Fitting Three-Parameter Weibull and Generalized Pareto Distributions to the Sloshing Impact Peak Pressures

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ABSTRACT
To evaluate the sloshing loads from the peak pressures of the model test, a proper statistical model and its parameter estimator should be properly selected. The three-parameter Weibull distribution with 5 different estimators and the generalized Pareto distribution with 3 different estimators have been studied based on the 2,321 model test cases. Three different goodness-of-fit tests have been used to test their fitness. Expected results of each statistical model are described and possible selection of the statistical model is suggested to obtain well-fitted distribution to the sloshing peak samples.

KEY WORDS: Sloshing experiment; the three-parameter Weibull distribution; the generalized Pareto distribution; parameter estimation; goodness-of-fit test.

INTRODUCTION
Assessing sloshing loads on the LNG vessels has been an important issue of the shipbuilding industry (Kuo et al., 2009; Royal Dutch Shell, 2020). Owing to the complex and stochastic nature of sloshing, conducting a model test has been the most common approach to evaluate the sloshing loads (Gervaise et al., 2009; Karimi et al., 2013; 2014; Malenica et al., 2017). Extensive studies have been conducted to develop a proper methodology of the model test (ABS, 2009; BV, 2011; DNV-GL, 2016; Karimi et al., 2013; 2014; Kuo et al., 2009; Graczyk and Moan, 2008). Korean shipyards have carried out numerous model tests for their products and cargo hold development following these suggested procedures. Seoul National University has supported to these model tests greatly commissioned by the industries and a huge database of the sloshing model test has been created (Ahn et al., 2019; Kim et al., 2013; Kwon et al., 2018; Oh et al., 2015).

One of the issues in conducting sloshing model test is to find a proper statistical model. Several extreme statistics have been described in the international guidance notes and a few studies (ABS, 2009; BV, 2011; DNV-GL, 2016; Kim et al., 2014; Graczyk and Moan, 2008), but no concrete solution has been made. The most commonly used statistical models are the three-parameter Weibull distribution (WE3) and the generalized Pareto distribution (GPD) (DNV-GL, 2016; Kim et al., 2014; Graczyk and Moan, 2008). As a parameter estimator, the method of moments has been a typical choice for two statistical models. However, the sloshing loads hugely vary according to the parameter estimators and the statistical models.

Since the WE3 and GPD have been mainly used for the sloshing experiment, these two statistical models are to be first studied. The maximum likelihood estimation (MLE) and the method of moments (MOM) have been the most traditional and standard estimators (Cousineau, 2009; Hosking and Wallis, 1987). These two estimators have been modified (the method of the modified moments, MMOM) for particular problems as introduced in Cohen and Whitten (1982) followed by a description of several consistency problems (Cohen and Whitten, 1982). For the WE3, many more parameter estimators have been suggested. One of the most popular estimators is a L-moment method (Hosking, 1990). This estimator has been developed as a trimmed L-moment (TLM) by Elamir and Seheult (2003) to be a more robust estimation. The maximum product of spacings (MPS) estimator is also popular and showed good performance for several engineering problems (Cousineau, 2009; Cheng and Amin, 1983).

The GPD has been used for numerous engineering fields and its estimator has been also extensively studied (Bermudez and Kotz, 2010; Castillo, 1998; Castillo and Hadi, 1997; Moharram et al., 1993; Rootzén and Tajvidi, 1997). The MOM, MLE, the method of probability-weighted moments (PWM), the generalized PWM are the most commonly used parameter estimators (Ashkar and Nwentsa Tatsambon, 2007; Castillo and Hadi, 1997; Moharram et al., 1993). A recommended selection of the estimators with respect to a possible shape and a number of samples might be able to be derived from the previous studies. It is, however, hard to directly use the recommendations of the previous studies. The previous studies usually considered a small number of sample sizes that are less than 500 while the sloshing problem handles ranging from 10 to 5,000 samples. In addition, possible shapes of the distribution of the sloshing problem hugely vary with many outliers.