International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 29, No. 2, June 2019, pp. 191–197; https://doi.org/10.17736/ijope.2019.jc738
http://www.isope.org/publications/publications.htm

# Relative Motions of FLNG and LNG Carriers Arranged Side by Side and an Assessment of Their Operation

Ryohei Yoshioka, Makoto Arai and Yoshiaki Hirakawa
Department of Systems Design for Ocean-Space, Yokohama National University
Yokohama, Japan

Ning Ma
State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University
Shanghai, China

Kazuo Nishimoto
Department of Naval Architecture and Ocean Engineering, University of São Paulo
São Paulo, Brazil

**Offloading operability is a critical issue in floating liquefied natural gas (FLNG). In the offloading process, because loading arms have track records in liquefied natural gas (LNG) terminals in ports, they will be used between FLNG and an LNG carrier arranged side by side. However, the environmental conditions of operation sites are harsher than those of ports. This paper presents the results of an offloading operability assessment. First, the ship motions and the wave elevations between the two vessels were obtained by model tests and numerical calculations. The operable conditions were investigated based on the relative motions and the criteria. Finally, the offloading operability was evaluated.**

## INTRODUCTION

Because of growing concerns regarding environmental issues, political instability in oil-producing countries, and volatile oil prices, the demand for natural gas is increasing. As a result of the increasing demand, many offshore gas fields are being developed. Submerged pipelines are usually used to transport natural gas from gas fields to land-based processing plants. The gas can be transported to the market by pipelines or liquefied natural gas (LNG) carriers after being converted to LNG at about −160 degrees Celsius. However, it is not profitable to develop gas fields that are too small or too remote by the above method. Such gas fields that have been discovered but have remained unusable for either technical or economic reasons are referred to as stranded gas fields. Considering that the demand for natural gas is expected to further increase, it might be beneficial to develop such stranded gas fields.

Floating LNG (FLNG) is expected to be a reasonable solution for developing stranded gas fields because it does not require pipelines or land-based plants. During operation, FLNG is continuously affected by wind, waves, and current. The offloading operability and reliability of the facilities in the ocean environment are critical factors that affect the facilities' safety, productivity, and profitability.

There are two methods of transferring LNG: loading arm systems and flexible hose systems. Because loading arm systems have a longer track record in land-based LNG terminals than do flexible hose systems, they are the preferred option. In the offloading operation, two vessels are moored in a tandem or side-by-side arrangement. Conventional LNG carriers have manifolds at midship and can be used in a side-by-side arrangement without modification. Therefore, the FLNG can offload LNG with a configuration similar to that between an LNG carrier and a land-based LNG terminal when a loading arm system is used in a side-by-side arrangement.

However, the environmental conditions at operation sites in the ocean are severer than those in ports. Also, vessels in a side-by-side arrangement are moored in close proximity to each other. Unexpected ship motions may occur as a result of gap resonance, sloshing, wind, and current, and this may affect the offloading operability. In this paper, the results of an operability assessment of the side-by-side offloading operation between FLNG and an LNG carrier are reported.

The resonance phenomenon occurring in the gap between the two vessels is similar to the pumping mode observed in the moon pools of drill ships, and it amplifies incoming waves. Another important issue is the sloshing of the liquid stored in the tanks because of ship motion. Sloshing is likely to occur when the tanks are in a partially filled condition of between 10% and 70% of the tank height. FLNG cannot avoid this condition during the production, liquefaction, and offloading processes of LNG. Faltinsen and Timokha (2009) gave a general overview of sloshing in a previous report.

Kim et al. (2017) performed an operability analysis of a small-scale LNG carrier and FLNG arranged side by side offshore of West Africa based on numerical calculation. In this study, first, ship motions were studied through model tests, considering the effects of liquid cargo in the tanks and the free surface elevations in the gap. Numerical calculations based on potential theory were then performed. Then, the limits of the environmental conditions under which the offloading operation can be performed were examined based on the relative motions at the manifold position and the criteria for side-by-side offloading. Finally, the offload-

Received January 10, 2018; revised manuscript received by the editors March 8, 2018. The original version was submitted directly to the Journal.
KEY WORDS: FLNG, LNG carrier, model test, relative motion, side by side, offloading operability assessment.