Finite Element Simulation of Micromechanical Bending Behavior of Typha Fiber Reinforced Composite

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Abstract

One of the natural fiber that have the potential to replace synthetic fibers is *Typha spp* fiber. Typha is mostly found in a stock of water and also in wastelands. A few studies have been done before to investigate mechanical properties of Typha fiber reinforced composite by experimental approaches. This work focuses on the study of the micromechanical bending behavior of Typha fiber reinforced epoxy resin and investigates the interface conditions between Typha fiber and matrix by numerical simulation approach. Micromechanical of Typha reinforced composite is modeled with bonded model contact and no separation model contact conditions, then three types of mesh were adjusted and analyzed using ANSYS. The result showed that with contact model applied, epoxy resin distributed load to fiber immediately and Typha fiber capable of carrying the load out properly. Based on the simulation result of two model contact we occurred the gap between fiber and matrix on the bottom surface where the area does not directly face load. The gaps indicate debonding fiber from the matrix.

Keywords : Finite element, micromechanics, bending, Typha, composite

Introduction

The use of natural fiber as an alternative reinforcement is suggested to reinforce composites because its superior properties such as high specific strength, low weight, low cost, eco–friendly and bio–degradable (Sanjay, *et al*., 2015). One of the natural fiber that have the potential to replace synthetic fibers is *Typha spp.* fiber. Typha is mostly found throughout the world (Baldwin *et al*., 2007) especially in province Aceh. Typha can be found in a stock of water and also in waste lands. Typha is still regarded as a plant that doesn't have a lot of benefits and has no sale value, therefore the growth of Typha is not expected. These plants are often considered parasitic. Despite Typha is mostly available and renewable, but their potential compared to other natural fibers is still underutilized (Ramanaiah, *et al*., 2011). Actually, a lot of things that can be provided from this plant, one of them is Typha fiber for reinforcing composite. A few studies have been done before by experimental approaches, Typha fiber reinforced composite has a good flexural strength (Bajwa, *et al*., 2015), low weight (Wuzella, *et al*., 2011), fairly good mechanical properties, low density and renewable (Ponnukrishnan, *et al*., 2014).

Ramanaiah, *et al*. (2011) investigated mechanical properties and thermal conductivity of *Typha angustifolia* fiber reinforced polymer composites. Based on his research he concluded that tensile strength of Typha fiber reinforced composites increases with increasing amount of fiber. As well as the same result conducted by (Ponnukrishnan, *et al*., 2014) he was studied the mechanical characteristic polymer composite reinforcing by *Typha domingensis*.

One limitation in the analysis of natural fiber composites is difficult to predict the condition of the interface between fiber and matrix. Instead of analytical methods, numerical simulation was used to predict contact interface. Finite element method has been used to analyze the global behavior of composite structures and plays an important role in detecting damage of composite (Alnafie, 2009). The aim of this work is to study micromechanical bending behavior of Typha fiber reinforced epoxy resin and investigates the interface conditions between fiber and matrix by numerical simulation approach.

Methods

Material

Unidirectional and continuous Typha fiber was modeled using ANSYS Workbench. Typha fiber length and fiber diameter is 220 mm and 26,6 µm (Wiztum *et al*. 2014). The Poisson ratio of epoxy resin was 0,4. Determination of the natural fiber Poisson ratio is extremely difficult. Thus, the Poisson ratio is determined randomly in the range of 0,00– 0,35(Leandro José *et al*., 2012). Material properties Typha fiber and epoxy resin presented in Table 1.

Table 1. Properties of Typha fiber and Epoxy Resin

Property	**Typha Fiber[1]**	**Epoxy Resin[2]**
Density (g/cm^3)	1,25*	1,16
Maximum Tensile Strength (MPa)	202	73
Young's Modulus (MPa)	11.565	5.000

[1] (Wiztum *et al*. 2014), [2] (Joao Marciano 2012),* (Mortazavi *et al*. 2009)

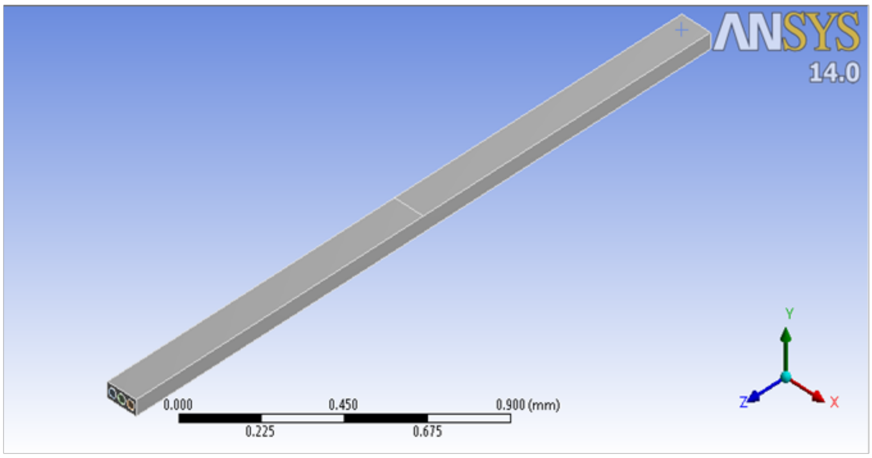

Figure 1. Model geometry

Contact Model

The micromechanical composite strength was affected by fiber, matrix and interface, all of the items are usually referred to the Unit Cell (UC) (J. Modniks, 2013). Matrix surface interacting with fiber surface causes the occurrence of contact. See Figure 2.

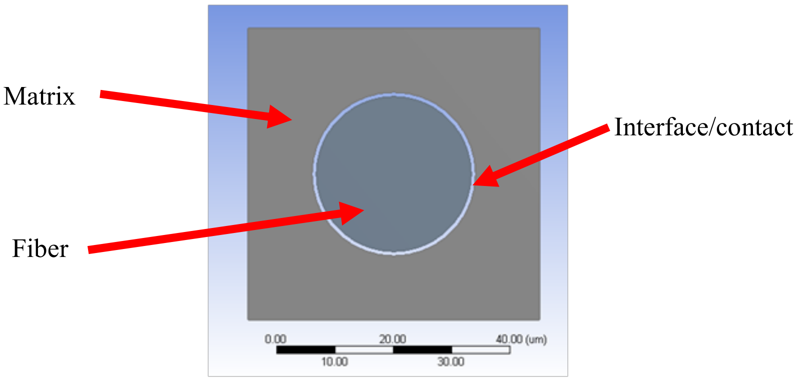

Figure 2. Schematic of the unit cell

Contact between the fiber and matrix was modeled with some contact features that exist in ANSYS Workbench. The blue highlights represent the target face and the red highlights represent the contact face. One thing that should be a concern in the modeling of contact is the target body should always be stiffer than the contact body. In this case, the matrix is stiffer compare to the Typha fiber. Therefore, matrix surface which is interacting with the fiber is highlighted in blue color and the fiber is highlighted in red color. As seen in Figure 3. In this case, contact condition was modeled by utilizing bonded contact and no separation contact features.

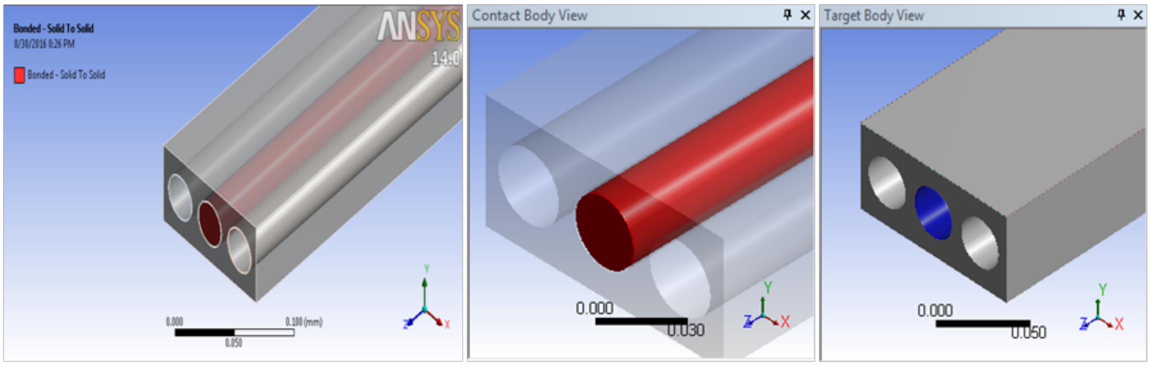

Figure 3. Unit Cell contacts model

Mesh and Boundary Conditions

There are three selected models of mesh, the first is adaptive mesh, the second is refine mesh relevance center, and the third is refine mesh center span angle. The difference type mesh after applying to the model was shown in Figure 4. The load applied to the central part of the micromechanical composite model geometry and fixed support was used to hold two edges of the model geometry shown in Figure 4d.

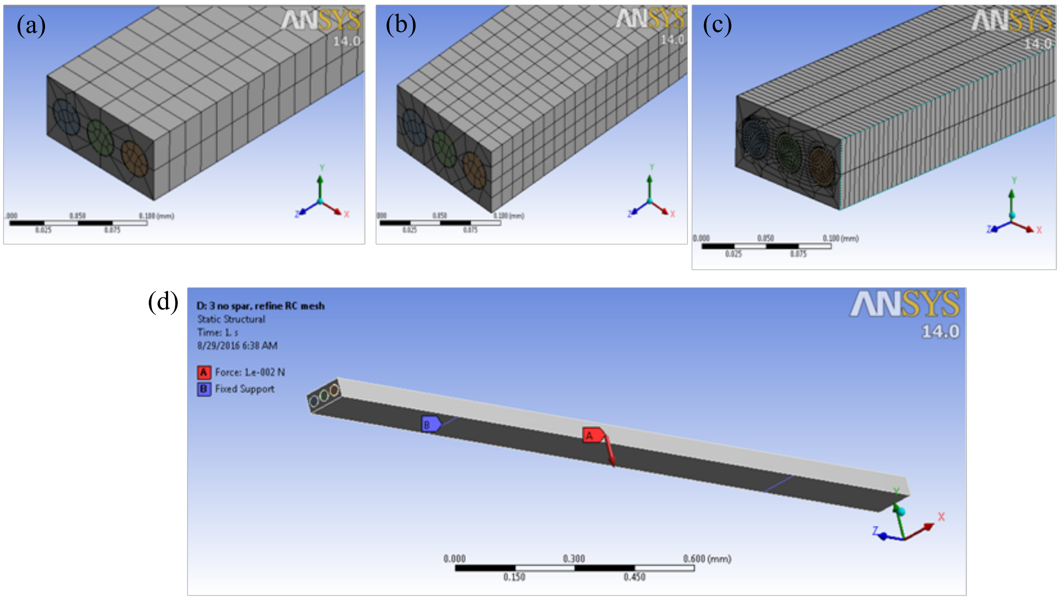

Figure 4. Mesh and Boundary Conditions (a) Adaptive mesh, (b) Refine Relevance center mesh, (c) Refine span angle centre mesh, and (d) Boundary conditions

Result and Discussion

The contact within applied on micromechanical composite showed the result that epoxy resin distributed immediately load to fiber and Typha fiber can be properly carried out the load. Adjusting contact is very important in micromechanical composite modeling to simulate the interface conditions between fiber and matrix. If model contact was not adjusted then the load received by matrix can’t be distributed to fiber. As we know that fiber is the component to carry the load out. The result with contact was not applied will be shown in Figure 5a. Afterward, the result within adjusted contact will appear in Figure 5b.

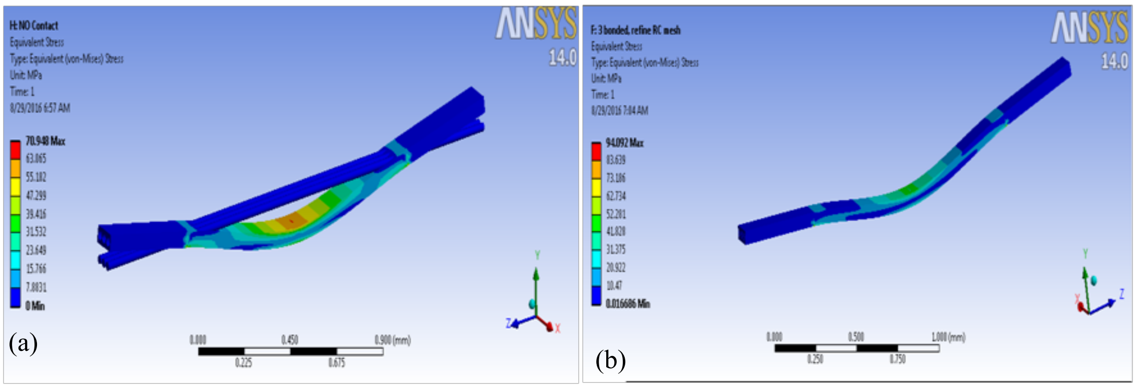

Figure 5. Result within and without contact, (a) No contact applied and (b) Contact applied

The accuracy of finite element method solutions is increasing as more as the element are used, but with more the time required for computing is also getting bigger. The value of maximum principal stress, maximum principal strain and maximum shear is affected by given mesh, as it is kwon that three types are used. In the adaptive mesh type maximum principal stress is smallest while with the refine span angle centre mesh is greater. It indicates the more detail mesh it will provide more accurate results. Bending behavior of Typha fiber reinforced epoxy resin as can be seen in Table 2.

Table 2. Bending behavior

Bending behavior	Elements	Maximum Principal Stress (MPa)	Maximum Principal Elastic Strain	Maximum Shear Stress (MPa)	Total Deformation (mm)
Bonded Contact Condition					
Adaptive Mesh	5313	36,336	0,01161	45,575	0,031374
Refine Relevance Center Mesh	8294	39,296	0,013378	53,755	0,031447
Refine Span Angle Mesh	355461	86,991	0,029563	110,5	0,031803
No Separation Contact Condition					
Adaptive Mesh	5313	36,564	0,011723	45,781	0,031396
Refine Relevance Center Mesh	8294	39,4	0,013417	53,911	0,031464
Refine Span Angle Mesh	355461	82, 672	0,028481	106,76	0,033542

Table 3. Contact status

Contact status	Maximum Frictional Stress (MPa)	Maximum Pressure (MPa)	Sliding Distance (mm)	Penetration (mm)
Bonded Contact Condition				
Adaptive Mesh	3,089	10,086	8,9891e^{-7}	2,3836e^{-7}
Refine Relevance Center Mesh	2,6666	6,5543	7,2807e^{-7}	1,3867e^{-7}
Refine Span Angle Mesh	5,2934	13,072	2,4529e^{-6}	4,0766e^{-7}
No Separation Contact Condition				
Adaptive Mesh	0	11,899	2,0189e^{-6}	2,8154e^{-7}
Refine Relevance Center Mesh	0	7,9933	1,5242e^{-6}	1,6927e^{-7}
Refine Span Angle Mesh	3,844	783,23	5,0218e^{-5}	2,4427e^{-5}

Frictional stress, pressure, sliding distance and penetration in contact status illustrate interface conditions between fiber and matrix can be seen in Table 3. On bonded contact condition, there is a gap at the bottom surface of the fiber which is surface doesn't directly deal with the applied load. The same situation occurs in no separation contact condition, the gap can be found at the fiber bottom surface. These gaps indicate that fibers are no longer attached to matrix, this condition commonly called debonding phenomena. Difference gap condition on two model contact types exists at the edges model geometry, besides fixed support area, where on the no separation contact condition larger gap was found. The gap condition of two types contact model can be viewed in Figure 6.

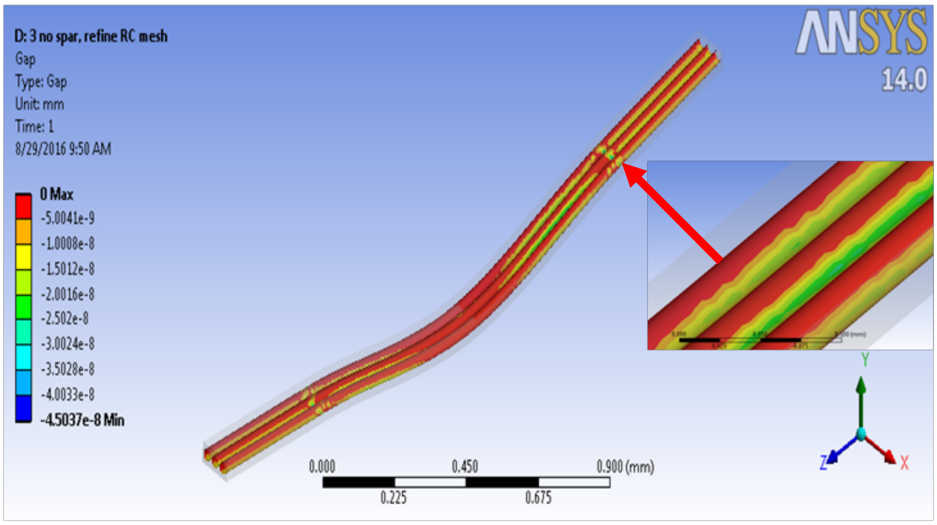

Figure 6. Gap status

Conclusions

In this paper, we suggested the micromechanical composite bending behaviour based on simulation result by adjusting contact to simulate interface conditions between fiber and matrix, the contact within applied on micromechanical composite showed the epoxy resin distributed load to fiber immediately and Typha fiber capable of carrying the load out properly. On two types of model contact, we occurred the gap between fiber and matrix on the bottom surface where the area does not directly face load. The gaps indicates debonding fiber from the matrix.

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