

Evaluation of Durability of Metal Materials in Offshore Structure Applications

Javier Gelvan Lebang^{1*}, Hansel Thea Palembang²

¹Global Scholarly Research, Indonesia

²Institut Teknologi Kalimantan, Indonesia

Abstract: Offshore structures such as oil and gas drilling platforms, underwater pipelines, and maritime operations support platforms operate in extreme environmental conditions, including exposure to seawater with high chloride content, temperature fluctuations, hydrostatic pressure, and biological activity of marine microorganisms. These conditions make the metal materials used in these structures susceptible to degradation in the form of corrosion, material fatigue, and degradation of mechanical properties over operational time. This problem is crucial considering that structural failures in offshore installations not only have an impact on economic losses, but also have the potential to pose occupational safety risks and pollution of the marine environment. This study aims to evaluate the durability of metal materials, especially carbon steel and stainless steel alloys, which are commonly used in offshore structures, by analyzing the influence of the seawater environment on corrosion rates, fatigue resistance, and changes in the mechanical properties of materials. The methods used include electrochemical testing to measure the rate of corrosion, tensile and hardness tests to evaluate the mechanical properties before and after exposure to the simulated seawater environment, as well as surface morphology analysis using a microscope to identify patterns of damage that occur. The results of the evaluation are expected to provide an overview of the level of resistance of materials to offshore operational conditions and provide recommendations related to the selection of appropriate materials and protection strategies, such as the application of cathodic protection or anti-corrosion coatings, to extend the service life of the structure and improve operational reliability in the marine environment. This research is expected to be a reference in the design and maintenance of offshore structures that are more durable and safe.

Keywords: Material Durability; Offshore Structure; Corrosion; Stainless Steel; Structural Integrity

1. Introduction

Offshore structures (*Offshore Structure*) is a facility that is widely used to support activities in marine areas, such as oil and gas exploration and production and other energy activities. In its construction, metal materials, especially steel, are widely used because they have good strength and are able to withstand various loads. However, marine environments have quite aggressive conditions due to the presence of seawater, salt content, moisture, and oxygen which can accelerate material damage. One of the main problems with metal materials in the offshore environment is corrosion. Corrosion can cause a reduction in the thickness and strength of the material so that it can affect the reliability and safety of the structure [1].

In addition to corrosion, repeated loading and changes in environmental conditions can also accelerate the decline in material performance. Therefore, the durability of the material needs to be considered so that the structure can function properly over a long period of time. Evaluation of the durability of metal materials is necessary to determine the material's ability to maintain its strength and function while in an offshore environment.

The results of the evaluation can be used as a basis for determining methods of protection, maintenance, and structural inspection. Thus, the study of "Evaluation of Durability of Metal Materials in Offshore Structure Applications" It is important to understand the factors that affect material durability and the efforts that can be made to extend the service life and maintain the safety of the structure[2].

* Corresponding author.

E-mail address: gelvanindsulseltator@e-mail.com (J. G. Lebang).

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2. Discussion of the Main Problem

The main problem in the use of metal materials in offshore structures is the damage caused by the marine environment. Seawater containing salt, oxygen, and high humidity can accelerate the corrosion of materials. Corrosion that lasts for a long time can cause the metal surface to be damaged, the thickness of the material to decrease, and the strength of the structure to decrease. In addition to corrosion, metal materials also experience various loads during the structure's operation. Ocean waves, winds, currents, and repetitive working loads can cause the material to experience fatigue (*fatigue*). These conditions can cause cracks in the material and if left untreated can develop into more serious damage [3].

Another problem is the difficulty of inspecting and maintaining structures in the middle of the sea. The inspection process requires considerable time, effort, and cost due to environmental conditions that are not always supportive. This makes damage to materials sometimes only known after the condition is severe enough.

Therefore, evaluation of the durability of metal materials needs to be carried out periodically to determine the condition and extent of material damage. The results of the evaluation can be used to determine the methods of protection, maintenance, or replacement of the necessary components. With proper management, the service life of materials can be extended and the safety of offshore structures can be maintained [4].

3. Review and Criticism of Existing Approaches

The approach used in maintaining the durability of metal materials in offshore structures generally focuses on corrosion prevention, material condition checks, and periodic maintenance of the structure. This is done because metal materials used in the marine environment continue to deal with seawater, salt levels, oxygen, and moisture that can accelerate the damage process. With protection and inspection, the condition of the material is expected to remain controlled during the life of the structure's use [5].

One of the widely used approaches is to provide protection in the form of *Coating* or coating on metal surfaces. The coating serves as a barrier between the material and the marine environment so that direct contact with water and substances that can cause corrosion can be reduced. Uses *Coating* It is quite effective if the material is properly prepared and applied. However, the protective layer does not always survive in the same conditions during the structure's operation. Damage to *Coating* can occur due to impact, temperature changes, exposure to seawater, or the aging process of materials. When the protective layer begins to crack or peel, exposed metal parts will be more susceptible to corrosion. Therefore, the use of *Coating* cannot be considered a permanent solution. Regular checks and maintenance are required to ensure the coating is still functioning properly [6].

Another approach is the use of cathodic protection to reduce the rate of corrosion in the part of the structure that is submerged in seawater. This method can be done by using a victim anode or a controlled current system. Cathodic protection can provide additional protection to materials, especially on parts of the structure that are difficult to protect with just coating. However, its application still requires planning and supervision so that the protection system can work as needed.

In addition to protection against corrosion, regular inspections are also an important part of maintaining the durability of offshore structures. Inspections are carried out to determine the condition of the material, such as corrosion, cracking, deformation, or other damage. The results of the inspection can then be used to determine the necessary maintenance measures. This approach is quite important because damage found earlier will be easier to deal with than damage that has already developed. However, periodic inspections also have limitations [7].

Offshore structures have parts that are above or below sea level, so not all parts can be easily inspected. Wave conditions, currents, weather, and the location of the structure can be obstacles in the inspection process. In addition, inspections in certain areas require specialized equipment and manpower that has the ability to inspect structures in the marine environment. An approach that relies solely on periodic inspections can also have risks because damage can develop between inspection times. For example, corrosion that initially appears small can develop into greater if environmental conditions continue to support the corrosion process. This suggests that inspections at any given time may not necessarily provide a complete picture of changes in material conditions throughout the entire operational life.

Technological developments then provide opportunities to improve material durability evaluation methods. Method use *Non-Destructive Testing* (NDT), sensors, structural condition monitoring systems, and digital technology can help detect damage without having to damage the material. These methods allow material conditions to be observed in more detail so that changes can be detected earlier. However, the application of such technology requires appropriate equipment, cost, and manpower [8].

From some of the approaches that have been used, it can be seen that there is no single method that can solve all the problems of the durability of metal materials in offshore structures. Corrosion protection needs to be combined with regular inspections and maintenance. In addition, environmental conditions and the type of load the structure receives also need to be considered in the evaluation. With a more comprehensive approach, the condition of the material can be better monitored.

Thus, the approach to the durability of metal materials should not only focus on handling damage after it has occurred. Evaluations need to be carried out on an ongoing basis by considering material conditions, marine environment, loading, and the effectiveness of the protection system used. This approach can help determine the right time and type of maintenance so that damage can be controlled from the beginning. Ultimately, a proper durability evaluation can help extend the service life of materials and maintain the safety and reliability of offshore structures.

4. The Author's Perspective or Argument

According to the authors, the use of metal materials in offshore structures needs attention because the marine environment is quite easy to cause damage to the material. Seawater, salt, and moisture that continue to hit the metal can trigger corrosion. If left for a long time, these conditions can make the material thinner and its strength reduced.

The author sees that the use of *coating* and cathodic protection can help reduce corrosion. However, protection alone is not enough because the condition of the material can still change during use. Therefore, periodic inspections and maintenance are still necessary to find out whether damage has occurred or not. Based on this, the author argues that durability evaluation needs to be carried out regularly and not only when damage is already visible. By knowing the condition of the material early, maintenance can be carried out more quickly and precisely. This is important so that the material can continue to function properly, the life of the structure is longer, and the safety of offshore structures is maintained.

5. Conclusion

Based on the discussion of the evaluation of the durability of metal materials in offshore structure applications, it can be concluded that the marine environment is one of the main factors that affect material durability. Seawater, salt content, moisture, oxygen, and repetitive working loads can accelerate corrosion, material fatigue, and various other forms of damage. These conditions can cause a decrease in material thickness and strength, affecting the safety and service life of offshore structures.

To maintain the durability of materials, a combination of corrosion protection, inspection, and regular maintenance is required. The use of *coatings*, cathodic protection, and inspection methods such as *Non-Destructive Testing* can help reduce and detect damage to materials. Continuous evaluations can also help determine appropriate maintenance actions before damage develops into more serious. Thus, the implementation of good durability evaluations can help extend the service life of materials, reduce the risk of damage, and maintain the safety and reliability of offshore structures.

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