OPTIMIZATION OF LIQUEFIED NATURAL GAS BUNKERING VESSEL DESIGN

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DEDICATION

"Imagine that you enter a parlor. You come late. When you arrive, others have long preceded you, and they are engaged in a heated discussion, a discussion too heated for them to pause and tell you exactly what it is about. In fact, the discussion had already begun long before any of them got there, so that no one present is qualified to retrace for you all the steps that had gone before. You listen for a while, until you decide that you have caught the tenor of the argument; then you put in your oar. Someone answers; you answer him; another comes to your defense; another aligns himself against you, to either the embarrassment or gratification of your opponent, depending upon the quality of your ally's assistance. However, the discussion is interminable. The hour grows late, you must depart. And you do depart, with the discussion still vigorously in progress."

Kenneth Burke, The Philosophy of Literary Form

With this spirit, I humbly dedicate my research to a long-standing academic and practical conversations.

Hamedullah Muhammad
Kuala Lumpur
2018

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ABSTRACT

Liquefied Natural Gas (LNG) has emerged as one of the alternative marine fuels for ship owners in order to comply with the Sulphur cap implemented under the IMO 2020. A new type of purpose-designed LNG Bunkering Vessel (LBV) has been in development to meet the demand for LNG bunkering operation. Based on the slow emergence of several competing designs since 2017, there is still uncertainty on what the dominant design would be for LBV. New firms entering into the market must look into and decide what will be the design of their choice. The objectives of this study are to evaluate the designs through benchmarking analysis of Charterers' requirement and selecting the design that is most likely would be the dominant design in the future. Three (3) worldwide tenders for LBV within 2017 – 2018 have been selected as the subjects for the case study. Through market analysis, Charterers' mandatory requirements and preferred solutions are identified. Focus groups consisting relevant stakeholders are engaged to provide additional solutions and also come out with several designs. The designs are then technically and commercially evaluated. The research identified fourteen (14) key functional requirements out of eighty (80) specified and also contributed ten (10) additional solutions. Three designs namely D1 (full compliance with best technical specification), D2 (full compliance with adequate technical specification) and D3 (optimized specification) are proposed through morphological analysis. The research found several key characteristics of Charterers' requirement; majority of them are payload functions, emphasis on compatibility and preference for flexibility to maintain worldwide trading. The commercial evaluation found that there is significant price differential between designs, with the extreme being 14% between D1 and D3. The study shows that there are trade-offs to be considered in terms of performance envelope, compatibility, flexibility, ease of operation and ship price when considering for the optimum LBV design.

Keywords: LNG Bunkering Vessel, Dominant Design, Morphological Analysis

ABSTRAK

Gas asli cecair (LNG) telah menjadi salah satu pilihan bahan bakar alternatif kepada pemilik kapal laut bagi mematuhi had sulphur bahan bakar kapal yang baru dilaksanakan dibawah IMO 2020. Kapal pengisi bahan bakar kapal jenis LNG (LBV) telah direka dan dibina untuk memenuhi keperluan LNG sebagai bahan bakar kapal. Perkembangan dan persaingan reka bentuk – reka bentuk LBV bermula dari tahun 2017 didapati agak perlahan dan masih terdapat ketidakpastian mengenai reka bentuk dominan bagi LBV. Syarikat-syarikat baru yang ingin menceburi pasaran bekalan LNG sebagai bahan bakar kapal harus meneliti dan memilih reka bentuk yang sesuai. Objektif kajian ini adalah untuk menilai reka bentuk LBV berdasarkan analisa keperluan pencarter dan memilih reka bentuk yang mungkin akan menjadi reka bentuk dominan Tiga tender untuk LBV daripada seluruh dunia sepanjang 2017 – 2018 telah dipilih sebagai subjek untuk kajian ini. Keperluan mandatori dan teknologi pilihan pencarter telah dikenalpasti melalui analisa tersebut. Sesi sumbang saran bersama kumpulan fokus yang terdiri daripada pengamal industri yang relevan telah dijalankan untuk mengenal pasti teknologi pilihan tambahan dan mengusulkan beberapa reka bentuk LBV. Reka bentuk – reka bentuk ini kemudiannya dinilai secara teknikal dan komersil. Kajian ini telah menegenalpasti empat belas (14) keperluan mandatory pencarter daripada lapan puluh (80) keperluan asal tender dan telah berjaya mengusulkan sepuluh (10) teknologi tambahan. Tiga reka bentuk iaitu D1 (patuh menyeluruh dengan spesifikasi teknikal terbaik), D2 (patuh menyeluruh dengan spesifikasi teknikal yang mencukupi) dan D3 (spesikasi optima) telah diusulkan hasil analisi morpologi. Kajian ini telah mengenal pasti ciri-ciri teknikal utama yang diperlukan oleh pencarter; fungsi teknikal yang berkenaan dengan beban bayar, penekanan terhadap keserasian reka bentuk dan kecenderungan untuk reka bentuk yang fleksibel bagi perdagangan laut dalam. Hasil penilaian komersil mendapati terdapat jurang harga kapal yang besar diantara reka bentuk – reka bentuk yang telah diusulkan; jurang terbesar adalah diantara D1 dan D3 sebanyak 14%. Kajian ini menyimpulkan bahawa dalam mencari reka bentuk LBV yang optimum, timbal-balik antara had prestasi, keserasian, kefleksibelan, kemudahan untuk operasi dan harga kapal perlu diambil kira.

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LIST OF ABBREVIATIONS

CCS	-	Cargo Containment System
ECA	-	Emissions Control Areas
HFO	-	Heavy Fuel Oil
IMO	-	International Maritime Organization
ITPS	-	Intermediate tank-to-ship (via pipeline)
LBV	-	LNG Bunkering Vessel
LNG	-	Liquefied Natural Gas
LNGC	-	LNG Carrier
LPG	-	Liquefied Petroleum Gas
LSA	-	International Life-Saving Appliance Code
MARPOL	-	The International Convention for the Prevention of Pollution from Ships
MEPC	-	Marine Environmental Protection Committee
MGO	-	Marine Gas Oil
NOx	-	Nitrogen Oxides
RFP	-	Request for Proposal
SOLAS	-	The International Convention for the Safety of Life at Sea
STS	-	Ship-to-ship
TTS	-	Truck-to-ship
TEU	-	Twenty Foot Equivalent Unit
VLSFO	-	Very Low Sulphur Fuel Oil

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CHAPTER 1

INTRODUCTION

1.1 Background of Eaglestar

Eaglestar Marine Holdings (L) Ltd was incorporated in 2017 as a ship management company. Previously it was part of the larger MISC Group under Fleet Management Services (FMS). Eaglestar is jointly owned by MISC Berhad and AET with a 50%-50% split. Currently Eaglestar is managing a strong fleet of 96 vessels ranging from LNGC, Aframax, Panamax, VLCC, Suezmax, Dynamic Positioning Shuttle Tanker (DPST) and LNG floaters. Eaglestar is also actively building new vessels and as of 2018, is managing 10 newbuilding projects in South Korean yards.

With rich experience in LNG shipping since the inception of Malaysia LNG exports in 1980s, Eaglestar has built a solid reputation as the reputable and reliable LNG operator. With that background, Eaglestar have keen interest to expand its ship management portfolio in LNG bunkering business. In fact, from early 2017, the company have entered into several tender bidding for the provision of LBV both in Europe and Asia. Along the way, Eaglestar have developed working relationships with small scale word class shipyards from Korea and China to source for the best designs that can suit the ever growing demand for LBV. The division that are responsible for technical proposal on any tender bid is the Project Management team. The same team will usually roll-over to detail engineering phase and project supervision; ensuring the continuity of supervision is not disrupted.

1.2 LNG as Marine Fuel and LBV

Large seagoing vessels traditionally use HFO with a Sulphur content of up to 3.5%, while smaller vessels use distillates with Sulphur content less than 1.0%. Heavy fuel oil, i.e. residual fuel, consists of the fractions of crude that remains in the refinery process after its extraction of lighter and more valuable fractions, such as naphtha, petrol, diesel, and jet fuel. The advantage of HFO for the ship-owners is its low price compared to distillates. For the refineries, selling residual fuel has been an alternative to making large investments (in process equipment) to convert more of the residual fuel to distillates (Lindstad, Rehn, & Eskeland, 2017).

IMO decided at its 70th session of the MEPC in October 2016 to reduce the maximum Sulphur content in the exhaust gas to air from 3.5% to 0.5% from 2020 as shown in Figure 1.1. It can be seen as an extension – a globalization – of the regionally motivated Emissions Control Areas (ECAs) already in place, though these impose a 0.1% Sulphur cap for areas near the coasts of North America and Northern Europe (North Sea and Baltic Sea). These ECAs establish stricter emissions requirements for vessels operating within coastal areas, e.g., 0.10% sulphur limits for marine fuels, Tier III NOx controls for engine exhaust.

One of the ways to comply with this regulation is via fuel switching; either switching to lower Sulphur distillates like MGO, blends like VLSFO or alternative fuels namely LNG, LPG, Methanol and Biogas. Figure 1.2 shows that it is anticipated that post-2020, VLSFO and MGO will dominate the fuel market mix with over 70% market share but among the alternative fuels, LNG is touted to be the main choice with 7% market share in 2020 (British Petroleum, 2018). LNG offers lower local pollution emissions compared to distillate fuels. For NOx emissions, current engine designs equal those of distillate fuels, and proposed improvements to engine design may reduce emissions to meet Tier III levels without after treatment**.**

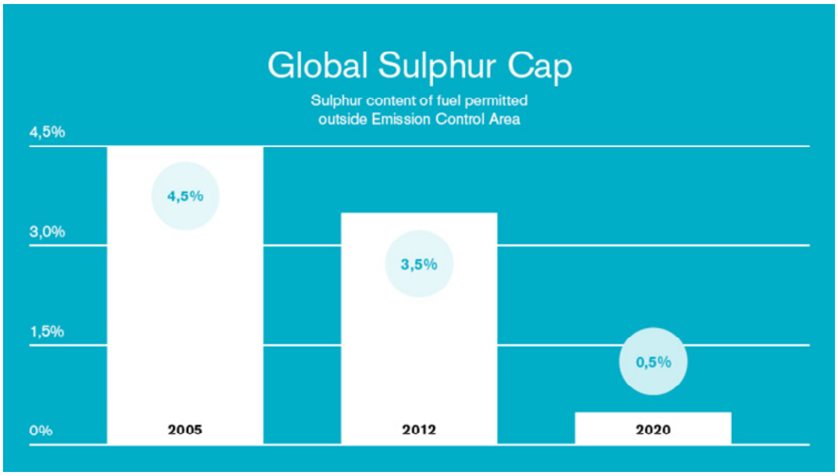

Figure 1.1 IMO Global Sulphur Cap

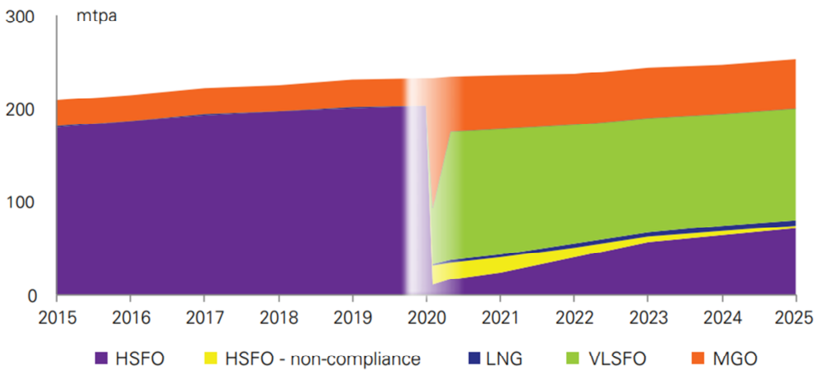

Figure 1.2 British Petroleum - Marine Fuel Market Transition Graph (British Petroleum, 2018)

Research indicates that the SOx and PM emissions of natural gas meet current, pending, and proposed standards for marine vessel operations and can significantly reduce local pollutants from vessel operations (Thomson, Corbett, & Winebrake, 2015). More importantly, LNG already fulfils the global availability criteria and already overcome the hurdles related to international legislation (DNV-GL, 2018). There is a strong growth anticipated for LNG as marine fuel in the future. Figure 1.3 shows that currently there are 233 vessels – in operation and on order book – that are equipped with LNG propulsion. The total outlook for LNG as marine fuel consumption in 2021 is expected to be around 1.95 MMt (IHS Markit, 2017).

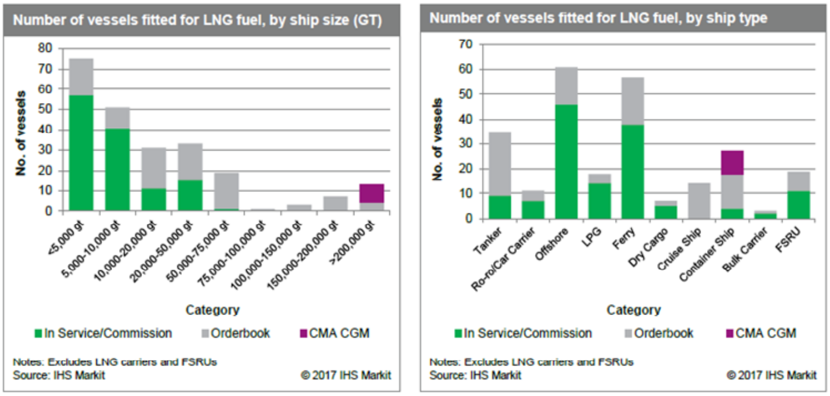

Figure 1.3 IHS Markit – Worldwide LNG Fuelled Database

The main sources for LNG as marine fuel are mainly two; (a) liquefaction plants/onshore import terminals/FSRU and (b) small local liquefaction facilities that uses pipeline gas. From here, it can be transferred for fuel using LNG deliverers such as containerized storage tanks, LNG road tankers or bunker vessels/barge. It is very unlikely that any of the LNG Suppliers and their facilities described above will bunker ships directly. The large amount of hazardous material involved (primarily LNG but also refrigerants and high-pressure gas) results in strict and onerous safety and environmental policies that normal shipping would find difficult and costly to comply with (SGMF, 2018).

Having said that, LNG terminals can technically transfer LNG to ships directly without using any intermediate transfer mode. This however, will require the ship to sail to the LNG bunkering terminal, a change of practice from oil bunkering. On the other hand, LNG can be transferred from barges or even small LNG carriers, which can be moored alongside a ship anywhere in a port (with the agreement of the port authority). In this regard, the current practice of marine fuel bunkering remains the same but the deliverer i.e. bunker vessel has to be developed. Against this backdrop, a new type of purpose-designed LBV has emerged to meet the demand for LNG bunkering operation. It utilizes the technologies used on board of conventional LNGC and small-scale LNGC with the addition of specialist equipment to handle STS LNG transfer.

1.3 Problem Statement

Previous studies of several industries show that product technologies do not fully developed at the outset of their commercial lives (Henderson & Clark, 1990). The emergence phase of a new technology or solution might possibly be a very confusing one. There will be a degree of agreement on what the major systems would be but little is foreseen on the ways they should be put together. There would be several experimental designs competing for the market but ultimately it will be brought to end by the emergence of a dominant design as illustrated by Figure 1.4. The same phenomena are observed in LNG bunkering industry which itself is a fairly new industry; the first LBV came into operation in 2013 and at the time of writing, there are only four LBVs in operation. All four are designed to perform similar functions yet the technologies used are somewhat different.

For firms that are looking into entering the LNG bunkering market, there are values in selecting a future dominant design. It has been shown that firms are not doomed when their entry design choices turn out to be ‘wrong’

(Tegarden, Hatfield, & Echols, 1999). For early entrants, switching to dominant design is associated with increased chances of survival and market share. In addition, the 'knowledge building phase' that they went through gives them technical and commercial edges against newcomers.

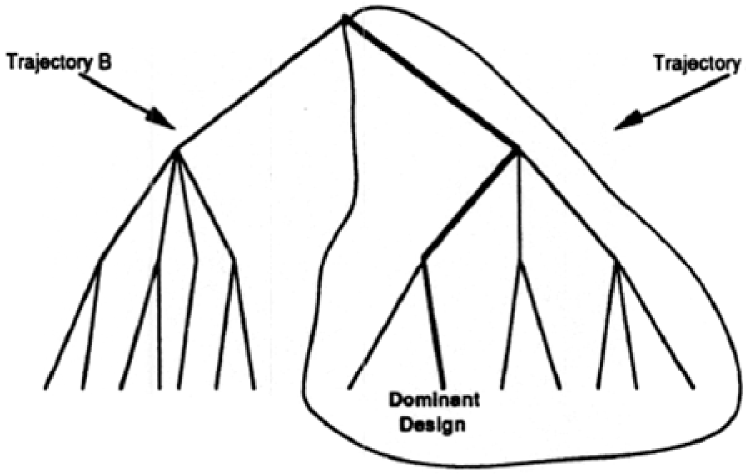

Figure 1.4 Dominant Design Paths (Henderson & Clark, 1990)

Compared to other methods e.g. containerized LNG, truck-to-ship, shore-to-ship, it is foreseen that LNG bunkering via ship-to-ship (STS) method would be the most feasible method of bunkering in the future (Choi & Navarro, 2017). With that said, based on the slow emergence of several competing designs since 2017, it is apparent that there is still uncertainty on what the dominant design would be for LBV. New firms entering into the market must look into and decide what will be the design of their choice.

1.4 Research Questions

The research will specifically try to address the following research questions:

1. How does one evaluate the various LBV designs in the market today?

2. How does design evaluation optimizes the final design of LBV?

1.5 Research Objectives

The research is focused on fulfilling two objectives:

1. Carrying out design evaluation for LBV through market analysis of Charterers' requirement.

2. Selecting the design that is cost-efficient and fit-for-purpose which will likely be the future dominant design through morphological analysis.

1.6 Significance of Study

The study contributes to the body of knowledge in several aspects;

1. The research complements the gap that is observed in the market. Since the market is still in its early phase and the dominant design is yet to emerge, the study provides a solution on how to evaluate competing designs against the actual customer requirement.

2. The study is done using data from actual tenders for LBV within 2017-2018, incorporating perspectives from Customer, Ship Operator and Shipyards. It provides a more realistic analysis on the matter to interested stakeholders.

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