Strategy for Effective Marine Transportation of Natural Gas Hydrate with Low Energy Consumption Type Container Carrier

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ABSTRACT

As natural gas hydrate (henceforth NGH) becomes popular as an upcoming alternative to using natural gas resources, a number of countries and institutions are attempting to develop related technologies. However, there are several technical, economic and procedural problems to solve. Despite the continued development in NGHP (Natural Gas Hydrate Pellet) production, a number of problems remained. Specifically, 'Mid' and 'Down-stream' steps have several issues to be considered. For bulk-carrier-type NGHP carriers, which were suggested to IMO(International Maritime Organization) MSC(Maritime Safety Committee) in 2007, the adhering problem duting marine transportaion and longer cargo working times are serious. In addition, several chemicals containing hot water are required for the unloading and regasification process. The glycol water should be purified before disposal. The need for new rules and regulations for NGHP carriers are also a barrier for NGHP carriers. Therefore, an alternative design for effective marine transportation of NGH has been studied. The pros and cons of the existing proposal for an NGHP carrier have been evaluated. Then a new type of NGH carrier has suggested on the basis of systems engineering process.

Keywords: natural gas hydrate, concept design, economic feasibility, energy saving, supply chain

1 INTRODUCTION

Since self-preservation effects of methane hydrates discovered in 1994, many countries study for the inexpensive and simple supply chain [1]. NGH is more favorable than LNG(Liquefied Natural Gas) as shown in table 1.

	NGH	LNG
Modes of transportation and storage	Solid	Liquid
Temperature to be maintained	-20°C	-162°C
Gravity	0.85 ~ 0.95	0.42 ~ 0.47
Cintents in 1 m^3 *NG: Natural Gas	NG: 170Nm^3 Water: 0.8m^3	NG: 600Nm

Table 1: Physical Properties of NGH Compared to LNG

Due to its self-preservation effect, NGH can contain natural gas in a solid state under a temperature of -20°C. This is significantly higher than -162°C, the temperature the LNG carrier should maintain for liquefied gas. As NGH comes under the spotlight as one of the leading energy sources of the future, associated researches are in progress including development of ship concepts and relevant technologies to build up the mid-stream of the NGH supply chain. In Figure 1, technologies for up-stream which including the natural gas mining and down-stream which including ground transportation and consumption are well developed. Since the capital cost for the Up and Down stream is settled, cost down in mid-stream is important [2] [3]. On the other hand, a solid technology standard has not been established for mid-stream, where the NGH pellets are produced through the NGH formation and pelletization, transported via carriers, unloaded, and regasified.

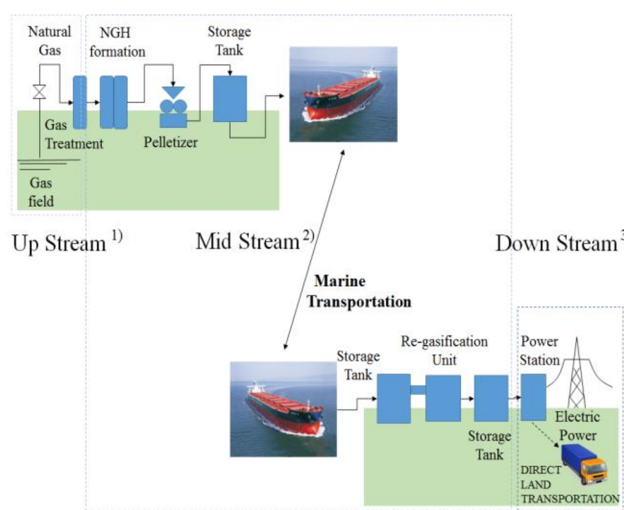

Figure 1:An example of NGH supply chain [4]

2 EXISTING TECHNOLOGIES

The NGHP carrier that has proposes to IMO is similar to a bulk carrier and transports massive amounts of stacked NGH, which is pelletized after formation. The cargo tanks, where the NGH pellets are stacked, are internally insulated in accordance with the IGC Code (International Code for the

Construction and Equipment of Ships Carrying Liquefied Gases in Bulk). In order for NGHP transports with large cargo tanks to be incorporated into the mid-stream supply chain along with the loading-unloading and regasification facilities, the transports should be able to sustain the pressure and temperature required for the self-preservation effect to take place inside the tanks and to solve the problem of plugging caused by the weight of the pellets [4].

From the study of suggested concept of the NGHP carrier, some requiremets are analized for the alternative design. Figure 2 shows summarized study result of existing NGHP carrier concept.

Figure 2: Requirements for improvements to existing NGHP carrier concept

3 DESIGH ALTERNATVE FOR MARINE TRANSPORTAITON OF NGH

Economic feasibility should be assured in order to proceed with the development of the small to medium gas fields. The economic feasibility requirements for construction and commercialization apply to the entire supply chain, which includes natural gas exploration and mining, NGH formation and pelletization, transportation, disassociation, and consumption. This proceeding conducts an analysis of the requirements to solve the identified problems based on the results of the analysis on the proposed NGHP carrier. Figure 3 shows 1-2 MMt(NG Equivelent) ocean transportation CAPEX-distance.

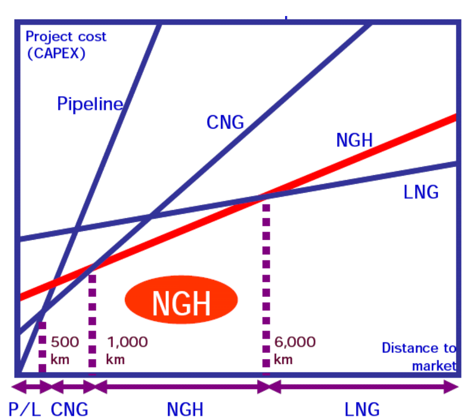

Figure 3: MMt (NG Equivalent) ocean transportation CAPEX-distance [5]

3.1 Target Gas Field

For the economic feasibility study, mid-size gas field choosen as shown in figure 4.

Figure 4: Target gas field information

3.2 Design Methodology

As an useful way for the alternative design of existing NGHP carrier, systems engineering process considered. As Kang et al(2011) sugested, business model used as an systems analysis and control tool in the design process. By using this design process, many controversal aspects managed efficiently[6]. Figure 5 shows applied design process and business model.

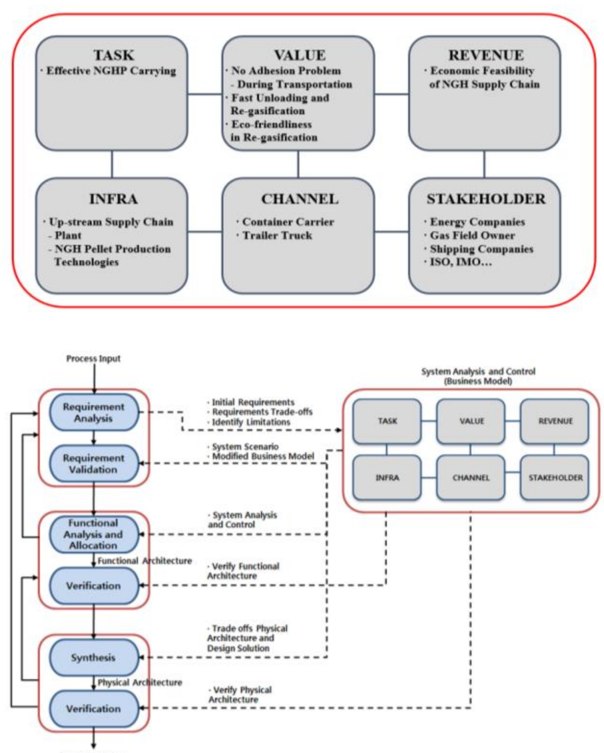

Figure 5: Systems engineering basis design process [6]

3.3 NGH Tank Conatiner Design

For the effective marine transportaion of NGH, modularization of the cargo considered. Tank container type cargo tank yields significant reduction in unloading time compared to existing NGHP carrier since crushing process of adhered NGH pellets on the cargo tank is not required. In addition, on-ground regasification does not affect ship availibility. By supplying calrories into the tank, glycol water free regasification process is enabled. Installed hot-water pipes or heating-coil inside the tank eleminates the need of glycol water and purifying facilities. Table 2 shows specifications of designed NGH Tank Container.

Tank Container Type NGHP Carrier		
Size		20/40 feet Equivalent Unit
Structure		Adiabatic Compression
Material	Tank	SA516-70($\sigma_y = 260MPa$)
	Frame	SPA-H ($\sigma_y = 355MPa$)
Weight	Full-loading	Abt. 20,000 kg (44,092 lb)
	Net	Abt. 6,870 kg (15,145 lb)

Table 2: Specifications of designed NGH tank container

Figure 6 and 7 show design concept and designed NGH tank container basis recomposed NGH mid-stream supply chain concept. The design reflects suggested requirements and meet the business model.

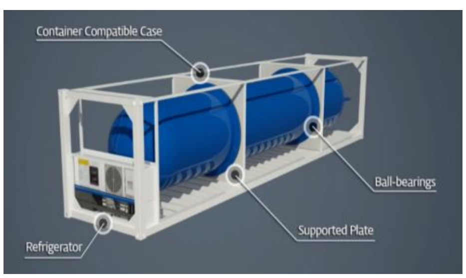

Figure 6:Construction drawings for the NGH tank container

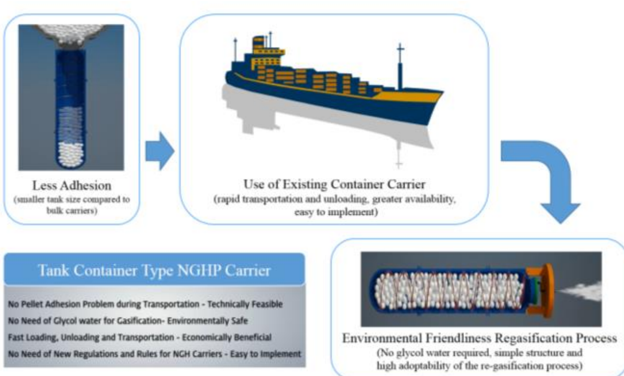

Figure 7: Recomposed NGH mid-stream supply chain

4 ECONOMIC FEASIBILITY STUDY

4.1 Cost Reduction with Proven Hull-form of Container Carrier

The existing design of NGHP carrier and the proposed NGH tank container have no history of construction. Therefore, their costs are estimated using historical data of similar configurations: a similar bulk carrier is used for the existing NGHP carrier and similar container carrier is used for the proposed NGH tank container carrier. Meanwhile the fuel consumption, fuel cost, and charterage are estimated based on the market price [7] [8] [9].

	NGHP Carrier	NGH Tank Container Carrier	
Size	46,000 DWT	4,000 TEU	
NGH(P) Capacity	60,000	67,200	ton (abt.)
Speed	15.00	17.00	kts
Fuel Consumption	29.30	43.20	ton/day
Fuel Cost	24,612	36,288	US dollar/day
Charterage	36,000	10,000	US dollar/day

Table 3: Major dimensions and costs of the existing NGHP carrier and proposed NGH tank container carrier

For the existing NGHP carrier, the total process time for disassociating the adhered pellets and moving contaminated water to the on-ground tank is assumed to follow the planned commercial land plant project [4]. On the other hand, the unloading time of the proposed NGH tank container is assumed to be one day, which is the same for the ordinary container ship. Under a premise that each carrier operates with an availability of 85% each year, the analysis results indicate that the existing NGHP carrier yields 14 round trips per year while the proposed NGH tank container carrier yields 28 round trips.

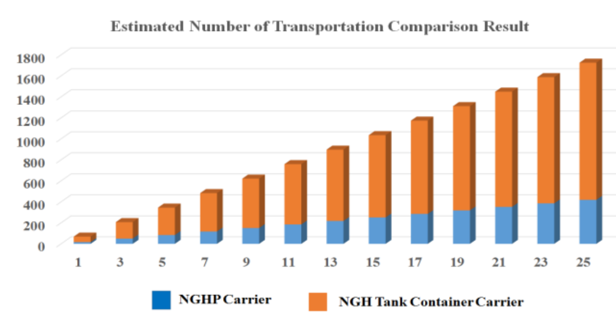

Figure 8: Estimated number of transportations

When these carriers have similar loading capacities and the other expenses, such as labor cost, are the same, 2.98 NGHP carriers or 1.62 NGH tank container carriers are required to transport 3 million tonnes of natural gas annually. This is described in the table 8, as it compares the two carriers in terms of fuel consumption and charterage based on the market price [7] [8].

	Total Cost for Transportation (Loaded)	Total Cost for Return (Unloaded)
NGHP Carrier	378,800	318,188
NGH Tank Container Carrier	260,693	214,405
	Annual Expenses / Ship	Total Cost for Annual Shipping
NGHP Carrier	10,058,079	34,849,354
NGH Tank Container Carrier	13,085,914	21,209,750

Table 3: Cost comparison for transportation of 3MTPA, fuel cost, and charterage (unit: U.S. dollar)

4.2 Cost Reduction with Proven Hull-form of Container Carrier

Container carriers have room for improvement. There are abundant experiments and measurement data available for the hull drag of the container carriers, and employing an ESD(Energy Saving Device) may result in gradual improvement of fuel efficiency. Furthermore, charterage can be saved by utilizing feeder class container carriers, instead of developing new carrier concepts. Therefore, these aspects should be revisited at the commercialization stages of the proposed NGH tank container technology. With only specific ESD, from 1 to 7% power reduction currently available for variable sizes of container ships[10]. Figure 9 shows specific energy saving device which adoptable to existing feeder class container carriers.

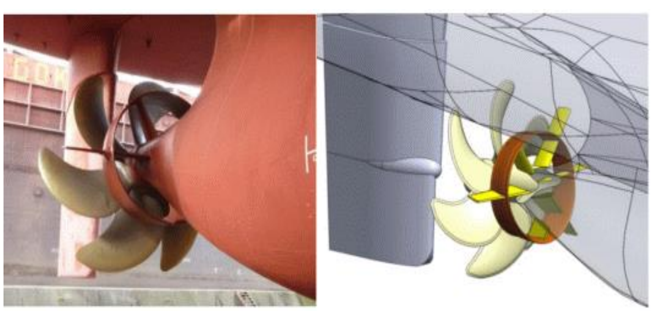

Figure 9:A example of energy saving device for container carriers (www.becker-marine-systems.com) [10]

5 CONCLUSION

In this study, NGH tank container concept suggested for the effective marine transportation of NGH. For the design, systems engineering process considered with the business model which act as the systems analysis and control tool. For the commercialization of the proposed design concept, the construction of a prototype and additional tests, including field tests and authentication procedures, are required. In addition, proven technologies for ESD and power reduction will enhance economic benefit of NGH tank container since it uses existing container carriers. Finally, way for using NGH tank container for marine transportation of carbon dioxide from on-land basis terminal to burring point is considerable since NGH tank container design endures storage condition of compressed carbondioxide. Despite these considerations, the proposed design concept is a sufficient first step to effective marine transportaion of NGH. We hope that many engineers, scientists and authorities will participate in the realization of this study.

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