Chapter

Finite Element Method for Ship Composite-Based on Aluminum

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Abstract

The structure and construction of ships made of aluminum alloy, generally of the type of wrought aluminum alloy, when experiencing fatigue failure caused by cracking of the ship structure, is a serious problem. Judging from the 'weaknesses' of aluminum material for ships, this chapter will explain the use of alternative materials for ship building, namely aluminum-based composite material which is an aluminum alloy AlSi10Mg (b) ship building material based on the European Nation (EN) Aluminum Casting (AC) - 43,100, with silicon carbide (SiC) reinforcement which has been treated with an optimum composition of 15%, so that the composite material is written with EN AC-43100 (AlSi10Mg (b) + SiC * / 15p. Composite ship model using ANSYS (ANalysis SYStem) software to determine the distribution of stress. The overall result of the voltage distribution has a value that does not exceed the allowable stress (sigma 0.2) and has a factor of safety above the minimum allowable limit, so it is safe to use. The reduction in plate thickness on the EN AC-43100 (AlSi10Mg (b)) + SiC * /15p composite vessel is significant enough to reduce the ship's weight, so it will increase the speed of the ship.

Keywords: ship composite based on aluminum, EN AC-43100 (AlSi10Mg (b) + SiC*/15p, software ANSYS, stress distribution

1. Introduction

The choice of material for ship building is carried out with several considerations, including physical properties, mechanical properties, material prices, and labor skills needed for the production process. Based on the material used to build ships, in fact it can be divided into two major parts, namely (a) steel ships and (b) non-steel ships. Non-steel ship materials include aluminum alloys which have been developing for more than 30 years and have replaced steel, namely in the use of commercial ships and on surface warships, especially for the deck and superstructure [1]. Even in Indonesia, on 18 December 2008, the Indonesian Navy (AL) launched its first warship (KRI), named KRI Krait-827 made of aluminum, with a speed of 25 knots. This warship is lighter than ships made of iron/steel (Jawa Pos, Desember 2008). The purpose of using aluminum/aluminum alloy is due to the density and modulus of aluminum 1/3 of the steel, thus significantly reducing the overall weight of the ship. The use of aluminum has become an alternative material used as a hull material in ship construction. Almost all of them use wrought aluminum with aluminum of marine grade: main alloy part magnesium (Mg) (alloys of marine grade), marine grade aluminum 5052 (used only for above water), marine grade a luminum 5083 (used for underwater hulls), marine grade aluminum 5086, and marine grade structure of aluminum 6061.

However, the structure of a ship made of aluminum alloy, if it experiences fatigue failure caused by cracks in the ship's structure, it is a serious problem. Cracking itself is usually caused by a combination of rotational stress (torque) and stress concentration interacting with areas of the weak material [2]. The rate of structural cracking in aluminum is 30 times faster than the crack rate in steel when tested at the same stress with the same crack size [3]. On the other hand, the wear resistance on aluminum is also low [4], because aluminum is classified as a "soft" material compared to other metals.

To 'fix' the aluminum material into a strong and hard material, namely adding/ mixing it with a reinforcing material, which is a research to get a new material, called Composite Material is grouped in Metal Matrix Composite (MMC) [5–7]. If the method of mixing between the matrix and the reinforcement uses the casting method, it is called Metal Matrix Cast Composite (MMCC). Furthermore, if the metal used is aluminum-based, it is called Aluminum Metal Matrix Cast Composite (AMMCC).

Centered on the 'weaknesses' of ship aluminum sheet, this chapter offers an alternative sheet for shipbuilding, namely silicon carbide (SiC) reinforcement composite material based on aluminum. This aluminum alloy is made by casting aluminum alloy. Aluminum casting (AC) alloy is written: AlSi10Mg (b) in accordance with DIN EN (European Nation) 1706 expressed in chemical symbols written as EN AC-AlSi10Mg (b) and expressed in numeric, written EN AC-43100, so that the writing is combined to become EN AC-43100 (AlSi10Mg (b)). Reinforcement is SiC which has been treated with an optimum composition of 15% (written SiC*), so that the composite material is written with EN AC-43100 (AlSi10Mg (b) + SiC*/15p.

From the background above, this chapter will explain about making a numerical model of ships from the composite material EN AC-43100 (AlSi10Mg (b) + SiC */ 15p with the help of ANSYS ver.12.0 software to find out how the stresses are distributed. Wave input given is still water and dynamic waves (induced wave), not wave spectrum. Can be applied therein. From the results, it will be known which part of the ship building, the composite material AlSi10Mg (b) + SiC */15p can be applied therein.

2. Ship composite base on aluminum

2.1 Aluminum alloy EN AC-43100 (AlSi10Mg(b)) as matrix

EN AC43100 (AlSi10Mg(b)) alloy is an alloy of silicon aluminum which cannot be heat treated. It has strong flowability in a liquid state and almost no cracks occur in the freezing process [8]. This alloy is commonly used in the welding of aluminum alloys, both cast and wrought alloys as a welding medium or metal [Bergsma & Kassner, 1996]. The physical and mechanical properties of AlSi10Mg (b) can be seen in **Table 1**.

While the mechanical properties of aluminum casting EN AC-43100 (AlSi10Mg (b)) are summarized in **Table 2**.

2.2 Silicon carbide (SiC) ceramic particles as reinforcement

Silicon Carbide is a chemical compound composed of carbon and silicon alone. Created by electrochemical sand and carbon reactions at high temperature s. Silicon carbide has excellent abrasive properties, and has been developed and

Physical and mechanical properties of aluminum AlSi10Mg (b)	Grade
Density (gr/cm^3)	2703
Crystal lattice	FCC
Melting Temperature (°C)	660,22
Boiling Temperature (°C)	2500
Elasticity modulus (GPa)	70,000
Tensile Strengh (Rm) (MPa)	180
Yield Strength (Rp0,2) (MPa)	90
Elongation crack (%)	2,5
Hardness (Brinnel)	55
Source: MKB-material standards.	

Table 1.
Physical and mechanical properties of aluminum AlSi10Mg (b) (casting material).

manufactured for over a hundred years into grinding wheels and other abrasive goods. High power, low heat expansion, high thermal conductivity, high hardnes, high elasticity modulus, excellent heat shock resistance and superior chemical inertness are the general properties of silicon carbide.In a crystal lattice, silicon carbide with a tetrahedral chemical structure of carbon and silicon atoms has a strong bond which results in a very hard and strong material. Silicon carbide prevents acids or alkaline salts to strike. In air, SiC forms a protective layer of silicon oxide at 1200° C, which can be used up to 1600°C. The high thermal conductivity combined with low thermal expansion and high strength gives this material exceptional resistance to heat shock.

Nowadays, silicon carbide has grown into a high technological quality ceramic with outstanding mechanical properties. Applications are commonly used in abrasive materials, refractories, electrical conductors and have resistance heating, ignition, and electronic component applications. The engineering properties of silicone carbide are shown in **Table 3**.

In fact, numerical modeling of wrought aluminum vessels has never been possible. It existed until recently, because small ships are already set and included. So it is necessary to decide if the material can be used for shipbuilding. Ship composite EN ACAlSi10Mg(b) + SiC*/15p must be numerically rendered Ship Modeling. Analysis of numerical computation using ANSYS software version 12.00 for seeing the stress distribution that occurs does not surpass the stress permits (0.2 sigma with that obtained from the tensile test), and also if it is safe for factor protection. The provided wave input is still induced by water and wave (the quasi-static one).

3. Numerical modeling ship

3.1 Type and sizes ship

Type of composite boats (EN AC-AlSi10Mg (b) + SiC*/15p) to be modeled numerically using software ANSYS version 12.0 is Fast Patrol Boats with length over all (LOA) is 42.0 meters. Ship size is as follows:

Material designation	Alloy description (DIN EN 1706)		Material short symbol	Material number	Material state*	Tensile strength	Yield strength	Elongation at break	Brinell hardness
	chem. Symbol	numeric	(DIN 1725–2)	(DIN 1725–2)		R_m (Mpa)	$R_{p0,2}$ (Mpa)	A_5%	HBS
GK AlSI12	EN AC-Al Si 11	EN AC-44000	G-AlSi11	3.2211	F	170	80	7	45
	EN AC-AlSi 12(b)	EN AC-44100			F	170	80	5	55
	EN AC-AlSi 12 (a)	EN AC-44200	G AlSi12	3.2581	F	170	80	6	55
GK-AlSI1DMg	EN AC-AlSi10Mg(a)	EN AC-43000	G-AlSi10Mg	3.2581	F	180	90	2,5	55
					T6	260	220	1	90
					T64	240	200	2	eo
	EN AC-AlSi10Mg(b)	EN AC-4310			F	180	90	2,5	55
					T6	260	220	1	90
					T64	240	200	2	80
	EN AC-AlSi10Mg(Cu)	EN AC-43200	G-AlSi10Mg(Cu)	3.2383	F	180	90	1	55
					T6	240	200	1	90
GK-AlS19Mg	EN AC-AlSi9Mg	EN-AC-43300	G-AlSi9Mg	3.2373	T6	290	210	4	90
					T64	250	180	6	80
GK-AlS17Mg	EN AC-AlSi7Mg	EN AC-42000			F	170	90	2,5	55
					T6	260	220	1	90
					T64	240	200	2	80
	EN AC-AlSi7Mg0,3	EN AC-42100	G-AlSi7Mg	3.2371	T6	290	210	4	90
					T64	250	180	8	80
	EN AC-AlSiMg0, 6	EN AC-42200			T6	320	240	3	100
					T64	290	210	6	90
GK-AlZn10SI8Mg						220	200	1	90

*****Material state:*** *F: Casting state; T6: Solution annealed and completely temper-hardened; T64: Solution annealed and not completely temper-hardened****Source:*** *Medjunarodna Klasifikacija Bolesti (MKB-material standards) [9].*

Table 2.
Mechanical properties of aluminum casting.

Properties of silicon carbide (SiC)			
Mechanical	**SI/Metric (Imperial)**	**SI/Metric**	**(Imperial)**
Density	gm/cc (lb/ft^3)	3.1	(193.5)
Porosity	% (%)	0	(0)
Color	—	black	—
Flexural Strength	MPa (lb/in^{2}x10^3)	550	(80)
Elastic Modulus	GPa (lb/in^{2}x10^6)	470	(64.5)
Shear Modulus	GPa (lb/in^{2}x10^6)	—	—
Bulk Modulus	GPa (lb/in^{2}x10^6)	—	—
Poisson's Ratio	—	0.14	(0.14)
Compressive Strength	MPa (lb/in^{2}x10^3)	3900	(566)
Hardness	Kg/mm^2	2800	—
Fracture Toughness KIC	MPa•m$^{1/2}$	4.6	—
Maximum Use Temperature (no load)	°C (°F)	1650	(3000)
Thermal			
Thermal Conductivity	W/m•°K (BTU•in/ft^2•hr.•°F)	120	(830)
Coefficient of Thermal	10^{-6}/°C (10^{-6}/°F)	4.0	(2.2)
Expansion			
Specific Heat	J/Kg•°K (Btu/lb.•°F)	750	(0.18)
Source: Silicon Carbide datasheet.			

Table 3.
Technical properties of silicon carbide.

• Length over all (LOA)	= 42,00 m
• Length between perpendiculars (LBP)	= 39,00 m
• Breadth (b)	= 7,00 m
• Height (H)	= 4,00 m
• Draft (T)	= 1,8 m
• Maximum speed	= 24,0 knot
• Crew of ship	= 18 person

Shape hull of Fast Patrol Boat is known as V shaped hull, especially on the front (**Figure 1**). Planning regulations adapted to use the class from the Bureau Classification Indonesia (BKI) [10].

3.2 Ship model making

ANSYS modeling can be done in two ways, namely direct generation and solid modeling. In direct creation, element creation is done directly by defining the nodes required for an element. This method is best used if only a small number of elements are planned. But for complex shipbuilding with a large number of elements, this method was impractical. Whereas in solid modeling, the definition of the model is from the points (keypoint) serving a line. From these lines an area can be made and then the area can be formed by volume.

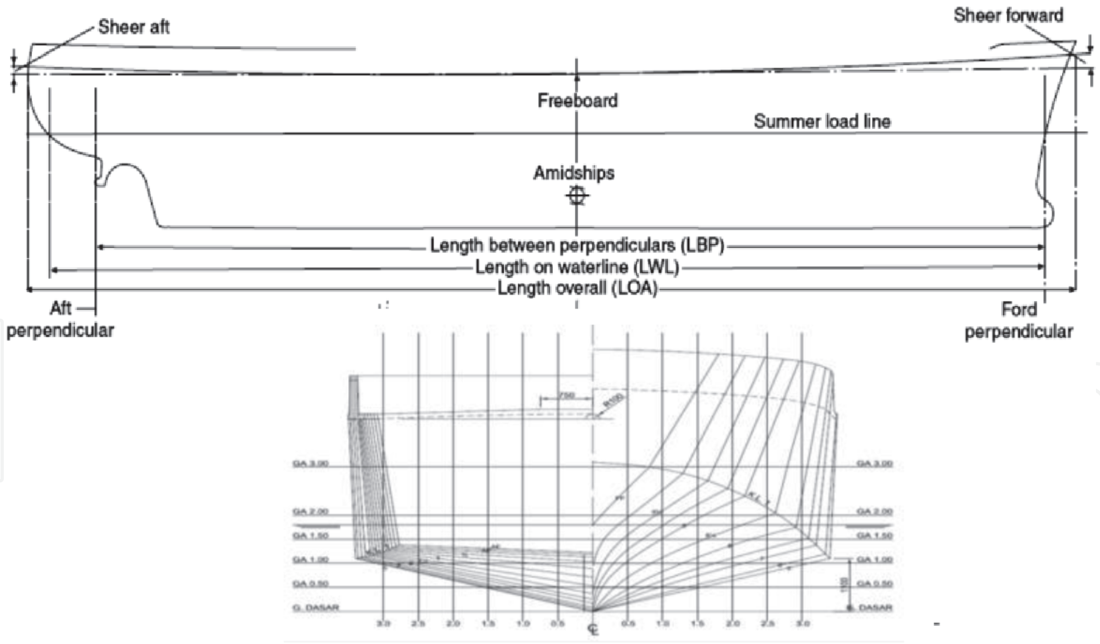

Figure 1.
Ship scheme. Source: (Model Fast Patrol Boat (FPB) 42m).

To make a ship model by means of solid modeling, the first thing to do is redrawing it. In this case, the drawing data obtained from AutoCAD is redrawn in ANSYS. This is done because it is difficult to make repairs if the drawing from AutoCAD is imported directly into ANSYS. In addition, this redrawing is done to avoid the possibility that there are parts that cannot be read in ANSYS during the model import process. Redrawing begins by entering the keypoint coordinates obtained from the AutoCAD drawing. The first keypoint coordinates entered are the lines plan coordinates followed by the accommodation deck coordinates. The keypoint formed is connected to a line. Then from these lines an area is made. So that the area formed consists of keypoints and lines. The area used for plate and line modeling is used for the modeling of the reinforcements (ivory and supports).

From the line plan drawing (station) from AutoCAD which is then converted into a line plan (ivory), the coordinates of the points that form the body plan curve can be obtained. The coordinates of these points are entered into ANSYS as a keypoint. Furthermore, the keypoints are connected into a curve to form an ivory curve (transom to ivory 84). These curves are then linked into areas. The area formed consists of keypoints and lines. Henceforth, the area formed is used for plate modeling and the curved lines forming the area are used as an enforcer (ivory).

After the hull area is formed, it is continued with the construction of the superstructure. Furthermore, from the geometric model formed, an element known as meshing is created. Before the meshing process is carried out, the element size must first be planned. In addition, it must also be determined the type of element and material properties to be used.

3.2.1 Selection and determination of elements

The elements contained in ANSYS can be categorized into 2D (2 dimensional) and or 3D (3 dimensional) element types. ANSYS elements consist of point elements, line elements, area elements, and solid elements. Several LINE elements in ANSYS can be selected according to your needs and analysis to be carried out.

For the modeling of the supports, supports, flanges, ivory, deck beams and other profiles used Beam 189_Quadratic Finite Strain Beam. Beam 189 is an element

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suitable for use in slender structure analysis to slightly thick structures of beams. This element is based on Timoshenko's beam theory [10]. The deformation effect of shear forces is also included. Beam 189 is a quadratic (3-Node) beam element in 3-D space. Beam 189 has six degrees of freedom, consisting of three translations and three rotations. This element is good for linear, large rotational or nonlinear strain applications.

Beam 189 is used for modeling ivory, beam, reinforcement, support, large ivory, flange and pillar because it has the ability to be a beam. In addition, the quadratic form gives more accurate results than the linear form.

3.2.2 3D Shell

The ANSYS element library contains many types of shell elements. As with line elements, these types of shell elements can be used according to needs and analysis to be carried out. For modeling composite ship plate, Shell 93_8node Structural Shell is used. Shell 93 is particularly good for modeling curved plates. This element has six degrees of freedom at each node: translation in the x, y and z directions and rotation in the x, y and z axes. The deformed form is quadratic in the plane of the element.

Shell 93 is used in ship plate modeling mainly because of its ability to model mostly curved ship plates. Also the deformed quadratic shape allows calculations in the middle of the element (mid-side node) to be more accurate. Element is formed by 8 nodes, 4 thicknesses and orthotropic material. Mid-side nodes on elements cannot be removed and thus these elements are only compatible with quadratic form elements. The orthotropic direction of the material corresponds to the direction of the element's coordinate system. All ship plates are modeled using shell 93, including flat parts such as on the superstructure or on the deck.

3.2.3 Structural mass

Mass modeling is carried out on the main engine, auxiliary engines, gear boxes, pumps, bollards, windlass, windlass foundations, hydraulic steering engines, anchors, anchor chains, and equipment with a large enough mass. These masses need to be modeled because they are part of the ship structure that must be included in the calculation. Mass modeling uses Mass 21, a point element that has six degrees of freedom and is a centered mass element.

3.2.4 Real constant and section determination

In determining the constants, the Real Constant set is used in accordance with the selection of elements used in modeling. The Real Constant set for Shell 93 is used to determine the plate thickness. Meanwhile, to determine the mass of each element, the Real Constant set for mass 21 is used. In addition to determining the constants, the beam and shell elements need to be defined sections.

In determining this section, the element size is determined in the cross section of the profile (beam) and plate (shell). For profiles, the thickness and size of the profiles are defined using the beam tool, while for plates the thickness is only defined using the real constant set for shell 93. The Real Constant set for shell 93 is used to determine the thickness of the plate. The Real Constant set for mass 21 is used to determine the mass of each element. **Figure 2** shows the beam section for the T profile.

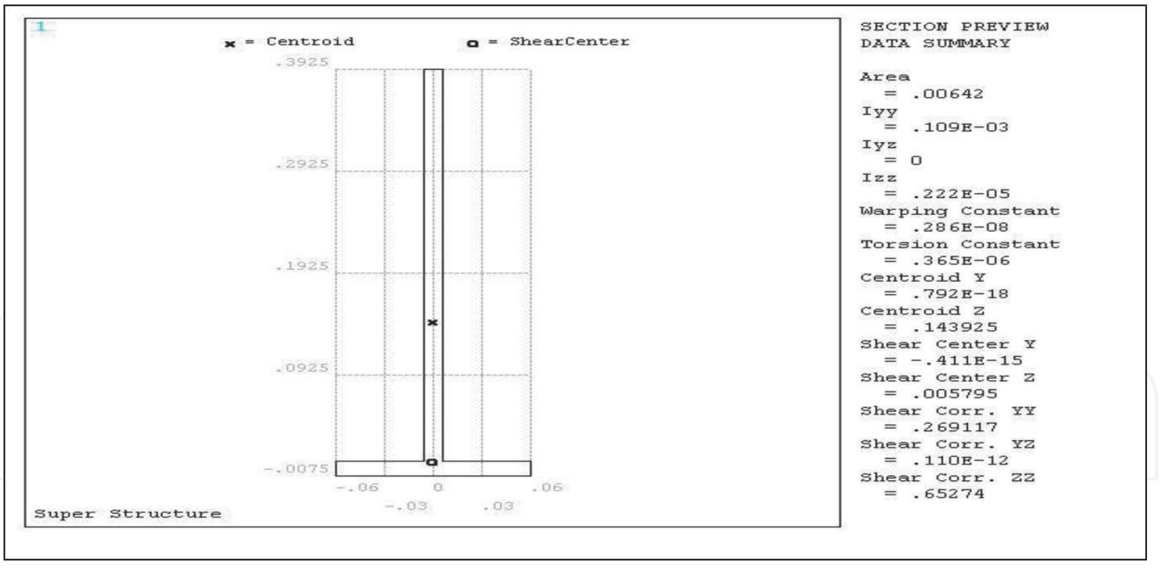

Figure 2.
Beam section for T profile.

3.3 Determination of material properties

In determining the material properties, this depends on the material used for the ship structure. The material in question is one that has a modulus of elasticity (Young's modulus), a poisson ratio and a certain density.

3.4 Finite element making (mesh density)

Determining the size of the element (mesh density) is very important. If the size of the element (mesh) is too coarse, the result may deviate considerably and may even result in an error. However, if the mesh is too fine then we will only waste computer resources, the time required to run is very long, or even the model is too large to be completed on the computer used [11].

The FPB 42 m fast boat model with a length of 42 m that has been made, has 155,988 degrees of freedom so it is hoped that the model can represent it well. The elements are tried to be the same as the example model above, namely all plate elements are expected to have a square shape, but because of the difficulties faced if all of them have to be squared, then there are elements that are made triangles or rectangles with a ratio of length to maximum width of 2.

The size of the largest element that can be created is limited by the following:

- The ivory spacing, which varies from 500 mm to 600 mm.

- Comparison of the length and width of the element for the plate in relation to the shape of the element which is good in this case the ratio of length to width is taken. 2. (Model fast boat FPB 42 m).

In the current model, it only consists of line and area elements, so only free mesh and mapped mesh are used. For the meshing area, this time, we use more meshing (free mesh) with the element length determined or the line division determined in advance. This is easier and you get the desired results. Meanwhile, for elements with identical shapes, meshing is performed using the mapped mesh, which is one of the elements that has been meshed for the first time as a reference using the free mesh. Then the next element can be meshed using a mapped mesh, with the size of the formed element the result will be the same as the element that was first meshed. However, not all areas can easily be elemented in this way. This is due to the size of the area that is too small and the various geometric shapes of the model. Thus, in making elements it is not possible to create elements with the size planned above. For that, a smaller element size is determined. If this still cannot be done, the area is redefined, that is, it is made the same area with a smaller line division but still close to the desired element shape.

To make a beam element, a line is needed, because the beam is a LINE element. The way to make it is almost the same as the meshing process on the plate elements, namely by first determining the element attributes, then meshing it using free mesh. It's just that in this meshing beam there is no need to divide the lines or determine the length of the elements, because this has been done during the meshing area. In addition, the meshing beam also has an orientation keypoint. Namely the keypoint that is used to determine the direction of the mesh section. Each line has a normal direction so that in making beam elements, the beam direction (node I and J) is meshed following the normal direction of the line. If after the mesh the beam direction is not as desired, the line must be reversed (reverse normal line). Because on a ship the entire profile faces the midship, whether the profile is on the base, deck, ivory or reinforcement, the orientation of the keypoint placement is attempted to be able to direct the section of the mesh beam (**Figure 3**) to face the midship.

For mass elements only a keypoint is needed. And for the manufacturing process, namely by selecting the keypoint closest to the location of the mass or center of gravity of the mass being modeled, then the keypoint is used as a mass element. The masses being modeled include the main motor, auxiliary motor, gear box, and other equipment which has a relatively large mass.

After the meshing process is complete, it is necessary to check the shell element whether the elements that have been made are in good condition or not. The maximum warping factor for the Shell 93 warning element is "none", the element may curve outward from the plane of the plate. From all existing tests it has been shown that all elements are in good condition, there are no warning elements or error elements. So that the model made, namely the EN AC-4310 (AlSi10Mg (b)) + SiC composite material ship, has represented the ship well, as shown in **Figure 4** is the image of the overall ship model.

The ability of a ship to float is based on Archimedes' law, the buoyancy force obtained is proportional to the weight of the water it displaces (hydrostatic support). Generally these ships are referred to as ships with hull displacement. The displacement weight is the volume weight of water displaced by the hull. So the weight of the volume of water displaced is the weight of the ship (Eq. 1) (Taggart, 1980):

$$\Delta_B(\text{Newton}) = \text{LxBxTxCBxgx}\rho \quad (1)$$

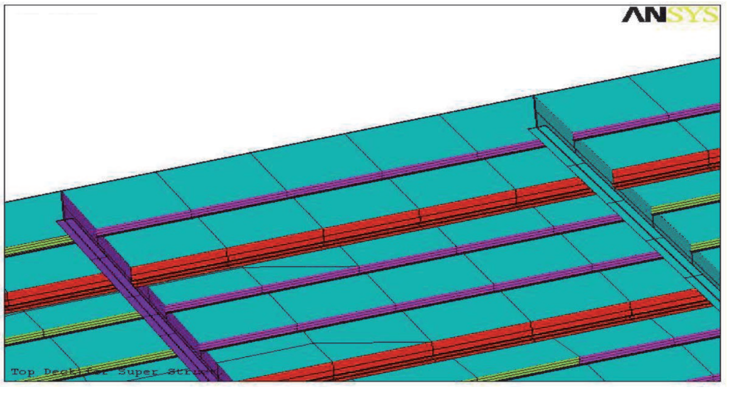

Figure 3.
Beam elements (beam and deck supports).

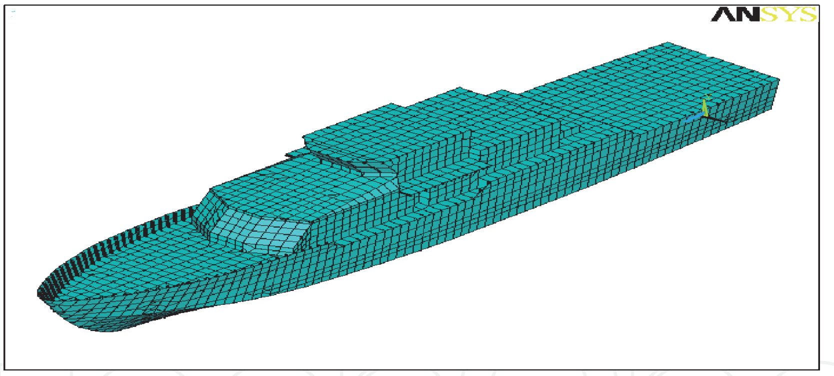

Figure 4.
Draw the whole ship model.

If it is used as mass displacement (ton) then it is divided by g, so that Eq. (2)

$$\Delta_m(\text{ton}) = \text{LxBxTxCBx}\rho \quad (2)$$

Information:

Δ_B = weight of displasmen (Newton)
Δ_m = *mass displacement* (ton)
L = lenght karene
B = wide karene (is the shape of the hull that is below water level, excluding: hull thickness, keel thickness, rudder, propeller and other equipment submerged below water level).
T = loaded with ships (is the vertical distance measured from the lowest point hull to the waterline).
CB = block Coefficient (is the ratio between the content of karene and the volume of blocks with length L, width B and height T).
ρ = water density (sea water = 1025 ton/m^3, fresh water = 1 ton/m^3)

3.5 Ship's displacement weight components

The ship displacement weight component consists of the ship's dead weight (DWT) and the weight of the empty vessel (light weight). Dead weight is the carrying capacity of a ship including the weight of: cargo, fuel, lubricating oil, drinking water, foodstuffs, crew + passengers and the goods they carry. Meanwhile, the weight of an empty ship can be divided into three major parts, namely: 1) Structural weight, consisting of ship weight, superstructures, and deck houses. 2) Equipment weight, consisting of anchors, anchor chains, windlass, rigging, capstans, steering machines, winches, derrick booms, masts, vents, navigation tools, lifeboats, davits, and other. 3) The weight of the motor and its auxiliary installations consists of the main motor, auxiliary engine, boiler, pumps, compressors, separators, pressure vessels, coolers, intermediate shaft, propeller, propeller shaft, shaft bearing, reduction gear, and all equipment in the engine room. The complete component of ship displacement weight is shown in **Table 4** (composite vessel). **Table 5** shows the weight of the engine and electrical parts, the hull weight and the interior for the composite ship.

3.6 Drawing of ship models

Modeling a ship made in conditions of calm water (still wet) and wavy (waves), then modeling the behavior of water (calm and wavy water) by considering water

No.	Ship dead weight	Value (ton)
1.	Composite ship weight (6 mm thick)	61.347
2	Machinery and electric weight	
	a. Engine room equipment	37,49
	b. Pump in engine room	2.463
	c. Seat of pump	0,193
	d. Deck equipment	0,35
	e. Air conditioning room	0,35
3	Weight of Hull Outfitting	24.219
4	Weight of Interior	7.611
5	Fuel Weight	36,96
6	Freshwater Weight	16,2
7	Ship Crew Weight (ABK)	2,6
	TOTAL	**189.783**

Table 4.
Force weight on composite ship.

1. M4CHINERY & ELECTRICITY PART WEIGHT						
No.	**ITEM**	**Weight (ton)**	**AE-G (m)**	**moment (ton.m)**	**KG (m)**	**moment (ton.m)**
	ENGINE ROOM EQUIPMENT					
1	Main engine: 2 MTU 16 V4000 M90					
	with ZF7550 gear boxes (wet weight)	19.130	11.052	211.432	2.147	41.074
3	Propeller shaft	2.486	5.441	13.527	0.846	2.104
4	Propeller	0.998	1.975	1.971	0.222	0.222
5	Boss bracket	1.270	2.531	3.215	0.950	1.207
6	Stern tube	1.310	6.554	8.586	1.003	1.313
7	Genset Yanmar 6HAL2-N	1.380	15.602	21.531	1.954	2.697
8	Genset Yanmar 6HAL2-N	1.380	15.602	21.531	1.954	2.697
9	Piping and valves	6.736	16.110	108.516	2.404	16.192
10	Steering gear	2.800	1.250	3.500	2.650	7.420
	PUMP IN ENGINE ROOM					
1	Bilge pump	0.250	7.661	1.915	1.570	0.393
2	Ballast pump	0.250	7.661	1.915	1.570	0.393
3	General service/fire pump	0.620	7.661	4.750	1.570	0.973
4	Fresh water pump	0.108	15.180	1.639	1.570	0.170
5	Fresh water hydrophore	0.020	13.566	0.271	2.100	0.042
6	Sea water hydrophore	0.020	13.566	0.271	2.100	0.042
7	Oil water separator	0.120	6.602	0.792	1.760	0.211

1. M4CHINERY & ELECTRICITY PART WEIGHT						
No.	**ITEM**	**Weight (ton)**	**AE-G (m)**	**moment (ton.m)**	**KG (m)**	**moment (ton.m)**
8	FO transfer pump (PS)	0.228	15.402	3.512	1.600	0.365
	FO transfer pump (SB)	0.228	15.902	3.626	1.600	0.365
9	Main switch board	0.120	16.913	2.030	2.500	0.300
10	Lubricating oil pump	0.039	16.376	0.639	1.650	0.064
11	Air compressor	0.400	6.690	2.676	1.700	0.680
12	Compressed air tank	0.060	5.450	0.327	1.800	0.108
	SEAT OF PUMP					
1	Seat of FO transfer pump (PS)	0.015	15.402	0.237	1.400	0.022
2	Seat of FO transfer pump (SB)	0.015	15.902	0.245	1.400	0.022
3	Seat of bilge pump	0.045	7.661	0.348	1.400	0.064
4	Seat of ballast pump	0.050	7.661	0.383	1.400	0.070
5	Seat of fire GS pump	0.040	7.661	0.305	1.400	0.056
6	Seat of fresh water pump	0.028	15.180	0.431	1.400	0.040
	DECK EQUIPMENT					
1	Windlass	0.350	37.313	13.060	5.510	1.928
	AIR CONDITIONING ROOM					
1	A.C. engine	0.350	20.000	7.000	3.500	1.225
	Σ Weight =	40.848	10.776	440.182	2.019	82.456
2. HULL OUTFITTING PART WEIGHT						
No.	ITEM	Weight (ton)	AE-G (m)	moment (ton.m)	KG (m)	moment (ton.m)
1	Stairway	0.083	20.400	1.690	4.505	0.373
2	Mounting gun	0.441	32.830	14.462	5.905	2.601
3	Wooden lining in chain locker	0.992	36.999	36.703	2.701	2.680
4	Windlass foundation	0.085	37.000	3.145	4.896	0.416
5	Bollard	0.712	20.500	14.588	4.910	3.494
6	Hatch coaming	0.222	18.235	4.039	4.793	1.062
7	Under main deck	0.073	20.524	1.499	1.792	0.131
8	On main deck and navigation deck	3.824	33.481	128.037	3.787	14.480
9	Safety equipment	1.768	9.980	17.645	4.950	8.752
10	Ventilation	1.389	18.536	25.746	3.330	4.625
11	Equipment on wheelhouse	0.426	22.880	9.747	7.194	3.065
12	Radar mast	0.226	19.750	4.459	10.356	2.338
13	Floor	11.448	21.624	247.549	4.602	52.686
14	Emergency genset & battery	0.286	19.000	5.438	7.256	2.077
15	Ceiling & wall covering	2.244	23.751	53.304	4.958	11.128
	Σ Weight =	24.218	23.456	568.051	4.538	109.908

3. INTERIOR						
No.	**ITEM**	**Weight (ton)**	**AE-G (m)**	**moment (ton.m)**	**KG (m)**	**moment (ton.m)**
1	Wooden door	1.029	22.326	22.967	4.383	4.509
2	Furniture under main deck	2.352	27.562	64.830	2.635	6.199
3	Furniture on main deck	2.447	21.880	53.531	4.974	12.170
4	Furniture on navigation deck	0.577	20.996	12.112	7.371	4.253
5	Partition wall	0.636	24.987	15.899	4.598	2.925
7	Steel door	0.382	18.778	7.169	5.715	2.182
8	Steering gear construction	0.188	1.023	0.192	1.946	0.366
	Σ Weight =	7.611	23.218	176.702	4.284	32.605

Table 5.
Force/weight on composite composite.

as a series of linear-elastic springs (springs) that are not related to one another. In the depiction of this model ship, the number of springs 'fixed' is placed on the entire hull as shown in **Figure 5**. In the figure, the distance between the ivory (frame) with symbols **h** and **a** is the width of each section. So that the water surface area (wáter plan are/**Awl**) can be calculated by Eq. 4. The overall volume is the surface area of the water multiplied by the displacement / displacement of the water which is analogous to the distance (x) spring motion, shown in Eq. 4

$$Awl = h.a \tag{3}$$

$$V = Awl.a.x \tag{4}$$

So that the value of the spring constant (k) can be obtained from the spring force (Fs) shown in Eq. (5)

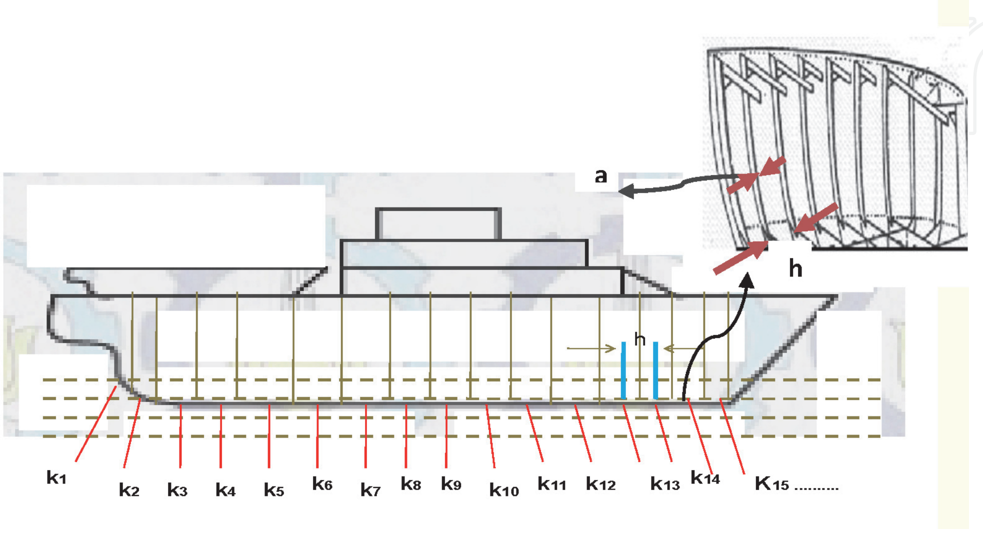

Figure 5.
Modeling of a series of springs on the hull.

$$Fs = \text{k.x} \tag{5}$$

$$m.g = k.x \tag{6}$$

Given the density equation (ρ), is:

$$\rho = \frac{m}{V} \tag{7}$$

so that with the substitution of Eqs. (4), (5) and (6), the value of the spring constant is shown in Eq. (8):

$$k = Awl.\rho.g \tag{8}$$

Information:

*Wáter plan ar*ea (Awl) = water surface area (meter^2)
k = spring constant (Newton/meter)
Fs = spring force (Newton)
x = displacement (meter)
h = distance between *frame* (meter)
a = width of each *section* (meter)
m = mass (kg)
ρ = density (kg/m^3)
g = gravity = $9806\left(\frac{\text{m}}{\text{detik}^2}\right)$
V = volume (m^3)

3.7 Properties of material

Determining the properties of the materials to be used is taken from all the composite stress mechanical test results data (EN AC-43100 (AlSi10Mg (b)) + SiC*/15p) as numerical input modeling vessel, which are summarized in **Table 6**.

Data	**Composite Material**	
	EN AC-43100	
	AlSi10Mg(b)) + SiC*/15p	
Density	2.904 (gram/cm^3)	
Modulus Elastisity	98,902.44	(MPa)
Poisson Ratio	0.3	
Tensile Strength	225.39	(Rm) (MPa)
Permit Stress		
(sigma 0,2)	59.30	(MPa)
Ship weight		
(thick plate 6 mm)	61,347	(ton)
Source: Tensile test.		

Table 6.
*Data for composite ship (EN AC-43100 (AlSi10Mg (b)) + SiC */15p).*

3.8 Loading

Generally, loads are estimated using the classification rules or direct hydrodynamic calculations. The loads that make the ANSYS version12,0 composite ship (EN AC43100 (AlSi10Mg(b)) + SiC*/15p) can be roughly divided in to two parts. Static Loads (still water) This consists of loads that do not differ with time, or even if they differ, the impact of time may be neglected; This category includes hydrostatic pressure, ship part weights, cargo and ballast loads. Besides these wave moments and forces resulting from ship components are often known as static loads. Wave Induced (Quasi Static) to consider water as a sequence of linear-elastic springs which are not connected to each other. In model ship numerics, the number of springs 'mounted' is put on the ship's entire body. Therefore it becomes important to properly understand the loads and evaluate the structure accordingly. Using ANSYS version12,0 makes the load application method very quick and manageable, also the chances of errors in combining the loads is eliminated.

Loads of wave induced *(quasi static)* what count is Coefficient Calculation, Bending Moment Wave Induced Load consists of Vertical Wave Bending Moment (MWV) or (B.M.W.V), Shear Force Wave Induced Load consists of Vertical Wave Shear Force (QWV) or (S.W.S.F), Permissible Bending Moment (S.W.B.M) and Vertical Wave Shear Force (S.F.W.V).

3.9 Component weight displacement ship

Weight component displacement vessel consists of Death Weight Tonnage / DWT and the full weight of the displacement weight component aluminum vessel and composites vessel is shown in **Table 7**. Values for the same weight, with uniform weight distribution, both for aluminum ship and composite ships.

Death Weight Tonnage	(Ton)
Weight of body aluminum ship (thick 6 mm)	54.865
Weight of body composite ship (thick 6 mm)	61.347
Weight of machinery and electricity	
a. Engine room equipment	37.49
b. Pump in engine room	2463
c. Seat of pump	0.193
d. Deck equipment	0.35
e. Air conditioning room	0.35
Weight Hull Outfitting	24,219
Weight Interior	7611
Weight fuel	36.96
Weight freshwater	16.2
Weight Crew of ship	2.6
Weight Machinery and electricity part weight consists of engine room equipment, pump in engine room, seat of pump, deck equipment, air conditioning room	40,848
Source: Fast Patrol Boats.	

Table 7.
Loads on aluminum ships and composite ship.

Differential value between aluminum ship body weight and composite ship. Body weight composite ship heavier than aluminum ship, so the expected stress distribution that occurs between the aluminum ship and the composite ship is not the same.

4. Discussion

4.1 Result loads of wave induced *(Quasi Static)*

Summary results of the calculation of wave loads induced (quasi static) in **Table 8** while the chart figure of wave induce in condition hogging and sagging shown in **Figure 6** condition S.F.W.V, **Figure 7** for B.M.W.V and **Figure 8** condition for wave induced stress.

Figures 9 and **10** show the distribution of stress in the composite ship numerical model EN AC43100 (AlSi10Mg(b) + SiC*/15p) for water and wave condition induced for the entire ship body, and the plate thickness of 6 mm was used.The maximum stress occurring in composite ship numeric models is 7.24 MPa. While the maximum stress that occurs in numerical composite ship models for the conditions induced by the wave is 14.1 MPa.

Ship numerical model for base (bottom) construction, shown in **Figure 11** for still water condition and **Figure 12** for wave-induced condition. The maximum stress in numerical composite ship models, when still water conditions are 7.24 MPa. While the maximum stress that occurs in numerical composite ship models reaches 19.1 MPa for the wave induced conditions.

Distribution of stress in main deck on **Figure 13** for still water condition and **Figure 14** for wave induced condition. The maximum stress that occurs in numerical models of composite ship when conditions still water is 6.67 MPa. While for the

Condition	S.W.S.F	S.W.B.M	S.F.W.V	B.M.W.V
Max.	7593.59	0.3	969.63	622.4
Min.	2.30	0.0	−348.46	−249.5

Table 8.
The calculation of wave loads induced (quasi static).

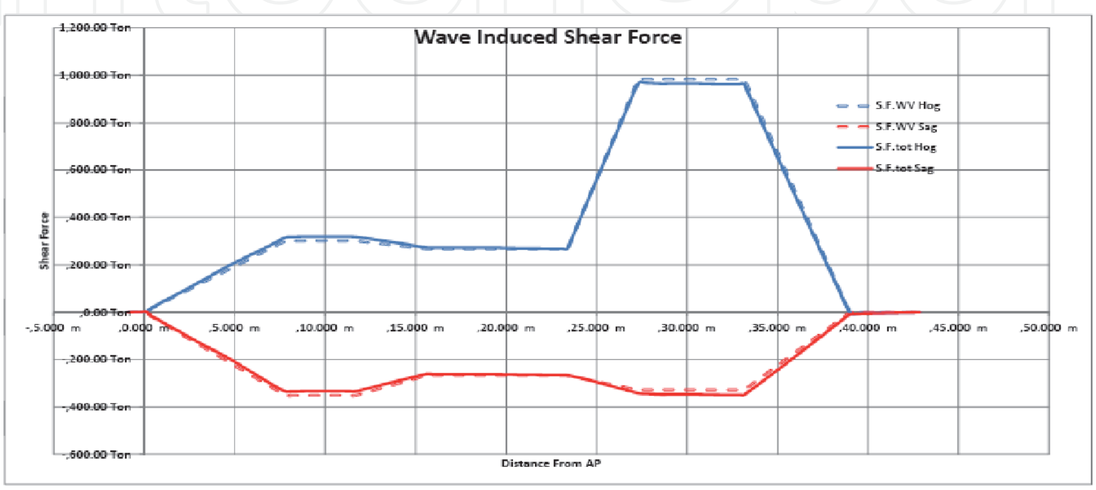

Figure 6.
Condition S.F.W.V.

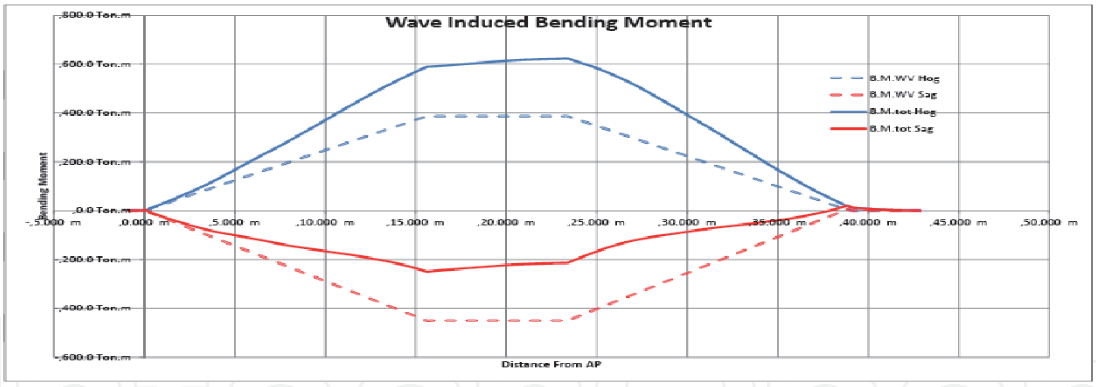

Figure 7.
Condition M.B.W.V.

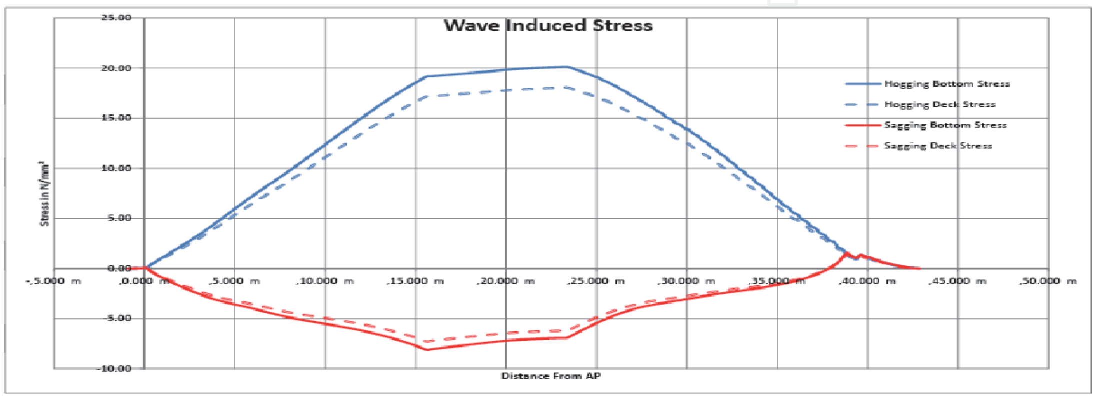

Figure 8.
Condition for wave induced stress.

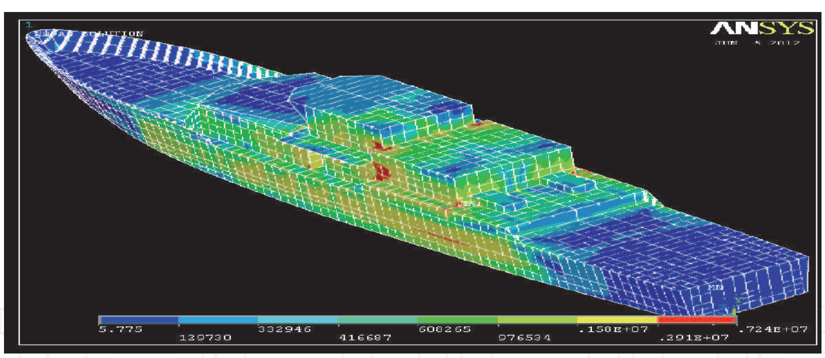

Figure 9.
Distribution of stress in model of numerical of ship composite EN AC-43100 (AlSi10Mg (b)) + SiC/15p for the full ship body for condition still water (maximum stress = 7,24 MPa).*

wave induced conditions, the maximum stress that occurs in numerical models of composite ship of 16.8 MPa.

Overall the above results are summarized in **Table 9**. From the results of the stress distribution shows that the maximum stress that occurs in induced wave conditions have higher value compared to still water conditions. This is because the load is included in the wave induced more numerous and complex than a given load on the still water. Composite ship (EN AC-43100 (AlSi10Mg (b)) + SiC*/15p), more weight than aluminum ship because in composite ship there have SiC as reinforcement, which causes the composite more heavier than the aluminum ship (for the same thickness = 6 mm). Conversely, aluminum ship lighter, so it automatically receives the maximum stress is greater than that received by a composite ship, for input the same load and the plate of the same thickness.

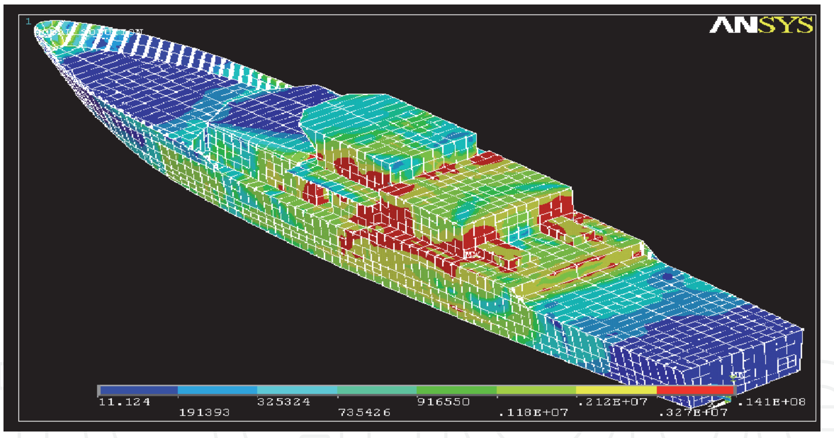

Figure 10.
Distribution of stress in model of numerical of shicomposite EN AC-43100 (AlSi10Mg (b)) + SiC/15p for full ship body for wave induced condition (maximum stress = 14,1 MPa).*

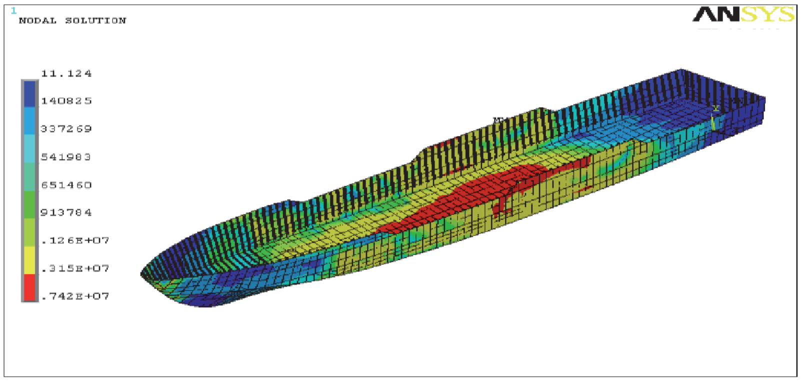

Figure 11.
Distribution of stress in model of numerical of ship composite EN AC-43100 (AlSi10Mg (b)) + SiC/15p for the hull and construction of the base (bottom) for still wave condition (maximum stress = 7,42 MPa).*

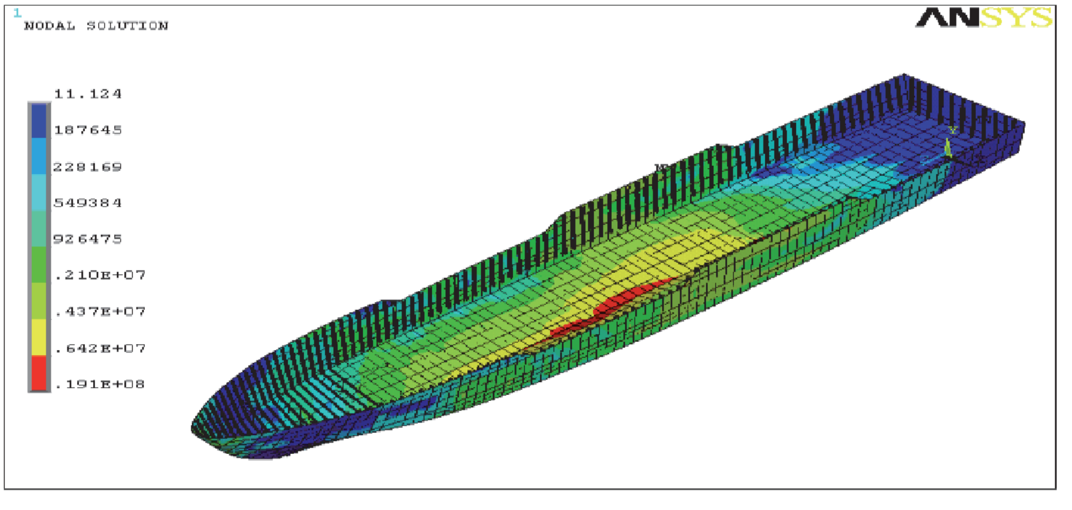

Figure 12.
Distribution of stress in model of numerical of ship composite EN AC-43100 (AlSi10Mg (b)) + SiC/15p for the hull and construction of the base (bottom) for wave induced condition (maximum stress = 19,1 MPa).*

Table 9 shows the maximum stress that occurs in composite ship more smaller than the ship of aluminum, this happens because the weight of ship of composite is heavier than ship of aluminum. So that when receiving weight distribution uniform, ship of composite are stronger hold so the impact on the value of the stress maximum is smaller. It seems that all the results obtained showed the maximum stress

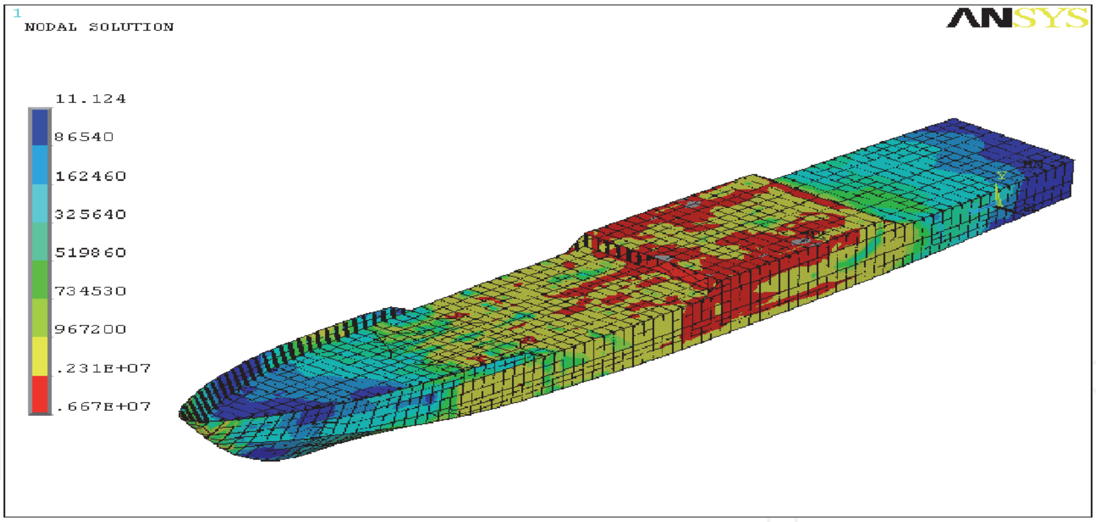

Figure 13.
Distribution of stress in model of numerical of ship composite EN AC-43100 (AlSi10Mg (b) + SiC/15p for* main deck *for still water condition (maximum stress = 6.67 MPa).*

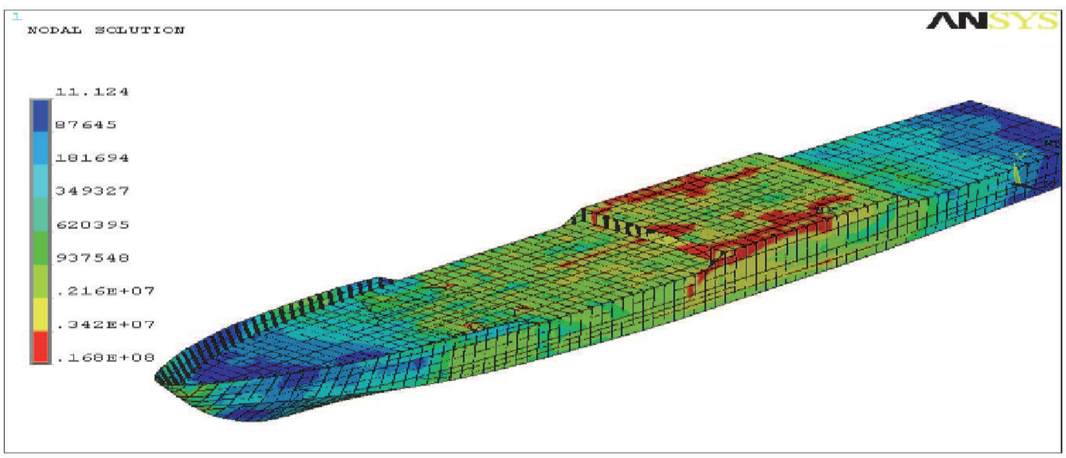

Figure 14.
Distribution of stress in model of numerical of ship composite EN AC-43100 (AlSi10Mg (b)) + SiC/15p for* main deck *for wave induced condition (maximum stress = 16.8 MPa).*

Distribusion stress	**Composite material EN AC-43100 (AlSi10Mg(b)) + SiC*/15p (thickness plate 6 mm)**	
	Still Water (MPa)	**Wave Induce (MPa)**
Full body ship area	7.24	14.1
Hull and construction		
of the base (bottom)		
area	7.24	19.1
Main deck area	6.67	16.8

Table 9.
Value of máximum stress of model of numerical of aluminum ships and the ship of composite.

does not exceed the value of the stress permits (0.2 sigma = 59.30 MPa) for composite materials. This means that composite materials EN AC-43100 (AlSi10Mg (b)) + SiC */15p) can be used throughout the full of body ship. This condition is amplified by a factor of safety which is the ratio between the material strength with strength design, where material strength is the stress permits (sigma 0.2) and the design strength is the maximum stress from the program ANSYS (FEM calculation). Factor of safety more than to 1. Factor of safety values are shown in **Table 10** indicated that the factor of safety for all conditions in still water and wave induced, has value above 1.00, so the overall material composite EN AC-43100 (AlSi10Mg (b) + SiC*/15p is safe to use.

4.2 Application analysis of modeling composite ship EN AC-AlSi10Mg (b) + SiC*/15p

Furthermore with using ANSYS software version 12.0, this research will analyze the application of composite materials EN AC-AlSi10Mg (b) + SiC*/15p that can use in ship building. Overall composite ship modeling EN AC 43100(AlSi10Mg (b)) + SiC*/15p), shows that the stress does not exceed the value limit stress 0.2 sigma. It means that this material can actually be applied to the entire body of the ship. But because it is brittle, then the selection of applications on the ship also should look at the nature of this material. Selected applications on top of the building wall (superstructure) that the wall plate height (h) = 2.2 meters and width (b) = 1.5, composite thick ship plate is 5 mm (**Figure 15**) and building applications on the deck plate (superstructure decks) on the size of 1 m x 1 m and thickness of 6 mm (**Figure 16**).

The maximum stress that occurs in ship composite EN AC 43100(AlSi10Mg (b)) + SiC*/15p) for building walls on the plate thickness 5 mm at 9.43 MPa and the deck superstructure with plate thickness 6 mm to obtain the wave-induced stress conditions maximum 10.7 MPa. Both of these results when compared with aluminum ship for the two applications (on the wall of the building) with the height and width the same, but with a thickness of 5 mm, the maximum stress value will be 9.26 MPa (**Figure 17**) and for the superstructure deck of the same size but the greater thickness of 7 mm is obtained at 10.8 MPa maximum stress (**Figure 18**). It means that the results obtained by the maximum strees between the composite ship

	Factor of Safety
	Composite material
	EN AC-43100
	(AlSi10Mg(b)) + SiC*/15p
	(thickness plate 6 mm)
Still Water:	
1. Full body ship	8.19
2. Hull and construction	
3. of the base (bottom)	8.19
Main *Deck*	8.89
Wave Induced:	
1. Full body ship	4.21
2. Hull and construction of the base (bottom)	3.11
3. Main *Deck*	3.53

Table 10.
Value factor of safety.

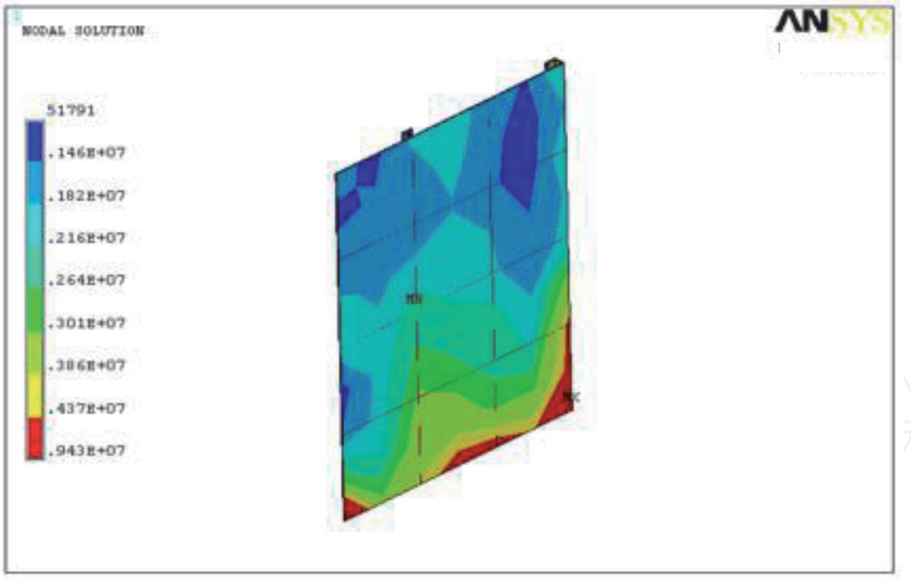

Figure 15.
Distribution stress of composite shipEN AC 43100(AlSi10Mg(b)) + SiC/15p) in superstructure wall with plate thick 5 mm (max. Stress =9.43 MPa).*

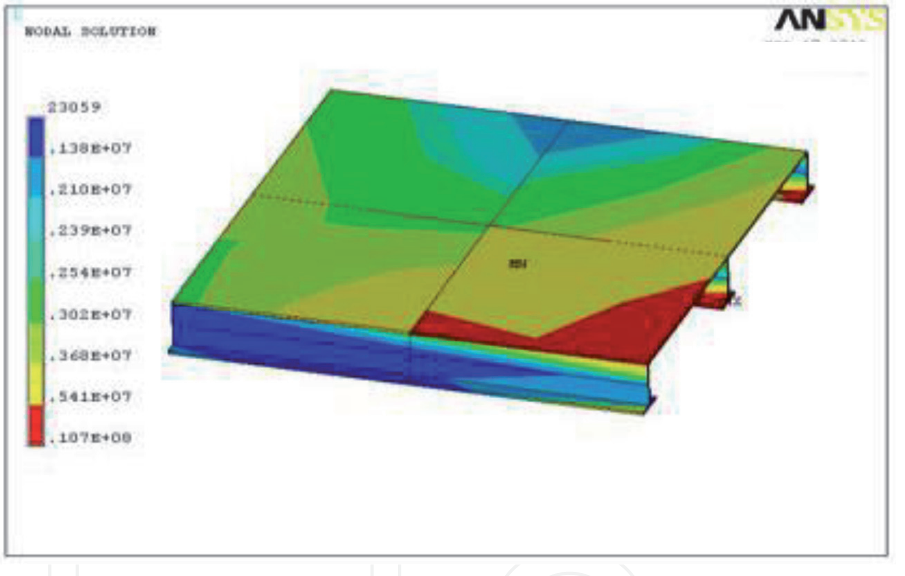

Figure 16.
Distribution stress of composite ship EN AC 43100(AlSi10Mg(b)) + SiC/15p) on superstructure deck with plate thick 6 mm for induced wave condition (max. Stress = 10.7 MPa).*

with aluminum ship are not a significant difference, in fact it can be said the maximum stress value approaching the same value.

Actually the main core of ship composite EN AC43100(AlSi10Mg(b)) + SiC*/15p) as an alternative material for building ships with reduced thickness is used in the composite material will impact on the weight loss, heavy displacement ship will be reduced, then for the length, width, and height of the vessel remains, laden vessel will be reduced. With a large reduction in the laden ship, the wetted surface area / WSA of the hull is submerged in water will also be reduced. This will reduce the size of the total water barriers experienced by vessels which in turn thrust (powering) ship engine fixed, it will increase the speed of the ship. Or conversely, if the desired speed of the ship is made permanent, this will lower the powering of the vessel and it will certainly reduce the relatively large ship main engine. So in general can decrease the volume of the cylinder marine engine. Thus the fuel consumption becomes smaller, thus making the vessel operating expenses generally become more efficient.

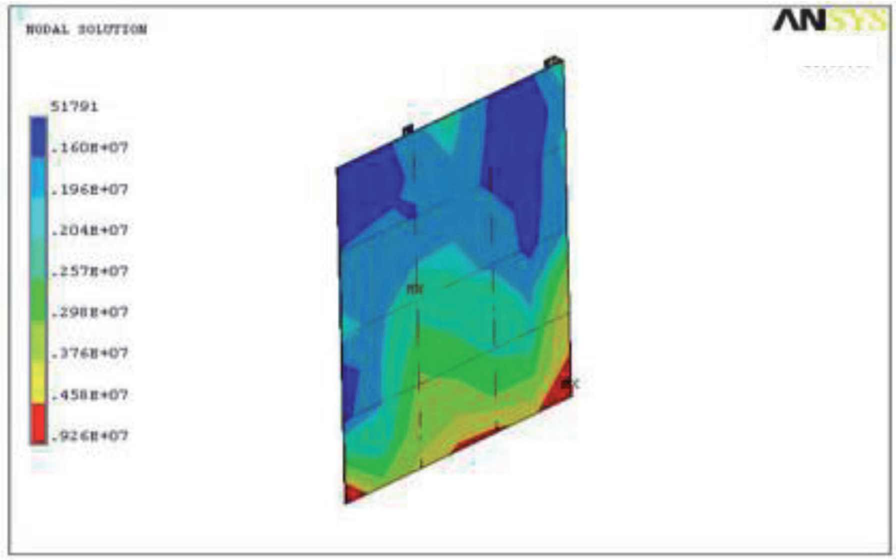

Figure 17.
Distribution stress of ship aluminum EN AC-43100(AlSi10Mg(b)) with plate thick 6 mm (max. Stress = 9.26 MPa).

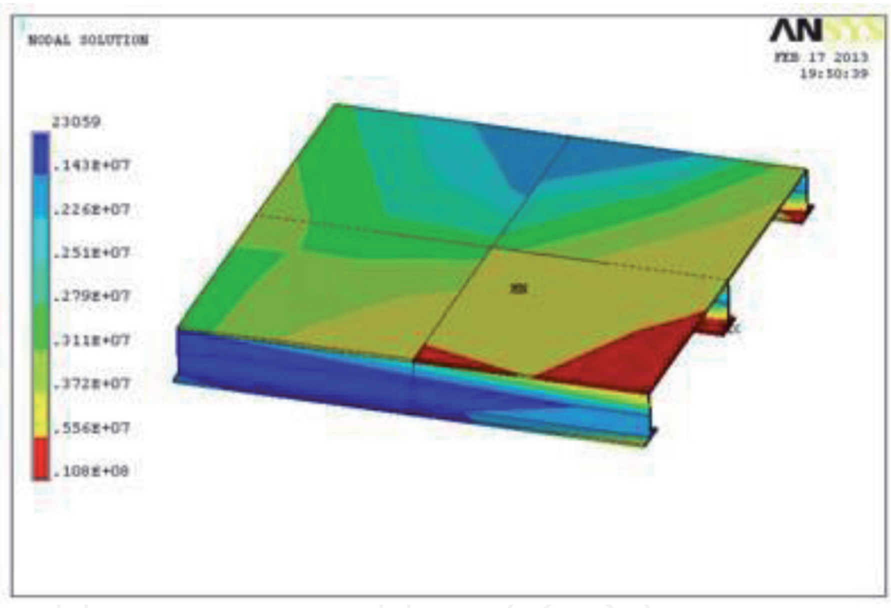

Figure 18.
Distribution stress of ship aluminum EN AC-43100(AlSi10Mg(b)) on superstructure deck with plate thick 7 mm for induced wave condition (max. Stress = 10.8 MPa).

5. Conclusion

The conclusion of this chapter is Numerical modeling of composite ship EN AC-43100 (AlSi10Mg (b)) + SiC*/15p) has successfully demonstrated the distribution stress to the full body ship, construction of the base (bottom), and main deck, for still water and wave conditions induced. The overall results of the stress distribution of model numerical of ship, its value does not exceed the stress permits (sigma 0.2) and have a factor of safety above the minimum allowable limit, so it is safe to use.In numerical modeling, the ship composite materials EN AC-43100 (AlSi10Mg (b)) + SiC*/15p) can be used as an alternative material for ship building, however is still needed comprehensive testing in the field. Reducing the thickness of the composite plate EN AC- 43100 (AlSi10Mg (b) + SiC*/15p) to be significant enough to reduce the weight of ship structure thus reducing the total water resistance experienced by the ship as a result of thrust force ship engine fixed, it will increase the speed of the ship. Conversely, if the speed of the ship is stable it will lower the thrust of force ship, so that the consumption of fuel becomes smaller, the effect on vessel operating expenses are generally becoming more efficient Generally ship-building from composite materials EN AC-43100 (AlSi10Mg (b) + SiC*/15p) can be made good, by using modeling ANSYS program ver.12, 0, used as an alternative material for ship building.

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