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Original Paper

Stability and hull characteristics of small sized fishing vessels below 10 GT according to hull type

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Abstract: Approximately 96% of fishing vessels registered in Korea are classified as small vessels with a gross tonnage (GT) of less than 10 tons, while accounting for more than 8% of total marine accidents. Despite this high accident rate, vessels shorter than 24 m are exempt from statutory surveys such as stability assessment and load line assignment, making it difficult to objectively evaluate their safety. This study aimed to classify the hull types of small fishing vessels, review International Maritime Organization and domestic stability standards, and conduct hydrostatic calculations for a representative hull type. The vessels were categorized into V-type, U-type, and T-type, with a clear transition from V-type to T-type observed as gross tonnage increased, the latter being dominant above 8 GT. Hydrostatic calculations for 28 vessels using the K-SHIP program indicated that the metacentric height (GM) ranged from 0.86 to 5.65. GM showed weak correlations with length and depth, but strong linear relationships with breadth/depth and breadth/draught ratios. V-type vessels consistently exhibited lower GM values compared to T-type vessels. The results not only suggest a practical method for estimating GM during the initial design and inspection stages, but also provide engineering contributions by offering a simple guideline for ship designers, an efficient tool for inspectors, and evidence to improve domestic stability standards in line with international practices.

Keywords: Small sized fishing vessel, Hull type, Stability, Metacentric height (GM), Hydrostatic

1. Introduction

Fishing vessels play a critical role in the Korean coastal and fishery industries. Among these, small fishing vessels below 10 gross tons (GT) are the most common, accounting for approximately 96% of the national fleet. Despite their dominance, these vessels are disproportionately involved in maritime accidents, and are responsible for more than 8% of all accidents **[1][2]**. This high accident rate highlights significant safety concerns for small-vessel operations. **Figure 1** illustrates the overall distribution of fishing vessels by gross tonnage, while **Figure 2** highlights the accident rates by size.

The high accident rate of small-sized vessels is attributed to several factors, including poor stability, absence of statutory surveys, and limited awareness of safety among operators. In particular, unlike larger vessels, fishing vessels under 24 m in length are exempt from statutory requirements such as intact stability assessment and load line assignment according to current Korean regulations, for example “Structure and Equipment Standards for Small Fishing Vessels with a Gross Tonnage of Less than 10 Tons” and “Stability and Load Line Standards for Fishing Vessels” **[3][4]**. Consequently, their stability characteristics often remain unverified in practice, creating difficulties in evaluating safety margins. This regulatory gap has been identified as a key factor contributing to the vulnerability of small vessels.

Standards and studies regarding stability have been developed for fishing vessels. While some previous studies have addressed stability, most have focused on case-specific analyses or larger vessel categories, leaving a gap in systematic research on the hull types of small fishing vessels. The International Maritime Organization (IMO) provides detailed stability standards for multiple

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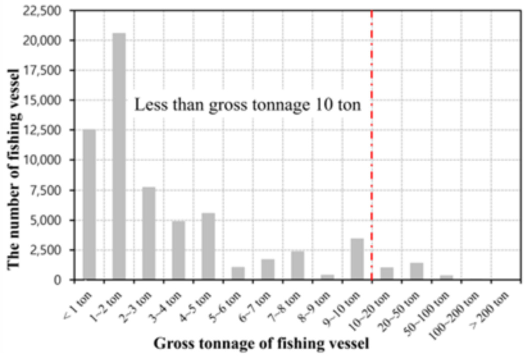


Figure 1: Distribution of fishing vessels registered in Korea by gross tonnage **[1]**

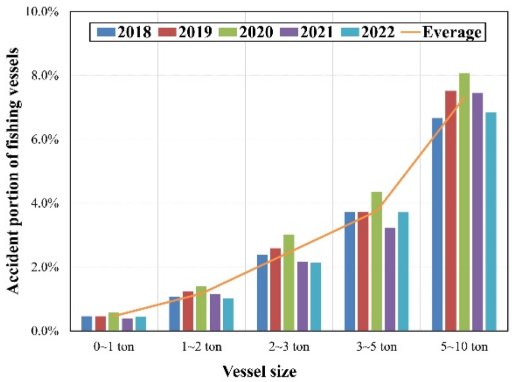


Figure 2: Marine accident rates of fishing vessels by size range **[2]**

parameters, such as length (L), breadth (B), depth (D), draft (T), and freeboard (f) **[5]**. In contrast, Korean domestic standards are comparatively simplified, relying mainly on B, D, and freeboard ratio, which may lead to an incomplete evaluation of stability and safety **[6]**. Kwon and Lee compared the actual GM with the GM requirement of fishing vessels more than 12 m in length and proposed stability criteria for small vessels by reviewing international regulations and combining empirical data with non-dimensional parameters T/D and B/D to evaluate stability and safety margins **[7]**. Oh and Lim compared the stability standards in Korea, Japan, China, and Canada together with IMO standards **[8]**. A couple of studies were conducted to estimate stability for small sized fishing vessels **[9][10]**. Recent studies have highlighted that inadequate stability assessment contributes significantly to accidents involving fishing vessels **[11][12]**. These studies still focused on accident statistics and stability rather than systematic relationships with hull types and hydrostatic characteristics.

In practice, small fishing vessels in Korea exhibit diverse hull forms, most commonly classified as V-type-, U-type-, or T-type. These hull types have markedly different hydrostatic properties and stability behaviors, which influence both operational safety and seaworthiness. However, few studies have comprehensively analyzed how these hull types affect the metacentric height (GM) and how domestic stability standards compare with international frameworks in evaluating vessel safety. Therefore, this study aimed to:

1. Classify the hull types of small sized fishing vessels below 10 GT.
2. Review and compare stability standards between IMO and Korean domestic regulations.
3. Evaluate hydrostatic characteristics and GM values through computational analysis using the K-SHIP program.

From these results, a practical method is proposed for estimating GM in the initial design, providing engineering insights to support the improvement of domestic safety standards for small-sized fishing vessels.

2. Preparation of Data and Analysis

2.1 Hull Type Classification

Most small fishing vessels in Korea are constructed using fiber-reinforced plastic (FRP) molds, which results in a relatively low production cost but high variability in hull dimensions. Variability in length (L), breadth (B), and depth (D) among vessels of similar tonnage was significant (**Figure 3**).

Based on hull data representative of 105 fishing vessels, three major hull types were identified: V-type, U-type, and T-type. Their primary characteristics are listed in **Table 1**.

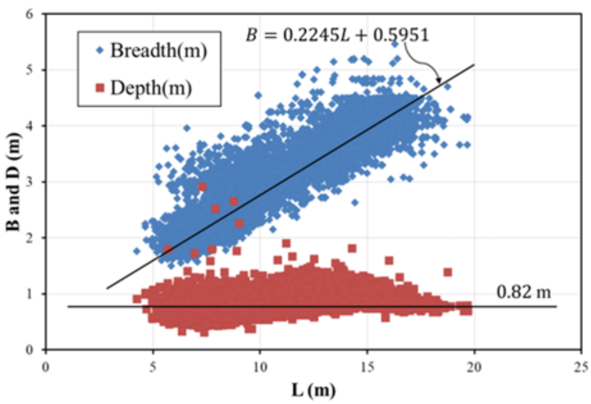
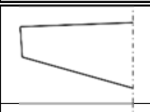
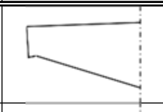
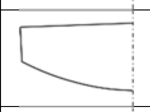
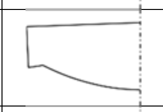
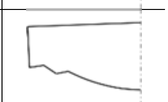
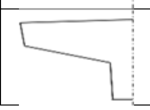
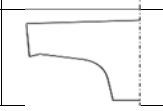


Figure 3: Principal hull dimensions (L, B, D) of small sized fishing vessels registered in Korea

Table 1: Classification of small sized fishing vessels by hull type

Type	No chain	Single chain	Double chain
V-type			
U-type			
T-type			

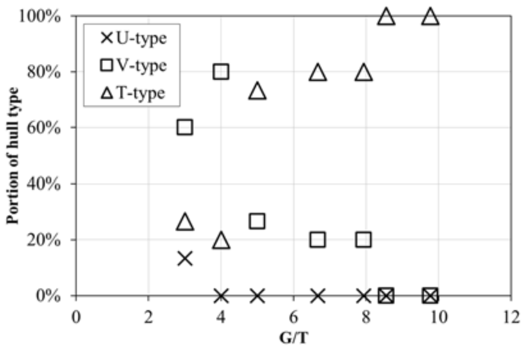


Figure 4: Distribution of hull types across gross tonnage ranges

Figure 4 shows the distribution of hull types across the gross tonnage. The vessels were distinctly categorized into V-type-, U-type-, or T-type. As the gross tonnage increased, a transition from V-type to T-type was observed, and the T-type was common in fishing vessels over 8 GT.

This distribution pattern reflects practical considerations. The V-type hulls perform better at higher speeds but provide less stability, whereas the T-type hulls sacrifice speed for greater stability and load-carrying capacity.

2.2 Review of Stability Standards

Stability criteria are crucial for preventing capsizing accidents. The IMO Intact Stability Code (IMO IS Code) specifies criteria based on GM and dynamic stability, applicable primarily to vessels over 24 m. Although recommendations for the minimum GM exist for fishing vessels under 30 m, the scope remains limited. Stability criteria according to the IMO IS Code are given in **Equation (1)**.

$$G_0M = 0.53 + 2B\left[0.075 - 0.37\left(\frac{f}{B}\right) + 0.82\left(\frac{f}{B}\right)^2 - 0.014\frac{B}{D} - 0.032\frac{l_s}{L}\right] \quad (1)$$

where G_0M is the minimum stability criteria, L is the length, B is the breadth, D is the depth, and f is the freeboard height.

Table 2: Comparison of IMO and Korean stability standards.

Standard	Parameters	Application	Note
IMO IS Code (2008)	L, B, D, f	≥24 m (Recommendation of GM for <30 m)	Comprehensive
Korean domestic (2019)	B, D, β	<24 m	Simplified

In contrast, Korean domestic regulations focus exclusively on vessels shorter than 24 m. These regulations consider breadth (B), depth (D), and freeboard ratio. The minimum G_0M of fishing vessels according to "Stability and Load Line Standards for Fishing Vessels" are given in **Equation (2)**.

$$G_0M = 0.04B + \alpha\frac{B}{D} - \beta \quad (2)$$

Here, G_0M is the minimum stability requirement, B is the breadth, D is the depth, α is a coefficient dependent on material (FRP: 0.54, wooden: 0.28), and β is the freeboard ratio.

Table 2 summarizes the differences between IMO standards and Korean domestic regulations.

Korean domestic regulations are simplified formulations based on an empirical method and do not adequately represent the actual stability conditions of small fishing vessels, underscoring the need for refinement.

2.3 Data Collection and Analysis Vessels

A total of 28 small sized fishing vessels below 10 GT were selected as representative vessels. These vessels were selected based on the most recent deliveries (latest registrations) of 10 GT in Korea to ensure data availability and reliability. The following vessel data were collected:

- Hull drawings and lines
- Compartments and loading conditions
- Input data for K-SHIP software

Principal dimensions (L, B, D, T) were considered for each vessel.

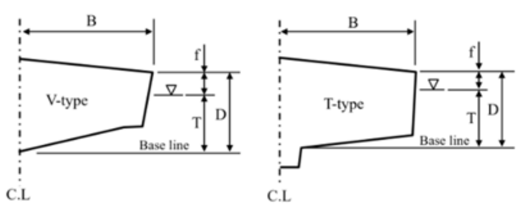


Figure 5: Definition of hull parameters for hydrostatic calculations

Table 3: Specifications of small sized fishing vessels for hydrostatic calculations

No.	Principal dimension			Draft (m)	
	L (m)	B (m)	D (m)	Dep.	Arr.
T-01	8.00	2.40	0.70	0.42	0.48
T-02	9.50	2.86	0.86	0.50	0.56
T-03	9.00	3.31	0.80	0.49	0.54
T-04	11.70	3.54	0.80	0.57	0.59
T-05	11.70	3.54	0.80	0.59	0.60
T-06	15.50	4.84	0.75	0.30	0.44
T-07	14.01	3.84	1.05	0.65	0.77
T-08	15.24	4.50	0.86	0.57	0.62
T-09	16.00	4.20	0.85	0.47	0.58
T-10	13.20	3.90	1.22	0.78	0.96
T-11	12.65	3.80	1.20	0.89	0.99
T-12	18.15	4.40	0.70	0.38	0.49
T-13	16.20	4.50	0.95	0.64	0.71
T-14	14.20	4.33	1.20	0.77	0.93
T-15	14.92	3.95	1.20	0.86	0.94
T-16	14.10	4.20	1.18	0.93	0.92
T-17	12.80	3.80	0.77	0.57	0.56
T-18	18.50	4.50	1.17	0.79	0.87
T-19	18.07	3.85	1.50	1.10	1.19
T-20	16.60	4.40	1.54	1.20	1.26
T-21	18.00	4.25	1.70	1.22	1.35
T-22	20.00	4.49	1.68	1.27	1.41
T-23	20.00	4.89	1.74	1.24	1.42
T-24	21.30	5.15	1.75	1.24	1.43
T-25	21.59	4.86	1.86	1.57	1.53
V-01	11.00	3.04	0.75	0.51	0.42
V-02	12.80	3.04	0.97	0.48	0.40
V-03	14.00	3.03	0.79	0.50	0.40

Table 3 summarizes the specifications of small fishing vessels for hydrostatic calculations.

For the hydrostatic calculations, 28 vessels were analyzed, comprising 25 T-type and 3 V-type fishing vessels. U-type hulls were not included because they are extremely rare among recently delivered small fishing vessels under 10 GT in Korea and their hydrostatic data were insufficient for consistent comparison. The number of V-type vessels was relatively small because only a limited sample was available among conventional fishing vessels. Therefore, while the analysis provided meaningful insights into the hydrostatic characteristics of both hull types, the representativeness of the V-type sample was limited and should be interpreted with caution.

2.4 Hydrostatic Calculation

Hydrostatic particulars and GM values were computed using K-SHIP software. The K-SHIP software was developed by the Korea Maritime Transportation Safety Authority to verify the stability of Korean vessels in accordance with Korean regulations. K-SHIP generally considers the stability calculation of coastal vessels in accordance with Korean regulations. The procedure involved the following steps.

1. Input of principal dimensions and hull form data.
2. Computation of displacement and buoyancy distribution from the hull form and calculation of hydrostatic parameters such as KG and GM.
3. Verification of GM.

The GM values were then compared across hull types (V-type- and T-type) to identify their stability. This analysis resulted in GM values ranging from 0.86 to 5.65, covering a wide range of stability parameters. **Figures 6–11** illustrate the relationships between GM and the principal hull parameters. First, as shown in **Figures 6–9**, GM exhibited weak correlations with single parameters, such as L, B, D, and T. This suggests that stability cannot be reliably evaluated using single parameters. In contrast, strong linear correlations were observed between the B/D and B/T ratios (**Figures 10** and **Figure 11**), which can serve as practical indicators for preliminary stability evaluation and estimation in the initial design stage.

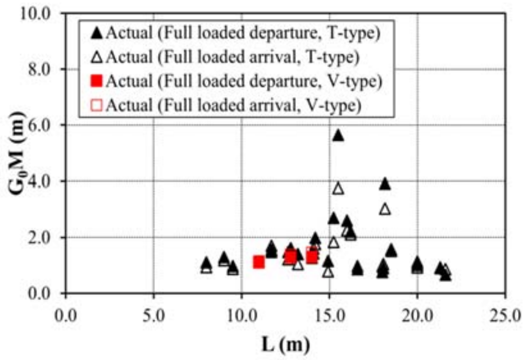


Figure 6: The relationship between G0M and length (L)

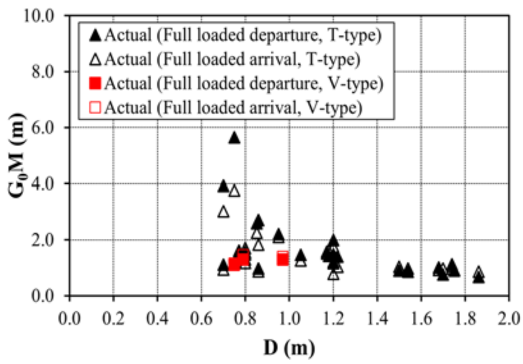


Figure 7: The relationship between G0M and depth (D)

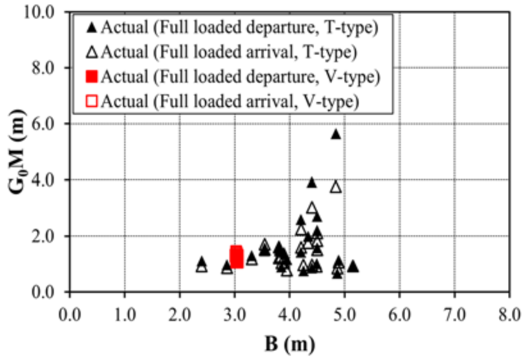


Figure 8: The relationship between G0M and breadth (B)

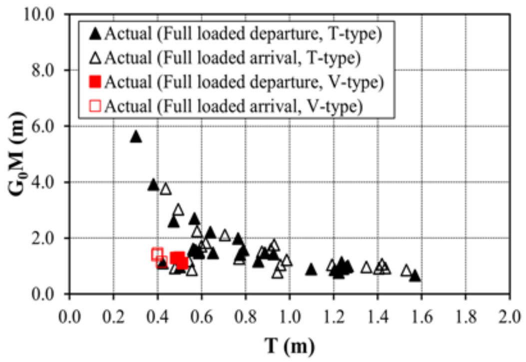


Figure 9: The relationship between G0M and draft (T)

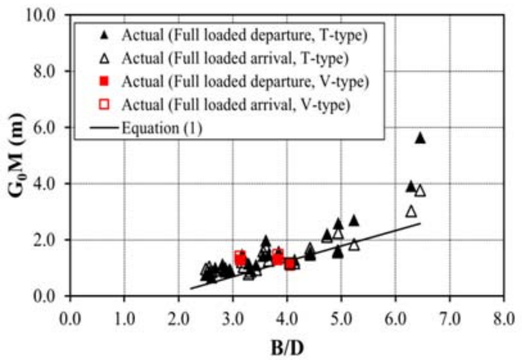


Figure 10: The relationship between G0M and B/D

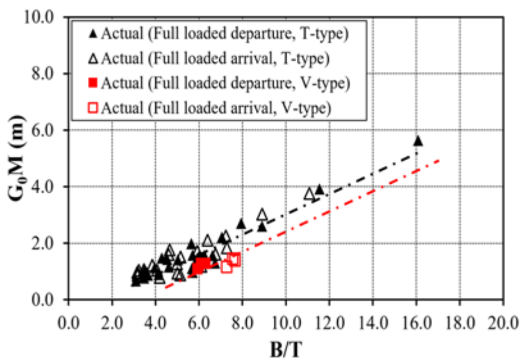


Figure 11: The relationship between G0M and B/T

3. Results and Discussion

3.1 Comparison of Standards

Comparison of stability standards highlights a regulatory gap. IMO standards are comprehensive, considering a variety of design parameters, whereas Korean regulations are overly simplified using only B, D, and freeboard ratio. This implies that criteria considering only dimensional parameters (e.g., B, B/D) may provide useful indicators of stability but cannot fully capture the effects of hull shape characteristics, which also play a critical role in vessel safety. This study demonstrates that the stability of small fishing vessels is strongly influenced by ratios such as B/D and B/T, which should be incorporated into future domestic regulations.

3.2 Hydrostatic Characteristics

Hydrostatic calculations for 28 vessels revealed considerable variation in the metacentric height, ranging from 0.86 m to 5.65 m. These differences are closely associated with the hull type and dimensional ratios.

- V-type hulls consistently exhibited lower GM values than T-type hulls. This result reflects their narrow breadth and sharp keel angle, which reduces the waterplane area and initial righting arm. Such characteristics imply a greater vulnerability to heeling moments under external forces, particularly wind and waves.
- T-type hulls demonstrated higher GM values than V-type hulls, which was attributed to their broader breadth and flatter bottom sections. Although this improves initial stability, it may also increase resistance and reduce fuel efficiency.

3.3 Correlation between GM and Parameters

Hydrostatic analysis confirmed that GM had weak correlations with single parameters such as L, D, and T, but strong linear relationships with dimensional ratios.

- B/D ratio: A significant correlation was observed. However, vessels with higher B/D ratios exhibited greater GM scatter. indicating that, while B/D influences stability, the correlation may not be consistent with the hull type.
- B/T ratio: A strong linear correlation was observed. This indicates that the B/T ratio can serve as a reliable predictor of stability according to the hull type.

These findings emphasize that stability depends more on the relative proportions than on the absolute vessel size. This is consistent with previous studies [7]-[12] and highlights the importance of considering dimension ratios in the initial design stage and feasibility studies.

4. Conclusion

This study classified the hull types of small Korean fishing vessels, compared IMO and Korean stability standards, and conducted hydrostatic analyses of representative vessels. The findings of this study were as follows:

1. The hull types of conventional Korean small-sized fishing vessels below 10 GT were categorized as V-type, U-type, and T-type, with a transition from V-type to T-type dominance as tonnage increased.
2. The IMO stability standards consider multiple hull parameters and are more comprehensive, whereas Korean domestic regulations are simplified and account for only B, D, and freeboard ratio, making them insufficient for consistent comparison.
3. Hydrostatic analyses of 28 fishing vessels were conducted and the results showed GM values widely ranging from 0.86 to 5.65 according to independent manufactures.
4. V-type hulls exhibit low GM and require design modifications or stricter loading limits.
5. GM correlated strongly with B/D and B/T ratios, whereas single dimensions such as L, B, D and T were less influential. In particular, B/T can serve as an effective design indicator according to the hull types of Korean fishing vessels.

From this study, implications from an engineering perspective were highlighted.

- Design application: the strong relationship between GM and dimensional ratios offers ship designers a simple yet reliable tool for evaluating stability at the earliest design stages, reducing trial-and-error in hull form selection.
- Inspection practice: for inspectors and regulators, ratio-based GM estimation provides a practical method for rapid assessment of small fishing vessels, especially in cases where detailed hydrostatic data are unavailable.
- Regulatory improvement: Korean domestic standards may be revised to align with the correlations of design parameters, such as B/D and B/T ratios, and safety margins.

Finally, this study established a foundation for further research. Future work should expand the dataset to include a broader range of vessels, integrate sea trial validations, and apply advanced computational methods such as CFD and time-domain simulation to capture dynamic stability behavior under realistic sea states.

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Author Contributions

Conceptualization, J. H. Pyun; Methodology, J. H. Pyun, M. H. Kim and S. G. Ryu; Formal Analysis, J. H. Pyun; Resources, J. H. Pyun and J. H. Kim; Writing-Original Draft Preparation, J. H. Pyun; Writing-Review & Editing, J. H. Pyun, M. H. Kim and S. G. Ryu; Supervision, M. H. Kim; Project Administration, S. G. Ryu; Funding Acquisition, S. G. Ryu.

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