker MT "Mikhail Ulyanov" "MT Kirill Lavrov"*. Helsinki, Finland:Brochure. 2010.
- [7] Tan, X. *Numerical Investigation of Ship's*. Ph.D Thesis. Norwegian University of Science and Technology; 2014.
- [8] Krzysztof Kubiak. *Russian Double Action Ships Arctic Shipping Revolution or Costly Experiment*. Ph.D Thesis. Jan Kochanowski University; 2014

- [9] Aker Arctic Technology. *Improve Double Acting Ship*. Helsinki, Finland: Artic Passion News. 2011
- [10] Vocke. M., Ranki. E., Uuskallio. A., Niini. M., Wilkman. G., *Experience of Vessels Operating in Ice in Double Acting Principle*. February 7-9, 2011. Offshore Technology Conference. 2011. 1-3
- [11] Watson, D. G. M. Some Ship Design Method. *Royal Institution of Naval Architects*. 183 Bath Street, Glasgow:IEEE. November 9, 1976. Page 279-302.
- [12] David, F and Linda,T. *Prediction of High-Speed Planing Hull Resistance and Running Attitude*. Master Thesis. Chalmers University of Technology; 2015
- [13] Wilcox, D.C. Simulation of Transition with a Two Equation Turbulence Model”, *AIAA Journal*. 1994. 32 (2). 247-255.
- [14] Andersson, B., Andersson, R., Håkansson, L., Mortensen, M., Sudiyo, R., van Wachem, B. G. M. *Computational Fluid Dynamics for Engineers*. 10th ed. Cambridge University Press. 2014.
- [15] Menter, R. B. Langtry, S. R. Likki, Y. B. Suzen, P. G. Huang, and S. Volker. A Correlation-Based Transition Model Using Local Variables, Part I – Model Formulation. *In Proceedings of ASME Turbo Expo 2004, Power for Land, Sea, and Air*. June 14-17, 2004. Vienna, Austria: ASME. 2004. GT2004-53452.
- [16] Tousif Ahmed, Md. Tanjin Amin, S.M. Rafiul Islam and Shabbir Ahmed. Computational Study of Flow around a NACA 0012 Wing Flapped at Different Flap Angles with Varying Mach Numbers. *Global Journal of Researches in Engineering*. 2013. 13 (4), 5-15.

- [17] Bardina, J., Huang, P., Coakley, T. *Turbulence Modeling Validation, Testing, and Development*. Technical report 110446. National Aeronautics and Space Administration (NASA), 1997.
- [18] Stern, F., Yang, J., Wang, Z., Sadat-Hosseini, H., Mousaviraad, M., Bhushan, S., et al. Computational Ship Hydrodynamics: Nowadays and Way Forward. *International Shipbuilding Progress*. 2013;60(1-4):3–105. doi: 10.3233/ISP-130090.
- [19] White, F. M. *Fluid mechanics*. 7th ed. Boston: McGraw-Hill. 2003.
- [20] Versteeg, H. K., Malalasekera, W. *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*. 2nd ed. Harlow: Pearson Education Limited. 2007.
- [21] Firdaus bin Mahamat. *Experimental Investigation and CFD Simulation of a Helicopter Tail Rotor Blade*. Master Thesis. Universiti Teknologi Malaysia. 2016.
- [22] Su, B. *Numerical Predictions of Global and Local Ice Loads on Ships*. Ph.D Thesis. University of Science and Technology; 2011.
- [23] Afrizal, E, Jaswar. Ice Resistance Performance Analysis of Double Acting Tanker in Astern Condition. *Jurnal Teknologi (Science and Engineering)*, 2014. 69 (7), 73–78
- [24] Edward, V.L. *Principles of Naval Architecture*. 2nd ed. Jersey City, NJ.: The Society of Naval Architects and Marine Engineers. 1988.
- [25] Wilkman, G, Juurmaa, K., Mattsson, T., Laapio, J., Fagerström, B. Full-scale experience of Double Acting Tankers (DAT) Mastera and Tempera, *Proceedings of IAHR 04*, June 2004, St. Petersburg, Russia. 2004. 1-9.

- [26] Eyres, D. J. *Ship Construction*. 5th ed. Woburn, MA. Butterworth-Heinemann 2001.
- [27] International Towing Tank Conference. *Practical Guidelines for Ship CFD Application*. No. 7.5-03-02-03. 2011.
- [28] Sridar.D, Bhanuprakash, T.V.K, Das. H. N. Frictional Resistance Calculations on a Ship using CFD. *International Journal of Computer Applications*. 2010. 11(5): 24-31
- [29] Watson, D.G.M. *Practical Ship Design*. Oxford, UK: Elsevier Science Ltd. 1998.