Numerical analysis of Composite with Natural Fiber Reinforcement using Finite Element Method: Leaf Spring Composite Application

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Abstract. Leaf spring is one of component that use to vibration damping on vehicle, where one of material that use to fabrication this component is 55Si7 steel. Currently, sustainable product is main focus in industry, so that composite is a potential alternative to replace steel as leaf spring. Materials that use to composite fabrication are sisal as fiber, epoxy as matrix, and honeycomb and alumunium alloy as core, where fabrication both 55Si7 steel and composite specimen are based on ASTM D638 standard. Fabrication of composite specimen conducted by hand lay-up technique, and mechanical properties analysis of thus specimen are conducted by finite element method. Tensile test is tested on 55Si7 steel and composite specimen using finite element method. According tensile test, steel of 55Si7 type have 2.92 mm of total deformation average, and 12583 MPa of strain, composite natural fiber with honeycomb core have 62.75 mm of total deformasi average, and 18590 MPa of stress, and composite natural fiber with aluminium alloy core have 15.47 mm of total deformasi average, and 12813 MPa of stress. According that results, composite with aluminium alloy core have the mechanical properties close to 55Si7 steel than composite honeycomb core.

Keywords: *Sisal Fiber, Finite Element Method, Hand Lay-up Technique, Leaf Spring.*

1 Introduction

Steel leaf spring is one of the component used in the automotive industry which use to reduce vibration. One of the problem caused by steel leaf spring is corrosive, so that it can cause steel leaf spring to degrade mechanical strength. alternatively, the development of suistanable and durable composite leaf spring with the natural fiber is needed, so that it become an economically valuable product. In generally, the development natural fiber as reinforcement in composite fabrication [7], and composite leaf spring fabrication have been succesfully with use the fiber glass which is conducted by [12, 15]. Analysis of mechanical properties of composite leaf spring has been conducted by Singh, H., et al, 2018 [11]. Composite have adventage such as not corrosion, light weight, and mechanical properties can be designed easily. The main porpose of mechanical design is to get the optimum compositions of the composite material, so that time

and cost can be efficient to material fabrications [5,6]. Optimum condition can be determined through the design and simulation of composite laminates. Finite element method has been succesfully bio-composite analysis with natural fiber to determine optimal of fraction volume of fiber. This work conducted by Silva, L.J.S., 2012 [10], and life time prediction for the subsurface crack propogation [14]. In addition, the finite element method have been applied to simulation of natural fiber in several composite [13]. the number and mesh model used in finite element method can affect to the accuracy of the material simulation [9]. In addition, this method have been used widely in many application to material analysis of both mechanical and physical properties such as composite, metal, ceramic, and polymer materials. Mechanical properties of natural fiber not only investigation through simulation but also experiment [1,4,7,14].

This research is go to design and simulate composite materials for leaf spring application to light vehicles, so that it has mechanical properties that are close to or equal to 55Si7 steel. Composite raw materials for leaf spring applications are composed of several laminas designed using hand lay-up techniques. Composite materials for leaf springs that use to design are sisal as fiber, honeycomb and aluminum alloy as core, and epoxy resin. The specimen design is done using design modeler and ACP Post software that has been integrated with ansys 19.1 software, while simulation and analysis of design results will be carried out using the finite element method as has been done by Nurhaniza, M. et al., 2010 [8] on aerospace application. Mechanical strength of composite able to enhance with fiber direction variation [3]. Based on the description above, this research is the development composite with natural fiber and its composition that thus materials can be applied to leaf spring technology that can be applied to light vehicles which generally leaf spring used in vehicles are manufacture from steel. The development carried out in this study are the materials design that applied to composite leaf spring to obtain ideal conditions so that they are compatible with steel leaf springs.

2 Material and Methods

This research was conducted by comparing the mechanical properties of steel 55Si7 with a composite design, where the research was carried out numerically using the finite element method [2]. Materials that used to design composite specimen in Fig. 1 namely sisal as fiber, honeycomb and aluminum as core, and epoxy resin. Physical properties of this raw material is isotropic. Composite design is done by using modeler design software for the laminas design and ACP Pre for fiber direction, laminate thickness and cores design, and combine laminas. the size of the specimen (Figure 1) that is used 99 mm x 21 mm x 2 mm which is based on the ASTM D638 standard. The specimens are tested by tensile test numerically with finite element method, and force is applied close to 200000 Newton on one side in right hand, and other side as fixed point.
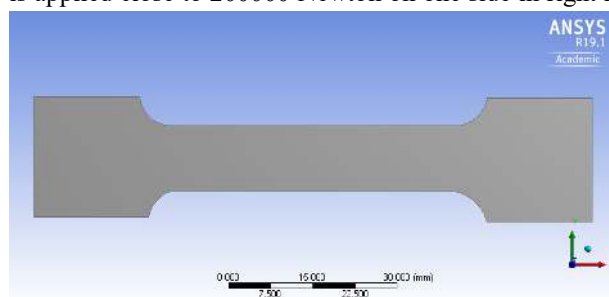

Figure 1. Specimen model of raw material.

The next step is manufcaturing composite laminas using hand hay-up techniques with a total thickness of 2 mm with nine laminas. The laminas that used to modeling ply are consists of four ply of sisal-epoxy, a ply aluminum alloy and honeycomb, and four ply of sisal-epoxy. Honeycomb and aluminum alloy are used as a core for composite compositions. The direction of the fiber used for the first four layers is 0 90 45 -45 as shown in Figure 2.
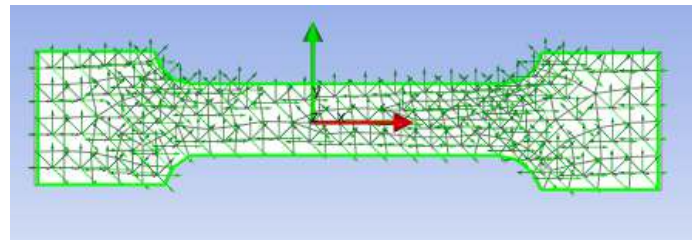

Figure 2 Fiber orientations of the fist four ply for sisal-epoxy.

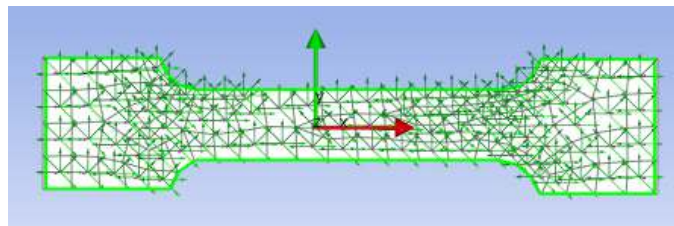and fiber orientasion of the next four ply that use in this research namely -45 45 0 90 at Figure 3.

Figure 3 Fiber orientation of the second four ply for sisal-epoxy.

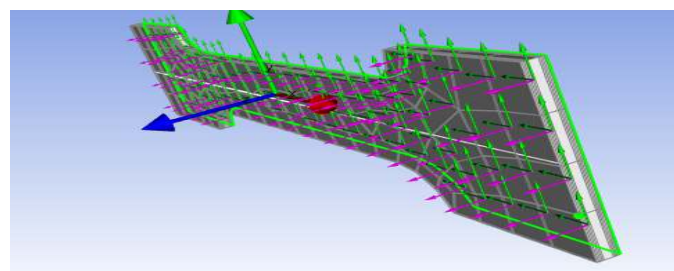Combination of all ply of sisal fiber and core of both aluminum alloy and honoycomb core show in Figure 4.

Figure 4 Raw material of composite.

Core thicknes at Figure 4 is equal to 0.8 mm dan thicknes eight ply of sisal epoxy laminas equal to 1.2 mm with thicknes of each ply is equal to 0.15 mm. Analysis of mechanical properties both 55Si7 steel raw and composite raw material was carried out using finite elemen method that integrate in ansys 19.1 software. Mechanical properties that produce by 55Si7 raw material is to be reference to composite raw material design.

3 Results and Discussion

This research is conducted to find out composition optimal of composite design that close to mechanical properties of 55Si7 raw material. Mechanical properties that is investigated such as deformation total, stress, and strain, where simulation both 55Si7 steel and composite raw material revealed by Figure 5, Figure 6, and Figure 7.
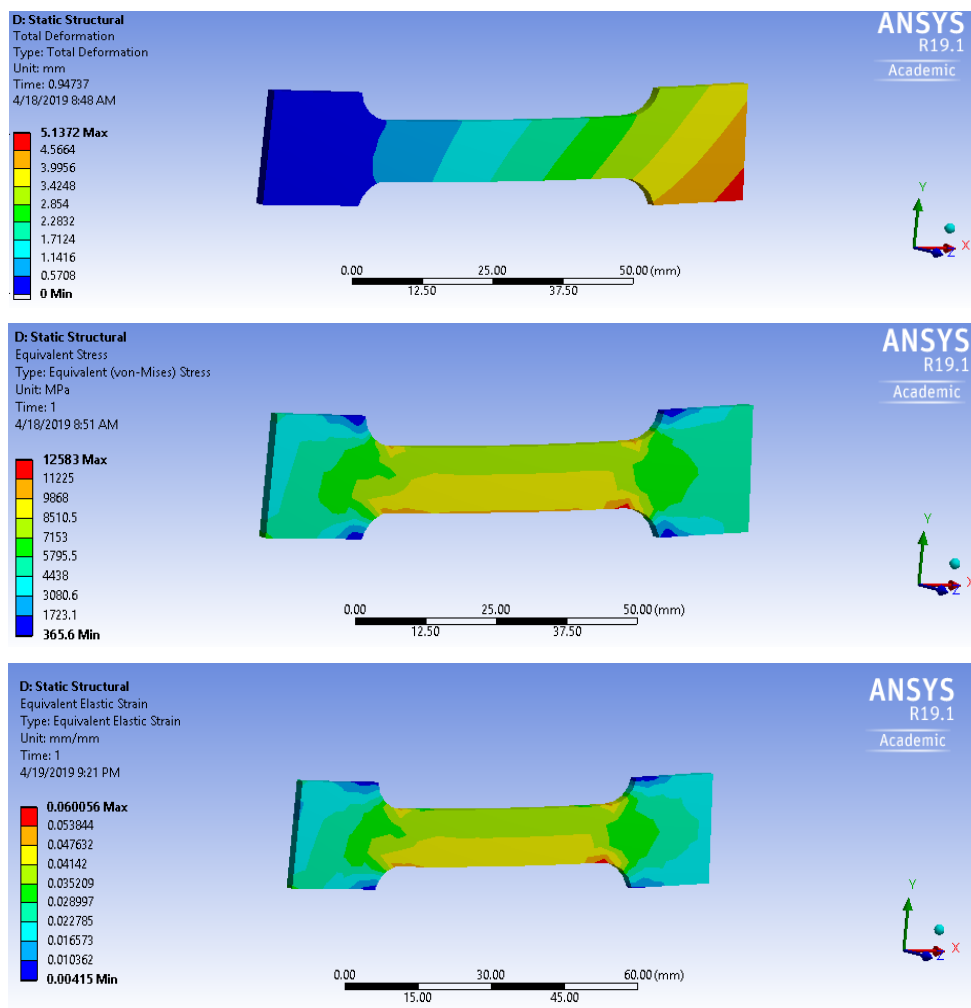

Figure 5 Total deformation, equivalen stress von mises , dan equivalen elastic strain of 55Si7 steel specimen.
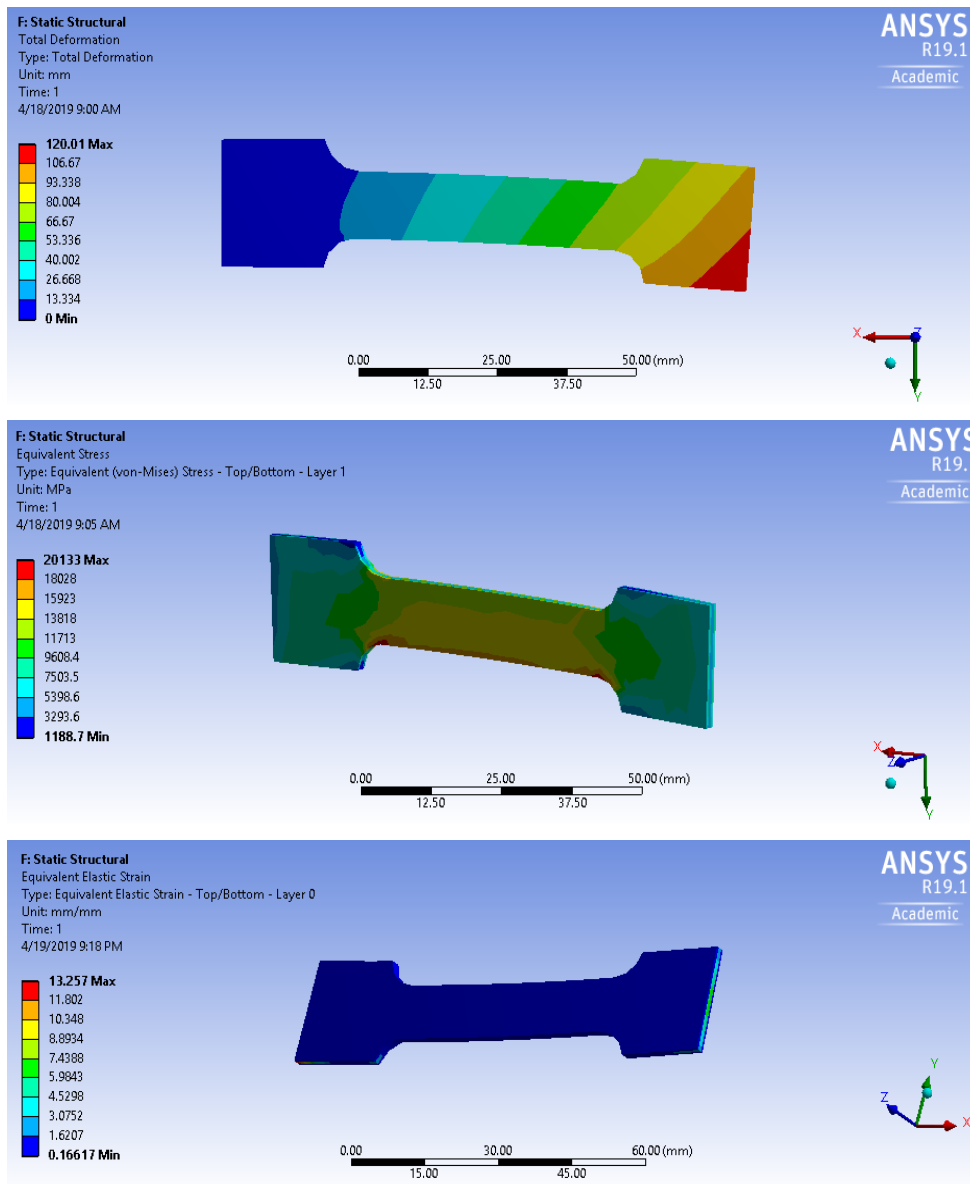
Figure 6 Total deformation composite, equivalen von mises stress, dan composite equivalen elastic strain of raw material base on honeycomb core.
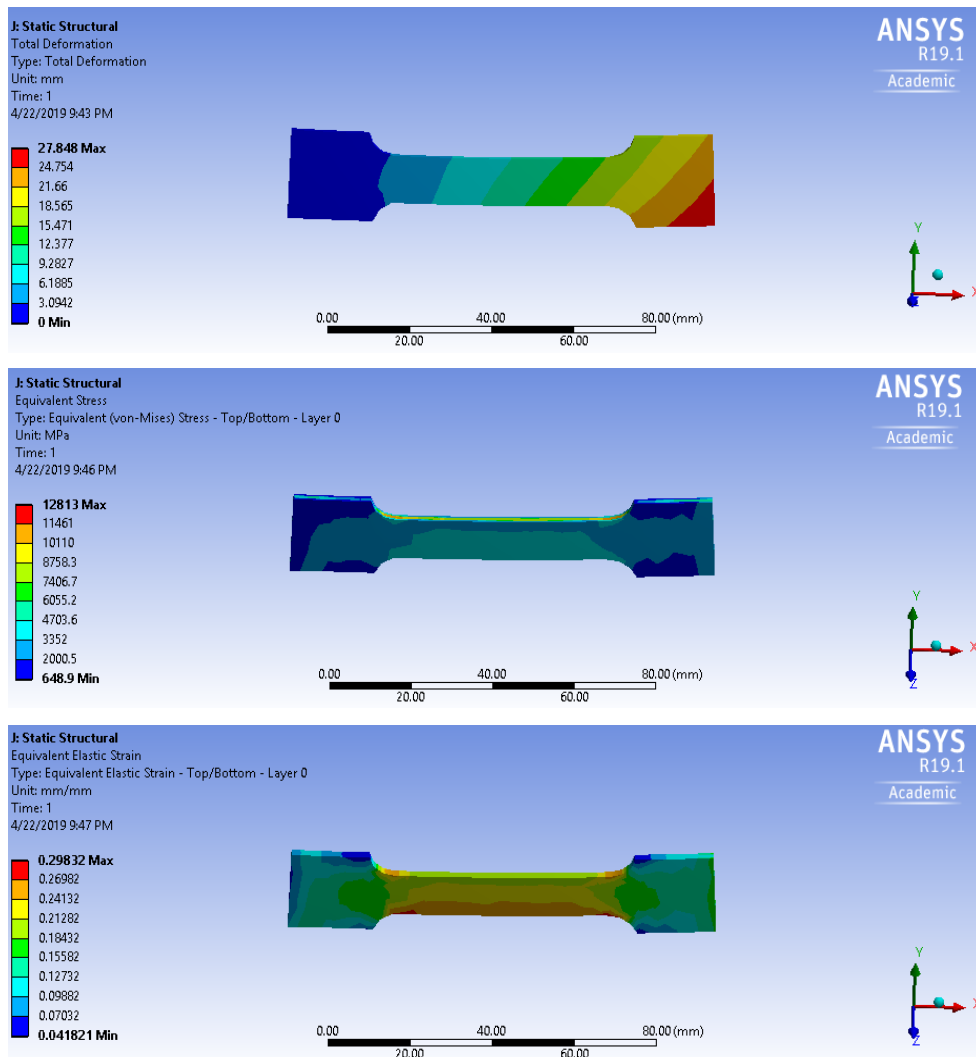
Figure 7 Total deformation composite, equivalen von mises stress, dan composite equivalen elastic strain of raw material based on aluminum core.

Figure 5, Figure 6, and Figure 7 show a comparison of the mechanical properties of the two raw materials, which are 55Si7 steel with composites base on both honeycomb core and aluminum core, where value distribution of mechanical properties are over the raw material. The results show that the total deformation averages of 55Si7 steel, composite base on honeycomb core, and composite base on aluminum core are shown in Table 1, where composite base on honeycomb core have the average total deformation is greater than 55Si7 steel and composite base on aluminum core. this result reveal that the composite based on honeycomb core designed has greater elasticity than composite base on aluminum core and 55Si7 steel. The large average strain is caused by the honeycomb material as the core as shown in Figure 6.

Table 1. Mechanical properties of raw material.

Raw Material	Average total deformasi (mm)	Min equivalent von mises strain (mm)	Max equivalent von mises strain (mm)	Min equivalent von mises stress (MPa)	Max equivalent von mises stress (MPa)
Steel 55Si7	2.92	0.04	0.06	365.60	12583
Composite base on honeycomb core	62.75	0.17	13.26	1403.10	18590
Composite aluminum core	15.47	0.04	0.30	648.90	12813

The equivalent elastic strain in Figure 6 shows the largest strain distribution (Table 1) in the core material, while the composite design of sisal-epoxy elastic has the strain distribution equal to 0.17 mm. This value approach to the elastic strain of 55Si7 steel at 0.04 mm, and composite aluminum core at 0.04 mm. In addition, the maximum stress that can be received by composite raw material is greater than 55Si7 steel and composite aluminum core as shown in Table 1. This shown that the ability to receive stress is better than 55Si7 steel and composite aluminum core.

Composite with aluminum core have the mechanical properties close to 55Si7 steel as shown by Table 1 such as minimal and maximal equivalent von misses strain, and minimal and maximal von misses stress. This means that combination composite design which is equal to steel 55Si7 are sisal as fiber, aluminum as core of composite, and epoxy resin.

4 Conclusion

Design raw material 55Si7 steel and composite have been succesfully using design modeler and ACP post software, and design model has been analysis using finite element method to determine mechanical properties such as strain, strain, and total deformation. According tensile test using finite element analysis namely 55Si7 steel have 2.92 mm of deformasi total average, 12583 MPa equivalen von mises stress, composite with honeycomb core have 62.75 mm of deformasi total average, and 18590 MPa equivalen von mises stress, and composite with aluminum alloy have 62.75 mm total deformation average, 12813 MPa equivalen von mises stress. According that results, composite design have mechanical properties higher than 55Si7 steel and composite with aluminum both in deformation total and strain.

Material compositions of composite raw material with natural fiber namely sisal fiber, resin epoxy, and honeycomb and aluminum alloy as core. The results of composite with honeycomb core design reveals the highest strain caused by honeycomb as core, and sisal-epoxy laminas design reveals equivalen von mises strain as 0.17. While composite with aluminum alloy have mechanical properties close to 55Si7 steel such as equivalent von mises stress and strain. This can be concluded that composition design composite that close to mechanical properties of

55Si7 are sisal as fiber, aluminum alloy as core, and resin epoxy with the fiber orientation 0º 90º 45º -45º for 4 ply, and others -45º 40º 0º 90º. the thicknes of each ply is 0.15 mm, and thicknes of core is 0.8 mm.

Acknowledgements

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