Research Progress in Mechanical and Manufacturing Engineering Vol. 2 No. 2 (2021) 1009-1016

RPMME

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

Crack Propagation Simulation Using Ansys for Bamboo Composites

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DOI: https://doi.org/10.30880/rpmme.2021.02.02.110
Received 15 July 2021; Accepted 25 Nov. 2021; Available online 25 December 2021

Abstract: Nowadays, natural fibre composite was suggested to replace the existing composite materials in the manufacturing sector. This is because natural fibre composite is more sustainability and environmental friendliness than another composite material. Moso bamboo and Guadua bamboo has been chosen to as the main material for the crack propagation in Ansys Workbench R3 software. The numerical simulation for both bamboos has been done by using quasi static loading method. This simulation focuses on the different type of specimen of bamboo composite which is rectangular path with right crack, rectangular part with left crack, beam under four-point bending and crack with one hole with cracking mode for mode l, K_I only. The relationship between stress intensity factor and length of crack, relationship between crack extension and crack propagation process had been discussed. The result shows that different type of specimen produce different type of propagation.

Keywords: Crack Propagation, Moso Bamboo, Guadua Bamboo, Stress Intensity Factor, Crack Extension, Ansys Workbench R3.

1. Introduction

Bamboo is a composite form of natural fibre known as stalk fibre. Within the kingdom of Plantae, bamboo is grouped under the subfamily Bambusoideae. Bamboo is divided into 70 groups and there are about 1,450 species in the world, including 14 species located in Asian tropics. Bamboo is a kind of the plant fibre that was known by natural fibre composite called stalk fibre. Within the Kingdom of Plantae, bamboo is grouped under the subfamily Bambusoideae [1]. There are approximately 70 bamboo species in general and globally there have been more than 1,450 bamboo species, 14 of them located in Asia's tropical zone. For this analysis, two separate types of bamboo, Latin American and Chinese have been picked. Following the procedures of the local provider, on-site, mature poles were gathered and processed. The goal of treatments is to keep bamboos safe from mould, rotting, and

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separating. Guadua bamboo was leached and air-dried, which involves immersing poles in a solution of sodium tetraborate and hydrogen borate for about 7 days literally and then air-drying them for 21 to 28 days on well-ventilated, direct sunlight-protected racks.

In the situation of moso bamboo, the treatment was also performed using carbonisation, with bamboo poles being horizontally positioned to oven of carbohydration at 348 K, 45% of humidity, and under 16 Bar for 1 hours and 30 minutes followed by 7 to 14 days on well-ventilated sunlight-covered racks [2]. As described above, bamboo's mechanical properties rely on several variables, such as species, location of the culm, and age. This impacts the bamboo for the density of fibre at some point on the bamboo. Fibre density has been identify based on the weight of the bambo. It is also known, in addition to these reasons, bamboo is a natural orthotropical material, which implies that in the longitudinal, radial, and tangential directions of bamboo, it has various mechanical characteristics [3].

Engineering systems are designed to handle the loads that they may encounter when being processes. Excessive quantities of stress are resisted and an appropriate margin of protection is followed to prevent the reaching of levels similar to the specified maximum stress. So, material improvements which take place at the time the material is processed or used, it was feasible and therefore must be considered. In fact, as they develop over time, even micro-scopic defects can cause systems that are supposed to be stable to failure. In the past, it was either restored or actually removed from service when a part of a system showed a crack. In certain cases, such procedures are now thought inadequate, impractical to implement, or can prove too expensive. In fact, on the one hand, as for growing in energy and material protection, the safety margins allotted to systems must be lower [4]. When it comes to costly materials or elements of systems whose use it will be impossible to disrupt, this is especially important. Fracture mechanics play a major part in this environment, since they offer essential tools for examining materials with fractures. The purpose is to determine if or how a failure occurs.

Fracture is essentially a problem of evolution and a successful fracture model would be evaluated by its dual ability to estimate the crack's spatial path, or cracks, as well as the movement of those cracks along the predicted path in time. In a brittle, elastic setting are the purposes of Griffith's philosophy Griffith mainly focused on the quasi-static related crack propagation in a 2d medium, linearly elastic, homogeneous and isotropic, and he believed that the crack path was identified a priori and that within the domain under investigation it consisted of a "nice enough" curve.

2. Materials and Methods

This chapter discusses the method and setting used in this simulation in more details starting from the parameter setup, shape of the specimen until the running of simulation to obtain the data needed. The purpose of this section is to help a better understanding on the process flow in this research.

2.1 Geometry and model

Four models including rectangular plate with right crack, rectangular plate with left crack, planar domain with an off-center hole and rectangular plate with two holes were generated using SolidWorks. The material assigned for the simulation is Moso bamboo and Guadua bamboo. Table 2.1 shows the material properties for two type of bamboo which is Moso bamboo and Guadua bamboo. While Figure 2.1 show the geometry of the specimen

Table 2.1: Parameters for Moso bamboo and Guadua bamboo [5]

	Moso	Guanda
Density (kg/m^2)	550	600
Young Modulus (GPa)	8.5	13.5
Poisson's Ratio	0.384	0.384
Coefficient of Thermal Expansion (C^{-1})	3.26 x 10^{-6}	3.26 x 10^{-6}

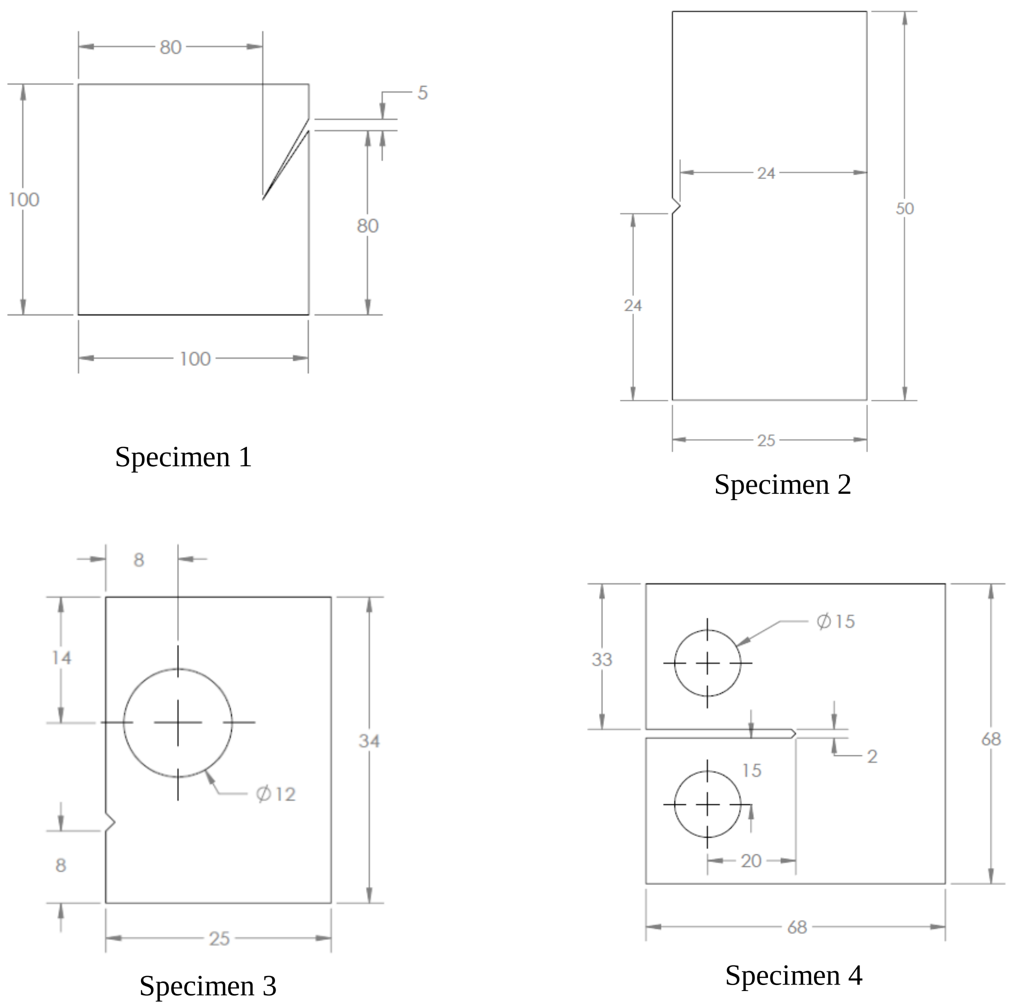


Figure 2.1 : Geometry of the specimen

2.2 Ansys Workbench R3 program

The process continue after the model for bamboo composite has been created from Solidwork program. First and for all, the file from Solidwork program has been import to the Ansys program. After importing the file, set up the engineering data for the bamboo composite’s mechanical characteristics. Another step is to generates mech of the models of bamboo composite. Each model is being set up with some boundary condition to perform the simulation. The side face of every model is set up with a fixed support. Opening Mode (Mode I) analysis is used by applying opposite forces at the top and bottom surface of the model. After set up , the the fracture criteria needed to select. Finally, run the simulation and analysis. When undergo meshing in simulation, it will be affecting the accuracy, convergence and speed. The mesh affects the simulation's precision, convergence and speed. Moreover, the faster and more precisely solution the simpler and more automatic meshing tools normally require a great amount of time to get simulation results.

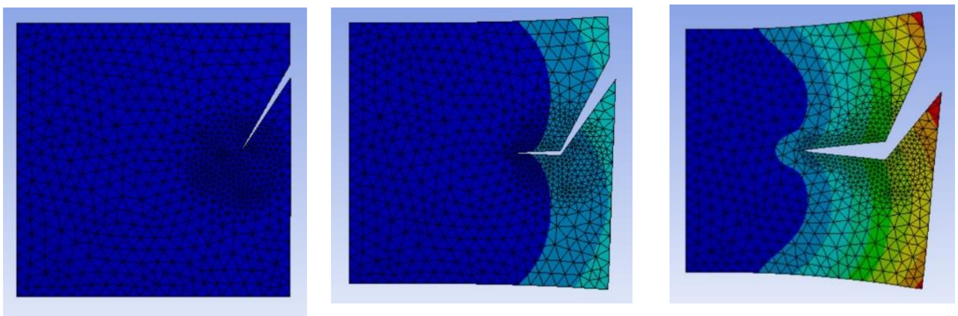
3. Results and Discussion

The results and discussion section present data and analysis of the study. Analysis of data is a process where the data collected is being analyzed according to the objectives of the study. The result obtained were discussed accordingly.

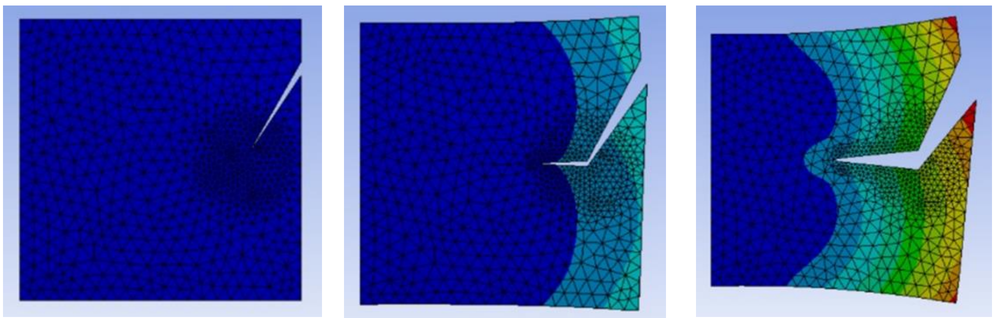
3.1 Comparison of crack propagation for each of the specimen

Pre-meshed crack is important in order to perform the crack propagation. In this simulation, two forces with the magnitude of 10000kN are applied oppositely on the top and bottom surface of the model. This allows the crack to propagate in opening mode, mode I. As can be seen from the Figure 3.1 until 3.4 the crack path grows horizontally due to the maximum principal stress which caused by the forces that being applied vertically. As the stress around the crack path increases, the crack will elongate along the crack path. According to Bouchard et al. the crack propagates in the cleavage mode (mode I), perpendicular to the maximal stress which is vertical due to the applied load [6]. This trajectory result also gives a good agreement with the previous researcher result [6,7].

Figure 3.1(a) and (b), 3.2(a) and (b), 3.3(a) and (b) and 3.4(a) and (b) shows the crack propagation process for different type of specimen and different type of bamboo. From all the figures, it can be concluded that there is not significant different in term of crack propagation trajectory for Moso bamboo and Guadua bamboo. Since there are from the same type of natural fibre,

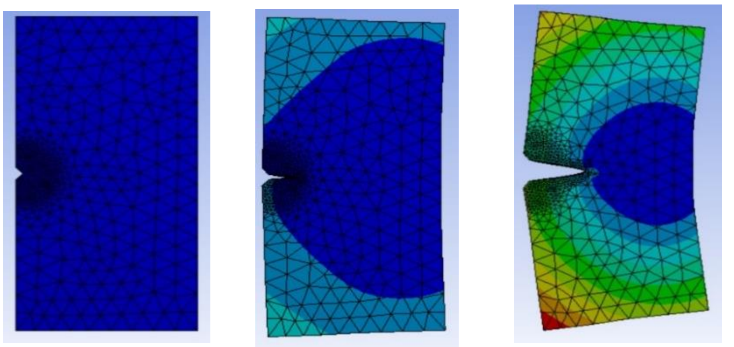


(a)

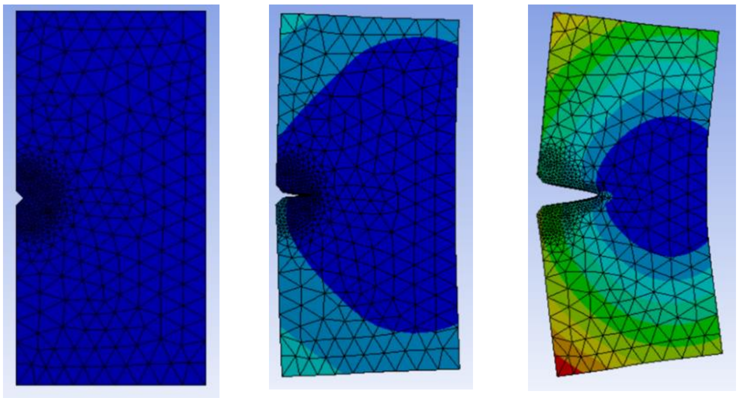


(b)

Figure 3.1 : Crack propagation for specimen 1 (a) Moso bamboo (b) Guadua bamboo

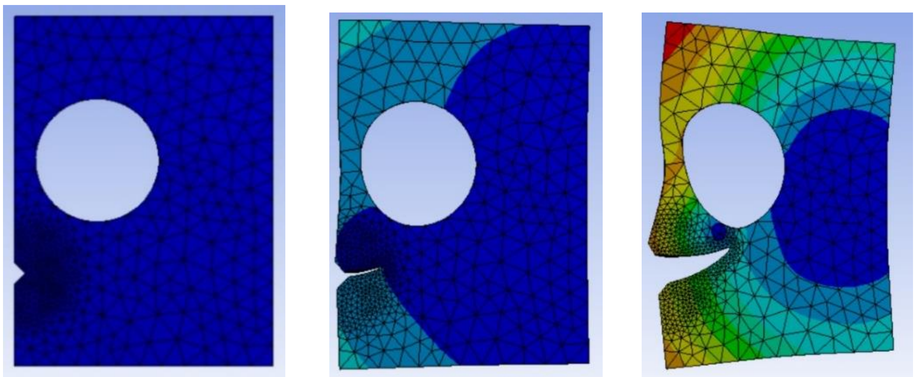


(a)



(b)

Figure 3.2: Crack propagation for specimen 2 (a) Moso bamboo (b) Guadua bamboo



(a)

(b)

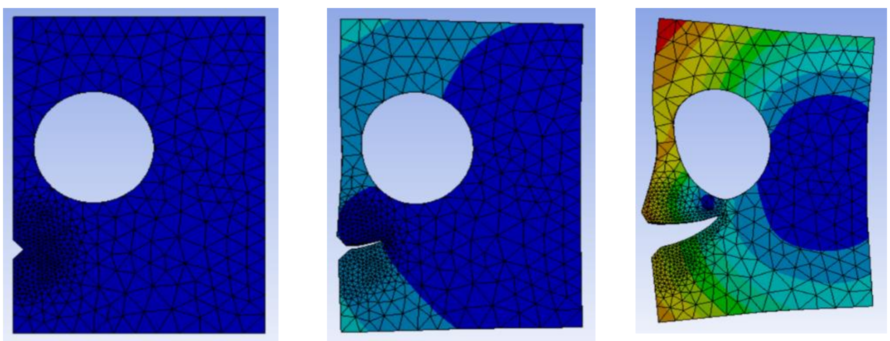
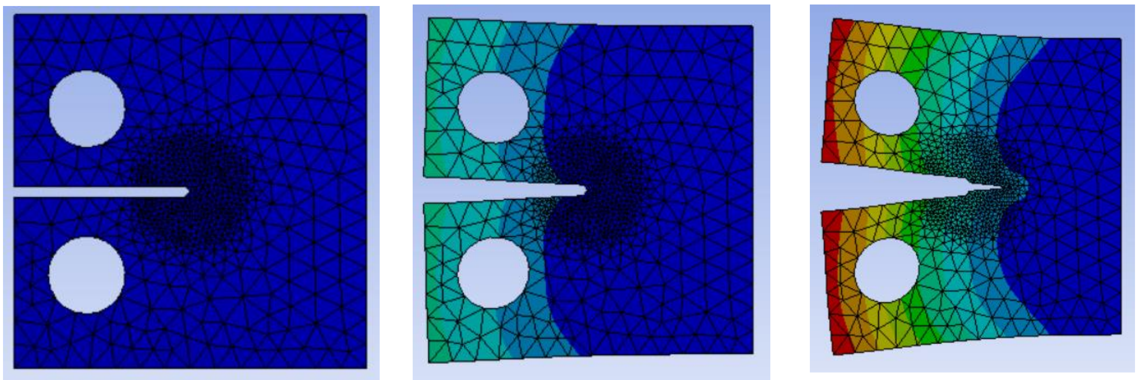
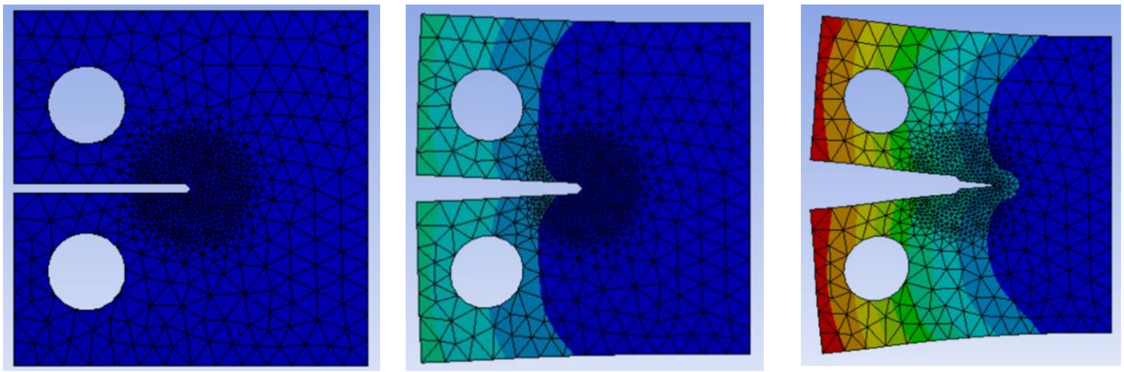


Figure 3.3 : Crack propagation for specimen 3 (a) Moso bamboo (b) Guadua bamboo



(a)



(b)

Figure 3.4 : Crack propagation for specimen 4 (a) Moso bamboo (b) Guadua bamboo

3.2 Comparison of stress intensity factor for K_I for Moso and Guadua.

Stress intensity factor along the crack front can be determined in solver output. The stress intensity factor will completely define the crack tip condition. At the stress level when the crack propagates, the stress intensity at the crack tip of the crack is called the critical stress intensity factor. For specimen 1, and specimen 3, moso bamboo has greater stress intensity factor compared to Guadua bamboo which is 8.5323×10^9 Pa$\sqrt{m}$ and 7.2584×10^8 Pa$\sqrt{m}$. While for specimen 2 and specimen 4, Guadua has greater stress intensity factor which is, 1.0428×10^{10} Pa$\sqrt{m}$ and 4.4616×10^7 Pa$\sqrt{m}$. This result shows that the notch and direction of the crack tip give effect to the value of stress intensity factor. From Figure 3.1, the notch is inclined position about 45° while the others specimen all in 0° direction.

Table 3.1 Stress Intensity Factor for different type of bamboo and specimen

Specimen	Moso Bamboo (SIF (K_I), Pa$\sqrt{m}$)	Guadua Bamboo (SIF (K_I), Pa$\sqrt{m}$)
Specimen 1	8.5323×10^9	8.4586×10^9
Specimen 2	5.2688×10^9	1.0428×10^{10}
Specimen 3	7.2584×10^8	7.2323×10^8
Specimen 4	4.4339×10^7	4.4616×10^7

4. Conclusion

Throughout this analysis, the crack propagation for natural fibre with different type of specimen had been simulated and verified with previous research. These results are in good agreement in term of the trajectories. There is no significant different in trajectories for Moso bamboo and Guadua bamboo. As for the stress intensity factor criterion, specimen 1 give the higher value of SIF which is 8.5323 x 10^9 Pa$\sqrt{m}$ for Maso bamboo and 8.4586 x 10^9 Pa$\sqrt{m}$ for Guadua bamboo.

As the stress intensity factor was known, it is possible to solve the other component of stress, strain and displacement. The design for the models can be improved by considering the very fine mesh in each of the crack tip and use another crack propagation criterion such as maximal normal stress, strain energy release rate and strain energy density.

Acknowledgement

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

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