International Journal of Offshore and Polar Engineering
Vol. 5, No. 1, March 1995 (ISSN 1053-5381)

Study on Impact Pressure Due to Sloshing in Midsized LNG Carrier

Satoshi Yamamoto, Fukuhiko Kataoka, Satoru Shioda and Yasuhiko Ashitani
NKK Corp., Tsu, Japan

ABSTRACT

As is well-known, liquid motion in a cargo tank with a free surface causes high impact pressures on the walls and ceiling of the tank. The authors have studied this problem for over 10 years and have established a procedure for estimating impact pressures caused by cargo sloshing in LNG carriers. The investigation, however, had mainly dealt with impact pressures occurring in large LNG carriers. The current situation causes increasing demand for suitable midsized LNG carriers, in addition to the 130,000 M3 type LNG carriers. Since it is generally understood that ship motions of small vessels tend to be relatively large in comparison with those of large vessels, the cargo sloshing in midsized LNG carriers is an even more important subject to be studied. From the above viewpoint, the authors have performed a large number of model tests for understanding the characteristics of the impact pressures and estimating the maximum impact pressure in a midsized LNG carrier. In this paper, the authors show not only the test results but also a new procedure based on a statistical approach for estimating the maximum impact pressure. Moreover a relationship between the maximum impact pressure and the power spectrum of ship motion is discussed.

INTRODUCTION

When designing membrane-type LNG carriers, it is important to estimate the impact pressures acting on the tank walls and ceiling. It is well-known that liquid motion in a cargo tank with a free surface causes high impact pressures not only on partially filled conditions but on fully filled conditions. A large number of experiments and computational studies, therefore, have been carried out to make clear the sloshing phenomena which cause high impact pressures. As a result, a procedure has been established for predicting the maximum impact pressure in prismatic tanks of large LNG carriers (Tanaka, 1984).

The use of liquefied natural gas as a clean energy resource is increasing even among midsized city gas companies in Japan. The situation has caused increasing demand for suitable midsized LNG carriers.

Since sloshing pressures vary greatly with many factors, such as the shape of the cargo tank, the filling height, the amplitude and periods of ship motions, the procedure established for large LNG carriers can not be fully applied for precisely predicting the maximum impact pressure in midsized LNG carriers.

Although computer programs have been developed to numerically simulate impact pressures due to sloshing (Mikels, 1984; Arai, 1992), it is rather difficult to get accurate estimates because of the complexity of the sloshing phenomena at present. Therefore, a series of model tests conducted by irregular oscillations simulating ship motions is still needed to predict the maximum impact pressure.

The aims of this study based on the irregular oscillation tests are to make clear the characteristics of the cargo sloshing in a midsized LNG carrier and to predict the maximum impact pressure during the lifetime of the vessel by using a statistical approach. How to select the sea states applied to the model tests is discussed using the experimental results.

Received June 1, 1993: revised manuscript received by the editors July 19, 1994. The original version (prior to the final revised manuscript) was presented at the Third International Offshore and Polar Engineering Conference (ISOPE-93), Singapore, June 6-11, 1993.
KEY WORDS: LNG carrier, sloshing, impact pressure, sea state, return period, Weibull distribution function.

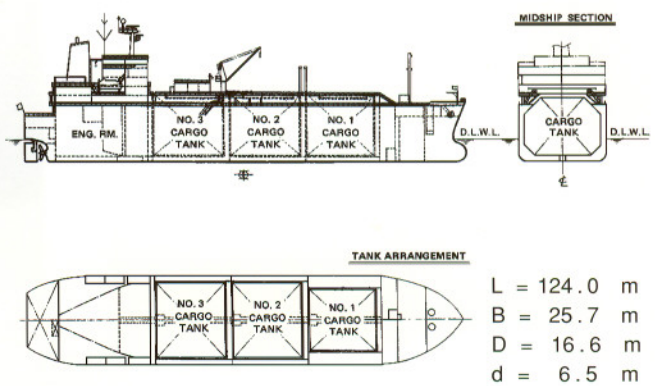

Fig. 1 General arrangement of 18,800 M^3 LNG carrier

OUTLINE OF STUDY

The midsized LNG carrier in question, the 18,000 M^3 class LNG carrier, has three cargo tanks, as shown in Fig. 1. These tanks are all of prismatic shape and sizes of the upper and lower chamfers are approximately 30% and 20% of the tank depth, respectively.

Fig. 2 shows a conceptual flow of this study. First of all, the maximum significant wave height corresponding to a 20-year return period is predicted on each wave period, taking into account the cruising area of the vessel. Next, a series of regular oscillation tests using a model tank is carried out to find the most severe oscillation period causing the maximum impact pressure on each filling height before performing the irregular oscillation tests. Based on the prediction of sea states and the experimental results, test conditions of the irregular oscillation tests are determined. Then the tests are carried out.

After the experiment, the probability distribution function of the impact pressures measured in each test is approximated with the three-parameter Weibull distribution function. Finally, the 2-h maximum expected impact pressure on the most severe sea state during the lifetime of the vessel is predicted by using the probability distribution function and a law of similarity.