PRACTICAL SHIP WEATHER ROUTEING FOR LIQUEFIED NATURAL GAS CARRIERS

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PRACTICAL SHIP WEATHER ROUTEING FOR LIQUEFIED NATURAL GAS CARRIERS

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To Maira and Ozil

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ABSTRACT

The research developed a realistic model which encompasses the ship routeing process, weather prediction methods, ship environment interaction and route optimization algorithm. The optimization models were constructed for Tenaga Class Liquefied Natural Gas Carriers (LNGC) using minimum time, minimum fuel consumption or combination of both as objective functions. The ship service performance data which was derived from the analysis of actual records of her past voyages are incorporated in the ship routeing algorithm. The data has enabled a good comparison between simulations and actual results. Ship routeing simulation based on two methods i.e. standard route and simplified shortest path algorithm was performed and the outcomes have demonstrated the economic and safety benefits. The results indicate that potential cost saving is high likely and optimum benefit is not fully acquired by the current standard route practice. Ship routeing may generate savings in terms of both time and fuel consumption. Furthermore, it was found that a shorter distance route is not necessarily an optimal solution. The optimal solution arise from the consideration of all aspects i.e. dynamic weather changes, voyage optimization, model constraints and objective function.

ABSTRAK

Kajian ini membina model realistik yang merangkumi proses penghalaan kapal, kaedah ramalan cuaca, kekangan model, interaksi kapal-persekitaran dan algoritma laluan optimum. Model optimum telah dibina untuk Kapal Pengangkut Gas Asli Cecair (LNGC) daripada Kelas Tenaga dengan pengunaan masa atau minyak yang minimum, atau kedua-duanya sebagai fungsi objektif. Data prestasi servis terbitan daripada analisis rekod-rekod sebenar perlayaran yang lampau adalah digabungkan bersama algoritma penghalaan kapal. Data ini telah membolehkan perbandingan yang baik diantara simulasi dan keputusan sebenar. Simulasi penghalaan kapal berdasarkan dua kaedah iaitu laluan standard dan algoritma laluan terpendek dipermudah telah dilakukan dan kebaikan ekonomi dan keselamatan telah dihasilkan. Keputusan menunjukkan bahawa potensi untuk menjimatkan kos adalah berkebarangkalian tinggi dan faedah teroptimum tidak dapat terhasil daripada praktis laluan standard semasa. Hasil daripada penghalaan kapal mungkin menghasilkan penjimatan untuk masa dan pengunaan minyak. Tambahan lagi, laluan berjarak pendek tidak semestinya adalah laluan optimum. Penyelesaian optimum hendaklah dihasilkan daripada pertimbangan semua aspek iaitu perubahan dinamik cuaca, perlayaran yang dioptimumkan, model kekangan dan fungsi objektif.

TABLE OF CONTENTS

7.1 Introduction

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

C_P	Trial allowance
Δ	Displacement
β	Model scale
V_S	Vessel's speed through water
R_{total}	Total ship resistance
R_{calm}	Calm water resistance
R_{added}	Added resistance
R_{wind}	Resistance increase due to wind
R_{AW}	Resistance increase due to waves
R_{rough}	Resistance increase due to hull and propeller roughness
R_{load}	Resistance change due to loading conditions
R_{steer}	Resistance increase due to steering, yaw and drift effects
$R_{current}$	Resistance increase due to ocean current
R_{sea}	Resistance change due to temperature and salt content effect
$R_{shallow}$	Resistance change due to shallow water effect
R_w	Wave-making resistance
R_f	Frictional resistance
Δ_R, ΔC_F	Added resistance coefficient
ρ_{air}	Density of air
V_{wind}	Relative wind speed
C_{wind}	Wind coefficient

$A_{projected}$	Lateral and/or longi. projected windage
ρ	Density of seawater
$S(w_e)$	Wave spectral value
ξ	Regular wave amplitude
w	Circular frequency
ΔR	Added frictional resistance
S	Ship wetted surface
V_C	Current drift speed
V_{rqd}	Required speed over ground (SOG)
μ_C	Encounter angle to stream on required trajectory
η_T	Total efficiency
P_E	Effective power
P_B	Brake power of engine (power output)
η_H	Hull efficiency
η_B	Propeller efficiency behind hull, is defined by $\eta_B = \eta_O \times \eta_R$
η_S	Shaft efficiency, taken as 0.98
η_R	Relative Rotative Efficiency
t	Thrust deduction factor
w	Mean wake fraction
η_O	Open propeller efficiencies
J, K_T and K_Q	Propeller coefficients
T_W	Wave period
H	Wave height
λ	Wave length
SWH	Significant Wave Height
AHR	Average Hull Roughness
B_n, BN or BF	Beaufort Number or Beaufort scale
FOC	Fuel Consumption
g	Gravity
LBP	Length between perpendicular

LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
KPI	Key Performance Indicator
IMO	International Maritime Organization
NMRI	National Maritime Research Institute
OBO Carrier	Ore-Bulk-Oil Carrier
BSRA	British Ship Research Association
BOG	Boil-Off Gas
NBOG	Natural Boil-Off Gas
NM	Nautical Miles
JIT	Just-in-Time
GHG	Greenhouse Gas
SSPA	Simplified Shortest Path Algorithm

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background and Problem Statement

Challenging world of shipping trade's today is in the context of time, cost, safety and seaworthy. The conundrum is become more complex given by the following factors:

1. Rising bunker fuel cost
2. More focus on the environmental impacts from ship emissions
3. Higher demands on the ship delivery reliability
4. Fierce competition in sea logistic markets
5. Greater awareness on the ship energy efficiency
6. Development of "green ship"

All of those factors are paramount importance and are the key performance indicators that control and determine the reliability, operability, safety, seaworthy, profitability, viability, efficiency, survivability and the future of shipping industry itself.

Whilst law makers are actively formulate and regulate rule-based environmental protection laws and human safety in ship design and operation; and ship designers around the world are now driven by the effort to optimize the efficiency and design of a ship at early stage of ship design process, ship owner or ship operator has to deal with most part of its; that is responsible to take and maintain appropriate and effective measures during ship operation. The measures taken are to ensure that the ship is operating at her optimal conditions i.e. meeting the business schedule within reasonable cost and in safest condition. In this regard, one of the recommended, recognised and proven measures is known as ship weather routeing.

By definition, ship routeing is a process in finding an optimum track for a particular ocean transit by incorporating and anticipating weather conditions and vessels characteristics in response. The optimization process will lead to cost-driven, energy-driven, time-driven, safety-driven, seaworthy-driven voyage or combination of these factors. When a merchant ship is on trading passage from terminal A to terminal B, she is on the mission to arrive in timely and costly manner, in which, safety and seaworthy are the constraints, and human is the decision maker. Through this process, ship routeing is also known as optimum routeing.

As defined by Bowditch (1826), ship weather routeing develops an optimum track for ocean voyages based on forecasts of weather, sea conditions, and a ship’s individual characteristics for a particular transit. Within specified limits of weather and sea conditions, the term optimum is used to mean maximum safety and crew comfort, minimum fuel consumption, minimum time underway, or any desired combination of these factors.

The complete ocean trading model consists of several successive stages where each stage is dependent on the preceding stage. The reliability of sea transportation mainly depends on the ability of the ship to perform it given task in specified trading areas within specified timeline. For that reason, the environmental conditions during transport and how the vessel reacts towards environment change could affect overall reliability of delivery (Grin *et al*., 2005).

International Maritime Organization (IMO) through Resolution A.528 (13) adopted on 17 November 1983 has since recommended and recognized ship routeing practice and it's contribution towards safety and economy benefit of ship operations, crew and cargoes. The recommendation was resulted from the awareness on the damage and total ship loss directly or indirectly caused by the meteorological and oceanographic factors. It was also, however, highlighted that the final decision regarding the ship's navigation rests always with the master.

IMO has then established the minimum standards for ship routeing services through circulation of MSC/Circ. 1063 on 19 December 2002, in following the new evidence and conclusion from the Derbyshire case. The OBO carrier, Derbyshire, was lost off Okinawa in 1980 despite having being supplied with weather routeing advice. It was concluded that the information provided to the master was insufficient to assist him in effectively avoiding the worst weather associated with the Orchid typhoon. This regulation also safeguards the master's right to deviate from advice given that might conflict with his/her professional judgement.

At present, in commercial operations, shipmaster shows a natural tendency to go for minimum passage time and minimum damage to ship and cargo at the earlier part of voyage. To ensure to arrive on time with minimum fuel consumption at the later part of the voyage would be the overall goal. Just-in-time arrival contributes to cost savings. The lesser fuel is consumed, the more environmental friendly the voyage has become. Similar kind of practice was reported by Hagiwara (1989) and Bottner (2007).

On the other practice, it was made clear by past evidence indicated that early concept of ship routeing was based on two different strategies i.e. route selection based on expected weather pattern rather than follow the seasonal route or based on seasonally recommended routes. These were reported by Chen (1978) and Bowditch (1826). Both ways proved beneficial and successful to a certain degree. It is however, the safety and economic benefits are obviously recognized and confirmed through out centuries.

There are different set of priorities in ship routeing problem. For instance, for cruise or passenger ship, passenger safety and comfort consistent with arriving on schedule are the main requirements. Merchant ships with important cargoes may pay little attention to crew comfort as long as schedule is met without jeopardising safety of ship and her crew (Motte, 1981).

In this research, more attention and flexibility is given to the economy and performance integrity of ship routeing i.e. flexibility in meeting schedule in costly manner with safety and seaworthiness aspects are the constraints. The research will also provide clear understanding and guideline on time, cost, safety and seaworthiness from which interrelation and benefits that can be drawn from them. The proposed approach can also be utilised with no or little modification to any other type of vessels in any sea zones for any particular purposes.

1.2 Objective of Research

The objective of this research is to determine a practical approach for an optimal ship weather routeing for Liquefied Natural Gas Carriers through utilisation of ship service performance analysis.

1.3 Scopes of Research

The current research is focusing on the ship routeing based on ship performance analysis in actual seas. Followings are the scopes of research, as listed and summarised in sequence working orders:

1. Collect, manage and analyse daily LNG carriers' onboard voyage data and observation (Noon Report).
2. Analyse and establish ship service performance in actual seas based on past voyage data recorded by LNG carriers.
3. Perform ship routeing for LNG carriers for laden case for Bintulu-Tokyo Bay sea passage by utilising the ship service performance.
4. The objective of ship routeing shall be based on total fuel consumption and passage duration. The result is validated against the actual past voyage of LNG carriers.

In ship routeing procedures, other than ship performance prediction, there are three (3) other elements required to produce more accurate and optimum results i.e. weather (including sea conditions) prediction models, system or model constraints and optimization algorithms. Those processes, with an exception of optimization algorithms, are intentionally being excluded from the research. Those elements will be discussed on its principle and also be implemented on "As If" basis. The justifications for these exemptions are provided as follows:

1. "As If" basis is considered and applied for the research. It means as if the ship routeing is made prior to the actual voyage had taken place on the past. Weather information and actual route will be based on the actual records. The main purpose of the inverse calculation is to generate more realistic scenarios for a fair comparison and validation. This is considered as the best method to prove the accuracy of the results.
2. Since the actual voyage had successfully taken place, it is being considered that the model constraint i.e. technical, safety, engine and seaworthiness

constraints were fully met during the entire voyage duration. The same principle is applied for the validation process since both validation and actual voyage are using the same routes.

3. Previous researches have shown that optimization algorithms will produce an optimum route as opposed to other route selections. Similarly, adoption any of these algorithms will also produce similar effect i.e. a better route as compared to the standard route taken by vessel during her past voyages. None of these established algorithms will be included in the current research, but few theoretical routes will be created in addition to the standard routes. Comparison between routes will be made to prove the objectives of ship routeing. In addition, simplified algorithm will be introduced to demonstrate the ship routeing process in simple yet realistic way.
4. Previous researchers have comprehensively studied those three (3) aspects. Their proposals or methods can be incorporated and integrated as add-on into this proposal without affecting the fundamental of this research.
5. Research gap is found in the ship performance analysis part. As discuss in item 3, most ship routeing methods relied on ship performance predictions or empirical formulae. It is well known that prediction or empirical methods have its own limitation and lower accuracy in some cases.
6. The case study is limited to LNG carrier operating on laden voyage from Bintulu (loading terminal) to Tokyo Bay (unloading terminal). But the proposed method shall valid for other cases, with no or little modification needed.
7. Implementation of “As If” validation concept will prove that the propose ship routeing is realistic and practical. This will be discussed in details in subsequence chapters.

1.4 Significance of Research

The significance of this research can be categorised into four (4) different stages i.e. voyage planning, in-service performance monitoring, post-voyage analysis and design improvement.

At first stage, obviously, ship routeing is also a strategic voyage planning and part of voyage optimization scheme. Clear benefits that can be obtained from these pre-voyage planning activities include potential of fuel savings, improvement of schedule reliability and integrity, and improvement in safety and seaworthiness aspect during ship operation. Furthermore, a thoughtful voyage planning will reduce green house gas emissions, provide protection of marine environment and reduce risk of damage or accident at seas. IMO through resolution A.893 (21) “Guidelines for Voyage Planning” adopted on 25 November 1999 and MSC.1/Circ. 1228 “Revised Guidance to the Master for Avoiding Dangerous Situations in Adverse Weather and Sea Conditions” on January 2007 has echoed similar objectives.

Secondly, throughout the ship routeing process especially on the ship performance analysis part, performance monitoring of in-service vessels can be made systematically and effectively. Ship’s officers can now have analysis tools that can be used in order for them, not only to monitor, but also to decide on any changes needed during voyage. This is especially needed when prevailing weather is different from the anticipated or forecasted data. An evaluation by Li (2006) has also confirmed that engagement of ship routeing services will help in resolving any claim dispute as related to charter party agreement.

Similarly, post-voyage analysis can be made by fleet managers or concerned parties. Performance comparison between fleet, mostly between sister vessels, can be measured and analysed. Comparison between different propellers, anti-fouling paints, service speeds, voyage route selections and ship’s draughts, to name a few examples, can be analysed and concluded. In addition, paint maker or equipment manufacturer can learn on how well their products or equipments responded or performed in actual operation environments. On separate note, it is also been proved that collections of wind data from ship's daily reports provide important and accurate weather information for specified sea areas.

Finally, all of the above will provide invaluable lesson, reference and input for a better future ship design. Design for service can be derived from the lesson of ship routeing process. For instance, through the ship performance analysis, designers can now have a clear picture on how the ship is performing in actual seas and it relation with operational efficiency. Therefore, anticipate service margin during ship design and new building stage can be accurately estimated. Another example, ship owner and ship charterer can determine the effective ship speed or fuel consumption of charter party contract beforehand and this will provide competitive edge benefits for both parties.

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