A Comparison of Seakeeping Predictions for Wave-Piercing Catamarans Using STF and URANS Methods

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ABSTRACT

Wave-piercing catamarans (WPC) consist of two demi-hulls with wave piercing bows that may pitch to immerse into or emerge out of the free surface when advancing in waves. So linear theories like STF are questionable to precisely predict the seakeeping performance of WPC in general cases. In this paper, URANS-based solver and STF method are employed to predict the pitch and heave motions of WPC for various speeds and wave frequencies in head seas. Furthermore, some extending studies, such as modifying the shape of wave piercing bows, disregarding the interaction between demi-hulls, and neglecting the viscosity of water, are also carried out using the URANS-based solver. Comparison of numerical and experimental results shows that under the Froude numbers of interest (0.3 < \(Fn\) < 0.6) good agreement is achieved by using the URANS-based method, while only similar trend is obtained by using STF. Based on numerical results, it could also be concluded that the forward speed effect on the free surface is significant, while the viscous effect is unimportant for the motions.

KEY WORDS: Wave-piercing catamaran (WPC); nonlinear; pitch; STF; RANSE-based method; wave amplitude; high speed.

INTRODUCTION

Wave-piercing catamaran (WPC) is a high performance multi-hull displacement vessel with super slender bodies and penetrating bows. Comparing with other high speed marine vehicles, WPC possess a remarkable advantage, that is, in rough seas it could pierce the wave rather than ride on it, which significantly reduces wave added resistance and diminishes speed loss. So the maximum speed of WPC is normally greater than 40 knots. However, the displacement and restoring force of penetrating bows of WPC is relative small, causing a low seakeeping performance in moderate to rough sea conditions. Hence the seakeeping performance is one of most important concerns for a WPC, and its analysis methods and optimization attract many researchers' attention.

A long line of researches has been carried out on the seakeeping problems of multi-hull ships including wave-piercing catamarans over the past decades. Most of these works are based on experiments or linear theories. One of most detailed experimental studies was accomplished by Soars (1993), who made various WPC proposals for model testing including seakeeping aspects under different wave headings, wave heights and finally developed a WPC with superior performance. Matsubara, Thomas, et al (2011) experimentally confirmed that the motions of a WPC is distinctly non-linear with respect to wave heights due to the immersion of centre-bow in large waves. Bouscasse et al (2013) experimentally investigated a fast catamaran advancing in regular, irregular waves, and assessed nonlinear effects on the hull motions.

As for the theoretical studies, strip theory and its modification form STF were the most widely employed methods for investigating seakeeping motions of catamarans (Lee, Jones and Curphey, 1973; Ohkusu and Wen, 1995; Deng and Ma 2006; Holloway and Davis, 2006; French, Thomas, Davis, and Holloway, 2012; Han, Wu and Zheng, 2012; Zheng and Dong 2012). However, a well known defect is that strip theory is unable to tackle the standing wave problem between demi-hulls. To overcome this problem, the STF solver Seakeeper (seakeeping analysis module of commercial soft Maxsurf) used by Deng and Ma (2006) ignores the interaction between two hulls and only analysis seakeeping performance of one hull from the WPC, while Ohkusu and Wen (1995) accounted for 3D effect in waves generated as a result of radiation and diffraction between demi-hulls of the catamaran.

Although some research works (Deng and Ma 2006; Zheng and Dong 2012) have reported that the STF can predict heave and pitch response of high speed catamaran while Froude number \(Fn\) < 0.6, most researchers agreed that the STF is unsuited for high Froude numbers, as it is unable to determine the interaction between strips, which is strong at high speeds. To this aim, some researchers (Falci, and Zhao, 1991; Hermundstad, Aarsnes, and Moan, 1999; Duan, Huang, Hudson, Price, and Wilson, 2001) developed a so-called 2.5D or 2D+ theory, where the free-surface condition is 3D but the control equation and body surface conditions are 2D. The 2.5D theory could take the interference between strips into account and solve the standing wave problem between multi-hulls. Duan, Ma, and Song (2002) concluded that the 2.5D theory is able to give satisfactory seakeeping performance prediction for high speed catamarans.

Instead of 2.5D theory, some other researchers directly proposed 3D Green function methods to solve the 3D problem for conquering the