TOW ROPE LENGTH AND ARRANGEMENT DESIGN FOR A TOWED SHIP

UMAR IMRAAN BIN ZAN

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Marine Technology)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

SEPTEMBER 2014

To my beloved mother, father and family members,

For your love and affection.

To my dedicated lecture,

For the encouragement and guidance.

To my loving wife and son,

Ashikin & Naimil

For having faith in me,

Your unconditional love and unfailing support

Those keep me going.

ACKNOWLEDGEMENT

First of all, I would like to express my gratitude to God Almighty because of His blessing finally, I have completed this research successfully even though there are so many obstacles that I had to go through during completing this research.

My special thanks to my supervisor, Dr. Koh Kho King, for his invaluable guidance, professionals comments and suggestions, as well as encouragement. He spends his precious time in refining my draft and sharing his knowledge with me. I learnt a lot from every moment of the meetings with him.

In completing this thesis, I would like to thank Prof. Dr. Adi Maimun Bin Abdul Malik and Dr. Ahmad Fitriadhy for spending their time to give comments and contribute ideas and also to Prof. Hironori Yasukawa from Hiroshima University for lending the Rake-barge model and FORTRAN source code.

Not to forget, I would like to thanks all the technicians for spending their time in conducting the model test for this research. I wish them all the best in whatever they do. Thank you.

ABSTRACT

This research presents the investigation on the effect of different tow rope lengths and arrangements for a towed ship in calm water by using the experimental model conducted at Marine Technology Centre, Universiti Teknologi Malaysia. Three variations of tow rope arrangements were tested in the experiment: Straight-tow, V-tow and Kite-tow. A total of fourteen types of tow rope arrangements were tested at a constant speed of 0.5 m/s and a rake-barge were captured via Qualysis Track Manager (QTM) 'Image Processing Techniques'. From the experiment, it was observed that for Straight-tow, the tow rope length increment was proportional to the oscillation where for every increment of Lv length (length of tow rope in V shape arrangement) reduced the oscillations by around 12%. Kite-tow arrangement design offered a better safety towing system and has nearly zero sway motion but large water width due to the drift distance from the tow point which is around 0.64 and 1.1 times barge length. The result from Straight-tow with different skegs arrangement s showed significant improvement in reducing the sway motion pf the towed barge. Similarly, V-tow barge with different skegs arrangements also presented a substantial improvement in decreasing the amount of sway motion. In the final part of the research, computer simulation using FORTRAN program and codes from Yasukawa & Fitriadhy (2010) were carried out and the results were compared with the experimental model of Straight-tow barge. Computer simulations and model experiment results showed less than 10% deviation in sway motions.

ABSTRAK

Kajian ini membentangkan hasil kajian penyiasatan kesan perbezaan panjang dan susunan tali tunda bagi tundaan kapal di air tenang dengan menggunakan model eksperimen ujikaji yang telah dijalankan di Pusat Teknologi Marin, Universiti Teknologi Malaysia. Tiga variasi susunan tali tunda telah diuji dalam eksperimen: Straight-tow, V-tow dan Kite-tow. Sebanyak empat belas jenis susunan tali tunda telah diuji pada kelajuan tetap 0.5 m/s dan rake-barge telah digunakan sebagai kapal yang ditunda dalam kajian ini. Pergerakan ayunan huyung daripada rake-barge direkodkan melalui Qualysis Track Manager (QTM) Image Processing Techniques. Daripada eksperimen ujikaji, dapat diperhatikan bagi Straight-tow; pertambahan kepanjangan tali tunda adalah berkadar langsung dengan pergerakan huyung di mana untuk setiap kenaikan 0.5L tali tunda tersebut, pergerakan huyung telah meningkat sebanyak 35%. Untuk V-tow pula, pertambahan panjang Lv (panjang tali tunda dalam susunan bentuk V) adalah berkadar langsung dengan pergerakan huyung di mana ia telah menyebabkan pengurangan pergerakan huyung sebanyak 12%. Reka bentuk susunan Kite-tow menawarkan tundaan kapal yang lebih selamat dan hampir tiada pergerakan ayunan huyung direkodkan tetapi ia memerlukan ruang air yang besar kerana jarak hanyut dari titil penundaan iaitu sekitar 0.64 dan 1.1 kali ganda kepanjangan kapal. Kombinasi Straight-tow dengan susunan skegs yang berbeza telah menunjukkan penambahbaikan yang ketara dalam mengurangkan gerakan huyung. Begitu juga dengan kombinasi V-tow dengan susunan skegs yang berbeza yang juga menunjukkan penambahbaikan dalam mengurangkan pembentukan huyung. Di bahagian akhir kajian ini, simulasi komputer yang menggunakan program FORTRAN dan kod dari Yasukawa & Fitriadhy (2010) telah dilakukan untuk dibandingkan dengan model eksperimen Strainght-tow tundaan barge. Hasil keputusan daripada simulasi berkomputer dan model eksperimen ujikaji tersebut menunjukkan kurang daripada 10% sisihan dalam pergerakan huyung.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to Toxopeus et al. (2013), offshore going barges are one of the preferred means of transportation for the transport of large structures over sea. This is because the barge is important in transporting the large quantity of cargo in the need for water way transportation. It is very convenient to use the barge since there are a lot of problems in inland way transportation such as cramped traffics, maintenance cost and etc. As mentioned by Yasukawa et al. (2007) and Phelan (2008), there are many potential hazards that might occur such as collision and/or grounding in barge towing system. Fitriadhy et al. (2012) mentioned that the barge towing system might intrude sea traffic ways, especially in the restricted waters where it will lead to serious towing accidents which might cause the towed barge collides and affects the safety of the ship or shore installations and even worse when tow rope breakage and barge capsizes.

It can be observed that not all ships have the ability to remain steady especially during the towing operations. Some of the ships might face problems in terms of steadiness. As a result, this may lead to the difficulty in towing progress where the ships tend to move in a dangerous pattern or motion; in other words, it can be regarded as the uncontrollable movement during towing as reported by Lee, (1989). The towline can cause fatal accidents and many forget how quickly things can go wrong when a line is under load.

According to Recreational Boating Statistics (2011) there were 22 cases reported on the vessel operation in year 2011 involving 1 death and 7 injuries. The Maritime Accident Casebook (2010) also showed an increasing number of incidents occurred during ocean towage. In 2007, Flying Phantom was girted and sank while acting as a bow tug for Red Jasmine which resulted in 3 fatalities and 1 injury as reported by European Maritime Safety Agency (2007). Because of the complicated routines in towing and lack of safety, there are many potential hazard and risks that could occur during ship towage as mentioned by Phelan (2008).

Generally, towing can be defined as an operation that often includes long hours of tedious routine which involving short periods of intense activities and works as stated in International Maritime Organization (1998). In order to reduce the risk of accidents, everyone especially the crew must be diligent and cautious towards the successful completion of the mission. This is because, even the slightest lapse in attention or effort may result in major accidents and mishaps as specified in International Maritime Organization (1998).

Based on the Canadian Coast Guard Auxiliary Search and Rescue Crew Manual (2011), the crew must ensure all gears (lines, shackles, messenger, drogues, tow bits, chafing gear, fairleads, etc.) have been checked for wear and tear. The inspection of equipment especially the towing gear and towline should be carefully carried out in order to have a clear and smooth towing operation. According to the International Maritime Organization (1998), the tow should not proceed to sea until a satisfactory inspection of the tow has been carried out by the towing master and if requested or for any reason considered necessary, by any other competent person. The tow assessment and planning are very important in considering the safety aspect of the towing operation. During the assessment, the obvious danger and primary factors to look for and be reported including the vessel state, people on board, environmental factors and so on as mentioned in Auckland Council Harbourmaster's Office, (2011). Besides that, it is crucial to communicate constantly and clearly during towing operations when asking questions and giving instructions. Other than that, all aspects of the towage should be planned in advance, taking into consideration the factors such as maximum anticipated environmental conditions, including tidal streams, current and water depths, as well as the size, displacement and draft of the tow as detailed in International Maritime Organization (1998).

Rescue and salvage towing generate a necessary sense of urgency. There are several important aspects that need to be considered while conducting the towing operations. One of the most significant aspects is the tow-rope used in towing a ship or vessel. According to The American Heritage Dictionary (2009), tow-rope is 'a line used in towing vessels and vehicles'. The function of tow-rope is to assist the tugboat by holding another vessel during the towing process. Because of that, there are many important aspects that need to be considered while conducting the towing operations. According to Wang et al. (2008) suitable tow rope length may contribute to towing maneuvering while offering the great level of safety and sway motion. According to Yang et al. (2010) the unstable motions such as the sway motion and yaw motion will occur inevitably during towing. Effects of sway motion need to be minimized in order to ensure safe and smooth towing operation as acknowledged by Shigehiro et al. (1998) and Bhattacharyya and Vendan, (2000).

In improvising the method of controlling the course stability in barge towing system, the skegs were later added in the rake barge model. According to Lee (1989) the course stability of the towed ship is significantly improved by adding the skegs. The advantages of the skegs are considered as one of the test subject in providing the smooth and safe barge towing system. Considering all these factors, this work focuses on the effect of two different parameters, tow rope length and tow rope arrangement design.

The main purpose of this research is to determine the optimum tow-rope length and arrangement for a towed ship (60.96 m rake barge) during a tow operation in calm water condition. This research also investigates the effectiveness of the kite-tow arrangement design in term of steadiness as compared to straight-tow and V-tow arrangement, while investigating the pattern of the towed ship motion during the towing operation. In addition, this research also determines the effect of the new design of towing arrangement which is called as kite-tow arrangement. As far as this study is concerned, this arrangement has never been investigated by any researchers before. From this type of arrangement, the ship will be towed from the port or starboard of the ship using the combination of tow-rope in certain angles. The details of this towing arrangement are discussed in the tow rope arrangement section.

As mentioned before, this study also caters on the arrangement of the rope which can be exploited during the towing progression. There are many types of tow rope arrangements used by ship towing company. Each of the arrangement will give a different effect on a towed ship in terms of controlling, course stability, safety and steadiness. As stated by Bernitsas (2004), the towed ship cannot be returned to their original path which resulted from the effect of the sway motion unless they are pulled by exciting forces or moments. In this research, the focus is more on the steadiness of towing a ship and at the same time learning and identifying the patterns of the towed ship motion.

1.2 Problem Statement

One of the problems that can be addressed to the need of this research is about the safety of the towing operation system. Today, towing a large ship is fraught with potential risks and accidents during towing operations. In port, tugs are often working in a restricted space with limited room for maneuver, while long distance offshore tows have their own particular problems. Safety can be regarded as the serious and important issues as it involves not only the ship and the lives of the crews but, any accidents happen will give a great impact to the environment such as oil spill.

The main problem that needs to be overcome is to determine the suitable tow rope length and applicable towline configuration. This is due to the fact that these factors may assist in reducing the sway motion which is regarded as one of six-degrees-of-freedom (6DOF) as stated by Price (1991). This is because the sway motion may lead to the uncontrollable or large oscillation movements during the towing operation. This is crucial as this issue involves the safety of the ship and the crews.

Considering of all these factors, this study emphasizes on several different tow rope arrangements designs and of towing methods in order to reduce the sway motions. Besides that, it also aims to produce a better towing operation where the towed ship can be towed steadily and has almost zero of the sway motion characteristics.

1.3 Research Objectives

The aims of this research are:

i. To examine the effect of tow rope length on sway motion and towline tension for barge towing system.
ii. To investigate the effectiveness of the kite-tow arrangement in term of reduction of barge sway motion and towline tension as compare to straight-tow and V-tow arrangement.
iii. To compare the experimental results with the established computer simulation results on the motions of the towed ship.

1.4 Scopes

The scopes of this research are:

i. Rake barge model as towed ship to be used in the study.
ii. Model experiments to be performed in Marine Technology Centre.
iii. Model test to be performed in calm water condition.
iv. Comparison with the established computer simulation programming.
v. Tug motion is assumed to be given.

1.5 Significance of Study

There are many significant points that can be highlighted from this research. One of the crucial points that can be seen is in terms of the safety aspect. Therefore, this study can offer some ideas on the optimal length of tow rope that can be used in order to avoid any accidents from occurring.

Besides that, this research could improve the ship steadiness and reduce the sway motion. So, from the various arrangements conducted, it may help in solving the problem of unsteady sway motion characteristics of the towed ship. This research also introduces the new tow rope configuration which is called as “Kite-tow”. This towline arrangement may reduce the huge oscillation of sway motion create by barge during towing operation.

REFERENCES

American Water Operators (AWO), (2006). Uninspected Towing Vessel Industry Analysis Project.

Auckland Council Harbourmaster's Office, (2011),"Navigation Safety Operating Requirements", Auckland Pilotage Area Tug and Tow Operations.

Bernitsas, M.M. (2004), Mooring Dynamic Phenomena Due To Slowly – Varying Wave Drift, Journal of Offshore Mechanics and Arctic Engineering, 126(4), 280.

Bernitsas, M.M, Chung, J.S, (1990), "Nonlinear stability and simulation of two-line ship towing and mooring", Applied Ocean Research, Volume 12, Issue 2, April 1990, Pages 77–92.

Bernitsas, M.M, Papoulias F.A, (1986), "Stability of single point mooring systems", Applied Ocean Research, Volume 8, Issue 1, January 1986, Pages 49–58.

Bhattacharyya, S.K. & Vendan, C.P. (2000). The finite Element Method for hydroelastic instability of underwater towed cylindrical structures. Journal of sounds and vibration (2000). 237(1), 119-143.

Bielanski, J. (2007). 3d Form Analysis Of Rope Deformation Withlong Towed Enderwater Hydroacoustic Antena. Archives of Civil and mechanical engineering. Vol VII. No. 3. Gdansk Universityof technology. Gdansk.

Calkins, D.E. (1999), "A metamodel-based towed system simulation", Ocean Engineering, Volume 26, Issue 11, November 1999, Pages 1183-1247

Canadian Coast Guard Auxiliary, Pacific Region & Canadian Coast Guard Marine SAR Programs, Pacific Region. (2011). “Canadian Coast Guard Auxiliary Search and Rescue Crew Manual: Chapter 8 Towing”, Canadian Coast Guard Auxiliary, 177-194, Victoria BC, Canada.

Chapman, D.A. (1984), “Towed cable behaviour during ship turning manoeuvers”, Ocean Engineering, Volume 11, Issue 4, 1984, Pages 327–361

Fitriadhy, A., Yasukawa, H., & Koh, K.K. (2013), “Course Stability of a Ship Towing System in Wind”, Ocean Engineering 64 (2013) 135-145

Fitriadhy, A., Yasukawa, H., Yoneda, T., & Koh, K.K. (2012), “Effect of Asymmetrical Bridal Towline Configuration on Course Stability of a Towed Ship”, the 6th Asia-Pasific Workshop on Marine Hydrodynamics (APHydro2012), Malaysia.

Fitriadhy, A., Yasukawa, H., Martio, J., Stück, A., Kröger, J., Rung, T., & Bole, M. (2011), “Course stability of a ship towing system”. Institute of Ship Technology and Ocean Engineering, Vol. 58 No. 1.

Fitriadhy, A., Yasukawa, H., & Yusaku, M. (2010), “Turning Characteristic of a tow ship in towing system”, Proceedings of the Twentieth (2010) International Offshore and Polar Engineering Conference Beijing, China.

Fitriadhy, A., Yasukawa. H., (2010), “Course stability of a ship towing system”, Ship Technology Research, Volume 58, Issue 1, January 2011, Pages 4-23

Gobat, J.I. & Grosenbaugh, M.A. (2001), “A simple model for heave-induced dynamic tension in catenary moorings”, Applied Ocean Research, Volume 23, Issue 3, Pages 159–174

Grosenbaugh, M.A. (2007) “Transient behavior of towed cable systems during ship turning maneuvers”, Ocean Engineering, Volume 34, Issues 11–12, Pages 1532–1542.

Harland, J. & Myers, M. (1984), Seamanship in the Age of Sail, Naval Institute Press, PP 327: 205-208, Dec. 02, 1983.

International Maritime Organization, IMO (1998). “Guidelines for Safe Ocean Towing”, Embankment, London.

Mudie, J.D., Ivers, W. D. (1975). “Simulation Studies of the Response of Deeply Towed Vehicle to Various Towing Ship Maneuvers”, Ocean Engineering, Volume 3, Issue 1, pg 37-46.

Koh, K.K., Yasukawa, H., Hirata, N., & Kose, K. (2008), “Maneuvering Simulations of Pusher-Barge Systems”, Journal of Marine Science and Technology, 13: 117–126.

Korkut, M. (2002). “The Nonlinear Dynamic of Close Proximity Ship Towing”. Naval Postgraduate School. California.

Latorre, R. (1988), “Scale effect in towed barge course stability tests”, Ocean Engineering, Volume 15, Issue 4, Pages 305–317.

Lee, M-L (1989), “Dynamic Stability of Nonlinear Barge-Towing System”, Journal of Applied Mathematical Modelling, Volume 13, Issue 12, Pg 693–701.

Marine Accident Investigation Branch, (2008), “ Report on the investigation of the loss of the tug Flying Phantom while towing Red Jasmine on the River Clyde on 19 December 2007”, United Kingdom.

Maritime Dictionary of safety for sea (2013), “bridle” http://www.safety4sea.com/maritime-dictionary-18254

Matter, G.B., Sales, S.S. & Sphaier, S.H. (2002). ”A Procedure To Analyze The Maneuvering Stability Of FPSO System In The Design Stage”. Department Ocean Engineering. Brazil.

Nelson, J. (1967), Yaw Control of Towed Barge, No. 521137-13 claims (CI. 114 - 234), 611 Las Palmas Drive, Santa Barbara California. Aug. 22.

Park, H.H. (1993), “A tension measurement method of a towing cable or a buoy cable”, Ocean Engineering, Volume 20, Issue 2, Pages 163–170.

Pike, J. (2005).Towing Operation. Global Security. Zulu.

Pinkster, J., Dercksen, A. & Dev, A. (1993), “Hydrodynamic Aspects of Moored Semisubmersibles And Tlp's”. Offshore Technology Conference.

Price, W.G.(1991). “Dynamics of Marine Vehicles and Structures in Waves”. Amsterdam : Developments in Marine Technology, Vol. 7

Phelan, (2008). “Towing Stability”. Offshore and Marine Department. Maritime Research Institute Netherlands (MARIN). Netherland.

Sarkar, A., Taylor, R.E. (2000), “Effects of mooring line drag damping on response statistics of vessels excited by first- and second-order wave forces”, Ocean Engineering, Volume 27, Issue 6, Pages 667-686.

Shigehiro, R., Ueda, K. & Nakayama, H. (1998), “Experiment Studies for Stopping and Hard Turning Maneuver of Tow and Towed Vessels”, J. Kangsai Soc.Naval Architects, Japan, No.230: 165-175

Shimo, L. (1986) “Twin-Skeg Power-Saving Ships”, Journal of Wuhan University of Technology Transportation Science & Engineering, 1986-03

Thomas, P. (2012), “Recreation Boating Statistics 2011”, United States Department Of Homeland Security, United States Coast Guard, Washington.

Tore, J. & Bernt J. L. (2012), “Numerical and experimental studies of submerged towing of a subsea template”, Ocean Engineering, Volume 42, Pages 147-154

Toxopeus, S.L., Stroo, K. and Muller, B. (2013), "Optimisation of Resistance and Towed Stability of an Offshore Going Barge with CFD" OMAE ASME 32nd International Conference on Ocean, Offshore and Arctic Engineering, Nantes, France, OMAE2013-10869

Wang, H., Zou, Z. & Tian, X. (2008). "Numerical Simulation of Transient Flow around a Ship in Unsteady Berthing Motion", Journal of Hydrodynamic, 21(3):379-385.

Wang, D.J, Ou, L.J, Li, J.Y. (2006), "Study on the model test of asymmetrical skeg" Ship Engineering journal

Yang, L., Hong, B., Inoue, K. & Sadakane, H. (2010)," Experimental Study on Braking Force Characteristic of Tugboat", 9th Intentional Conference of Hydrodynamic, Journal of Hydrodynamic, 22(5):343-348.

Yang, L., Hong, B., Li, J., Inoue, K. & Sadakane, H. (2010). "Effect of Ship-Tugboat Hydrodynamic Interaction on the Braking Force of Tugboats", Proceedings of the Twentieth (2010) International Offshore and Polar Engineering Conference Beijing, China.

Yasukawa, H., Nakamura, N., Hirata, N. & Koh, K.K. (2007). "Maneuvering Simulations of Tow and Towed Ships in Still Water", International Conference on Towing and Salvage of Disabled Tankers, University of Strathclyde, Glasgow, United

Yasukawa, H., Hirata, N., Nakamura, N., & Matsumoto, Y. (2006). "Simulations of slewing motion of a towed ship". Journal of the Japan Society of Naval Architects and Ocean Engineers, 4, 137-146.

Zhu, Y.X &Yin, T.C. (2003) "Research and test on twin-skeg energy-saving ship type", Journal of Ship & Boat，2003-06.

Zhenju, C. & Sverre, S. (2012). “Speed loss due to seakeeping and maneuvering in zigzag motion”, Ocean Engineering,Volume 48, , Pages 38–46