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Study of the Effect Launching System using Airbags on the Hull Structures of Pinisi Ship

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ABSTRACT

Using airbags for ship launching is a technological innovation with promising implications for the shipbuilding industry. Considering the inefficiency and time consumption of the traditional Pinisi ship launching method, an airbags system is considered an alternative technology. This research involves a simulation of applying airbag technology for ship launch on the Pinisi Ship to assess stress concentration and magnitude. The Pinisi ship, airbags, and skates are designed in three dimensions on a real-size scale for analysis and then analysed using Finite Element Analysis (FEA) in ANSYS software. During the launch, the keel of the ship and airbags were subjected to a compressive force with a 3-millisecond analysis time. The stress and stress concentration levels in the Pinisi ship's structure vary between using airbags and the traditional launch method during launch. The ship's engine room bulkhead and the bow collision bulkhead structure underwent considerable tensile and compressive stresses in longitudinal and transverse orientations. The average maximum compressive stress and maximum tensile stress that occur in the longitudinal direction of the ship are around 50.2 MPa and 87.3 MPa, respectively. Compared to the maximum compressive stress, which accounts for 36% of the overall maximum stress encountered, the highest tensile stress experienced by the ship's structure is 64%.

1. Introduction

The launch process is considered one of the most significant and critical processes because the process is time-consuming and involves high operating costs, and specific installation times. Furthermore, caution is required during the launch process because even a minor error could result in a catastrophic failure. Nevertheless, no research has been done in the literature that takes the launching method's effectiveness into consideration [1]. The launching activity is carried out using marine airbags ship system that is placed under the ship which will support the entire ship's body to launch from land to sea. This needs to be considered because the process has a very high potential hazard and can result in huge losses. Some of the potential failures can be in the form of

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overturning the ship during the launching process, bursting the airbag that supports the ship so that the body bottom (base of the hull) of the ship collides with the runway (slipway), and also the breakage of the ship's fastening sling, which can cause the ship to slide without control and hit the ship or other objects around it [2].

Until now, research on ship launching using airbags is still lacking, so scientific information about it is very minimal. Some of the obstacles that exist in field practice include the difficulty of predicting the behaviour of ships when launched with airbags, the difficulty of investigating the critical conditions of ship launching, and the unavailability of safety operational guidelines. The advantages of using airbags based on the results of the study concluded that there was a reduction in man-hours of about 41% compared to the slipway, while the investment cost is 37% lower than the slipway. From previous studies the results of the man-hour analysis, it was found that the increase in productivity occurred by 69% in the use of airbags for docking and undocking activities [3]. Launching a ship using airbags has a large potential risk of ship damage due to ship launch failure. So, it is necessary to analyse the risk of ship damage in the launching process with the airbag method. This works to ascertain the proper calculating procedure, potential hazards, and preventive advice to minimize or eliminate risks during a ship's launch using the airbag method [4].

In previous studies [5], the traditional launching process of Pinisi ship involves a significant thrust force, which necessitates craftsmen and expensive resources, and it takes three to four weeks. So, it is necessary to apply the appropriate technology, one of the alternatives is launching using airbags. Longitudinal launch systems using airbags (pressurized balloons) can be used in people's shipyards in Bulukumba, with consideration of ship pressure smaller than the airbags permit pressure [6]. The shape of the wooden ship's hull construction is different from the steel ship, with the position of the wooden ship's keel outside the ship's skin so that the ship's pressure is very large for airbags. To minimize the pressure of the wooden ship on the airbags, a sliding shoe is used as a support for the hull and keel bearing on the airbags, as shown in Figure 1. To ensure the safety of the ship and guarantee safety in the launching process, the launching skates need to be designed by looking at the aspects of strength and stability. The length of the launching skate is 10% longer than the length of the keel of the ship and just below the keel of the ship is placed a transverse board that is in direct contact with the airbag. The Pinisi ship launched with airbags is seen in Figure 1 together with the design model of the launching skates.

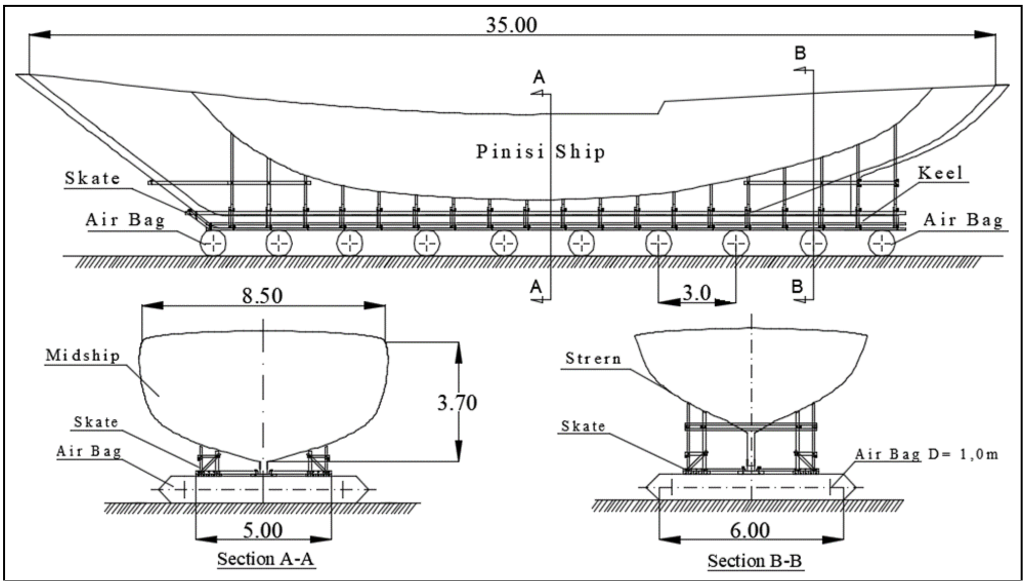


Fig. 1. Pinisi ship launching design using airbags

The part of the glide skate that is in contact with the ship is the glide platform board that contacts the keel of the ship and the bending beam (support) that contacts the left and right hulls of the ship. Just below the keel of the ship, there is a transversely arranged glide platform board which is designed in such a way as not to separate when under pressure from the keel. Bending beams (supporters) or pressure beams are right on the sides of the ship's hull, total 4 beams to maintain the balance of the ship's body. Under the bending beams, there are longitudinally arranged flexed beams designed to direct contact with the airbags. There is a tie beam between the construction of the gliding platform board, flexed beam, and bending beam that connects and keeps the launching skate structure remains intact and sturdy. Using airbags and launching skates, this research aims to identify the stresses that arise in the Pinisi ship structure during the ship launching process. This is very important to know and predict where the critical location of structural failure is before launching using airbags is applied in the field.

2. Methodology

There are two testing approaches available to design engineers who need to know about a structure's nonlinear behaviour. The first is based on laboratory testing (laboratory tests), and the second is computer-aided representation and modelling (structural modelling) [7]. It is the physical sciences that are necessary to understand the complexities of modern technology, hence it also forms the basis for understanding many practical applications and ideas in other fields of science [8]. Many experiments are carried out to investigate specific structural components and the stability of structures under various loading scenarios and many sectors [9]. The real behaviour of the structure is provided in this way. But it takes a lot of time and money [10]. Although the first option provides results that accurately reflect realistic reality, the applicability of this option is limited to special cases of dimensions and sizes. In addition, there are limited shapes, loading models, and idealized dependency conditions. As for the second option, its application has no limitations and FEA modelling is a valuable tool for simulation [11], but it needs to be carefully considered to ensure accurate and reliable results [12]. The finite element method (FEM) is adept at providing clearer and more precise information, but the time required to produce an exact model is a large amount [13]. However, the reliability of the representation and results depend mainly on the application of nonlinear laws of material structure, the accuracy of building the studied finite element model, and the capabilities of the program used. Finite element modelling is a commonly used engineering research tool due to the complexities that accompany experimental approaches, related facilities, and limitations to achieve reliable data [14]. When evaluating a structure, the Finite Element Analysis (FEA) method has been employed because it can accurately predict the behaviour of structural elements under different kinds of structural loading. The finite element analysis (FEA) method has replaced experimental work as the preferred method of choice for understanding the behaviour of concrete elements since it is faster and less expensive [10].

Complex structural engineering problems can be solved using ANSYS structural analysis software. It is feasible to automate the solution of structural mechanics problems and parameters to examine several design scenarios using finite element analysis (FEA) technologies. One of the conveniences of using ANSYS is that it's easy to link to other software. As previous studies that reasonable agreement between experimental results and ANSYS can analyse better [15]. With the use of ANSYS structural analysis software, engineers can directly study the behaviour of structures, design them, analyse them, and optimize them [16]. From the previous studies, ANSYS can analyse relatively easy linear to the most difficult nonlinear simulations, numerical methods of Computational Fluid Dynamics (CFD) [17], Computational Heat Transfer (CHT) technique for real working environment [18,19], even for thermal analysis and thermoelectric simulation [20]. ANSYS is a potent collection of engineering simulation programs built on the finite element approach. ANSYS can perform pressure loading resulting in geometry deflection [21], automatically determines suitable load increments and convergence tolerances in nonlinear analysis. Using ANSYS software, the numerical 3D model of the Pinisi Ship is analysed using the Explicit Dynamic sub-analysis method to launch of the airbag system using the Finite Element Method. Explicit dynamics analysis is able to examine complicated structures and changes in body interactions [22], while also allowing the examination of physical changes in elements over shorter time variables (short duration). Large material deformations can be analysed by explicit dynamic analysis when loadings occur [23]. Explicit dynamics analysis can be used to examine intricate ship structures and dynamic shape changes during ship launch. Both implicit and explicit solutions can be used for dynamic analysis. When the model and time significantly alter, the implicit analysis that was done implicitly becomes unstable, and the problem can be solved with explicit dynamic analysis [24]. The following equation represents the fundamental structural analysis equation that explains the original structure's response:

$$\boxed{[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{F(t)\}} \tag{1}$$

Where F is the external force vector concerning time t, K is the stiffness matrix (N/m), C is the damping matrix (N s/m), and M is the mass matrix (Kg). The Courant-Friedrichs-Lewy (CFL) condition equation is used to limit the time step size to guarantee the stability of the Explicit Dynamics analysis [25]. By estimating the result in the first step and using that estimate to calculate the result in the next, the small-time step keeps the analysis stable. This process is repeated until the last step's last solution [26]. To put it simply, it is represented by the following equation:

$$\Delta t \le f * \boxed{\left[\frac{\mathrm{h}}{\mathrm{c}}\right]_{\mathrm{min}}} \quad \text{where, } c = \boxed{\sqrt{\frac{\mathrm{E}}{\rho}}} \tag{2}$$

Where in this case, h is the characteristic size of a finite element (m), c is the material wave speed (m/s), E is Young's modulus value (Pa), ρ is the material specific gravity (kg/m3), f is the safety factor (f ≤ 1) and Δt is the time step size (s). Since the equation implies that the analysis time step should be smaller than the time it takes for a stress-strain wave to pass through the smallest element of a discrete mesh, the dynamic analysis time step is dictated by the wave compression velocity c [27].

In the steps of completing this research, a research stage is made in the form of an analytical framework that describes the sequence of work and the planned results in completing the research as a whole as shown in the flow chart Figure 2. This research begins with a review of the literature on ship launching and collecting ship data as a research sample, then designing the shape and size of the launch shoe for the launch of the Pinisi ship using airbags. Based on the design data from the Construction Plan, General Design of the Pinisi ship, airbags specifications, and gliding shoe design, solid 3D design data is then made which becomes the object of analysis.

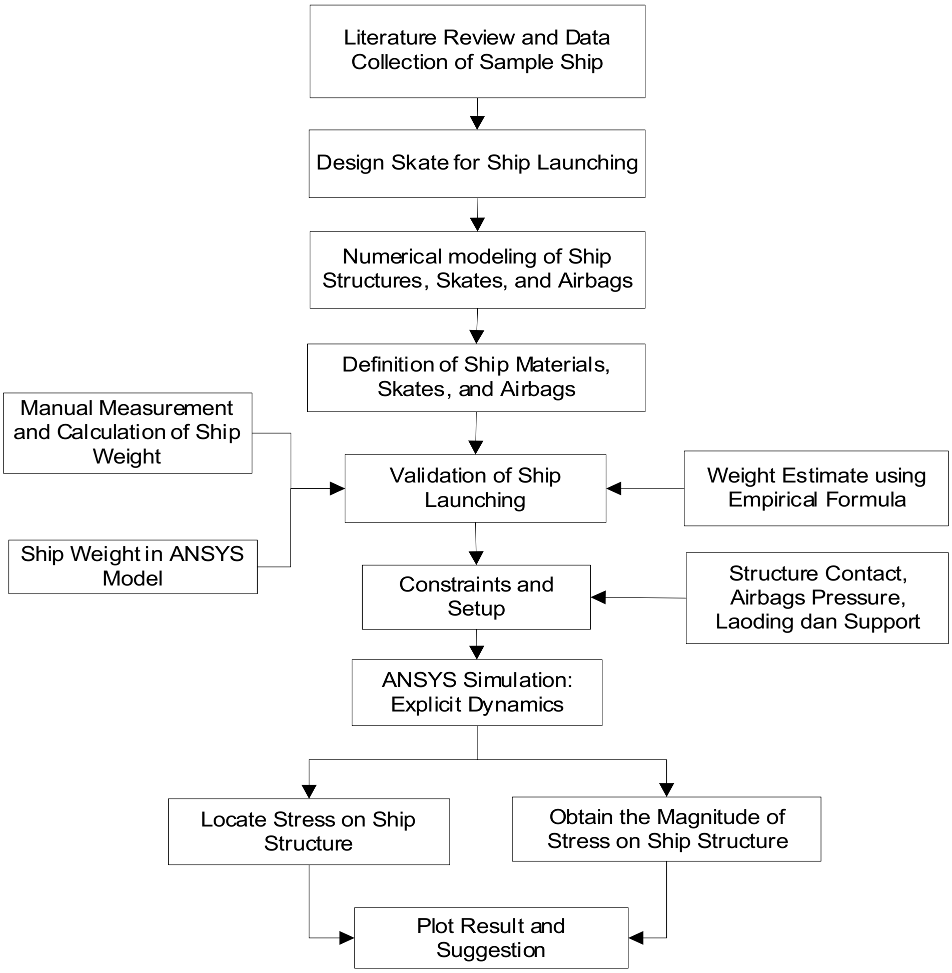


Fig. 2. The flowchart of research method

2.1 Dimension of Structure

The Indonesian people's historic cultural heritage, the Pinisi ship, defines their identity as a maritime nation. Pinisi ships are constructed by skilled shipwrights without the use of contemporary machinery [28]. The Pinisi ship sampled in this study is the Lambo-type Pinisi with a deck length of 35 meters, the main size of the Pinisi ship can be seen in Table 1.

Table 1
Pinisi primary dimension

Dimension	Dimension	nit
Deck Length (L)	35,00	
Keel Length	25,85	
Beam (B)	8,50	
High of Beam (H)	3,70	
Draught (T)	2,70	
Ship Displacement	332	on

Pinisi ship was constructed at the People's Shipyard in Tanah Beru (Bulukumba, Indonesia) with the weight of the ship when launch process of 99.29 tons is the weight of the overall construction of the ship that has been completed. The block coefficient of the Pinisi ship is 0.35, which identifies the slim shape of the hull that needs to use launching skates in order to sit stably on the airbags in the launch system. The proportion of the real-size three-dimensional Pinisi ship's structure and construction varies according to the field conditions during the conventional launching procedure. 90% of the hull's primary structure should be finished when the ship is launched, and the area beneath the waterline has been finished. The accommodation rooms beneath the deck, the auxiliary engine, the main engine, the plumbing system, and the electrical system are all still not installed, and the engine room is still vacant. To find the suitability of the ship model geometry size with the actual size in the field, model validation is carried out by comparing the calculation and estimation of the ship's weight. The Pinisi ship weighs a total of 99.33 tons determined by manual calculation and measurement of the ship's weight, the estimated calculation of the ship's weight using the empirical formula obtained 92.40 tons [29], and the weight of the ship model in ANSYS is 99.61 tons with a volume of 99.1 m^3, so the percentage of comparison is 0.28%.

2.2 Materials of Structure

Ulin wood often known as iron wood, is used almost exclusively in Pinisi ship building, with the exception of the frame, bulkheads, and interiors. Ulin wood is a form of construction wood that can be used in all areas of the ship, particularly in areas that need longitudinal and transverse strength, according to the Wooden Ship Regulation book. Table 2 displays the material properties of the Pinisi ship hull structure employed in this investigation.

Table 2
Materials in Pinisi ship launching analysis using airbags

Type of Material	Young's Modulus, MPa	Poisson's Ratio	Density, kg/m^3
Steel of Keel	2.0x10^5	0.30	7850
Iron Wood (E25)	25.0x10^3	0.35	1040
Bitti Wood (E13)	12.7x10^3	0.24	740
Jati Wood (E13)	12.5x10^3	0.20	700
Launching Way (Concrete)	12.7x10^3	0.18	2300
Airbag	4.0	0.49	1200

Figure 3 shows the six types of materials used in the analysis of which parts of the structure and construction of the Pinisi ship are used for these materials. Steel plates are used for the keel shoes on Pinisi ships with a 25-meter keel length. These plates are attached up to 60% of the bow height and cover the inside of the propeller bosh where the keel meets the runway. Steel (ASME BPV Code, 1998) is the material used for keel shoes, with a density of 7850 kg/m3 and a Young's Modulus value of 200 GPa, and a Poisson ratio of 0.30 [30]. The ironwood is very strong and durable, which is categorized as class I strong and class I durable wood, with a density of 1.04 kg/m^3 [31]. Ulin wood is resistant to termites and stem-boring insects, as well as resistant to changes in humidity and temperature, and resistant to sea water. It is very difficult to nail and saw, but easy to split [32]. Ironwood has an average compressive and tensile strength of 26.69 MPa [33], so that in the design specifications for wood construction can be categorized with E25 quality code wood. As from the test results that have been carried out, the average Poisson's Ratio value of ironwood is 0.35 [34].

The next material used in Pinisi hull construction is teak wood (Tectona grandis). Teak wood is a wood that is included in class I and II durable wood, and is categorized as class II strong wood [35]. In the construction of wooden ships, teak wood can be used for all parts of ship construction, and in this Pinisi ship research object, the bulkhead walls use teak wood. Teak wood has a Poisson's Ratio value of 0.20 [36], and has a specific gravity of 0.7 and an elastic modulus (MOE) value of around 12.5 MPa [31] so that in the design specifications for wood construction can be categorized as E13 quality code wood [37], as shown in more detail in Table 2. Bitti wood by the people of Bulukumba known as *na'nasa* has long been used as one of the materials for making Pinisi ships. The main reason for using bitti wood in Pinisi shipbuilding is because bitti wood is durable against wood destroying insects and durable when exposed to sea water [38]. Bitti wood (vitex cofassus) also referred to locally as *sassuwar, gofasa, bitum, gupasa,* and *bana*, is used to make the frames of Pinisi ships [39]. According to test results previous studies, bitti wood has a Poisson's ratio value of 0.35 and a density of 1.04 kg/m^3 [40], which has the same characteristic value as ironwood.

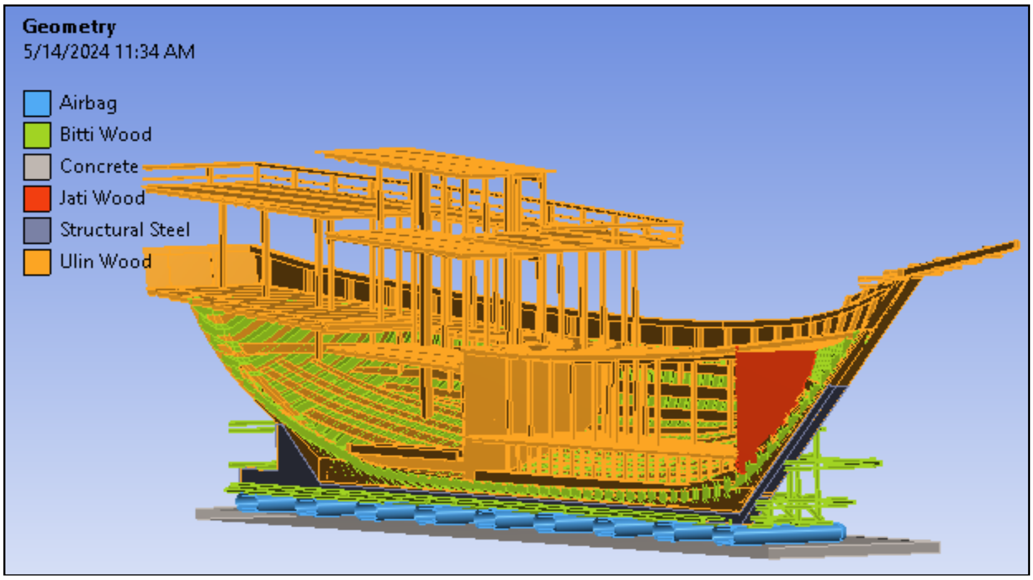


Fig. 3. Geometry of Pinisi ship with materials type

One of the most significant characteristics of wood is its specific gravity, which has a close relationship with the majority of its mechanical characteristics [41]. In this study, the Poisson's ratio value of bitti wood used was the same as pine wood, because the specific gravity value of bitti wood was almost the same as pine wood. The average specific gravity of spruce wood is 0.75 kg/m3 and based on the test results it was found that the Poisson's ratio value ranged from 0.2-0.24 [42]. In several references that are widely used in the construction of wooden ships, bitti wood is a class II durable and strong wood with an average density of 0.74 kg/m3 which certainly has a Poisson's ratio value according to its density value. Bitti wood has an elastic modulus (MOE) value of around 12.7 MPa [31], so that in the design specifications for wood construction can be categorized with E13 quality code wood. The addition of material data in the launch analysis using airbags is airbag material and the concrete used as a launching pad. Marine airbags or glide balloons, are typically made of rubber material such as vehicle tires in general so that the density for rubber is 1200 Kg/m^3 with a Young's Modulus value of 4.0 MPa [43], and the Poisson's ratio value for rubber material is 0.499 [44]. The launching way is used as a fixed support which is assumed to be able to withstand the launch load so that the analysis uses Concrete material, with a density of 2300 Kg/m^3, with Young's Modulus value of 30,000 MPa and a Poisson's ratio value for rubber material of 0.18 [45], and has a tensile strength of 3.90 MPa [46] as shown in Table 2.

2.3 Constraints

The stages of analysis of the launching of the Pinisi ship with an airbags system are the same as the stages of analysis in ANSYS Workbench with Explicit Dynamic analysis which has six stages, namely Engineering Data, Geometry, Model, Setup, Solution, and final results in Results. In the Engineering Data and Geometry stages, the model uses material data as shown in Table 2 and the display is as shown in Figure 3. The distinction lies in how the analysis stages are built up in the Model stage, where it's important to specify how the ship's construction, skates, airbags, and launch path interact. Figure 4 shows the definition of launch contact using airbags at the sub-Model stage in defining the contact between the constructions on the structure specified in the Contacts bar.

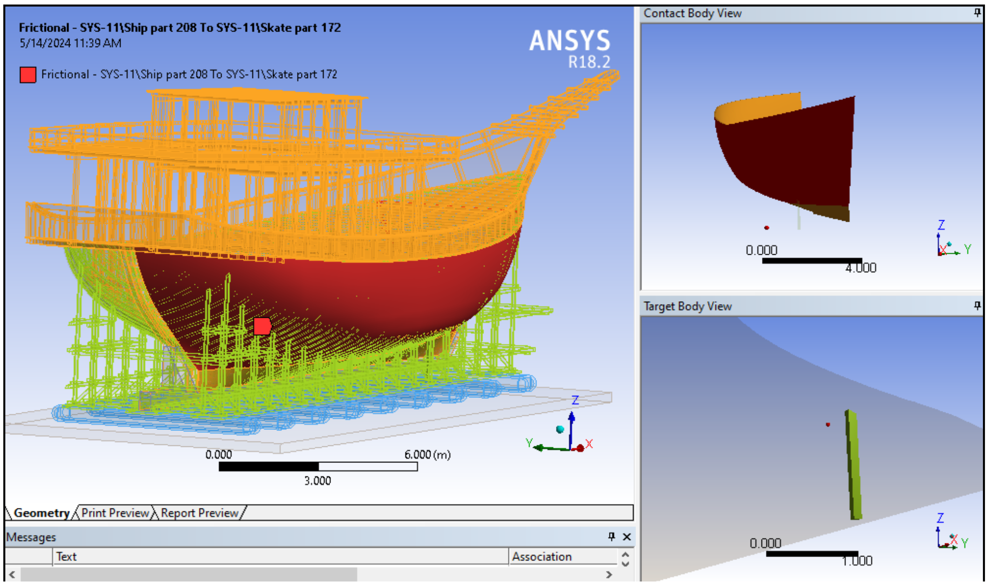


Fig. 4. Process of determining contact type

If the surfaces of two objects touch so that they are tangent to each other, the objects are said to be in contact. In this model analysis there are 3950 contacts in the structure, where the contact on the ship structure is defined as Bonded type contact and the contact between the ship, launch shoes, airbags, and launch pad is defined by frictional contact with coefficient values according to the material in contact. The friction coefficient (μ) between the launch pad beam and the keel material is 0.4 [47], indicating that the contact between the keel and the pad is defined as a frictional contact in the analytical process, where the touching elements encounter friction. The contact between the hull and the sliding shoe is a wood-to-wood contact with a friction coefficient of 0.55 [48]. The contact between skates, airbags, and the launching way is a rolling friction coefficient with a coefficient value of 0.012 [49]. As shown in Figure 4, the process of defining contacts in the analysis of the traditional launching process of the Pinisi ship, where there are 77 frictional contacts between the ship and the launching skates, 27 frictional contacts between the launching skates and airbags, and 9 frictional contacts between the airbags and the launching way and other contacts are Bonded contacts.

At the Model stage namely at the Mesh sub-stage, where Meshing is the process of dividing the components to be analysed into small or discrete elements. The smaller the mesh size, the higher the convergence rate and the accuracy of the analysis results. The curvature type mesh (discretization) with fine size (maximum face 0.67 m) and gradual transition (scale growth rate 1.2) is the type of mesh that was chosen, as demonstrated in Figure 5, which displays the output of the ANSYS software's meshing process and includes 62332 Nodes and 98597 Elements. In the setup configuration, the Global Coordinate System is used to apply the Standard Earth Gravity of 9.8 m/s^2 to both the ship and the runway. During the ship launching procedure, all translational and rotational movements are restricted by the longitudinal launching path.

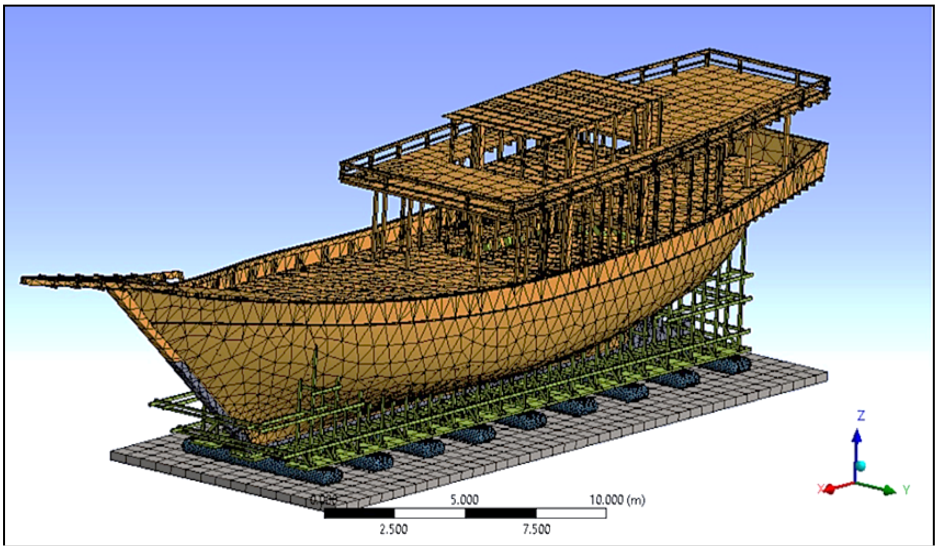
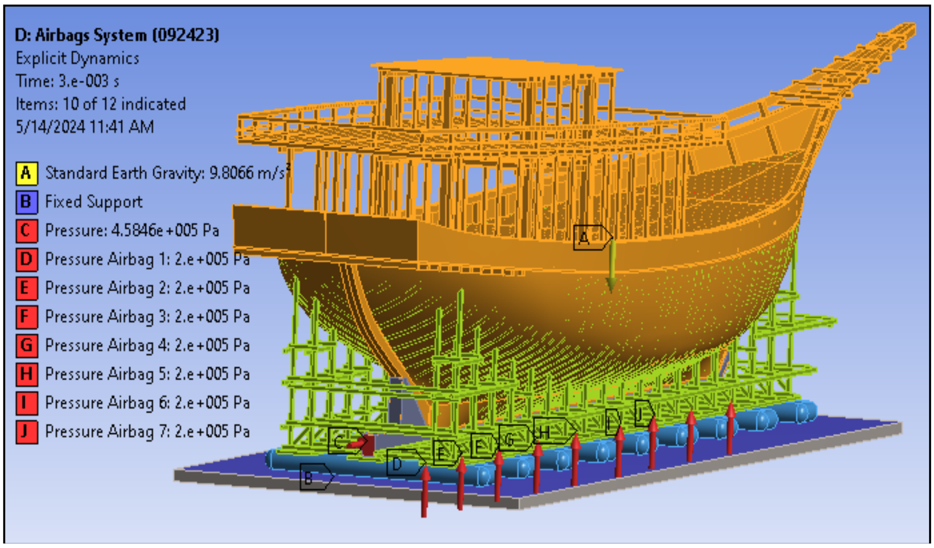


Fig. 5. Result of discretization of ship launching using airbags

As shown in Figure 6 is a display of labels, values, and force directions based on the settings that have been given. The compressive force (pressure) applied is 0.458 MPa, the same as previous studies the compressive force applied to Bulukumba conventional launch pulley [5]. The applied pressure force and pressure position are the same in the traditional launching process to compare the effects on the ship structure. There are 9 airbags with a diameter of 1 meter between the launching way and skates, where each balloon has a compressive force of 0.20 MPa according to the selected airbag specification [50]. The airbags have a lift capability of 157 KN/m or 6 Ton/m with a height that can be lifted by 0.5 meters from the initial height.



D: Airbags System (092423)
Explicit Dynamics
Time: 3.e-003 s
Items: 10 of 12 indicated
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A Standard Earth Gravity: 9.8066 m/s^2
B Fixed Support
C Pressure: 4.5846e+005 Pa
D Pressure Airbag 1: 2.e+005 Pa
E Pressure Airbag 2: 2.e+005 Pa
F Pressure Airbag 3: 2.e+005 Pa
G Pressure Airbag 4: 2.e+005 Pa
H Pressure Airbag 5: 2.e+005 Pa
I Pressure Airbag 6: 2.e+005 Pa
J Pressure Airbag 7: 2.e+005 Pa

Fig. 6. Complete Setup including pre-analyst and boundary conditions

Because of fatigue, stress conditions, material flaws, and inter-construction joints, ship constructions are prone to cracking. The majority of studies concentrate on the development or expansion of fractures from a fatigue perspective. However, harm itself could occur during the construction stage, following fabrication, and during the launching process, and not all of it can be found and fixed [51]. As a result, this simulation provides a general overview of the ship's structural components that could sustain damage when launching a Pinisi ship with airbags.

3. Results and Discussion

The result of data modelling of Pinisi ships, including launching skates, airbags, and analytical boundaries is axial stress on the x (longitudinal) and y (transverse) axes of the ship that occurs during the launching process. There are differences in the amount of stress and stress concentration in the structure of the Pinisi ship at launch using airbags compared to the traditional launch of the Pinisi ship, where the traditional launching of a Pinisi ship was found to concentrate stresses in the bow structure from the previous studies [5]. In the launching of a Pinisi ship using airbags, obtained the Pinisi ship's bow and midship structures suffer tensile and compressive stress as a result of the thrust force and pressure distribution during launch. It can be seen that the launch shoe structure can support the ship on airbags with stresses not exceeding the design compressive and tensile strength of the material used, as shown in Figures 7 and 8 which show the results of the ship launching analysis using airbags.

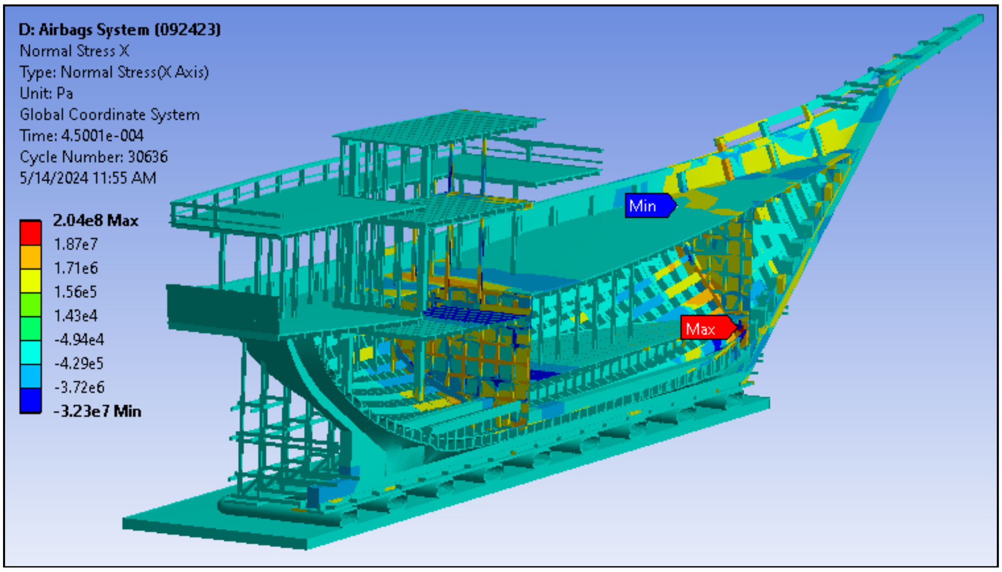

Fig. 7. Stress in the longitudinal axis of ship

3.1 Axial Stresses in Ship Structures

The construction of the bow bulkhead, engine room bulkhead, bow deck structure, bow bulwark construction, and stringers in contact with the bulkhead are all stressed during the longitudinal launch of a Pinisi ship utilizing airbags and launching skates. As illustrated in Figure 7, the bow impact bulkhead construction in contact with the frame and main deck has the highest compressive stress is 134 MPa, and the bow impact bulkhead construction in contact with the keel and stringer has the highest tensile stress with value 204 MPa, surpassing the ultimate stress of Ulin wood is 140 MPa [31]. The engine room bulkhead, bow bulkhead, bow structure, stringer on the bow, and bow bar of a Pinisi ship are all under stress during the transverse launch process when employing airbags and launching skates. As shown in Figure 8, the engine room bulkhead stiffener construction in contact with the frame and stringer exhibits the largest tensile stress, with a maximum compressive stress value of 82.4 MPa. The greatest compressive stress of 81.9 MPa is experienced by the bulkhead construction of the bow collision when it comes into contact with the frame and inner keel. However, the forces experienced in shipbuilding are lower than those allowed by the type of wood used.

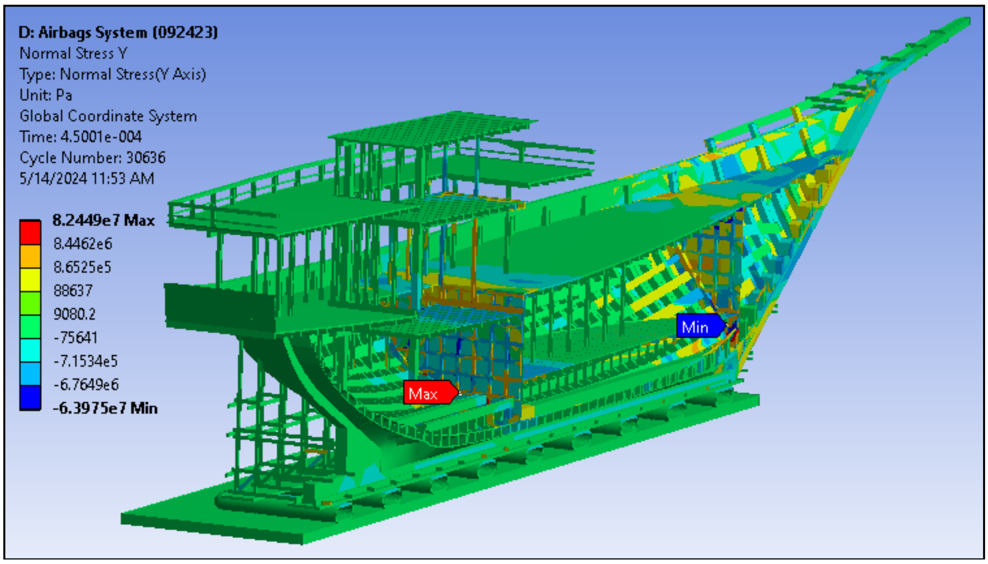

Fig. 8. Stress in the transverse axis of the ship

The graph of the relationship between tensile stress (Pa) and time (s) analysis that takes place in the ship structure during the airbag and skate launching procedure is displayed in Figure 9. The average maximum compressive stress and maximum tensile stress that occur in the longitudinal direction of the ship are around 50.2 MPa and 87.3 MPa, respectively. In this case, the greatest compressive stress roughly 36% of the overall maximum stress is less than the maximum tensile stress roughly 64% suffered by the ship construction. Tensile stress and compressive stress trendline graphs tend to decrease in the longitudinal direction of the ship, as can be seen from the relationship between tensile stress (Pa) and time (s) analysis. This is because the structure under tensile stress is trying to dampen the stress or vibration into a stationary or stable condition. During the first second of ship launch is when the largest compressive and tensile stresses occur, and they continue to decrease until the very last second of launch.

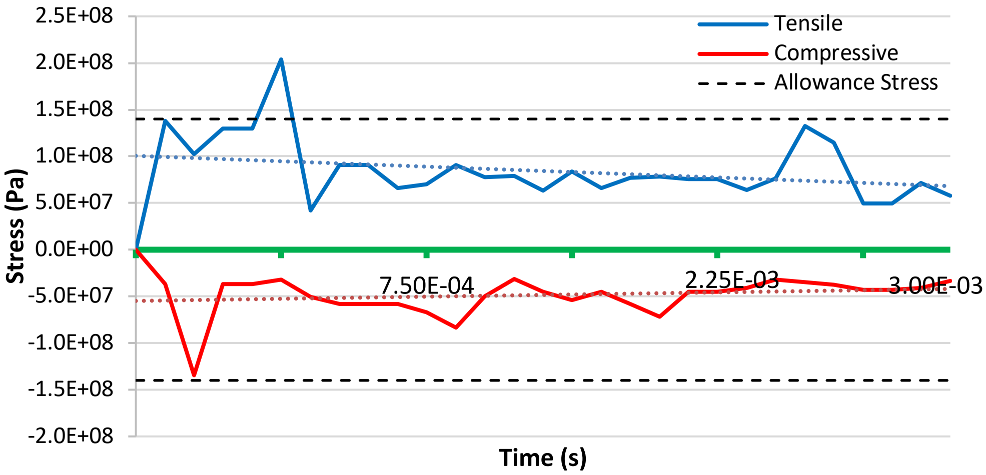

Fig. 9. Maximum stress-time graph of ship longitudinal direction

3.2 Shear stresses in ship structures

A Pinisi ship equipped with an airbag system experiences shear stress in its structure in addition to axial stress during launch. When an external force is parallel to the cross-sectional area and has the potential to displace or split the material into two portions in opposite directions, shear stress is an internal stress that the material mobilizes to resist the action of the force. Along with the axial stresses discussed before, the shear stresses also have an impact on the structure of the ship's engine room bulkhead and bow bulkhead. The longitudinal shear stress (xy plane) in the Pinisi ship structure as a result of the airbag-assisted ship launching mechanism is displayed in Figure 10. As illustrated in Figure 10, the engine room bulkhead stiffener and the bow impact bulkhead, which meet the bottom stringer and frame construction, have the highest tensile-compressive shear stress, with a maximum tensile stress value of 275 MPa and a maximum compressive stress of 150 MPa. Significant strains are placed on the main deck structure, the galar structure located in the midship section, the bulkhead stiffener structure, and the bow structure.

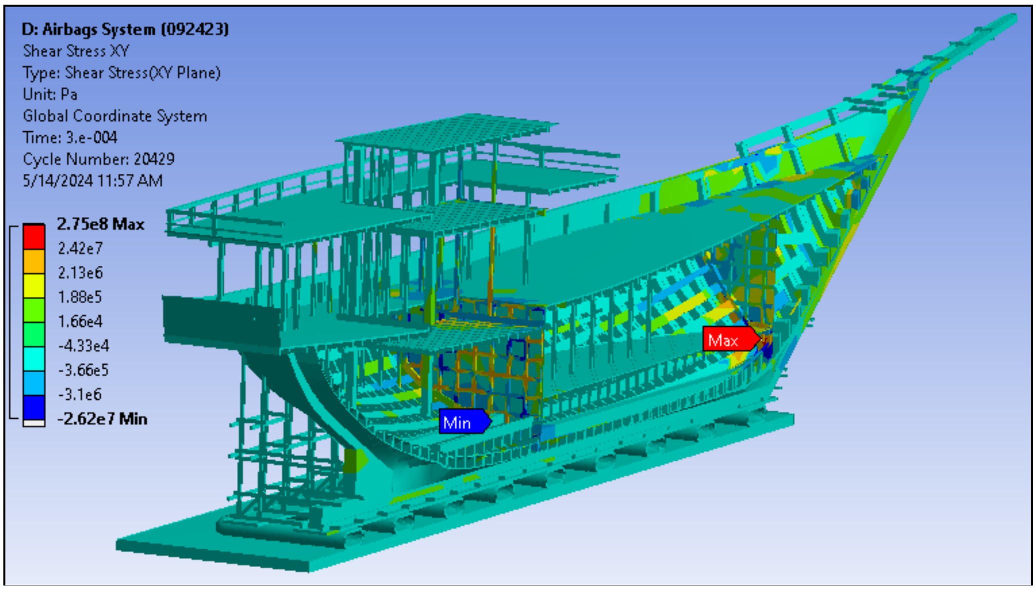

Fig. 10. Shear stress in the longitudinal direction of the ship structure

The graph showing the relationship between compressive and tensile shear stress (Pa) and time (s) analysis that is performed in the ship structure during the launching process employing skates and airbags is displayed in Figure 11. The average maximum compressive shear stress and maximum tensile shear stress that occur in the longitudinal direction of the ship are around 42.1 and 54.7 MPa, respectively. In cases where the highest compressive shear stress experienced by the ship structure accounts for a higher percentage of the total maximum shear stress, approximately 57%, than the maximum tensile stress, approximately 43%. The trendline graph of tensile shear stress and compressive shear stress tends to decrease, as can be seen from the relationship between tensile-pressure stress (Pa) and time (s) analysis in the longitudinal direction of the ship. This is because the damping in the ship structure experiences tensile-pressure shear stress, and is attempting to dissipate the stress into a stationary or stable condition. The first second of the ship's launch is when the compressive and tensile shear stress is at its highest, and it declines until the very last second of the launch.

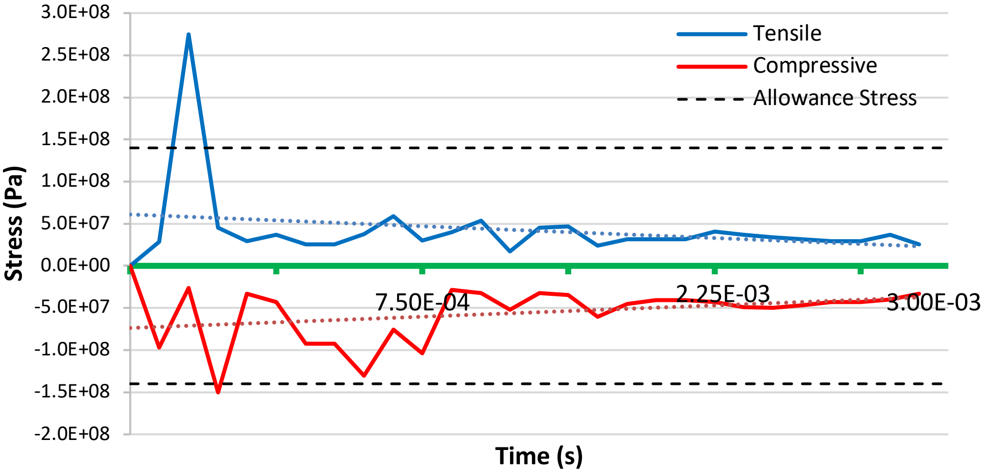

Fig. 11. Maximum shear stress in the ship structures

3.3 Total Deformation and Velocity of the Ship Structure

Deformation is typically a physical change in the shape of a structure due to external or internal forces. However, in contrast to the discussion in this ship launch analysis, it refers to the magnitude of the displacement of the ship's structure in the direction of the thrust vector given. As shown in Figure 12 is the result of an analysis that displays the deformation of the ship's structure during the process of launching the ship using airbags, where in a span of 3 milliseconds, the maximum change or displacement of the ship's structure is 12.89 mm in the direction of the bow of the ship (x-axis). Where the maximum deformation that occurs in the ship's structure is in the construction of the engine room bulkhead, some of the construction of the bow bulkhead stringers, deck construction and bulwarks at the bow of the ship, all side supports of the launch shoes and airbags. Maximum deformation also occurs in the skate structure with the direction of deformation in the Z and Y axes following the force vector applied in launching process.

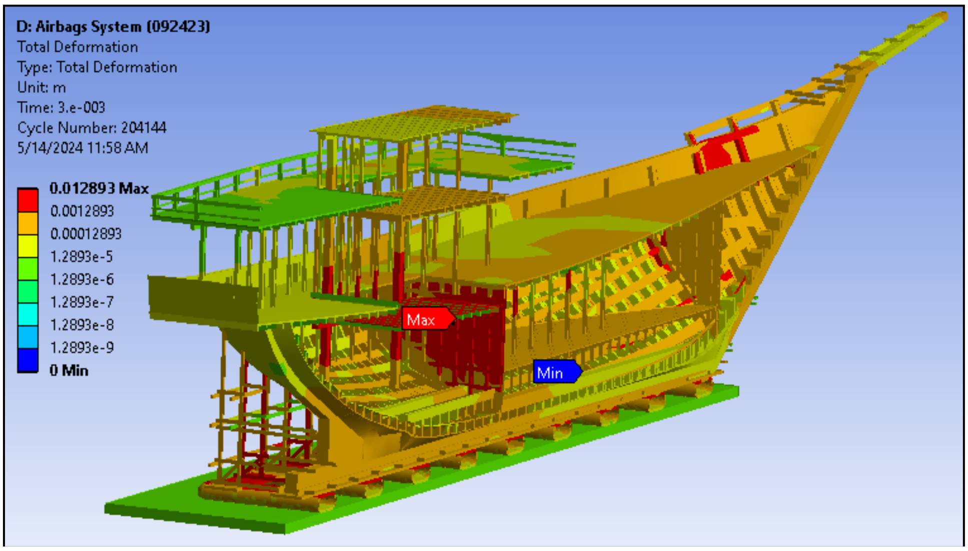

Fig. 12. Total deformation of the ship structure

Velocity is the distance travelled per unit time by an object, where in the process of launching a ship the definition of speed is the amount of displacement or deformation that happen in the ship's structure over the travel time, caused by a compressive force or thrust force. Figure 14 displays the total velocity that occurs on the ship structure during the launch process, with an analysis time of 3 milliseconds. The total velocity of movement of the ship's structure occurs in the construction of the bow bulkhead and engine room bulkhead, which is the part that experiences maximum stress. The velocity of the bulkhead construction was 56.7 m/s at the initial second of launch due to a thrust force of 0.458 MPa for 3 milliseconds. Based on the colour degradation seen in Figure 13, it shows that the dominant speed of the ship structure is 0.0056 m/s or 18 m/h, so that using airbags during the process of launching a Pinisi ship with a launch distance of 200 meters at the Bulukumba People's Shipyard takes 11 hours.

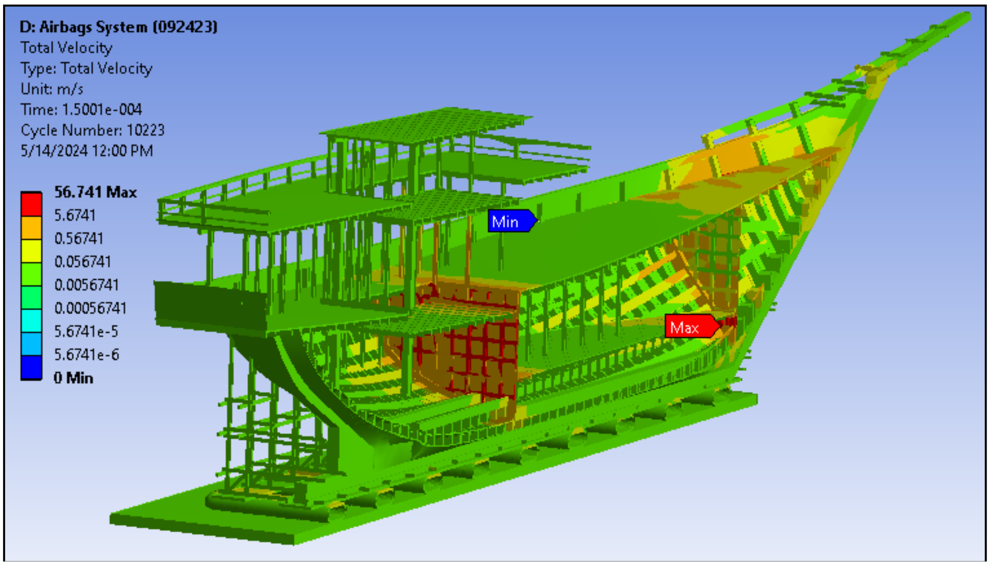

Fig. 13. Total velocity on the ship structure

Figure 14 shows the relationship graph of total deformation (mm) and total velocity (m/s) over time (s) analysis that happen in the ship structure in the process of launching a traditional system ship. Starting from the initial second of launching there is a deformation of 2.02 mm and continues to increase deformation until the final second of launching of 12.89 mm. The velocity of the ship structure experiencing maximum stress is at the initial second of launching, and the velocity decreases during the launching process. As shown in the curve, there is a change in the velocity of the ship structure and a significant change in deformation in the middle of the launch.

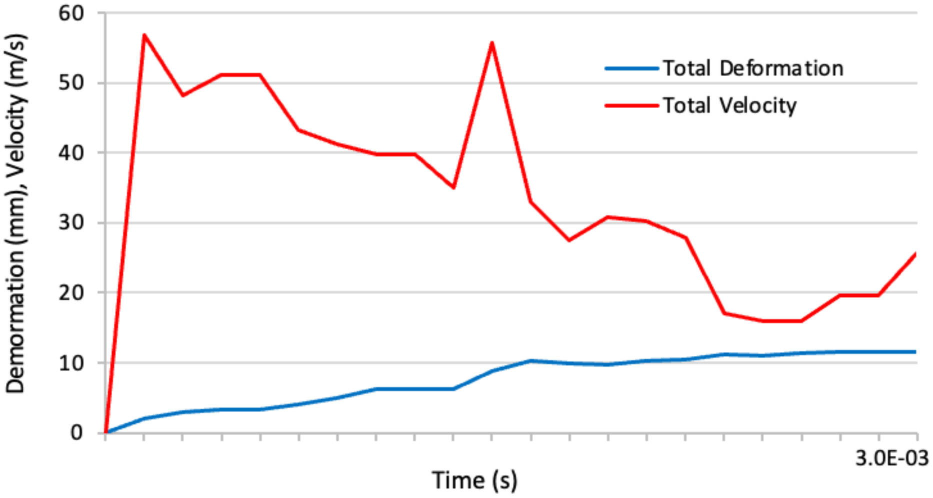

Fig. 14. Total deformation and velocity in the launching process

4. Conclusions

This study presents a three-dimensional finite element model of a Pinisi ship that utilizes airbags for launching is presented here. The study focuses on the concentrations of stress and the magnitude of stress that the ship structure experiences during the Pinisi ship launch with airbags. It has been determined that the largest stress concentration is located in the bow bulkhead construction and the engine room bulkhead construction at midship. There are differences in the amount of stress and stress concentration in the structure of the Pinisi ship during launch when using airbags compared to the traditional launch method of the Pinisi ship. The initial stress suffered by the ship's structure exceeds the allowable stress of the material used during the application of launching a Pinisi ship using airbags. Additional investigation is required to determine the optimal size of bulkhead construction or the potential inclusion of special reinforcements to strengthen the structure in the area of the ship that is subjected to the greatest amount of stress.

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