Investigation of Structural Behavior of Deformed Bottom Plate on KMP. Kerapu III using Vacuum Testing at PT. Dutabahari Menara Line Dockyard

Ignatius Aldo Kristanto[1], Zulfaidah Ariany[2], Jamal[3]
[1] Student of Teknologi Rekayessa Konstruksi Perkapalan, Vocational Collage, Semarang, Indonesia
ignatiusaldokristant@students.undip.ac.id
[2] Departments of Industrial Technology, Vocational Collage, Semarang, Indonesia, 50275
zariany@live.undip.ac.id
[3] Jurusan Teknik Perkapalan, Politeknik Negeri Bengkalis, Bengkalis, Indonesia, 28734
jamal@polbeng.ac.id

Accepted on May 14, 2025
Approved on June 12, 2025

***Abstract*— In the shipping industry, shipyards are common and widely encountered. The construction of new ships and ship repairs are routinely carried out here. The research was carried out during an internship at PT in Banjarmasin. Dutabahari Menara Line Dockyesrd. This study discusses the obstacles to conducting a hull vacuum test. The test passes through a deformed plate (convex or concave), making the vacuum test tool impermeable. In the first test of the vacuum test process, which passed through the deformed plate, the pressure could not raise only 0.10 bars. The standard pressure value is 0.20 – 0.30 bar, so leakage cannot be observed. The author is trying to find a solution to this problem. In the second test, with position adjustment and a slight push, the pressure can touch 0.19 bars. Basically, the vacuum test method is effective for use on parts of the ship that have an open space, such as the hull of a ship that has been welded due to re-plating with a small volume. The work on the vacuum test at PT. DML Dockyard is carried out at the request of the ship owner. The author recommends finding the correct test position, placing the vacuum tool and the vessel plate, and using other methods for tightness testing.**

Index Terms—*vacuum test; deformation; keel deflection; welding; welding check.*

I. Introduction

In today's modern industry, especially in the shipping industry, steel is still widely used in constructing the hull and various outfitting. Steel materials are still widely used because of their strength and durability in withstanding existing loads. Because it uses steel materials, uniting various construction series that will be arranged requires a welding process.[1] According to Sunaryo, 2008 welding connects two metal parts with a heating process obtained from the combustion of a gas, namely acid gas and acetylene gas (carbide). In its development, many types of welding are used. The types of welding widely used in the shipbuilding industry are SMAW and MIG welds. This type of welding is popular because of the speed at which welding is performed.[2]

Core Principles of Welding are as follows:

- Heat Application: Welding uses a concentrated heat source to raise the temperature of the base materials to their melting point. Common heat sources include electric arcs, gas flames, or lasers. For instance, in arc welding, the heat is generated by an electric current passing between an electrode and the work-piece, often exceeding 6,000°C at the arc’s core.[3]
- Fusion: The melted base materials mix together, often with a filler material, in a molten pool. As the heat dissipates, this pool solidifies into a unified joint. The process relies on the principle of coalescence, where liquid metal bonds at the atomic level. [4]
- Shielding: Molten metal reacts with atmospheric gases like oxygen, leading to oxidation, or nitrogen, causing porosity. Shielding prevents this, using inert gases (e.g., argon in TIG welding), flux (e.g., in stick welding), or slag from the electrode coating. This concept is rooted in protecting the weld’s integrity. [5].

Metallurgy and Heat-Affected Zone (HAZ): The heat alters the metal’s microstructure beyond the weld pool, forming the HAZ. This zone may experience changes in hardness or strength due to rapid heating and cooling. Understanding a material’s thermal properties—melting point, conductivity—is critical.[6].

In the implementation of welding, it is necessary to check the results after completing welding, especially in welding the tank or hull of both new buildings and repair ships. The Quality Control (QC) or similar divisions usually carry out this check. Many kinds of tests can be done here. Among them are visual tests, air tests, vacuum tests, hose tests, and many other tests that may still be developed. The selection of this test depends on the request of the owner surveyor or the ship owner's representative, as well as adjusting to the conditions in the field. Among the various tests that are commonly used, the air test is the most popular test for checking for leaks in the hull of a barge. As for checking the bottom, the vacuum test is the most popular. Many reference sources list the method of testing plate tightness with vacuum tests, including testing requirements and procedures.[7], [8]

Weld tightness testing is carried out while the ship is built in the shipyard. The results of this test significantly impact the ship's safety factor when it is in operation—minimizing the occurrence of leaks, fractures, or cracks in the ship, which can impact economic and life losses. There are many methods in the process of testing for tightness. The method is considered based on several factors. These factors include the place of testing, operational costs, operational time, and accuracy of test results.[9]

As the most popular test, the vacuum test still has obstacles in its implementation. The most common obstacle experienced is when the welding position to be tested by this air test is on a deformed plate.[6] This deformed plate makes it difficult for the vacuum to make the air around the weld area to be tested impermeable. The situation is because the deformed plate will be curved (convex/concave) so that the rubber on the vacuum tool, which helps insulate air, cannot accommodate it so that air escapes and the tool is not airtight.[10]

Previously, this air test had been published by Mayes Ode Duu Honggo and Tri Agung, and the vacuum test was based on the position of the Hull Plate. However, in the study, only a study was conducted on the duration of the vacuum test based on the position of the hull plate. This contrasts with the author, who will conduct a study on how the vacuum test should be carried out on a deformed plate.[11]

This study aims to show workers what to do when the vacuum test process can be carried out when passing through a deformed plate. It is still important to get leak test results when ship welding. Therefore, testing must still be carried out to prevent problems that will be bigger in the future.

II. THEORETICAL FOUNDATIONS

A. *Welding Theory*

A welded joint is bonding two or more pieces of metal due to metal diffusion. Welded joints in solid condition are called welded joints in solid condition (SSW) or pressure welds, and welded joints in liquid condition are called welded joints in liquid condition (LSW).

The pressure joint (SSW) process is usually carried out by pressure, also called a pressure joint. SSW's advantages include the ability to connect two different types of materials quickly, precisely, and with almost no heat-affected zone (HAZ). However, the disadvantage of SSW is the preparation of the joints and their complex processes, which require very high precision.[12]

LSW weld joints, which are caused by the melting of the two ends of the spliced material, are very popular in our society. Thermal energy is generated from electric arcs, gases, electrical resistance, laser beams, electrons, and plasma. To connect the materials in this way, the temperature of the materials must be the same because otherwise, the splicing process will not occur. The advantages of this welding method are that it is easy to implement, the process and preparation of the joint are not complicated, and the cost is affordable.[2][12]

In anticipating failures in welding joints, currently, many shipbuilding companies have used automatic welding or robots in order to minimize the occurrence of failures that have an impact on human safety and financial losses. The combination of the tuning and joining process at each stage has different types and forms of work and joining methods, so stages are needed for the formation of construction and more significant ship parts.[13]

Metal Inert Gas (MIG) welding is the process of joining two or more metal materials through a local melting process using coil electrodes (filler metal) and protective gas (inert gas), which is identical to the base metal. In MIG welding, electrodes and welding wires are used, and electric motors regulate the movement of the electrodes. Argon and helium gases protect arcs and metals from atmospheric influences [14].

B. *Testing Theory*

Testing on ship construction or ship repair before conducting a layer test is an item that requires approval from the classification bureau. Tensile testing is a mechanical test that aims to determine a material's response, mechanical behavior, or atomic and microscopic phenomena to external reinforcement or deformation. This phenomenon does not depend on the shape or size of the test piece [12].

The method of testing materials can be classified into two types. The first is destructive testing, also called destructive testing and non-destructive testing. Destructive testing is testing a material, but the final result is that the material will be defective or damaged. This test is carried out by damaging the test piece, namely by loading or pressing until the tester is damaged. From this test, the mechanical properties of the material will be obtained. The second part is Non-Destructive testing. Testing of material, but the final hill of the material will not be damaged. Non-destructive testing consists of liquid penetrates, eddy currents, ultrasonic testing, visual inspections, radiography inspections, acoustic emission tests, and magnetic particle inspections.

According to field surveys, the vacuum testing process on a ship's hull in a flat bottom or flat area (Down Hand) is usually relatively easy to do, but testing in an inclined position with a hull obstruction condition that is too low makes it difficult to do. In this case, the position will affect the difficulty level of preparation and implementation of the vacuum test inspection. Position, accuracy, time, and operational costs affect the vacuum, chalk, and pressure testing process.[11]

III. METHODE

The research data used KMP Kerapu III and PT. Duta Bahari Menara Line Dockyard as the object of research. Observations were made during the vacuum test process of the bottom part of KMP. Kerapu III. When the test was carried out, the workers found it difficult to carry out the vacuum test. At that time, the author also got the data discussed here.

In this study, the author uses a vacuum device as a fixed variable and pressure as a variable variable. The rise and fall of this pressure will later indicate what workers can do to get maximum test results.

In this study, the author observed workers checking the vacuum test and recorded the pressure used as an indicator. This pressure is recorded when it successfully seals the air and is obtained when passing through the deformed plate.

The tools and materials used in this study are the same as the vacuum test equipment, including:

1. Air Compressor
2. The vacuum apparatus consists of:
   - Air pressure indicator
   - Mika
   - Valve
   - Sealing Rubber
3. Compressor air hose

IV. RESULTS AND DISCUSSION

From the results of the observations made by the author, the author noted several obstacles experienced during the vacuum test process. Some of the obstacles noted include:

- There is a lack of vacuum equipment, so we must first wait for a test on other ships.
- Lack of clarity of mica screen on the vacuum test tool, which results in inaccuracy during the inspection and
- During the test, it was found that the plate was deformed, so the shape was more convex than other plates, and the vacuum tool was difficult to seal.

From the results recorded, 6 points experienced leaks spread over four areas. One area referred to here is the time range of vacuum equipment. From the data obtained, one area has also undergone deformation. The data shows that the pressure in the vacuum device drops drastically. Usually, a vacuum tool has a pressure of 0.2 – 0.3 bar. However, in the first experiment, only 0.10 bar was obtained. This is because, in area 6, which experiences low pressure, there are plates that are deformed (concave) so that the air in the vacuum cannot be compressed and leak out.

After the first experiment is completed, a second experiment is repeated. The result of the leak is equal to the number of 6 points spread over four areas; the amount of deformation is the same, only 1 point, but the pressure on the vacuum device can rise. For this reason, the author recommends several things if similar things occur in the vacuum test, including:

- Finding the right position

Sometimes, difficulties in doing something can still be solved when we try to rack our brains to outsmart them. When we try to do a vacuum test in one position through the deformed plate, and the pressure on the vacuum tool cannot rise, then try it in its vertical or horizontal position. This can be done if it is still in the area where the leak is checked with a vacuum test.

- Applying more pressure

When workers have tried vertical and horizontal positions, there is still no pressure compression. It can be tried again while giving a little push to the vacuum device to be able to stick to the ship plate better so that it is expected that the air is compressed and the pressure can rise.

- Recommend other tests

Suppose it is still impossible to compress air and increase the pressure on the vacuum device rather than risk it in the future. In that case, it is better to communicate with the owner surveyor and recommend other leak tests, such as hose and air tests, to adjust the situation and conditions if possible.

The results of the first test vacuum test are displayed in table 1.

TABLE I. EXPERIMENTAL VACUUM TEST RESULT 1

Area	Pressure (bar)	Deformation (yes/no)	Leakage (yes/no)
1	0.21	no	no
2	0.18	no	yes
3	0.17	no	yes
4	0.20	no	no
5	0,23	no	no
6	0.10	yes	-
7	0.17	no	yes

A second test is carried out to get more detailed test results, which are displayed in the following table 2.

TABLE II. EXPERIMENTAL VACUUM TEST RESULT 2

Area	Pressure (bar)	Deformation (yes/no)	Leakage (yes/no)
1	0.22	no	no
2	0.22	no	yes
3	0.20	no	yes
4	0.19	no	no
5	0,21	no	no
6	0.19	yes	yes
7	0.18	no	yes

The test parameter that needs to be considered in the vacuum test is the vacuum pressure (mmHg / kPa); this result can indicate the amount of vacuum pressure applied.

The test time in minutes is how long the pressure is maintained during the Test. Another thing that needs to be noted is the volume of the test chamber in m³ or liters; the results show the size of the test chamber in the ship's hull.

Another thing that needs to be noted is the condition of the Test. Ambient Temperature (°C) is the ambient Temperature when the Test is performed because it can affect the pressure.

The humidity (%) of the air content around the yang can affect the test results.

Test Location: This research was conducted at a national shipyard in Banjarmasin, South of Kalimantan.

Figure 1 shows the location and results of the yang test carried out and the surveyor's inspection and testing by the shipyard team.

Fig. 1. KMP. Kerapu III Vaccum Test Results

V. CONCLUSION

Based on the author's observations, the vacuum test process on the deformed plate may still get the correct results by finding the proper position between the vacuum tool and the ship plate. This can be seen from the data displayed that in the first test of the vacuum test process that passes through the deformed plate, the pressure can rise, the number of 0.10 bar from 0.20 – 0.30 bar that should have been obtained so that no leakage can be observed. However, in the second test, a position adjustment was made, and a slight push was given; the pressure could touch 0.19 bar, and the bump could be observed. However, if we have tried to change the position and boost the vacuum to follow the plate curve, try to recommend another possible test.

ACKNOWLEDGMENT

In particular, the author would like to thank PT—Duta Bahari Menara Line Dockyard, who allowed the author to carry out practical work for 3 months—not forgetting also the author's close friends who provided support and encouragement so that he can complete this journal well.

REFERENCES

[1] Asfarizal, “Pdf-1735-Prospek-Dan-Kendala-Pada-Pemakaian-Material-Baja-Untuk-Konstruksi-Bangunan-Di-Indonesia_Compress,” vol. 2, no. April, pp. 53–53, 2008.

[2] H. Sunaryo, Teknik Pengelasan Kapal, vol. 7, no. 2. 2008.

[3] S. Edition and R. Singh, Applied Welding Engineering. 2020. doi: 10.1016/c2019-0-03490-5.

[4] AWS, Welding Handbook - Fundamentals of Welding, vol. 1. 1993.

[5] W. H. Kearns, Diffusion Welding and Brazing, vol. 3. 1980. doi: 10.1007/978-1-349-04961-5_10.

[6] N. R. Mandal, Ship Construction and Welding, vol. 2. 2017. [Online]. Available: http://www.springer.com/series/10523

[7] ASME Boiler & Pressure Vessel Code, “Non Destructive Examination Section v,” An Int. Code, p. 262, 2019.

[8] A. W. Society, American Welding Society, vol. 12, no. 3. 2004.

[9] K. Putri Dewi, “Studi Perbandingan Beberapa Metode Pengujian Kekedapan Pengelasan Pada Kapal Bangunan

Baru," PPNS, 2015. [Online]. Available: http://repository.ppns.ac.id/122/

[10] M. Ali Reza, "Strategi Inspeksi Peralatan Pressure Vessel Pada Offshore Platform Dengan Metode Risk Based Inspection," 2024.

[11] O. D. Honggo et al., "Ge-STRAM: Jurnal Perencanaan dan Rekayasa Sipil Studi Durasi Proses Vacuum Test Berdasarkan Posisi Pelat Lambung Kapal," Ge-STRAM J. Perenc. dan Rekayasa Sipil, vol. 05, no. 2, pp. 111–117, 2022, [Online]. Available: https://doi.org/10.25139/jprs.v5i2.4893

[12] Mulyadi and Iswanto, Buku Ajar Teknologi Pengelasan. SIDOARJO: UMSIDA Press, 2020.

[13] K. Susanta and K. Syauqi, Dasar-Dasar Teknik Pengelasan Dan Fabrikasi Logam. 2023. [Online]. Available: https://buku.kemdikbud.go.id

[14] F. B. Nduru and N. Y. Nugroho, "Effect of Air Humidity in MIG Welded Joints on Tensile Strength and Impact Strength of Aluminum 5052," Berk. Sainstek, vol. 11, no. 2, p. 129, 2023, doi: 10.19184/bst.v11i2.37546.