Engineering prediction on ship motion and green water of hatchless container ship under extreme sea conditions
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ABSTRACT
This paper takes a hatchless container ship as a research object, applies the numerical calculation software SMAR and HydroStar to forecast the ship motion under extreme sea conditions. Also, Seakeeping model test to estimate ship motion and green water ingress in open cargo holds is carried out to compare with the numeric results. It proves the numerical calculation software meets the computational accuracy requirement. And the maximum green water ingress in open cargo holds happens in bow-quartering seas, and satisfies the requirements.

KEY WORDS: hatchless container ship, numerical calculation, extreme sea conditions, ship motion, green water

INTRODUCTION
Hatchless container ship has been developed rapidly in recent years, and it is regarded as a realistic alternative for application to conventional containerships because of its advantages. For example, it has a simple structure, the loading and unloading of containers is convenient, so it can shorten the time of ship in port and has good economic efficiency, and so on. But under extreme sea conditions, the research of wave-induced ship motion and green water ingress in open cargo holds is important for the safety navigation in waves.


In this paper, a hatchless container ship is taken as the research object. A series of numerical calculations are executed by numerical calculation software SMAR (Ship Motion and Add Resistance due to waves), which is independently developed by SSSRI, and HydroStar, which is developed by BV, is applied to forecast the ship motion under extreme sea conditions. The extreme sea conditions means the irregular long-crest waves which is simulated by JONSWAP spectrum, its worst wave spectrum peak period is 8.5s, which is determined by the theoretical calculation, and the wave height is chosen as 8.5m. Seakeeping model test to estimate ship motion and green water ingress in open cargo holds, which is executed according to the criteria proposed by IMO, is carried out under the same extreme sea conditions. The numeric results is compared with model tests, and it proves the numerical calculation software meets the computational accuracy requirement. The green water ingress in open cargo holds is one of the most important factors for designing a type of hatchless container ship, which has the fear of the flood of shipping water in hold. The model test result of green water ingress in open cargo holds shows that the maximum green water ingress in open cargo holds happens in bow-quartering seas, and it is smaller than the required value in specification, which satisfies the requirements.

NUMERICAL METHODS
SMAR software method
2.5D theory (also known as the high-speed slender body theory) has developed fastly in recent years to calculate ship motions and added wave resistance in waves. CHAPMAN R B. (1975) was the first to propose the high-speed slender body theory. FALTINSEN O et al.(1991) applied the high-speed slender body theory to seek the solution of motion problem of high-speed ship. After that, WANG C(2000), Ma Shan(2002), MA Xing-lei (2008) and more scholars have done in-depth research on this subject.

SMAR software (also known as Ship Motion and Added Resistance) was developed on the basis of a method firstly proposed by Duan & Li (2013) to predict added wave resistance and has been continuously promoted in recent years. The SMAR method is based on the 2.5D theory, and gives the formula of added resistance due to wave reflection, which is as follows:

\[ R_{\text{swr}} = \frac{\rho g \zeta^2}{2} \alpha_d \left( a \cdot k L_{\text{pp}} F_r^2 + b \cdot \sqrt{k L_{\text{pp}} F_r} + c \right) \]

Among the above formula:

\[ \alpha_d = \frac{\pi^2 I_1^2 (kT)}{\pi^2 I_1^2 (kT) + K_1^2 (kT)} \]
\[ a = -2 \int_C \sin^5 \theta \cdot |C_{\text{swr}}| \, d\ell \]
\[ b = 4c = 4 \int_C \sin^3 \theta \cdot |C_{\text{swr}}| \, d\ell \]