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Finite element analysis of material $AlSi_{10}Mg(b)$ and $AlSi_{10}Mg(b)+SiC*15p$

Prantasi Harmi Tjahjanti*, Mulyadi*, A. Zubaydi** and S.H. Sujiatanti**

**Department of Mechanical Engineering, Universitas Muhammadiyah Sidoarjo, Jalan Raya Gelam 250 Candi Sidoarjo, Jawa timur, Indonesia*
***Faculty of Marine Technology, Institute Technology of Sepuluh Nopember (ITS), Jalan Abdul Rachman Hakim, Surabaya, Indonesia*
**Corresponding Author: prantasiharmi@umsida.ac.id*

ABSTRACT

The purpose of this study was to evaluate the maximum stress and maximum deformation of aluminum material $AlSi_{10}Mg$ (b) and composite material $AlSi_{10}Mg$ (b) + SiC*/15p if bending tests were carried out for the application of bilge plates and on the body of the ship by finite element method. The application of these two materials is an alternative material for ship building. Modeling and analysis are done using ANSYS version 14.5 software. The results indicated that the aluminum material $AlSi_{10}Mg$ (b) always has a higher value for maximum stress and maximum deformation compared to the composite material $AlSi_{10}Mg$ (b) + SiC*/15p), even though the difference is relatively small. Overall the impact and implication of this research showed that composite material reinforcement SiC could reduce the occurrence of large maximum stresses.

Keywords: $AlSi_{10}Mg$ (b); $AlSi_{10}Mg$ (b)+SiC*/15p; ANSYS version 14.5; finite element analysis; maximum deformation; maximum stress.

INTRODUCTION

Making composite material Aluminum Metal Matrix Cast Composite by using Al-Mg alloy matrix and 10% SiCox amplifier can make it strong. In the sense that it has high wetness between the matrix and its amplifier, it is necessary to add 0.5 and 1 wt% of Mg, so that it will form $MgAl_2O_4$ compound, in which functions are increasing wetness and reducing the surface tension force between the matrix and the amplifier (Surappa, 2003). Composite material that is combination of aluminum alloy ($AlSi_{10}Mg$; as a matrix) and silicon carbide (SiC; as a reinforcement) is typically used as an alternative material for ship. This material can be made using a steel casting process. But this material is typically brittle. The composition of 15% of SiC is the optimum composition for bending and impact values (Maurya *et al.*, 2019). If a fracture occurs, the composite material EN AC-43100 ($AlSi_{10}Mg$ (b)) + SiC * / 15p can be re-welded and the best welding electrode used is made according to the composite material (Tjahjanti *et al.*, 2012). Stress distribution of material EN $ACAlSi_{10}Mg$ and composite material EN AC-$AlSi_{10}Mg$ (b)+SiC*/15p have been analyzed by ANSYS 12.00. The results of the stress value distribution in both of model numerical of ship do not exceed the stress permits (sigma = 0.2) and have safety factor to minimum allowable limit; thus, this material can be classified as safe material to be used. In general, in the use of numerical modeling, the ship material (containing aluminum) and ship composite materials are used, which can be classified as an alternative material for building ship. However, comprehensive testing is still needed in the field (Tjahjanti *et al.*, 2013). Application of composite material EN AC-$AlSi_{10}Mg$ (b) + SiC * / 15p using Numerical Modeling ANSYS ver. 12.00 can be used for wall and deck superstructure with the result that the reduction in thickness of this composite material is significant enough to reduce the weight of the ship so it will reduce the size of the total water barriers experienced by ship. As a result, the thrust (powering) ship engine fixed will increase the speed of the ship.

On the contrary, if the speed of the vessel was made permanently, it will lower the powering of the vessel; thus, the fuel consumption becomes smaller. Indeed, the effect on vessel operating costs generally becomes more efficient (Tjahjanti *et al.*, 2013). Corrosion Penetration Rate (CPR) of Aluminum matrix composite materials ($AlSi_{10}Mg$ (b)) and Silicon carbide (SiC*) is reinforced by the variation of matrix composite percentage. A wet corrosion test was conducted by dipping $AlSi_{10}Mg$ (b) and $AlSi_{10}Mg$(b)+SiC* in the solution containing HCl, NaOH, and NaCl. The wet corrosion tests were also being done in different pH (1, 3, 5, 7, 9, 11, and 13). This pH is important since it can create corrosion reaction (Hamidah *et al.*, 2018; Asmara *et al.*, 2018; Hamidah *et al.*, 2018b). It was found that the highest corrosion penetration rate occurred when the specimen dipped on HCl solution when the pH is 1. We also observed that the addition of SiC* could decrease the corrosion rate of materials. Finally, this study showed that composite material, AC-43100 ($AlSi_{10}Mg$ (b)) 85% + 15% SiC*, is the best material in resisting corrosion attack because it has the smallest CPR value, in which the value is below the standard of corrosion (<0.5 mm/yr) (Zhao *et al.*, 1991; Kharghani *et al.,* 2019; Sielski *et al.,* 2008; Huang *et al.,* 1998; Tzimas *et al.*, 1999).

Here, the purpose of this study was to determine the maximum stress and maximum deformation in aluminum material $AlSi_{10}Mg$ (b) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p if bending tests were carried out for the application of bilga plates and on the ship body to finite the element analysis using ANSYS version 14.5 software.

METHOD

Numerical modeling ship

In modeling using finite element analysis, ship data were modeled. The model of the ship made is the Ro-Ro 750 GT Ferry Crossing Ship that has 155,988 degrees of freedom so it is expected that the model can represent it well. The elements attempted are the same as the example of the above model that all plate elements are expected to have a square shape. However, because difficulties are faced when all elements are rectangular, there are elements that are made triangles or rectangles with a ratio of length to maximum width with the main dimensions of the ship (shown in Figure 1). The plan is adjusted to the applicable regulations using classes from Indonesia, namely, the Indonesian Classification Bureau (BKI 2009).

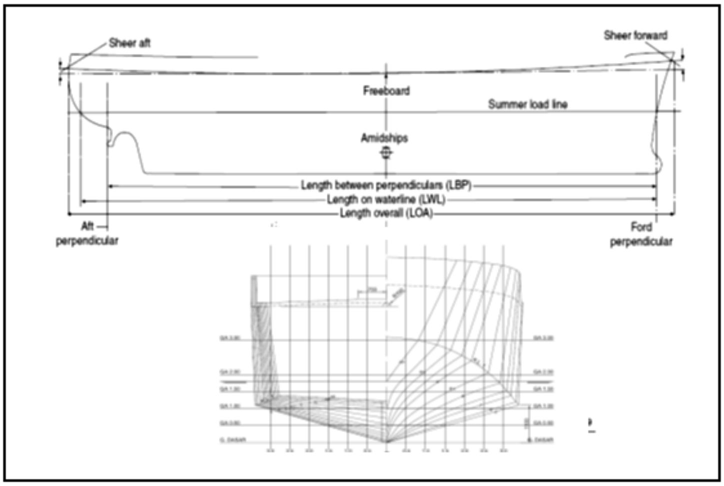


Fig. 1. Ship schematic illustration.

Type and sizes ship

Aluminum ship ($AlSi_{10}Mg$ (b)) and composite ship ($AlSi_{10}Mg$ (b)+SiC*/15p) were modeled numerically using a software (ANSYS version 14.5). The ship had dimension of length over all (LOA) of 56.02 meters. Detailed dimension of ship is explained as follows: length between perpendiculars (LBP) = 48.82 m, breadth (b) = 14.00 m, height (H) = 3.80 m, draft (T) =2.7 m, maximum speed = 12,0 knot, coefficient block (Cb): 0,78, crew of ship = 22 person. Planning regulations are adapted to use the class from the Bureau Classification Indonesia (BKI) 2009 (Asmara *et al.*, 2018).

The curved plate model made of aluminum material $AlSi_{10}Mg$ (b) and $AlSi_{10}Mg$ (b) + SiC * / 15p composite material will be applied to the bilge plate (Figure 2). The bilge plate is a strip of plate that has a certain radius of curvature and is affixed between the side plates and the base plate.

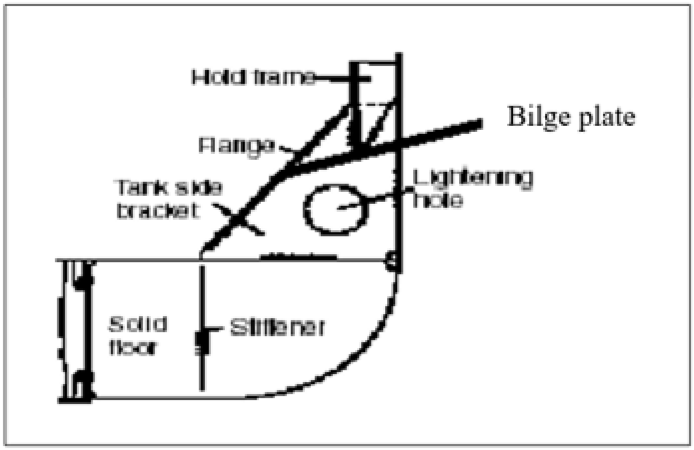
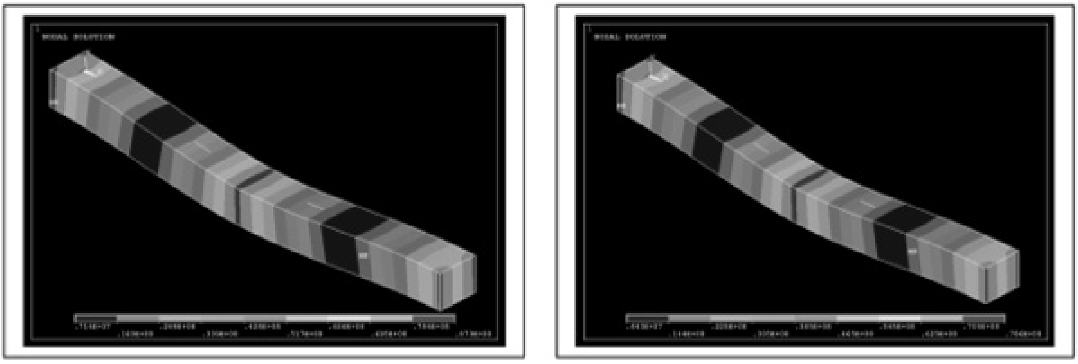


Fig. 2. Bilge plate design.

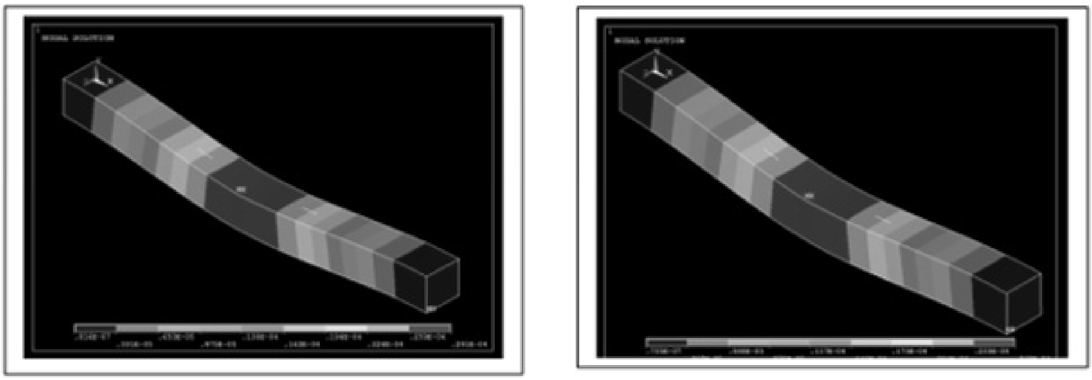
RESULTS AND DISCUSSION

Results of maximum stress and maximum deformation for bending test are shown in Figures 3 and 4. Figure 3 is the stress distribution at 5kN load, for aluminum material $AlSi_{10}Mg$ (b) of 87.3 MPa (Figure 3a) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p with a magnitude of 78.6 MPa (Figure 3b). Figure 4 is maximum deformation at a load of 5kN, for aluminum material $AlSi_{10}Mg$ (b) of 0.0291 mm (Figure 4a) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p with a size of 0.0262 mm (Figure 4b).



(a) (b)

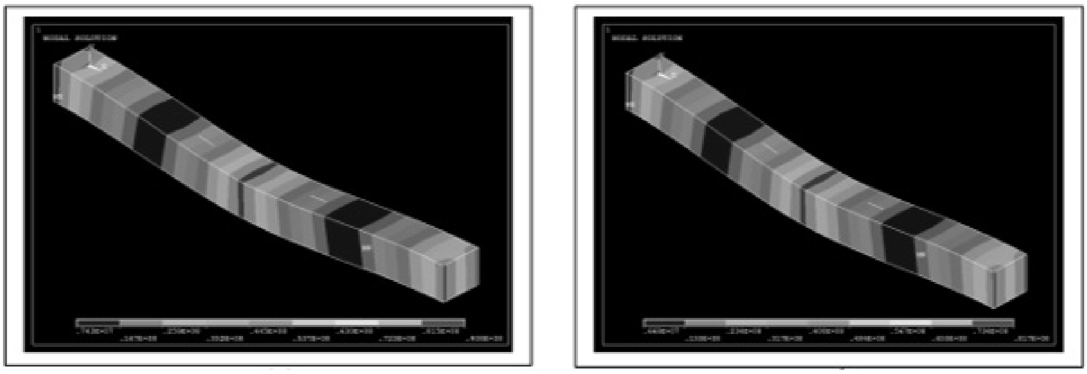
Fig. 3. Stress distribution at 5kN load on materials: (a) Aluminum $AlSi_{10}Mg$: maximum stress 87.3 MPa, and (b) Composite $AlSi_{10}Mg(b)+SiC*/15p$: maximum stress 78.6 MPa.



(a) (b)

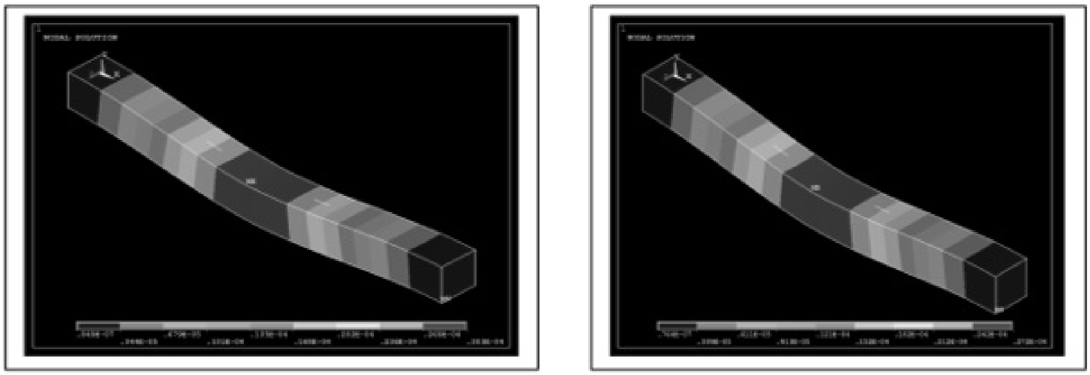
Fig. 4. Maximum deformation at 5kN load on materials: (a) Aluminum $AlSi_{10}Mg$: maximum deformation 0.0291 mm, and (b) Composite $AlSi_{10}Mg$(b)+SiC*/15p: maximum deformation 0.0262 mm.

Figure 5 is the stress distribution at a load of 5.2 kN, for aluminum material $AlSi_{10}Mg$ (b) of 90.8 MPa (Figure 5a) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p with a large 81.7 MPa (Figure 5b). Figure 6 is the maximum deformation at a load of 5.2 kN, for aluminum material $AlSi_{10}Mg$ (b) of 0.0291 mm (Figure 6a) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p with a large 0.0262 mm (Figure 6b).



(a) (b)

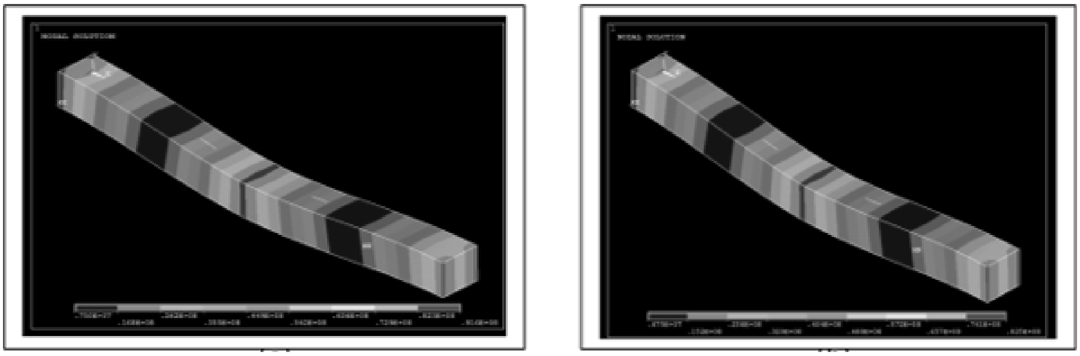
Fig. 5. Stress distribution at 5.2 kN load on materials: (a) Aluminum $AlSi_{10}Mg$: maximum stress 90.8 MPa, and (b) Composite $AlSi_{10}Mg$(b)+SiC*/15p: maximum stress 81.7 MPa.



(a) (b)

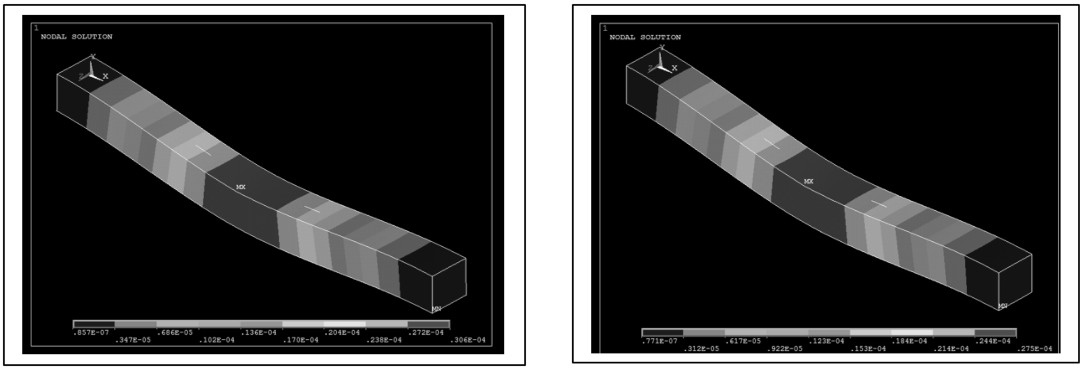
Fig. 6. Maximum deformation at 5.2 kN load on materials: (a) Aluminum $AlSi_{10}Mg$: maximum deformation 0.0303 mm, and (b) Composite $AlSi_{10}Mg$(b)+SiC*/15p: maximum deformation 0.0272 mm.

Figure 7 is the stress distribution at a load of 5.25 kN, for aluminum material $AlSi_{10}Mg$ (b) at 91.4 MPa (Figure 7a) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p with a magnitude of 82.5 MPa (Figure 7b). Figure 8 is the maximum deformation at a load of 5.25 kN, for aluminum material $AlSi_{10}Mg$ (b) of 0.0306 mm (Figure 8a) and composite material $AlSi_{10}Mg$ (b) + SiC * / 15p with a large 0.0275 mm (Figure 8b).



(a) (b)

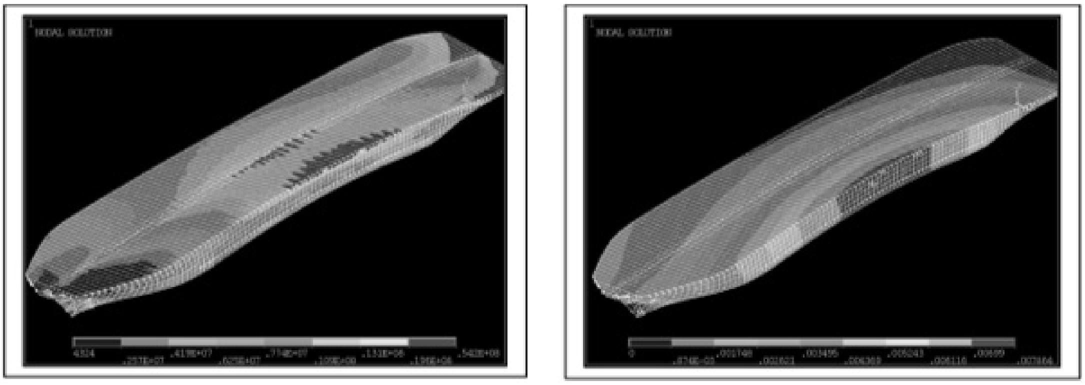
Fig. 7. Stress distribution at 5.25 kN load on materials: (a) Aluminum AlSi10Mg: maximum stress 91.4 MPa, and (b) Composite $AlSi_{10}Mg(b)+SiC*/15p$: maximum stress 82.5MPa.



(a) (b)

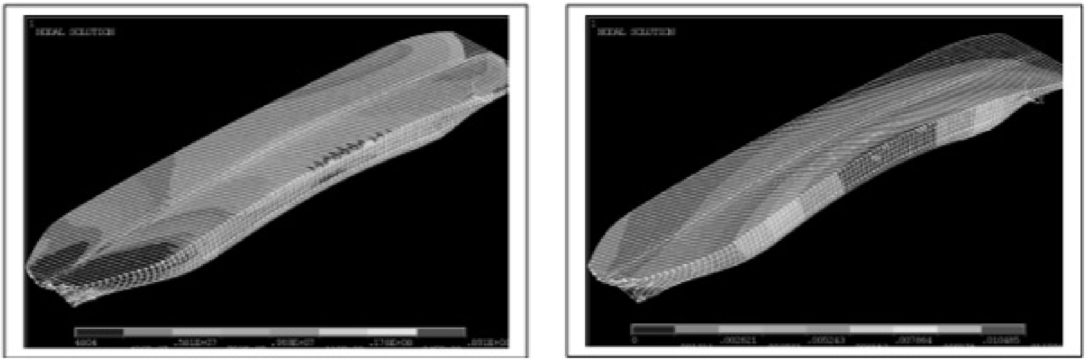
Fig. 8. Maximum deformation at 5,25 kN load on materials: (a) Aluminum $AlSi_{10}Mg$: maximum deformation 0.0306 mm, and (b) Composite $AlSi_{10}Mg(b)+SiC*/15p$: maximum deformation 0.0275 mm.

Results of the stress distribution and maximum deformation in the finite element analysis of the ship using aluminum $AlSi_{10}Mg$ and composite material (b) + SiC * / 15p with a load on the bilge lane of 25.31 kN / m² are applied to the two ship models. The burden on the bilge lane is calculated based on the rules of the Ship Classification Bureau (BKI) Volume II 2009. The maximum stress that occurs in the ship model is made from composite that is 54.2 MPa with a maximum deformation of 7.86 mm (Figure 9), while the maximum stress on the aluminum ship model is 89.1 MPa with a maximum deformation of 11.7 mm (Figure 10).



(a) (b)

Fig. 9. The finite element model uses composite material: (a) Tress distribution, and (b) Maximum deformation.



(a) (b)

Fig. 10. The finite element model uses aluminum material: (a) Tress distribution, and (b) Maximum deformation.

In the comparison of the results of the above modeling with the research carried out by previous studies (Tjahjanti *et al.*, 2013; Sielski *et al.*, 2008; Huang *et al.*, 1998; Tzimas *et al.*, 1999) about Composite-Based Numerical Modeling of Ship on Aluminum Casting as Alternative Materials for Ship Building, it shows that numerical modeling of ship aluminum (AC-43100 EN ($AlSi_{10}Mg$ (b)) and composite ship EN AC-43100 ($AlSi_{10}Mg$ (b))+SiC*/15p) has successfully demonstrated the distribution stress to the full body ship, construction of the base (bottom), and main deck in the condition of under water, and induced wave. Stress distribution value in both of model numerical of ship did not exceed the stress permits (sigma = 0.2) and had a factor of safety above the minimum allowable limit. This, it can be concluded that this ship is safe to be used.

CONCLUSION

The overall results for maximum stress as well as for maximum deformation in both bending specimen and the vessel with finite element analysis show that the aluminum material $AlSi_{10}Mg$ (b) always has a higher value compared to the composite material $AlSi_{10}Mg$ (b) + SiC * / 15p, even though the difference is relatively small. This condition occurs because the overall weight of aluminum alloy vessels is lighter than composite vessels (because composite vessels have SiC reinforcement). Therefore, for the same load treatment, aluminum alloy vessels will receive more stress or greater maximum stress.

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