Development of Freeboard Formula for Open Top Vessels in Indonesian Waterways

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Abstract— ***in this study, a minimum freeboard formula was developed based on seakeeping performance for open-top vessels. The open-top container vessel was selected as a subject ship. To obtain a simplified formula of minimum freeboard, the subject vessel is transformed to be 16 model series which were constrained by displacement and block coefficient. Seakeeping analysis was conducted to obtain the motion responses for the transformed models. Based on the results, the probability of green water (P_s) due to coupled heave and pitch motions and probability of capsize (P_c) due to roll motion can be predicted. ITTC spectrum was used as wave spectrum based on the Indonesian waters. It was observed that the values of P_c in various wave height were small and it confirmed that the situation of ship capsizes did not occur. The value of P_s up to wave height H_w = 7 m were small and the highest P_s in long-term statistics occurred at H_w = 3.5 m. From those probabilities, a formula of minimum freeboard was derived.***

Keywords—freeboard, seakeeping, open top container, spectrum

I. INTRODUCTION

One of the typical vessels that sail in the island countries is a container vessel without hatch cover or popular known as open-top vessel. The purpose of removing the hatch cover (hatch coverless) is to optimize the arrangement of containers in cargo holds, to minimize the empty spaces in the cargo area, to accelerate the process of loading and unloading of the containers due to hatch coverless, and to increase the quality of containers lashing becomes tighter.

Initially, those vessels were operated in the inland and sheltered waters with the conditions of wave and wind are moderate. These situations may allow the ship behavior are not excessive, and it results in the probability of sea water into the cargo are small. Although the small amount of waters into cargo holds from seawater splashes and rainwater may occur. In further developments, the area of operation of ships became expanded. In order to ensure the safety for those vessels, IMO issued a guideline for open-top container vessels as according to MSC/ Circular.608/Rev.1 adopted on July 5, 1994 [2]. The required assessment on these guidelines include the stability calculation and seakeeping qualities, freeboard calculation, model test, and the treatment in flooding conditions at the cargo holds trough by the bilge system.

In recent years, the population of open-top vessels in Indonesian waters increased. BKI as Indonesian classification society has the authorities to assess the performance of these vessels to be seaworthy. Then one important parameter that needs to be formulated is the minimum magnitude of freeboard especially for open top vessels. Several studies were conducted to develop a formula for minimum freeboard. Journee et al. [3] developed a regression formula of bow height for various kind of ships based on the probability of deck wetness. Zaky [5] proposed a modified formula from ICLL Protocol 88 for Indonesian flagship, and it was investigated based on the probability of green water and the results confirmed that a minimum bow height can be reduced 35% for Indonesian waters when compared to ICLL Protocol 88. However, their studies only mentioned a developed formula for vessels with hatch covers not hatch coverless or open-top.

This study performs several seakeeping simulations for series transformed models of container vessels. The couple motions heave and pitch due to head waves, and roll motion due to beam waves were considered as motion response to predict a long term of probability of green water and probability of capsize. Based on both probabilities, a minimum freeboard was obtained from each model. The acceptance criteria for probability of deck wetness according to Nordforsk [1]. The wave scatter diagram corresponds to Indonesia waterways and ITTC spectrum was used as a wave spectrum. Thus, a regression formula of minimum freeboard was derived from the transformed hullforms.

II. STUDIED SHIP

A container vessel was selected as a parent ship in this study, and it is referred to as A0. Fig. 1 illustrates the body plan of A0. Table 1 shows the principal particulars of the ship. In the table, L denotes length between perpendiculars, B denotes ship breadth, H denotes ship depth, T denotes ship draft, C_b denotes block coefficient, Δ denotes volume of displacement, and F_b denotes freeboard. Next, a hullfrom of parent ship was transformed to be 16 model series by enlarging and reducing of L/B dan B/T ratios. To obtain the transformed models, the values of C_b, Δ, and F_b were assumed to be constant. From the transformation, new main dimension of models which have the same typical hullfrom as A0 were obtained. The results of the transformed model are mentioned in Table 2.