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Hinge and Pin Stress Analysis as a Function of Barge Opening Angle on Split Hopper Barge

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Abstract

An important construction to note on a split hopper barge ship is the hinge pin on the deck that connects the two sides of the hull. This is because the role of the hinge pin is very vital, so damage or failure of the hinge pin will result in failure of the entire barge. This study aims to analyze the stress, strain, and deformation in hinge and pin construction. Modeling and calculations are carried out using the ANSYS workbench software. Based on the results of the analysis on hinge and pin construction, it is found that the greater the angle of the barge opening, the value of the XY shear stress, XY shear strain, and the normal stress in the X direction will also increase so that the critical point for shear stress is at the maximum barge opening, which is an angle of 20°. For von-Mises stress, von-Mises strain, and normal stress in the Y direction, the larger the barge opening angle, the smaller the stress and strain values, so that the critical point for the von-Mises stress and Y-direction normal stress occurs when the barge is closed, namely 0° angle. As for the total deformation, the maximum value for the hinge is at an angle of 15° and the pin is at an angle of 10°, but the deformation values for the hinge and pin construction are almost uniform and there is no significant deformation change.

Keywords: Pin; Hinge; Split hopper barge; Stress; Deformation

1. Introduction

Split Hopper Barge is a type of barge that serves to transport and dispose of dredged materials such as sand, mud, clay/clay, coral, and others intended for reclamation purposes, deepening harbor pools or shipping lanes, and so on. Split Hopper Barge is a combination of Split Barge and Self-Propelled Hopper Barge where the ship can dump cargo like a Split Barge ship and can carry its own cargo from the place of origin such as Self-Propelled Hopper Barge. Split Hopper Barge is designed to facilitate the process of disposing of cargo or material through the bottom of the ship by separating the hull using a hydraulic cylinder so that the halves of the hull can approach and move away from each other. The two sides of the hull that can open and close are connected to the shaft by a hinge on the deck.

Split Hopper Barge consists of two connected shafts, namely the body of the ship that floats in this case the hinge on the deck and a hydraulic cylinder to control the closing and opening of the cargo space which is limited between the body of the ship that floats with a pressurized hydraulic pump, the load in the cargo space, and buoyancy. each element of the ship's body [1]. Split Hopper Barge has two sides of the hull that are pivotally connected to each other on the deck, where when the loading / loading position the two sides of the hull are tied together and when the unloading / unloading position, both sides of the hull are released so that the bottom area of the ship will open, and in the loading room there is at least one control unit whose working principle is like a jack to control the position of the loading space opening [2].

Hinge on the Split Hopper Barge is a hinge-like construction that connects the portside and starboard hulls, because the Split Hopper Barge has a hull that can split when dumping cargo [2]. The hinge which is located on the bow and aft deck serves as the shaft or center of movement of the half-barge when opening or closing the hopper barge. The hinge on the Split Barge ship is tied by a hinge shaft or better known as a pin hinge, where the hinge pin has a vital role, namely holding the barge pedestal load. The hinge pin is made using a round bar whose diameter depends on the size or load of the barge.

Load is a force, deformation, or acceleration applied to a member. Loads cause stress, deformation, and displacement in the structure [3]. Loads can be classified into several types, namely sustain load, occasional load, and operational load. Sustain load is a load due to the weight caused by the material itself and is continuous, that is, the load is always there during the material operation process. Occasional load is the load received by the material due to natural phenomena such as wind, earthquake, snow, and others. Occasional load is rare, but it is still taken into account in calculating the load of a material. While the operational load is the load that arises due to the movement or action of the material, such as the load that arises due to rotation that produces torque.

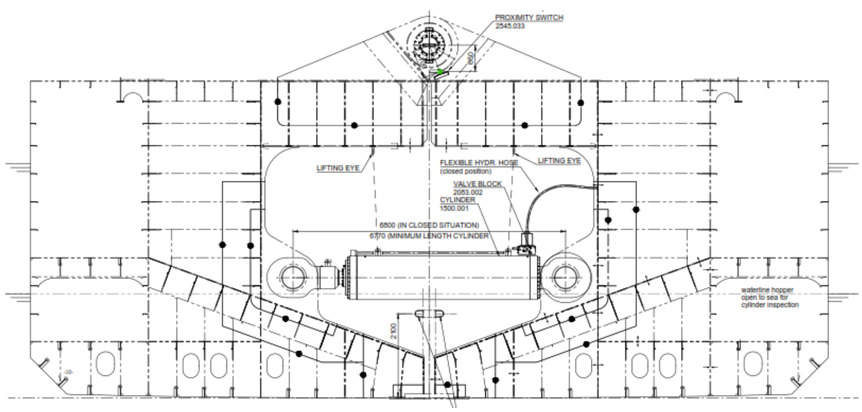


Figure 1. Hinge and hydraulic cylinder construction for opening and closing both sides of the barge hull.

A structure is a set of material elements that can transmit loads or loading forces to other material elements. The building structure is designed to be able to withstand the load of the building. General building structures including ships, buildings, bridges, aircraft, machinery, and other load-bearing frame buildings, building structures can be broken down into parts that form a single unit in their analysis and design [4]. Similarly, the Split Hopper Barge ship has structural parts such as the frame structure, shell structure, pedestal structure, bow structure, stern structure, and deck structure. On the deck there are hinge and hinge pins designed to withstand the force and load of the barge.

In principle, a structure must have a balance of forces so that the structure can work according to its function to withstand the load. The structure is connected to its environment by a support where the main purpose is to fix the structure in a certain position, besides that the support also functions to continue the forces acting on the structure [5]. Stress is defined as the force acting on the surface of an object in unit area [6]. Stress is also known as force intensity (i.e. force per unit area) and the International Standard unit for normal stress is Newton per meter squared (N/m^2) or Pascal (Pa).

The pin hinge of the Split Barge is one of the most common examples of a structure in which the shear stress is assumed to be equal on an imaginary surface perpendicular to the pin axis. Other examples such as bolts, screws, nails and rivets are more or less like pins if the main function of these mechanical fasteners is the transfer of shear forces from one member to another. However, if the main function of this mechanical fastener is to press two solid objects against each other (seal), then this fastener cannot be approached as a pin because the force transferred is a normal force [7].

An important construction to note on the Split hopper barge is the hinge pin on the deck that connects the two sides of the hull, this is because the role of the hinge pin is very vital, so damage or failure of the hinge pin will result in failure of the entire barge. The pin hinge construction on the deck has the potential to be easily damaged due to the support load when the hinge is operating. The problem of damage to the hinge pin can occur due to deflection or deflection problems caused by construction design errors. The hinge pins on the deck must be able to withstand various variations in the load caused when the hydraulic cylinder operates, closing and fully opening the hull. The design and dimensions of the pin hinge must pay attention to the dimensions of the ship and the weight of the ship's cargo itself so that the hinge pin has the ability to withstand the maximum load and so that permanent deformation does not occur.

This study aims to analyze the maximum stress and strain values at the hinge and pin hinge for each variation of the barge opening angle, analyze the maximum deformation value at the hinge and pin hinge, analyze the magnitude of the change in stress, strain, and deformation at the hinge and hinge pin as a function of the opening angle. barge. To get a picture of the stress along the hinge and pin hinge construction with static loading conditions and the appropriate boundary conditions. The position of the maximum deflection at the load must be in accordance with conventional logic and stress calculations.

To calculate and analyze the magnitude of the stress that occurs in the hinge and hinge pins on the deck as a function of the angle of the barge opening, the problem limitation in this study is to only model the hinge and pin construction parts attached to the Split hopper barge ship, only to analyze the forces acting on the hinge. and pin hinge deck Split hopper barge ship, the load used is the maximum load in accordance with the data obtained from the PT. Graha Trisaka Industri, the analysis was carried out using ANSYS software.

2. Stress, Strain, and Elasticity

2.1 Stress

Stress is defined as the force acting on the surface of an object in unit area [6]. Stress is also known as force intensity (i.e. force per unit area) and the International Standard unit for normal stress is Newton per meter squared (N/m^2) or Pascal (Pa).

2.1.1 Normal Stress

Normal stress is the stress perpendicular to the surface to which the stress is applied. Normal stress can be tensile and compressive. Tensile is positive and compressive stress is negative [8]. The formula for the stress equation can be seen in Equation 1.

$$\sigma = \frac{F}{A} \tag{1}$$

Where, σ is stress (N/mm^2), F is force or load (N) and A is area (mm^2). The equations for the normal stresses in the three-dimensional plane can be seen in Equations 2 to 4.

$$\sigma x = \frac{E}{(1+v)(1-2v)}[\varepsilon x\,(1-v) + v(\varepsilon y + \varepsilon z)] \tag{2}$$

$$\sigma y = \frac{E}{(1+v)(1-2v)}[\varepsilon y\,(1-v) + v(\varepsilon x + \varepsilon z)] \tag{3}$$

$$\sigma z = \frac{E}{(1+v)(1-2v)}[\varepsilon x\,(1-v) + v(\varepsilon x + \varepsilon y)] \tag{4}$$

2.1.2 Von-Mises Stress

Analysis using finite element software has the advantage that it can produce Von Mises stress values or equivalent stresses, namely the type of stress that causes failure in the material structure formulated by its inventor named Von Mises. Based on Shigley [9] to determine the Von Mises stress, first calculate the main stress acting on the structure using equation 1, after the main stress is found, the Von Mises stress can be obtained using Equation 5.

$$\sigma = \{\frac{[\sigma^1 - \sigma^2]^2 + [\sigma^2 - \sigma^3]^2 + [\sigma^3 - \sigma^1]^2}{2}\}^{1/2} \tag{5}$$

2.1.3 Shear Stress

A force on an object causes a change in the size of the object. The effect of the force vector on the x-axis produces a tensile stress with the symbol x. The x axis represents the direction of the force vector. The effect of the force on the y and z axes produces a moment called shear stress. Shear stress occurs when an object acts with two forces in opposite directions, perpendicular to the axis of the rod, and not in line with the force but in the cross section there is no moment. Shear stress is mathematically defined in equations 6 and 7.

$$\tau = \frac{V}{A} \tag{6}$$

$$\tau = \frac{V \,.\, St}{I \,.\, b} \tag{7}$$

Where, τ is the shear stress (N/mm^2), V is the force parallel to the plane of the element (N), A is the area (mm^2), St is the static moment (mm^3), I is the Inertia (mm^4), and b is the cross-sectional thickness. (mm). The shear stress equation for the three-dimensional plane can be seen in equations 8 to 10.

$$\tau xy = \frac{E}{2\,(1+v)}\gamma xy = G.\gamma xy \tag{8}$$

$$\tau xz = \frac{E}{2\,(1+v)}\gamma xz = G.\gamma xz \tag{9}$$

$$\tau yz = \frac{E}{2\,(1+v)}\gamma yz \tag{10}$$

The pin hinge of the Split Barge is one of the most common examples of a structure in which the shear stress is assumed to be equal on an imaginary surface perpendicular to the pin axis. Other examples such as bolts, screws, nails and rivets are more or less like pins if the main function of these mechanical fasteners is the transfer of shear forces from one member to another. However, if the main function of this mechanical fastener is to press two solid objects against each other (seal), then this fastener cannot be approached as a pin because the force transferred is a normal force [7].

Shear Pins are mechanical axes designed for breaking shear forces when the transferred force exceeds a level that would damage critical components. In the sliding pin of a lawn mower, for example, the blade is attached to the transmission shaft and it breaks if the blade hits a large rock that can bend the transmission shaft [7].

2.1.4 Permit Stress

The permit stress is the maximum stress required by the classification system. The stresses that occur due to loading that take place are not limited to the structural elements, without causing fracture or deformation or deformation. The determination of the allowable stress determines the calculation and inspection of the size of the structure.

When a steel material with a minimum yield stress R_{eH} other than 235 N/mm^2 is used on a ship, the hull scantling is determined taking into account the material factor (k) defined in Table 1. The allowable normal stress for the construction of the deck section is $\frac{170}{k}$ N/mm^2 and the allowable shear stress for deck construction is $\frac{110}{k}$ N/mm^2, while the allowable von-Mises stress is $\frac{235}{k}$ N/mm^2 [11].

Table 1. Material factor K.

R_{EH} in N/mm^2	**k**
235	1
315	0,78
355	0,72
390	0,68

2.2 Strain

Strain is the ratio of the deformation of a structure to the initial length due to a force whose direction is parallel to the change in the length of the structure [10]. So it can be concluded that strain is a relative change in the size of an object under stress, in addition, strain is a measure of how much the object changes shape. Hooke's law states that within certain limits the stress of an object is directly proportional to the strain. Strain can also be defined in equation 11.

$$\varepsilon = \frac{\Delta L}{L} \tag{11}$$

Where, ε is the strain, ΔL is the increase in length (mm), and L is the original length (mm). The ratio of stress (stress) and strain (strain) will be linear and end up at the yield point. The relationship between stress and strain is no longer linear when the material reaches the phase limit of the plastic properties.

2.3 Elasticity

Elasticity is defined as the property of a material to undergo stress without causing a permanent change in size or shape after the stress is removed. This phenomenon is also known as elastic deformation. Elastic deformation occurs when a material is subjected to a force. If the stress is caused by a tensile force, the material will experience an increase in length. After the force is removed, the material will return to its original shape. On the other hand, if the stress is caused by a compressive force, the material will be shorter than its original shape [10].

Each material or object has a different elasticity limit. The limit of elasticity is defined as the maximum force that can be exerted on an object before the object changes size or shape permanently (becomes plastic). If the force applied to an object is less than its elastic limit, the object will be temporarily deformed and will return to its original shape and size if the force acting on the object is removed. On the other hand, if the applied force exceeds the elastic limit, the object will experience permanent deformation.

The elasticity of a material is largely determined by the modulus of elasticity (Young's modulus). Young's modulus is the ratio between stress and strain. The Young's Modulus (E) equation is defined in Equation 12.

$$E = \frac{\sigma}{\varepsilon} \tag{12}$$

Where, E is Young's modulus (N/mm^2), $\boldsymbol{\sigma}$ is stress (N/mm^2), and ε is strain.

3. Research Method

This research was conducted at the Ship Structure Laboratory of the Department of Naval Architecture, Faculty of Engineering, Hasanuddin University to obtain data in the form of ship structure responses seen from the stress and displacement acting on the ship. Numerical simulations were carried out to analyse the change in the hinge pin stress as a function of the angle of the barge opening on the Split hopper barge ship, so that the model made in accordance with reality used data on the ship that had been completed. The data in this study were obtained from data originating from the PT. Graha Trisaka Industri Batam and Royal IHC, including pictures 1) General arrangement of the Split Hopper Barge, 2) General arrangement of hinges and chocks: Summary loads, and 3) Deck hinges arrangement, details, and machining. For details on the size and shape of the hinge and pin hinge, see Table 2 and Figure 2(a) for detailed images of the hinge and pin hinge longitudinally and Figure 2(b) for detailed images of the hinge and pin hinge transversely. The hinge and pin hinge modelled in Ansys software can be seen in Figure 3. Material properties of the hinge and pin hinge was shown in Table 3.

This research was conducted by numerical simulation using Ansys software. The work step in analysing the longitudinal strength of the structure of the research object begins with structural modelling using Ansys software and then proceeds with loading the hinge and pin hinge structures when the barge opens and closes the hull, and determines the type of pedestal. The opening angle studied is from an opening angle of 5 to 20 degrees with an increase in the opening angle of 5 degrees.

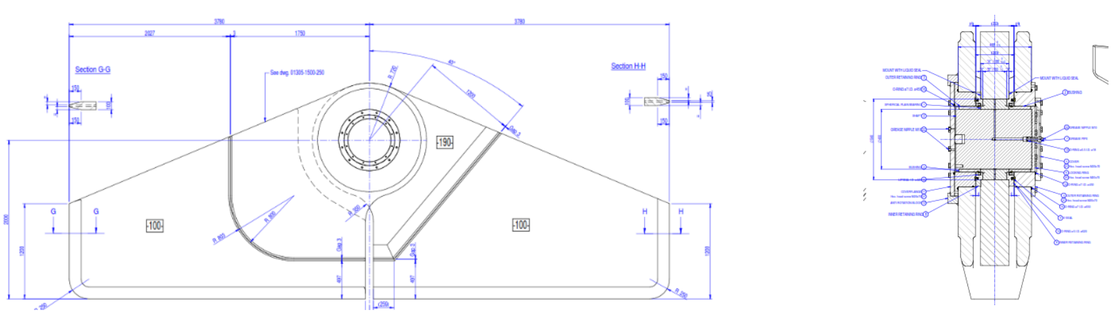
4. Result and Discussion

4.1. Analysis strength of Hinge and Pin Hinge

4.1.1 Shear Stress and Strain at Hinge and Pin Hinge in XY Direction

Based on the results of the analysis using the ANSYSTM Software, the results of the analysis of the strength of the hinge structure and hinge pins can be seen in Table 4. The critical point for hinge construction at an angle of 0° to 20° is located in the hinge starboard construction (hereinafter written Hinge SB in the table) precisely at the hole for attaching the pin. Especially in pin construction, the critical point is located at the bottom of the pin.

From the results obtained, the greatest XY shear stress and strain occurs when the maximum barge hull opening is an opening angle of 20° and is located in the hinge starboard construction of the hole where the pin is attached with an XY shear stress value of 86.202 N/mm2 and an XY shear strain of 1.067. x10-3. This is because the hinge construction model for the starboard section is in the form of a single shear so that the resulting shear stress is greater than the hinge construction for the portside section, which is a double shear construction model. The graph of changes in the maximum XY stress and shear strain can be seen in Figure 4.

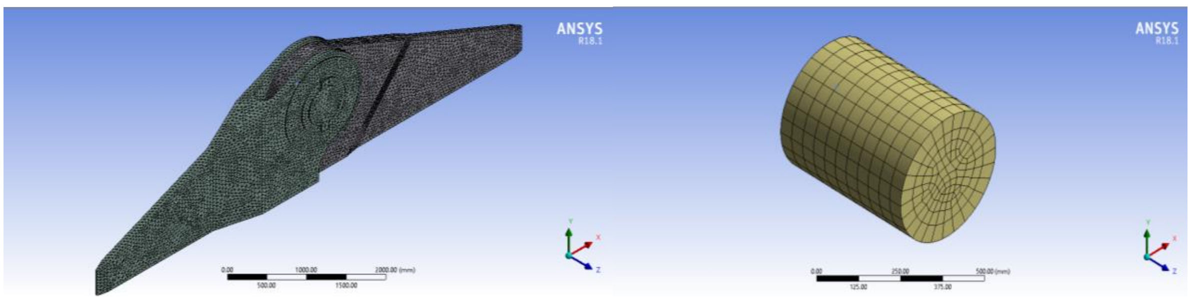


(a). hinge (b). Pin hinge

Figure 2. Details shape and size of the hinge and pin hinge.

Table 2. Detail dimensions of the hinge and pin hinge.

Description	Dimension (mm)	Weight (kg)
Hinge Starboard	4500 x 190 x 1895	5906,5
Hinge Portside	4500 x 600 x 1895	8148,4
Shaft (Pin)	ø484 x 504	485,9
Cover	ø440 x 36	38,8
Locking Ring	ø438 x 30	24,4



(a). hinge (b). Pin hinge

Figure 3. The hinge and pin hinge modelled in Ansys.

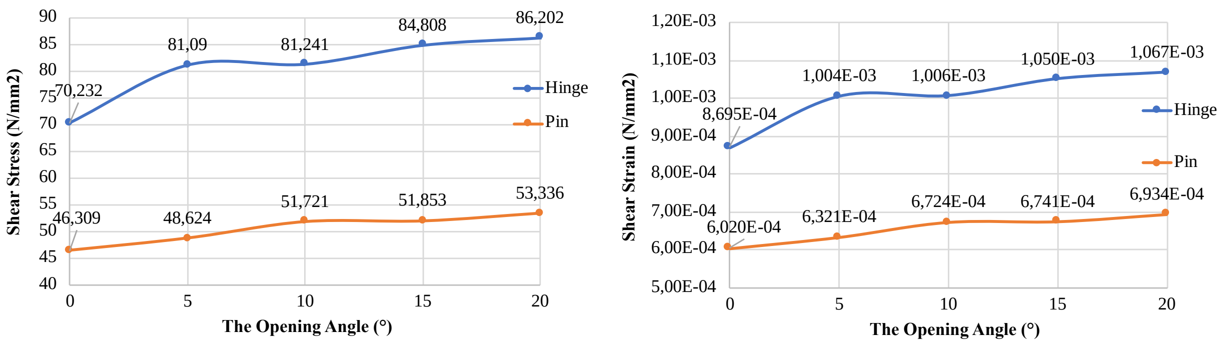
Table 3. Material properties of the hinge and pin hinge.

Descriptions	Hinge (S235JR Structural Steel)	Pin hinge (42CrMo4 Alloy Steel)
Density (kg/m^3)	7800	7830
Modulus Young (MPa)	210000	200000
Poisson Ratio	0,3	0,3
Yield Strength (MPa)	235	550
Ultimate Strength (MPa)	510	950
Shear Modulus (MPa)	80000	80000
Bulk Modulus (MPa)		140000

Table 4. Hinge and pin construction stresses and strain.

No.	Analysis	Shear Stress XY (N/mm^2)			
		Value	Location	Value	Location
1.	Angle 0°	70,232	Hinge SB	46,309	Pin
2.	Angle 5°	81,090	Hinge SB	48,624	Pin
3.	Angle 10°	81,241	Hinge SB	51,721	Pin
4.	Angle 15°	84,808	Hinge SB	51,853	Pin
5.	Angle 20°	86,202	Hinge SB	53,336	Pin

No.	Analysis	Shear Strain XY (N/mm^2)			
		Value	Location	Value	Location
1.	Angle 0°	8,695 x 10^{-4}	Hinge SB	6,020 x 10^{-4}	Pin
2.	Angle 5°	1,004 x 10^{-3}	Hinge SB	6,321 x 10^{-4}	Pin
3.	Angle 10°	1,006 x 10^{-3}	Hinge SB	6,724 x 10^{-4}	Pin
4.	Angle 15°	1,050 x 10^{-3}	Hinge SB	6,741 x 10^{-4}	Pin
5.	Angle 20°	1,067 x 10^{-3}	Hinge SB	6,934 x 10^{-4}	Pin



(a) Shear stress (b) Shear strain

Figure 4. Maximum change of shear stress and shear strain in XY direction.

Figure 4 shows a graph of the maximum XY stress and shear strain values as a function of the barge opening angle. The value of the XY shear stress for both hinge and pin construction increase linearly from the barge angle of 0° to the maximum opening angle of 20°, as well as the XY shear strain. This means that the barge opening angle affects the value of the XY shear stress and strain on the hinge and pin construction. The greater the angle of the barge opening on the split hopper barge ship, the greater the shear stress produced in the hinge and pin construction.

4.1.2 Von-Mises Stress and Strain on Hinge and Pin Hinge

The results of the von-Mises stress analysis on hinge construction and pin construction can be seen in Table 5. The critical point for hinge construction at an angle of 0° to 20° is located in the hinge portside construction, precisely at the hole where the pin is attached, while the critical point for pin construction at an angle of 0° to 20° is located at the bottom of the pin.

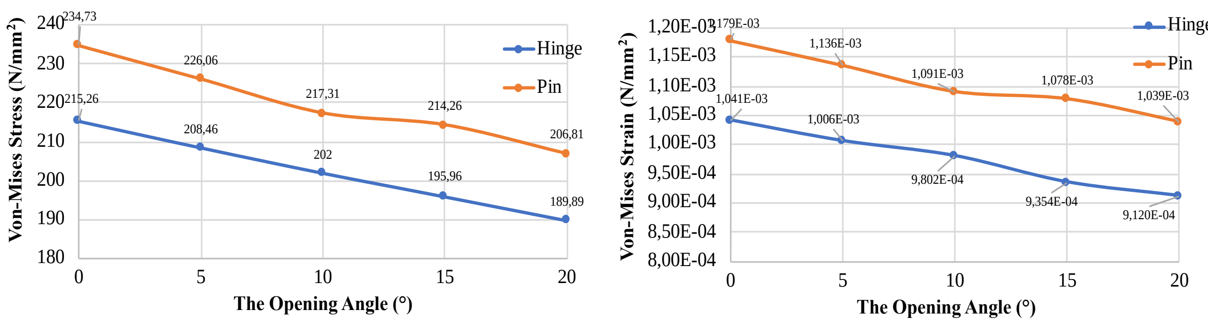
Based on Table 5, it can be seen that the largest von-Mises stress and strain occurred when the split barge hull was still closed at an angle of 0° and was located at the bottom of the pin construction with a von-Mises stress value of 234.730 N/mm^2 and a von-Mises strain of 1.179. x10^{-3}. So, for the von-Mises stress, the critical point lies in the pin construction.

Table 5. Von-Mises stress and strain on constructions of the *Hinge* and *Pin.*

No.	Analysis	Von-Mises Stress (N/mm^2)			
		Value	Location	Value	Location
1.	Angle 0°	215,260	Hinge PS	234,730	Pin
2.	Angle 5°	208,460	Hinge PS	226,060	Pin
3.	Angle 10°	202,000	Hinge PS	217,310	Pin
4.	Angle 15°	195,960	Hinge PS	214,260	Pin
5.	Angle 20°	189,890	Hinge PS	206,810	Pin

No.	Analysis	Von-Mises Strain (N/mm^2)			
		Value	Location	Value	Location
1.	Angle 0°	$1,041 \times 10^{-3}$	Hinge PS	$1,179 \times 10^{-3}$	Pin
2.	Angle 5°	$1,006 \times 10^{-3}$	Hinge PS	$1,136 \times 10^{-3}$	Pin
3.	Angle 10°	$9,802 \times 10^{-4}$	Hinge PS	$1,091 \times 10^{-3}$	Pin
4.	Angle 15°	$9,354 \times 10^{-4}$	Hinge PS	$1,078 \times 10^{-3}$	Pin
5.	Angle 20°	$9,120 \times 10^{-4}$	Hinge PS	$1,039 \times 10^{-3}$	Pin

The maximum von-Mises stress that occurs in the hinge and pin for each variation of the barge opening angle meets the rules or the BV (Bureau Veritas) classification rules because the von-Mises stress in the hinge and pin construction is below the allowable stress limit of the material, which is $\frac{235}{k}$ [N/ mm^2] where the hinge is 235 N/mm^2 and the pin hinge is 345 N/mm^2 (k hinge value = 1 and pin = 0.68). For the percentage change in the maximum von-Mises stress and strain on hinge and pin construction, see Figure 5.



(a) Stress (b) Strain

Figure 5. Maximum change of Von-Mises stress and strain.

Figure 5 shows a graph of the maximum von-Mises stress and strain values as a function of the barge opening angle. The value of the von-Mises stress and strain for both hinge and pin constructions decreased linearly starting from the barge angle of 0° to the maximum opening angle of 20°. The larger the angle of the barge opening on the split hopper barge ship, the smaller the value of the von-Mises stress and strain generated in the hinge and pin construction will be.

4.1.3 Normal Stress on Hinge and Pin Hinge

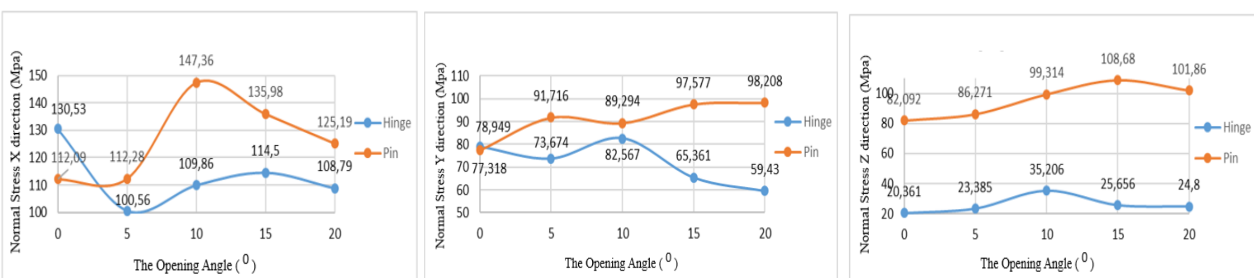
The results of the analysis of the strength of the hinge structure and hinge pin at the barge opening angle of 0° to 20° can be seen in Table 6. Based on Table 6. the largest normal stress in the X direction occurs at the hinge of the 10° opening angle, precisely at the hinge pin with a stress value of -147.36 MPa, the maximum Y-direction normal stress of -98.208 MPa occurs at the hinge pin of the barge opening angle of 20°, and The maximum normal stress in the Z direction of -108.68 MPa occurs at the hinge pin at the barge opening angle of 15°. The biggest change in normal stress X occurs when the hinge pin hinges at an angle of 5° open to an angle of 10° with a percentage change in stress of 31.24%, the largest change in normal stress for the Y direction occurs when the hinge position at an angle of 10° opens to an angle of 15° with a percentage change in stress of -20.84%, while the largest change in normal stress in the Z direction occurs when the hinge position at an angle of 5° opens to an angle of 10° with a percentage change in stress of 50.55%. The maximum normal stress graph can be seen in Figure 6.

Table 6. Maximum normal stress.

No.	Analysis	Normal Stress in X Direction (MPa)			
		Value	Location	Value	Location
1.	Angle 0°	-130,530	Hinge SB	-112,090	Pin
2.	Angle 5°	100,560	Hinge SB	-112,280	Pin
3.	Angle 10°	109,860	Hinge SB	-147,360	Pin
4.	Angle 15°	114,500	Hinge SB	-135,980	Pin
5.	Angle 20°	108,790	Hinge SB	-125,190	Pin

No.	Analysis	Normal Stress in Y Direction (MPa)			
		Value	Location	Value	Location
1.	Angle 0°	78,949	Hinge SB	-77,318	Pin
2.	Angle 5°	73,674	Hinge SB	-91,716	Pin
3.	Angle 10°	82,567	Hinge SB	-89,294	Pin
4.	Angle 15°	65,361	Hinge SB	-97,577	Pin
5.	Angle 20°	59,430	Hinge SB	-98,208	Pin

No.	Analysis	Normal Stress in Z Direction (MPa)			
		Value	Location	Value	Location
1.	Angle 0°	20,361	Hinge SB	-82,092	Pin
2.	Angle 5°	23,385	Hinge SB	-86,271	Pin
3.	Angle 10°	35,206	Hinge SB	-99,314	Pin
4.	Angle 15°	25,656	Hinge SB	-108,680	Pin
5.	Angle 20°	24,800	Hinge SB	-101,860	Pin



(a) X direction (b) Y direction (b) Z direction

Figure 6. Maximum normal stress.

The normal stress that occurs in the hinge and pin hinge for every variation of the angle meets the requirements for the BV (Bureau Veritas) classification because it is below the allowable stress for the material, which is $\frac{170}{k}$ [N/mm^2] where for the hinge it is 170 N/mm^2 and the hinge pin is 250 N. /mm^2 (k hinge value = 1 and pin = 0.68).

4.1.4 Shear Strain XY

The largest XY shear strain occurs at the hinge with an opening angle of 20° which is the same as the shear stress in the hinge starboard part of the hole where the hinge pin is attached with an XY shear strain value of 1.036 x 10-3 as shoe on Table 7. The percentage value of the XY shear strain is the same as the shear stress where the largest change in shear strain occurs when the hinge pin position at an angle of 0°

opens to an angle of 5° with a percentage increase in stress of 50.68%. The graph of the maximum XY shear strain can be seen in Figure 7. Overall, the hinge operates to open and close the barge starting from the barge opening angle of 0° to the opening angle of 20°, the hinge has an XY shear strain increase of 7.79% and the pin hinge is 10,40%.

Table 7. Maximum shear strain.

No.	Analysis	Maximum Shear Strain XY			
		Value	Location	Value	Location
1.	*Hinge* and *Pin hinge* 0°	$9{,}610 \times 10^{-4}$	Hinge SB	$1{,}924 \times 10^{-4}$	Pin
2.	*Hinge* and *Pin hinge* 5°	$1{,}019 \times 10^{-3}$	Hinge SB	$2{,}899 \times 10^{-4}$	Pin
3.	*Hinge* and *Pin hinge* 10°	$9{,}923 \times 10^{-4}$	Hinge SB	$3{,}085 \times 10^{-4}$	Pin
4.	*Hinge* and *Pin hinge* 15°	$9{,}870 \times 10^{-4}$	Hinge SB	$3{,}954 \times 10^{-4}$	Pin
5.	*Hinge* and *Pin hinge* 20°	$1{,}036 \times 10^{-3}$	Hinge SB	$2{,}124 \times 10^{-4}$	Pin

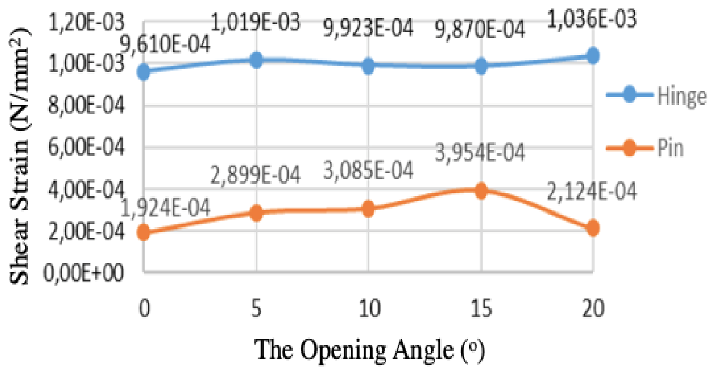


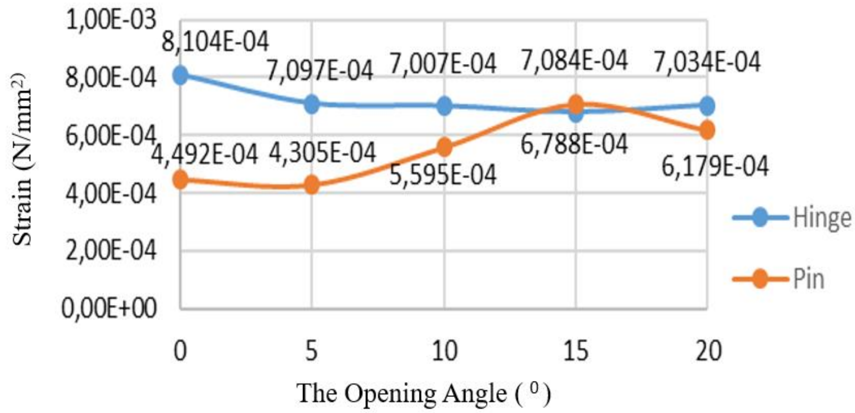
Figure 7. Maximum exchange of shear stress on XY directions.

4.1.5 Von-Mises Strain

The result of Von-Mises Strain was show on Table 8. The largest von-Mises strain occurs at the hinge of the 0° opening angle, precisely in the hinge starboard part of the hole where the hinge pin is attached with a strain value of 8.104×10^{-4}. The biggest change in von-Mises strain occurred when the hinge pin position was opened at an angle of 5° to an angle of 10° with a percentage change in strain of 29.97%. The graph of the maximum von-Mises strain can be seen in Figure 8. Overall, the hinge operates to open and close the barge starting from the barge opening angle of 0° to the opening angle of 20°, the hinge experiences a decrease in the von-Mises strain by 13.20% and the pin hinge experienced an increase in von-Mises strain by 37.56%.

Table 8. Maximum Von-Mises strain.

No.	Analysis	Maximum Von-Mises Strain (N/mm^2)			
		Value	Location	Value	Location
1.	*Hinge* and *Pin hinge* 0°	$8{,}104 \times 10^{-4}$	Hinge SB	$4{,}492 \times 10^{-4}$	Pin
2.	*Hinge* and *Pin hinge* 5°	$7{,}097 \times 10^{-4}$	Hinge SB	$4{,}305 \times 10^{-4}$	Pin
3.	*Hinge* and *Pin hinge* 10°	$7{,}007 \times 10^{-4}$	Hinge SB	$5{,}595 \times 10^{-4}$	Pin
4.	*Hinge* and *Pin hinge* 15°	$6{,}788 \times 10^{-4}$	Hinge SB	$7{,}084 \times 10^{-4}$	Pin
5.	*Hinge* and *Pin hinge* 20°	$7{,}034 \times 10^{-4}$	Hinge SB	$6{,}179 \times 10^{-4}$	Pin



Gambar 8. The change of maximum Von-Mises strain.

4.1.6 Total Deformation

The result of total deformation was show in Table 9. Based on Table 9, the largest total deformation occurs at the hinge of the 0° opening angle, precisely at the hinge portside with a total deformation value of 0.703 mm. The biggest change in total deformation occurs when the pin hinge position at an angle of 15° opens up to an angle of 20° with a percentage change in deformation of -16.44%. The graph of the maximum total deformation can be seen in Figure 9. Overall, the hinge operates to open and close the barge starting from the barge opening angle of 0° to the opening angle of 20°, the hinge has decreased the deformation value by 1.79% and the pin hinge is 44.29 %.

Table 9. Total deformation.

No.	Analysis	Total Deformation (mm)			
		Value	Location	Value	Location
1.	*Hinge* and *Pin hinge* 0°	0,703	Hinge PS	0,219	Pin
2.	*Hinge* and *Pin hinge* 5°	0,699	Hinge PS	0,194	Pin
3.	*Hinge* and *Pin hinge* 10°	0,701	Hinge PS	0,169	Pin
4.	*Hinge* and *Pin hinge* 15°	0,701	Hinge PS	0,146	Pin
5.	*Hinge* and *Pin hinge* 20°	0,691	Hinge PS	0,122	Pin

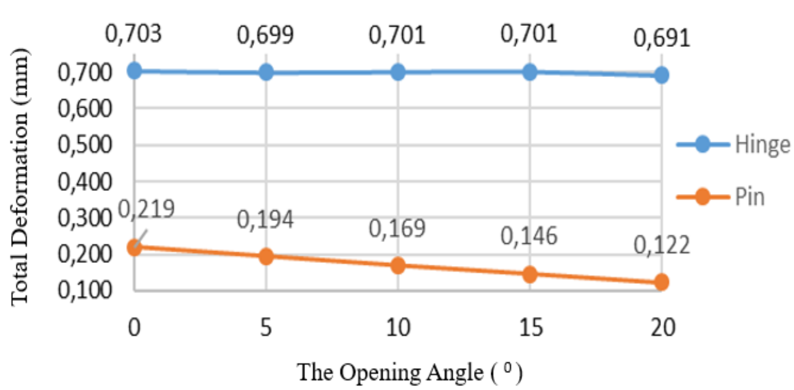


Figure 9. The change of total deformation.

4. Conclusion

The results of the analysis of the strength of the hinge and pin hinge by using software Ansys may shows the maximum stress and strain values when the hinge & pin hinge operated. The maximum shear stress of 83,659 MPa occurs at an opening angle of 20°, a maximum von Mises stress of 161.97 MPa occurs at an opening angle of 0°, and the maximum normal stress in the X-axis direction is 147.36 MPa (10° angle), the Y-axis direction of 98.208 MPa (20° angle), and the direction of the Z axis of 108.68 MPa (15° angle). All of these values still meet the maximum stress requirements issued by class BV.

The maximum shear strain that occurs is 1.036 x 10-3 at an opening angle of 20° and the maximum von-Mises strain is 8.104 x 10-4 at an opening angle of 0°. The maximum deformation of 0.703 mm occurs at an opening angle of 0°. The total deformation that occurs is -1.79% for the hinge and -44.29% for the hinge pin.

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