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Preliminary Study of an Integrated Calculation of Ship Strength on Tankers with Applicable Regulations

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ABSTRACT

Recently, the development of the digital era has increased significantly. Industry 4.0 began to be discussed and applied in the early 21st century. Cyber-Physical systems are becoming a trend in current technological developments. Several technologies in Industry 4.0 are being applied, such as the internet of things, cloud computing, automated simulation, intelligent robots, big data analysis, augmented reality, and additive manufacturing. The shipyard industry is one industry that must be able to adapt to keep up with technological developments. In the ship's preliminary design stage, the strength calculation process that refers to certain regulations has an important role in the design process. The integrated calculation system will make working easier for a naval architect. This paper aims to conduct an initial study in calculating ship strength integrated in real-time with the regulations that govern it. This study produces an idea to integrate the calculation of ship strength with regulations from a class society that continues to grow. The research is expected to provide further development to assist in the preliminary design process that provides efficiency and more accurate monitoring of results.

Keywords: *Digital Era, Industry 4.0, Integrated Calculation, Ship Strength.*

1. INTRODUCTION

Technological developments in various ways lead to concerns about the adaptation process between users and the social behavior of the users themselves. The growing pattern allows less human intervention and is replaced by physical machines, even with virtual machines that are increasingly real in 21st century life. These changes require efforts from consumers as end-user objects and producers as technology developers to transfer knowledge to speed up the adaptation process and simplify the work process going forward.

In the shipbuilding industry, shipbuilding manufacture is generally made by order. It will be slightly different from other manufacturing industries, such as the automotive industry, which conducts product research for mass products for consumers. This difference is what makes the shipping industry unique. Researchers are competing to innovate to overcome it. Certain patterns in several parts of the ship design began to be developed to speed up the ship design process. Making the typical pattern in the design section and certain types of ships will have an effect on accelerating the design process and make it easier for a naval architect to work even though it will be challenging to apply to the entire ship design.

Similar patterns in certain parts, such as the parallel middle body, after body, and fore body can be used in the database system, which can be processed according to a specific purpose. An integrated database system with regulations from class society used in scantling calculations can positively minimize errors and be detected earlier before the application process. The changes in ship regulations will certainly change according to the times and environmental changes. Inputs from ship operators, shipbuilding industries, supporting industries, environmental issues, and others should be distributed quickly to a naval architect. A naval architect will adapt faster if the distribution of information changes can be carried out with the application of Industry 4.0, which is increasingly being discussed in various industrial sectors. The delivery process from an agency to related parties will be one of the determining factors in the speed and updating of information. Minimizing undelivered information must be handled and monitored closely. This monitoring and evaluation process certainly requires improvement from various things, including the system and technology that were applied at that time.

As an initial overview, this paper will present technological developments in the next chapter. This chapter will explain technological developments that started from the late 18th century (Industry 1.0) to the early 21st century (Industry 4.0). The next chapter will give an overview of traditional calculations with integrated calculations on ship strength calculations. In this study, an idea regarding the integration system in calculating the strength of the ship against the applicable regulations will be presented. Its idea will explain the traditional methods carried out previously with the offered system integration to speed up the design process and minimize errors. As it is known, the many regulations on ships that must be applied will very likely provide room for error for a naval architect.

2. TECHNOLOGICAL DEVELOPMENT AND BEYOND

2.1 Technology Development

The development of ship manufacturing is felt in the 21st century. There are many improvements in various sectors with the implementation of cyber-physical systems in them. Collaboration between work units in the shipbuilding industry is getting faster and in real-time. Changes in behavior from the design process into the production process were also felt to increase productivity. This change certainly creates much positive enthusiasm for related industries in various sectors. The technological development will certainly trigger the growth of new industrial sectors that did not exist before. Opening new job opportunities is certainly very helpful in the global economy. Good economic turnover will lead to good economic growth as well.

The development of technology based on time can be seen in Figure 1. In Figure 1, the start of the industrial era occurred at the end of the 18th century, named Industry 1.0. Industry 2.0 began to roll in the early 20th century. Rapid development occurred with the presence of Industry 3.0 at the end of the 20th century. At the beginning of the 21st century as now, the application of Industry 4.0 was intensively carried out in all fields of technology, which caused very significant changes. It will be explained in more detail in the next paragraph.

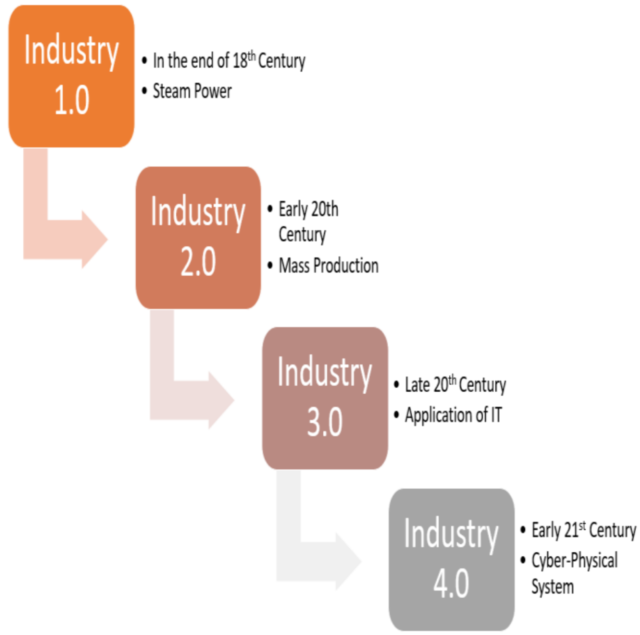

Figure 1. Technology development timeline

Figure 1 describes the development of technology over time. At the beginning of the 18th century, the industrial revolution began with the invention of the steam engine, which also marked the start of the Industry 1.0 era. At the beginning of the 20th century, mass production began to be carried out by utilizing electrical energy, which marked the end of Industry 1.0 and was replaced by Industry 2.0. Industry 3.0 began at the end of the 20th century with the development of information technology (IT). The existence of IT causes industrial behavior to develop and change very quickly and significantly. Nowadays, at the beginning of the 21st century, Industry 4.0 began with the application of automated systems through cyber-physical systems.

The German government initiated and announced the Industry 4.0 program as a high-tech strategy project [1]. This idea can be explained by combining a working system between the real world and virtual space, which is expected to provide efficiency and autonomous technology. In 2014, the Korean government also campaigned for Industry 4.0, called Manufacturing Innovation 3.0. The Korean government took this step to reduce and compete in the global arena regarding the issue of Industry 4.0. The smart factory system is focused on Manufacturing Innovation 3.0 to overcome the problem of the industrial crisis that has occurred in Korea lately. With the implementation of Manufacturing Innovation 3.0, the Korean government hopes to be able to suppress conditions regarding high production costs, reduce production efficiency and be able to increase the added value of a product [2]. Several technologies that allow it to be carried out in Industry 4.0 such as internet of things (IoT), cloud computing, automated simulation [3,4], intelligent robots, big data analysis, augmented reality, and additive manufacturing [5]. In 2019, the Japanese government issued an idea which is a continuation of Industry 4.0, namely Society 5.0. This concept does not differ much from Industry 4.0 but has a different focus. Industry 4.0 tends to make human life easier by using artificial intelligence (AI) as its main component. Nevertheless, in Society 5.0, humans are the main component in the use of today's technology. This concept is expected to be able to minimize the condition of inequality in humans.

2.2 Ship Production Technology

The progress and application of modern technology make global competition very tight with unlimited space and time. This development has been felt in ship technology and has begun to respond to problems that will arise in the application of digital technology lately. The modelling process in the virtual shipyard and virtual shipbuilding is done using a computer device before being applied in the real world. This modelling is expected to be able to provide input and progress as well as detect possible errors in the virtualization stage before the reality in the field. However, this model has a weakness in the form of a supporting system from computer hardware that meets and is relatively expensive [6]. Simulation-based ship design processes related to functional and manufacturing processes are carried out to respond to global challenges. Several stages of the validation process were carried out to answer the gap between the virtual simulation and the real product produced. This validation process is known as the virtual assembly simulation system for shipbuilding (VASSS) [7]. In the other case, there are several problems in the process of making ship blocks. This problem occurs because of the large number of ship blocks and the difference between the planning process and the production results in the field. Integrating process mining (PM) and data envelopment analysis (DEA) are offered to solve the problems that occur [8].

In the design and construction of ships such as tankers, several regulations issued by the class society must be met in order to meet the desired standards. In general, the ship's length will influence choosing the right rule. Figure 2 provides an overview of the selection of tanker rules based on the ship's length.

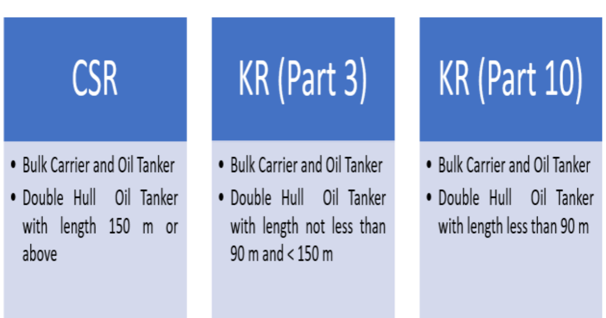

Figure 2. Rule selection based on ship length

Based on Figure 2, the selection of rules for tankers with a length of 150 m or more can use the Common Structural Rule for Oil Tanker (CSR-OT). However, ships with a length of less than 90 m can use the rules in the class society. According to Figure 2, the rules from the Korean Register Part 10: Hull Structure and Equipment of Small Steel Ship, are selected. For ships with a length of 90 meters or more but less than 150 m, they can choose the rules in the Korean Register Part 3: Hull Structure [9-11]. The selection of rules that are not suitable will cause problems such as overdesign related to the strength of the ship or vice versa. Examples of this error can be minimized by having an integrated system in the ship design process carried out by a naval architect. In the next chapter, the traditional and integrated calculation methods will be explained to determine the advantages, disadvantages, and weaknesses of each method implemented.

3. DISCUSSION

3.1 General Traditional Method

Ship strength calculation is one of the ultimate goals in ship scantling. The ship structure design should meet the requirements specified in the rules of the ship classification society. The complex process starting from calculating the load, the size of the profile, plate thickness, and position, makes this calculation require high accuracy. It is not uncommon to find calculation errors at several steps that cause calculations not to comply with the applicable rules. It will slow down the process because it takes time to revise and check repeatedly until it gets the right results. Figure 3 shows an overview of the traditional methods that are still used by certain groups.

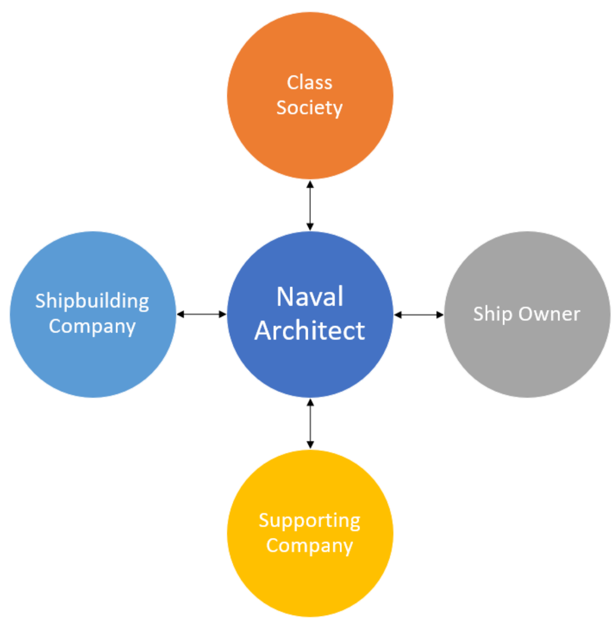

Figure 3. Communication system in traditional method

Figure 3 describes the flow work system for traditional methods. A naval architect plays a critical role in connecting class society, shipbuilding companies, supporting companies, and ship owners. Information systems in the form of rules from class society are sent in the form of chapter books and e-books which still require the accuracy of a naval architect in translating into a design of ship structure. It will greatly allow for misinterpretation in the application of regulations. A lack of understanding of the existing regulations causes an inappropriate structure design and wastes time in the revision process. Other parties, such as shipbuilding companies, supporting companies and ship owners, will depend on the quality of a naval architect. In other words, the naval architect is at the center of all workflows starting from planning design until the delivery process to the ship owner. Inconsistency between the design and the actual in the field often occurs and causes debate when the ship classification party conducts inspections. It will further aggravate the time of ship production and cause delays that are difficult to find a solution.

3.2 Integrated Calculation Method (ICM)

The integrated system for calculation method can be seen in Figure 4 in general. Cloud system implementation plays a significant role in delivering information from a class society to a naval architect. The cloud systems should be recognized and managed by class society and updated under the development of regulations that apply in real-time.

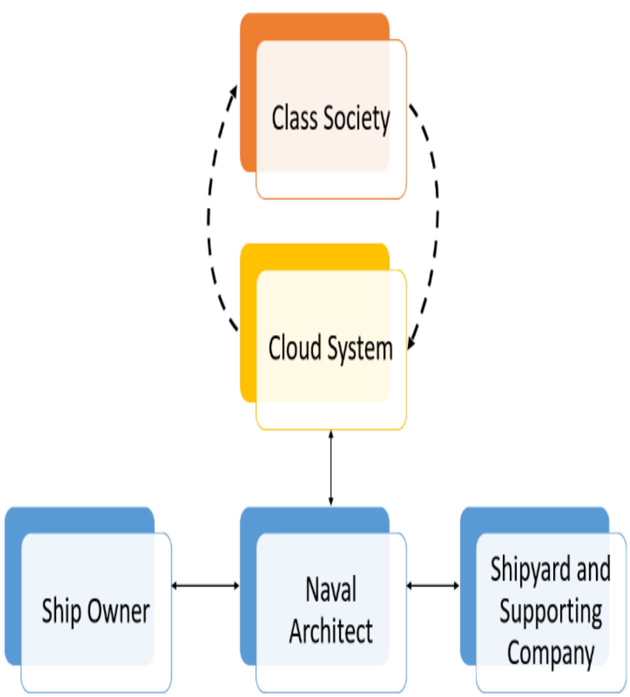

Figure 4. Integrated calculation method

Application cloud systems require new technological devices when compared to traditional methods. Its technology device requires adaptation for an admin and additional costs to be invested by the class society and naval architect in order to create synchronization as needed. With the implementation of the cloud system, information will be sent quickly and in real-time to the naval architect. Ship class rules in the process of calculating the design of ship structure, starting from determining the type of rules to the creation of a proven design, are carried out in real-time with an integrated system. During the process of designing the ship structure, a naval architect will recognize mistakes in the early stage if design calculations are not appropriate. The cloud system will warn the system and give clues to fix it. The system will be integrated continuously throughout the design process.

In the application process, the naval architect will design and define class rules, such as minimum plate thickness, minimum profile dimensions, and others, which will be carried out automatically by a cloud system that has been integrated with servers in the class society. On the other hand, the class society will have a real-time record of the structural design, which will later be approved. It will greatly speed up the structure calculation stage until the class society approves the design. The naval architects will find it easier to work because the system is well integrated during the work. If this system is implemented and monitored closely, the approval process can be carried out in real time during the design process. If there is a design change, it will facilitate the tracking process according to the history of the work. The integrated calculation method (ICM) has many advantages in terms of accuracy and speed of work as long as synchronization with the cloud system can be maintained properly, and all users are able to adapt quickly to the implementation of the new system.

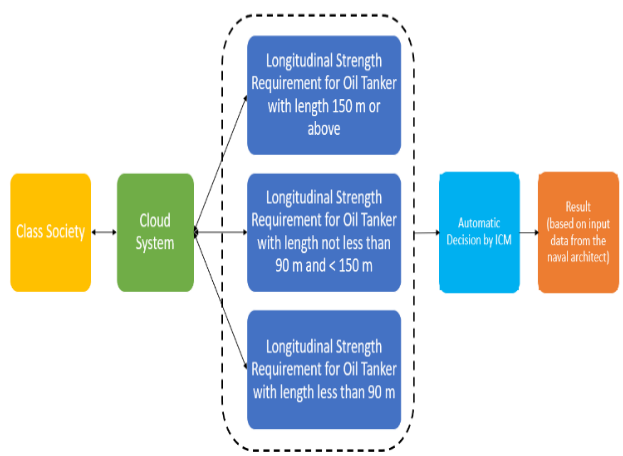

Figure 5. Integrated system with cloud management implementation

Figure 5 describes the selection of regulations related to longitudinal strength on tankers with variations in ship length. In the case of longitudinal strength, the selection of applicable regulations is conducted automatically by ICM with the initial input of ship length carried out by a naval architect. The calculation process and any variables in it will be updated automatically according to the cloud system controlled by the class society. It will significantly minimize the miscommunication between the class society and the naval architect during longitudinal strength calculation.

The selection of rules on ship longitudinal strength with various variations of ship length is shown in Figure 6 as follows. The selection of rules for the minimum requirement for section modulus and inertia moment is decided based on the class society and the common structure rules used. Based on Figure 6, I_{min} indicates the minimum requirement of inertia moment, while Z_{min} indicates the minimum requirement of section modulus [10,11]. Meanwhile, $I_{v\text{-}min}$ and $Z_{v\text{-}min}$ are the minimum inertia moment and section modulus requirements, respectively [9].

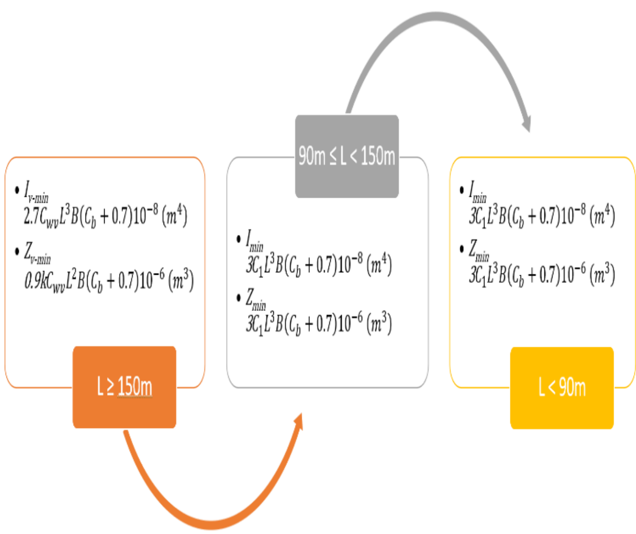

Figure 6. Minimum requirements for section modulus and inertia moment for variations in ship length

4. CONCLUSION

Information about technological developments has been provided. Technological changes from time to time take place very quickly. There are many changes that must be made by the industry, one of the changes is the shipyard industry. Technological developments in the shipbuilding industry have experienced significant developments that require rapid adaptation for a naval architect. There are various methods that must be developed to overcome the various weaknesses of the existing method. The utilization of traditional methods has a weakness to make mistakes or lack of updating of information from the class society, but it does not require several new devices and technologies that require additional costs. The problems that occur may have an effect in the future to increase costs due to work that may need to be reworked.

The implementation of the integrated calculation system (ICM) provides real-time information updates to minimize errors significantly. Integration of a naval architect worksheet with rules from the class society connected to the cloud server system will make it easier if there are changes at any time. However, this system needs adaptation from users and additional technological devices to support the smooth synchronization process. This study is expected to be the basis for innovation in ship design, which will then be developed in more detail and intensely to carry out a comprehensive integration. This study provides further development to assist in the preliminary design process that provides efficiency and more accurate monitoring of results.

REFERENCES

1. H. C. Moon, J. E. Chung and S. B. Choi, "Korea's Manufacturing Innovation 3.0 Initiative," Journal of Information and Management, pp. 26-34, 2018 https://doi.org/10.20627/jsim.38.1_26.
2. J. Lee, E. Lapira, B. Bagheri and H.-a. Kao, "Recent Advances and Trends in Predictive Manufacturing Systems in Big Data Environment," Manufacturing Letters, pp. 38-41, 2013 https://doi.org/10.1016/j.mfglet.2013.09.005.
3. R. Ridwan, T. Putranto, F.B. Laksono, A.R. Prabowo, "Fracture and damage to the material accounting for transportation crash and accident," Procedia Structural Integrity, pp. 38-45, 2020 https://doi.org/10.1016/j.prostr.2020.07.006.
4. M.L. Hakim, B. Nugroho, R.C. Chin, T. Putranto, I.K. Suastika, I.K.A.P. Utama, "Drag Penalty Causing from the Roughness of Recently Cleaned and Painted Ship Hull Using RANS CFD," CFD Letters, pp. 78-88, 2020 https://doi.org/10.37934/cfdl.12.3.7888.
5. IEC, "Factory of the Future—White Paper," Geneva, 2015.
6. H. Kim, J. K. Lee, J. H. Park, B. J. Park and D. S. Jang, "Applying Digital Manufacturing Technology to Ship Production and The Maritime Environment," Integrated Manufacturing Systems, pp. 295-305, 2002 https://doi.org/10.1108/09576060210429748.
7. H. Kim, S. S. Lee, J. H. Park and J. G. Lee, "A Model for A Simulation-based Shipbuilding System in A Shipyard Manufacturing Process," International Journal of Computer Integrated, pp. 427-441, 2007 ttps://doi.org/10.1080/09511920500064789.
8. J. Park, D. Lee and J. Zhu, "An Integrated Approach for Ship Block Manufacturing Process Performance Evaluation: Case From A Korean Shipbuilding Company," International Journal Production Economics, pp. 214-222, 2014 https://doi.org/10.1016/j.ijpe.2014.06.012.

9. IACS, Common Structural Rules for Bulk Carriers and Oil Tankers, IACS, 2022.
10. KR, Part 10: Hull Structure and Equipment of Small Steel Ships, Busan: Korean Register, 2021.
11. KR, Part 3: Hull Structures, Busan: Korean Register, 2022.