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

Vol. 31, No. 2, June 2021, pp. 153–159; https://doi.org/10.17736/ijope.2021.ts22

http://www.isope.org/publications

An Investigation of the Performance of a Pusher–Barge System Considering Advancing Velocity in Regular Waves

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This study investigates the performance of a pusher–barge system advancing in regular waves. The numerical simulation is carried out through the implementation of an in-house code, “AdFlow” (Advanced Analysis System for Floating Bodies in Waves), for the evaluation of first-order hydrodynamic properties. AdFlow allows the numerical analysis of motion responses by solving the potential flow around multi-bodies using a higher-order boundary element method (HOBEM) and wave Green function in the frequency domain. In this investigation, a pusher tug is arranged and located at the stern notch of a barge in a linear combination, connected with a well-proven coupling system. The study considers a coupling system configuration for the pusher–barge system using a connection pin, which allows the system to work as a single unit. The chosen connection pin system allows an independent pitch motion, while roll and yaw motions remain coupled. This research analyzed the advancing velocity condition for the pusher–barge system by considering three different heading angles in deep water. Moreover, this study evaluates six-degrees-of-freedom motion and calculates loads and moments acting on the connecting pin for different wave periods. Finally, this study compares and discusses response amplitude operators.

INTRODUCTION

A pusher–barge system is an alternative mode of transportation that is rapidly growing as a result of the expected development in processing, storage, and offloading facilities in deep water. In recent years, many efforts have been made to study the significant advantages and disadvantages of pusher–barge systems. Figure 1 shows the general arrangement of a pusher–barge system. Compared to a towed barge configuration, the pusher–barge system offers several significant advantages, including increased speed, reduced fuel consumption, ability to transit in higher sea states, access to the barge at any time, and the elimination of the vulnerable tow wire connection (Wolff, 2003). On the other hand, disadvantages are unavoidable: severe discontinuities in the hull shape and induced turbulence at the notch area are some examples of disadvantages that should be assessed and considered.

So far, extensive research in model experiments has been conducted on pusher–barge systems. Valkhof et al. (2000) performed a series of experiments with a tug and barge system for sea and river services. However, these experiments overlooked forces and moments in the adopted coupling system. Luo et al. (2006) carried out a series of experiments that calculated loads on the articulated connectors between a tug and barge in irregular waves. Although several cases were performed, the experiments did not consider numerical simulations. Koh and Yasukawa (2012) conducted a comparison study of a pusher–barge system in different water depth conditions, where the course-keeping ability of the system was evaluated. While shallow and deep-water conditions were analyzed, the coupling system between both vessels did not consider any articulated configuration.

On the other hand, regarding numerical simulations, Choi and Hong (2002) investigated the radiation and diffraction problems for two rectangular barges. Maimun et al. (2004) developed a mathematical model for a pusher–barge system to study zigzag and maneuvering simulations. Hong et al. (2005) applied a higher-order boundary element method (HOBEM) to predict the hydrodynamic interactions of a multi-body system where side-by-side moored vessels were analyzed. While information regarding model experiments is available, numerical simulations require further development in order to accurately approach the research related to multi-body coupled hydrodynamic problems.

This study investigates the performance in regular waves of a pusher–barge system in forward velocity. The numerical simula-

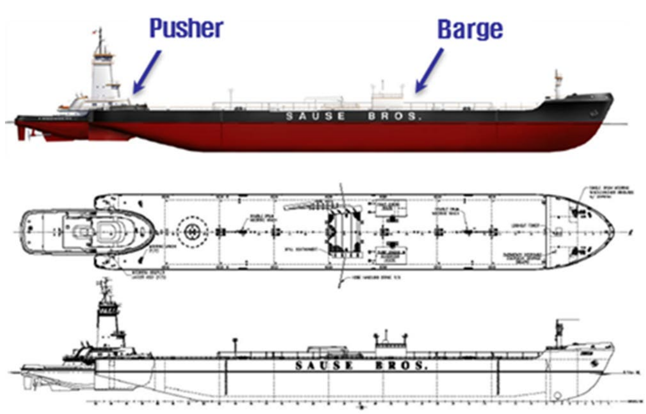

Fig. 1 General arrangement of a pusher–barge system

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Received July 13, 2020; revised manuscript received by the editors August 30, 2020. The original version was submitted directly to the Journal.
KEY WORDS: Pusher–barge system, higher-order boundary element method (HOBEM), wave Green function, connection pin system.