Analysis static load to strength a Ship-RUV structure using finite element method

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Abstract. Conditions of accidents or marine transportation incidents can cause several conditions in the ship's part to experience structural deformation or a condition to experience cracks in the hull of the ship which causes the ship to experience flooding and sinking. The latest method of technology that is developing in the world today has used the unmanned dive method using RUV (Remotely Underwater Vehicle). It is a specific solution with Ship-RUV technology was developed by prioritizing simpler technology of size and function capacity but using reliable technology and materials. At first, the technology developed in Ship-RUV with design and analysis using finite element. Finite element used to solve the problem; it subdivides a large system into smaller, simpler parts with a numerical approach. Structural Ship-RUV is acceptable when actual stress 60.16 N/mm² less than allowable stresses. In the initial ROV design structure analysis, it was found that the bending stress value reached 102.01 N/mm² obtained from the calculation of cremona or mechanical in the stanchion structure. While in the analysis of new Ship-RUV model uses the Finite Element method and gets the value of the bending stress of 60.16N/mm² is obtained which is equipped with a visual stress distribution

1. Introduction
Here Some of the ship's hull damage in operations include deformation, crack, fatigue, fouling, corrosion so that it requires an earlier process of investigating the hull so that there is no more damage to the hull. The number of sea transportation accidents, such as collision vessels, can cause some parts of the ship to be deformed or the condition of the ship's hull to rupture which. Some cases of ship crash in Indonesia were caused by collisions, that caused the ship's hull to break and sink. For example, the events in July 2018, the source of the Badan Nasional Pencarian dan Pertolongan (BASARNAS) information, where there were two ships colliding, which were types of tugboats (Tugboat) with the name of the TB Buana Express 10 ship which had 10 crew members serving the Kabaena (Southeast Sulawesi) route-Morowali Central Sulawesi) was hit by a passenger ship with the name of the KM Bunga Melati ship which had 17 crew members on the Tanjung Bakau (Southeast Sulawesi) route - Luwuk (Central Sulawesi) which crashed around the waters of Wawonii Island at coordinates 04 11 350 - 122 55 297E [8]. The investigation process in identifying leaking hulls must be carried out quickly and accurately before the ship sinks. Therefore, some special equipment is needed to deal with leaks. Some conventional tools for repairing ship leaks include axe and hammer, Rubber (it can be
also a flip flops), water pumps and hoses, cement dried quickly, but it becomes inefficient when do not knowing the position of the leak on the hull of the ship. So that will cause a collapse [2].

Ship navigation is the most important part of the system on a ship. In the past, people always used celestial bodies such as constellations in determining the position of the direction of the voyage. This condition must require a deepening of knowledge that not everyone can understand in doing so. The ship navigation system can also function as a means of communication between other ships and can communicate with land. Such as Bio-fouling conditions in the hull of the ship, conditions where the thickness of the hull plate is reduced due to the presence of marine biota attached to the hull of the ship, these conditions can include deposit formation, encrustation, curding, deposition, scaling, scale formation, slagging, and bud formation [3]. Therefore, the Classification Bureau will always check the level of thickness of the ship's hull plate each year in terms of issuing the vessel's feasibility in operation at sea but docking must be carried out and this will require not a small cost. Therefore Ship-RUV technology is urgently needed to directly navigate hull conditions that are immersed in water, both due to fouling and even deformation conditions or cracks on the hull of the ship for a low-cost investigation process with a simpler arrangement of size and function but using technology and reliable material.

In the process of designing the Ship-RUV design methods are needed with the latest technology so that the optimum product results are obtained with a little row of residual waste material. The latest product design technology can control material requirements, structural strength, product optimization forms and can be more easily carried out by the process of designing the product. Some of the processes for designing Ship-RUV products with product design methods can be grouped into two parts, including Computer-Aided Design (CAD) is a computer device program for the process of drawing a product or part of a product component. Products that are designed can be represented by objects or symbols that have a specific purpose according to the standards that apply in the design. In CAD it can be 2D or 3D images. Computer-Aided Engineering (CAE) which is the use of Computer software in product design that assists technical analysis tasks. Including Finite Element Methods (FEM), Computer Fluid Dynamics (CFD) and optimization.

At first, the technology developed in Ship-RUV with design and analysis using finite element. The finite element method is used to solve problems, which divides large objects into smaller and simpler parts of elements by applying a numerical approach. Focus to strength a Ship-RUV Structure with analysis static load using FEM. The problem with the initial RUV structure is there are a lot of used the non-material standards in the stanchion structure, it will easily to occur the corrosion and crack because the structure is less strong caused the structural reinforcement is not well-defined for stress distribution.

2. Structure Analysis
Operational ships can experience damage to the ship's hull during operation, among others: deformation damage, fatigue, corrosion, etc. There are some hull conditions which cause it to be repaired as well as welding [7]. This is indeed the case: the vessel plate is hollow due to rust, the plate of the ship has holes with a large area, The thickness of the ship's plate has decreased to 20% from the standard thickness, The ship's plate is pushed into or deformed due to a collision with another object and Leather plate in the form of a double or double wave. So analysis structure is needed to ensure strength Ship-RUV structure.
2.1. Structure Design
In designing the ship wherein determining the main size and line plan includes several designs, among others: determine the main size of the ship, determine the design of the comparison ship, make Curve Section Area (CSA) and shape control body plan. Some designs of floating objects have a fairly high degree of difficulty. The amount of weight placed on the lightweight and death weight should not be more than the displacement of the planned vessel. In its development, the design of RUV can be done with three latest technologies, including: CAD technology and CAE technology. CAD is a computer device program for the process of drawing a product or part of a product component. In CAD it can be 2D or 3D images. CAE which is the use of Computer software in product design that assists technical analysis tasks. Including FEM, CFD, and optimization [4].

2.2. Remote Underwater Vehicle
For the development of underwater technology has less attention from the public. There are still many underwater activities carried out in conventional ways such as underwater observation, monitoring of dam fractures, surveys of underwater natural resources, search for victims of natural disasters or sinking ships and many more underwater activities so far carried out conventionally by humans [6]. Therefore, robots that can move freely in water are needed to help human tasks [5].

2.3. Fabrication
Fabrication of aluminum alloy 5083 while welding Aluminum 5083 to itself or another alloy from the same sub-group, the recommended filler metal is 5183. Other suitable fillers are 5356 and 5556.

| Process Rating       | Result    |
|----------------------|-----------|
| Workability – Cold   | Average   |
| Machinability        | Poor      |
| Weld ability – Gas   | Average   |
| Weld ability – Arc   | Excellent |
| Weld ability – Resistance | Excellent |
| Bras ability         | Poor      |
| Bras ability         | Poor      |

2.3.1. Temper Notation Code.
The most common tempers for aluminum 5083 are:
0 Annealed wrought alloy
H111 Some work hardening imparted by shaping processes but less than required for H11 temper.
H32 Work hardened and stabilized with a quarter hard tempers.

2.3.2. Applications of Aluminum Alloy 5083.
Aluminum 5083 is used in:
a. Shipbuilding
b. Rail cars
c. Vehicle bodies
d. Tip truck bodies
e. Mine skips and cages
f. Pressure vessels

2.4. Loads and Stress
In this case, the Ship-RUV has two kinds of loading, they are Static loads and gravity are a fixed load, both the magnitude (the intensity), the point of work and the direction of the line is fixed. In this case, it is the weight of the ship-RUV assuming the weight does not change.

The uniform load and the stresses that occur in the structure of Ship-RUV are analyzed by calculating the structure components. The calculation of the formula below to get the bending moment value can be used with the following equation:

\[ M_{\text{max}} = \frac{1}{12} q \ell^2 \]  

(1)

While the results of the calculation of bending stress are used to calculate the value of the maximum bending stress that occurs in a structure with existing loading, the following equation is shown:

\[ \sigma = \frac{M_y}{I_{xx}} \]  

(2)

2.5. Safety Factor
The safety factor in structural design can be used as an anticipation in the structure so that it can be precisely safe in its operation [1]. The development of planning methods based on security factors can be sorted as follows:

2.5.1. Ultimate Stress Method.
This method has two main methods: Plastic Method and Ultimate Stress Method.

2.5.2. Limit Stress Method.
Method of working stresses limit or often referred to as the stresses tension calculation, this is because of the metode used by stresses permits which is the melting stress (collapsed) material divided by a certain number called the safety factor (SF) like the following equation:

\[ SF = \frac{\sigma_u}{\sigma_i} \]  

(3)

SF: Safety Factor
\( \sigma_u \): Melt / Ultimate Stresses
\( \sigma_i \): Per mission Stresses actual
Safety Factors can also be calculated from the BKI regulation for the construction of steel vessels as follows:

\[ SF = 1.5 \] (in general)
\[ SF = 1.2 \] (for construction that only accepts local load)
\[ SF = 1.05 \] (for free static load combinations)

It can be concluded that the commonly used safety factor is 1.5. The safety factor used to analyzed the behavior of the ship-RUV is with a value of 1.5 for structure.

3. Methodology
Stresses analysis that occurs seen on the structure with used FEM, which can be calculated with the following steps design model. The design of the structure on the ship-RUV to be analyzed is modeled first with the AutoCAD software. Then it can export with ACIS file type (.sat). Then determination of the type of design by study. Based on BKI regulation Vol. II Year 2016 material used is marine used with maximum tensile pressure 400 N / mm2. In this step enter the mechanical properties to determine
the constraints possessed by the material. And then meshing where model of navigation lampposts made in the form of three-dimensional given solid mesh form which is the recommended meshing type. Analysis of the behavior of the Ship-RUV is using fine mesh for accurate results. The method allows for discontinuities, internal to the elements, in the approximation across the interface. Finally, Analysis Structure, in the behavior analysis of Ship-RUV structure, post-processing analysis was performed with deformation and stresses simulations that occurred in the structure.

4. Result and Discussion

In the Ship-RUV structure analysis will be shown several stages and analysis process. So that the maximum results obtained in the analysis of Ship-RUV structure. This will be shown in several analysis designs by giving location of loading and constrain. Stress and strain will provide structural behavior when receiving operational loading.

4.1. Model 3-D Ship-RUV

In designing Ship-RUV modeling is done using Computer-Aided Design (CAD). With a modern design pattern where the design process begins with the making of 3D models then a modeling simulation using Computer-Aided Engineering is then carried out. Whereat the CAD stage it includes making a sketch area of a polyline and then forming a solid with an extrude pattern or revolved shape. For editing 3D models you can use a press pull or modify.

![Figure 1. 3D Model of Ship-RUV](image)

4.2. Simplify Menu for Structure Analysis

In this process, it is analyzed in the Ship-RUV structure and this is because the structural part is the component's constituent strength so that its strength is very calculated. It is unnecessary for simulation without affecting its production geometry (structure of ship RUV). In figure below shown simplify model of ship-RUV. It is not change native file if simplify menu to applied.
4.3. Material Ship-RUV

In the process of designing the Ship-RUV, use aluminum allow 5083 (marine used) material. Where the material is indeed designed for very corrosive ocean conditions and can reduce the marine biota attached to the Ship-RUV structure or in other words anti-fouling. The following is shown the chemical composition of the 5083 aluminum alloy material as follows:

Table 2. - Chemical composition for aluminum alloy 5083

| Element | % Present |
|---------|-----------|
| Si      | 0         |
| Fe      | 0.4       |
| Cu      | 0.1       |
| Mn      | 0.4-1.0   |
| Mg      | 4.0-4.9   |
| Zn      | 0.25      |
| Ti      | 0.15      |
| Cr      | 0.05-0.25 |
| Al      | Balance   |

While it’s the mechanical composition of the 5083-aluminum alloy is used as a reference for the material's ability to accept loads against the designed structure. In this case, it is taken at the elastic stretch limit, as the yield stresses limit where the material structure is in an inelastic condition which will be divided by the material standard factor and the structural safety condition factor. The following is shown the mechanical composition of the 5083-aluminum alloy material as follows:
Table 3. Mechanical properties for aluminum alloy 5083

| Property          | Value          |
|-------------------|----------------|
| Proof Stress      | 125 Min MPa    |
| Tensile Strength  | 275 - 350 MPa  |
| Hardness Brinell  | 75 HB          |

*Properties above are material in the Soft O/H111 condition*

To show the physical properties of the 5083-aluminum alloy material, to determine the weight of the designed structure, after previously calculating the designed Ship-RUV volume. The following is shown the physical composition of the 5083-aluminum alloy material as follows:

Table 4. Physical c for aluminum alloy 5083

| Property               | Value          |
|------------------------|----------------|
| Density                | 2650 kg/m³     |
| Melting Point          | 570°C          |
| Modulus of Elasticity  | 72 GPa         |
| Electrical Resistivity | 0.058x10⁻⁶ Ω.m |
| Thermal Conductivity   | 121 W/m.K      |
| Thermal Expansion      | 25x10⁻⁶ /K     |

4.4. Constrain

Constrain is a placement condition in the operational conditions of Ship-RUV in maneuvering in seawater. The constraint condition can be shown in the figure below, where the sagging maneuver hogging conditions are applied to the Ship-RUV structure to placement condition.

Figure 3. Constrain of Ship-RUV Structure
4.5. Constrain
Loading on Ship-RUV is emphasized on the trust that works on ship-RUV where it can be shown in the loading panel as follows:
   a. Thruster after @ 100 N
   b. Thruster bottom @ 100 N
   c. Body @200 N

Figure 4. Load of Ship-RUV Structure

Contact (Connection Part) is Automatically calculates the contact types between all body and component that overlap or touch each other. To ensure all contacts are included in the simulation, run automatic contact before assigning manual contact. Note it can the later change manual types fro, the automatically generated one to the desired type. Also, you can suppress contacts to be excluded from the simulation. Meshing At this stage, the structure is divided into various constituent elements consisting of nodal and element parts which are engineering solver for the characteristic of the finite element method.

Figure 5. The Meshing of Ship-RUV Structure
Meshing properties result:

Table 5. Element Properties

| Component                  | Value                        |
|----------------------------|------------------------------|
| 164387 Tetrahedral         | 100.0% of elements           |
| Face Angle min             | 1.98                         |
| Face Angle max             | 176                          |
| Dihedral Angle min         | 1.02                         |
| Dihedral Angle max         | 178                          |
| Worst shape ratio          | 92.2 on element 18385        |
| Worst aspect ratio         | 9.23 on element 5246         |
| Shortest edge              | 0.000162,                    |
| Longest                    | 0.0334                       |
| Lowest collapse ratio      | 0.0157 on element 1908       |
| Worst Jacobian ratio       | 3.89 on element 11317        |
| Base mesh nodes            | 300083 nodes                 |
| Base mesh elements         | 164387 elements              |
| Solver mesh nodes          | 300083 nodes                 |
| Solver mesh nodes          | 164387 elements              |

Job has finished successfully.

4.6. VonMisses

Von Misses is a combined result of the value of the stress that occurs in the RUV ship structure where after the loading occurs.

Figure 6. VonMisses Stresses of Ship-RUV Structure
Allowable stresses

\[ \sigma_a = \frac{\sigma_{\text{yield}}}{SF.K} \]  

Where:
\( \sigma_y \) = Yield Strength, N/mm\(^2\)
SF = Safety Factor
K = Factor Material

Result: structural is acceptable (60.16 \( \leq \) \( \sigma_a \))
\[ \sigma_a = \frac{125}{1.5.1} \]
\[ = 83.33 \text{ N/mm}^2 \]

4.7. Deformation Result

Deformation is a structural behavior that occurs as a result of loading the structure that occurs. Where it’s must be referred to the permissible limits of deformation that occurs.

![Image](image-url)

**Figure 7.** Deformation of Ship-RUV Structure

Allowable deformation

\[ \frac{L}{28} \text{ for both end continuous} \]  
\[ \frac{L}{28} = \frac{250}{28} \]
\[ = 8.9 \text{ mm} \]
Result of deformation structural is acceptable

5. Conclusion

Static Load is applied to strength a Ship-RUV Structure by Finite Element Analysis. It is a solution specific with Ship-RUV technology was developed by prioritizing simpler technology of size and strength of function capacity but using reliable structure technology and materials. At first, the technology developed in Ship-RUV with design and analysis using finite element. The finite element method is used to solve problems, which divides large objects into smaller and simpler parts of elements by applying a numerical approach. Focus to strength a Ship-RUV Structure with analysis static load using finite element method. Structural Ship-RUV is acceptable when actual stress 60.16 N/mm\(^2\) less than allowable stresses 83.33 N/mm\(^2\). The behavior of Ship-RUV structure can be analyzed by actual deformation. Maximum deformation is 2.9 mm less than allowable deformation with value 8.9 mm. In the initial ROV design structure analysis, it was found that the bending stress value reached 102.01 N/mm\(^2\) obtained from the calculation of cremona or mechanical in the stanchion structure.
while in the analysis of new Ship-RUV model uses the Finite Element method and gets the value of the bending stress of 60.16N/mm² is obtained which is equipped with a visual stress distribution.

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