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Analysis of Changes in First Mode Natural Frequency of Palm Trees Caused by Geometrical and Morphological Aspects

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ABSTRACT

Tree is an important part of urban ecology. However, the condition of trees from time to time should be routinely observed in order to avoid the case of falling trees that often take casualties. There are several types of tree defects that can trigger the fall of a tree, such as decay, cancer, crack, etc. So far, there have been several methods to detect such defects as an early indicator of tree condition, for example by acoustic tomography, intrusive indentation, etc. In this study, a detection method is proposed by using natural frequency analysis (modal analysis) of a tree. The selected tree is palm tree. As an initial step, an analysis is required to determine the changes occurring in the natural frequency of palm trees that are affected by, 1) geometric aspects, such as diameter and tree height, 2) morphological aspects, such as the presence or absence of decay and its position on the tree. Natural frequency analysis is done with the help of FEM software. The result shows that the change in natural frequency is not very significant, in the range of 10% to 11%. Therefore, to be able to identify the condition of a tree, further research is needed.

KEY WORDS: *Vibration, modal analysis, trees, condition monitoring.*

1.0 INTRODUCTION

Tree is an important component in every urban area because it has a great influence on the quality of the environment compared to other plants. Therefore, the condition of the tree becomes a matter of concern. Poor physical strength of the tree can cause the tree to collapse. The incidence of fallen trees can cause many losses ranging from economic losses to loss of life. There are already many incidents of fallen trees that occurred and consuming more than 1 victim, as an example on February 4, 2017 a fallen tree in the area near Universitas Indonesia befall a passing motorcycle resulted in 2 deaths [1].

The incidence of falling tree can be triggered by many factors, ranging from external factors such as wind, internal factors of the tree such as poor growth form, to combination of factors that affect the tree. There are 7 types of defects that can be identified on trees, including decayed wood, crack, and root problems [2]. The defect or damage on a tree can be used as a sign to predict the fall of a tree. Although healthy trees can also collapse, trees with defect or damage have greater potential to collapse. Therefore, it is necessary to identify the condition of a tree so that the potential collapse of the tree can be well predicted.

There are various methods to identify the condition of a tree, from conventional methods by inspecting the physical condition of the tree, or by the help of various tools such as the most frequently used is Acoustic Tomography. The conventional method is the easiest method to use because only by inspecting the physical condition of the tree but this method has many limitations. Acoustic method is a method that is commonly used by using the principle of measuring wave transmission time from the sensor which is installed around the tree trunk [3]. This method produces tomographic image depicting the physical condition of the tree [4]. However, data retrieval by using this method is not easy, because measurement should be done along the tree height.

The purpose of this research is to try a method by using condition monitoring technique to identify the condition of the tree. By using this method will be obtained information about the natural frequency of some tree models. Using this method is expected to be able to identify the condition of the tree more

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efficiently.

2.0 THEORY

The natural frequency of the tree can be predicted by considering it as a cantilever beam that oscillates freely. The free vibration equations can use the general equation [5]. Therefore, the natural frequency will be affected by several variables of geometry and its material properties such as L (cantilever strength), I (inertia), k (elasticity constant), E (Young Modulus).

The concept of tree condition identification from its vibration is a concept based on condition monitoring method. Condition monitoring is a common method used to identify and predict the conditions on the machine. By observing some parameters on the engine such as vibration and temperatures, if there is a significant change, then it could be an indication that the machine suffered a malfunction. Condition monitoring is also an important component in Condition Based Maintenance. Condition monitoring method is usually used on rotating machines such as pumps, electric motors, turbine and other machinery [6].

3.0 METHODOLOGY

The object of this research is set to palm tree because for initial research it is easier to model and analyze than any other tree. For further research, another tree will be used. The research was conducted using a simplified palm tree model and then simulated to predict the natural frequency of the model. Each tree model has a diameter 250 mm on the bottom of the tree and the Diameter at Breast Height (DBH) measured at 1400 mm from the ground surface has a diameter of 150 mm as shown in Figure 1. The measurement of tree diameter at adult mean height of the chest or DBH is a standard used by experts and researches to measure the size of the tree [7].

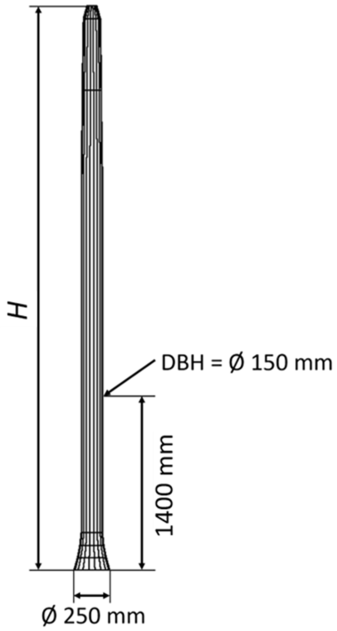

Figure 1: Geometry of the tree model

Modeling is done using the help of 3DS Max software, the tree is modeled in accordance with predetermined parameters. The model generated from 3DS Max is still in mesh form so it needs to be converted to solid using 360 fusion software. After getting the final model, to predict the natural frequency from the model is done using ANSYS simulation software. The modeling work process shown in Figure 2.

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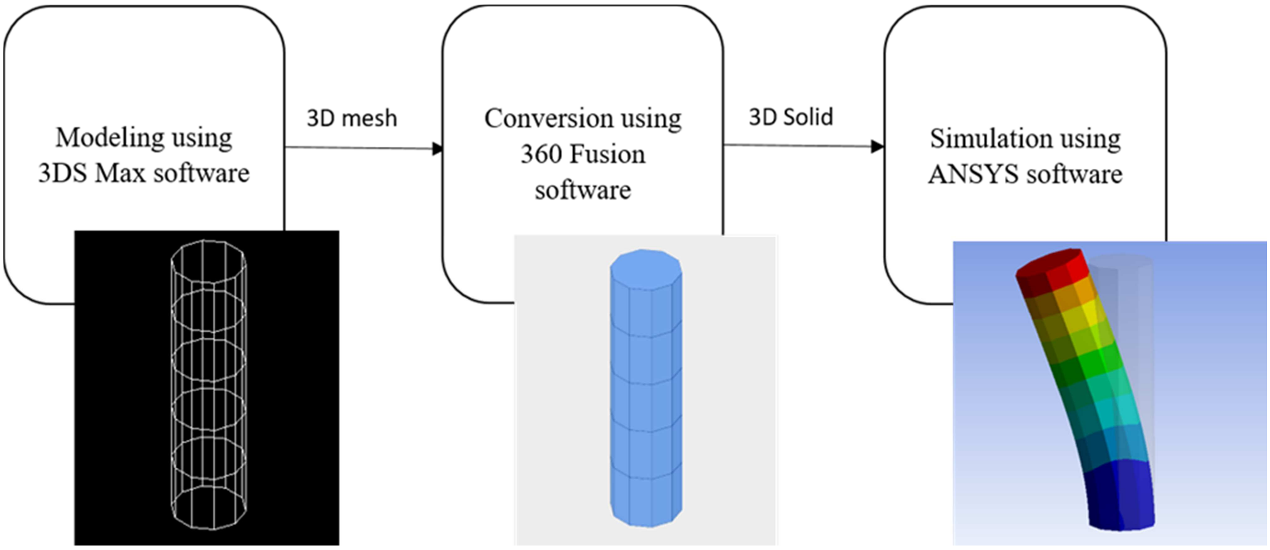

Figure 2: The process of modeling work and the results obtained from each software used

In this research, there are 4 types of simulations with different geometry parameters to predict the geometrical effect on the natural frequency of the model. In the first simulation, the geometry parameter varied is the height of the tree model (H). Based on observations, the height of palm trees encountered varies from 5 m to 7 m. Therefore, the height of the tree model used is 4 m, 5 m, 6 m, 7 m, 8 m, and 9 m.

Among many defects that often happen, decayed wood is set to be the main focus in this paper. For the next three simulations, it aims to determine the effect of defects on the natural frequencies of the tree model. Simulation is done to the model of tree having same height that is 7 m which will be given a defect in the form of decay in tree. In this modeling, the defect is modeled as a cylindrical cavity within the tree which will have the geometry varied according to the specified parameter. As can be seen in Figure 3, the parameters to be varied are the cavity position of the tree model (Hcavity), the diameter of the cavity (d), and the height of the cavity (hcavity). In the first cavity simulation, the tree model is given a cavity that has d of 130 mm and hcavity 600 mm, the geometry varied in the form of Hcavity that has been specified which are 1 m, 2 m, 3 m, 4 m, 5 m, and 6 m in the tree. In the second simulation, the tree model is given a cavity at a height of Hcavity = 1 m which has a specified d variation of 130 mm, 110 mm, 90 mm, 70 mm, 50 mm, 30 mm. In the third simulation, the tree model was given a cavity at a height of Hcavity = 1 m which has d of 130 mm and a specified hcavity variation which are 600 mm, 500 mm, 400 mm, 300 mm, 200 mm, 100 mm.

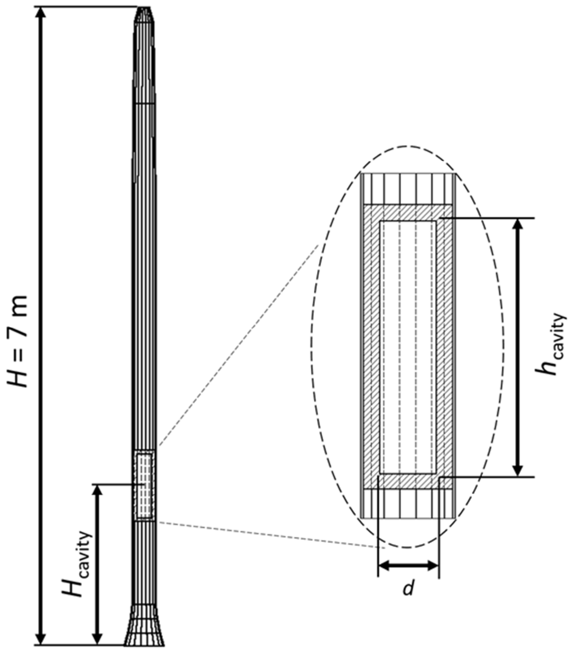

Figure 3: Geometry of cavity modeling on tree model

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Table 1: Variation of cavity modeling on tree model

Simulation	Position (m)	Diameter (mm)	Height (mm)	Parameter Varied
1	1	130	600	The cavity
	2			position on
	3			the tree
	4			(H_{cavity})
	5			
	6			
2	1	130	600	The cavity
		110		diameter
		90		(d)
		70		
		50		
		30		
3	1	130	600	The cavity
			500	height
			400	(h_{cavity})
			300	
			200	
			100	

4.0 RESULT AND DISCUSSION

To validate the accuracy of the model and the simulation process, an initial simulation was performed where the height of the tree model was varied. The natural frequency used is the first mode frequency of the simulation result. The typical first mode free vibration of the palm tree model is given in Figure 5 with color indicating deflection. Based on Table 2, it can be seen that the natural frequency of the tree model decreases. From the plot of the curve in Figure 4 the trendline has a power coefficient of -2.13. This number is very close to the power coefficient of the general equations in the cantilever beam that oscillates freely. This shows that the simulation method performed demonstrate the scientific validity because it corresponds to the theory of vibration on the cantilever beam.

Table 2: Simulation results of tree height variations

Height (m)	First Mode Frequency (Hz)
4	6.2403
5	4.0212
6	2.7150
7	1.9646
8	1.4470
9	1.1149

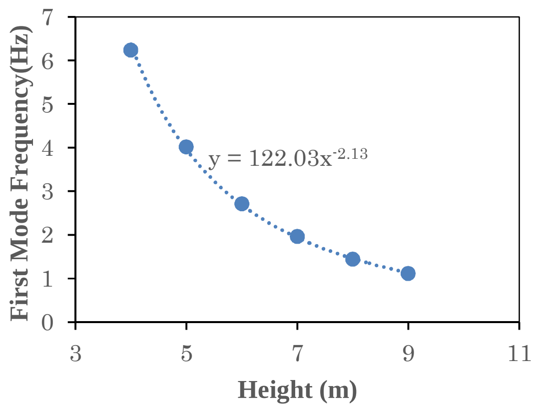

Figure 4: Graph of relationship between the height of the tree model and the first mode frequency of Table 2 based on the simulation

From the results of the first simulation in Table 3 where the cavity on the tree model is varied in position, the natural frequency can increase and decrease from the condition of the tree without cavities. When the cavity is positioned at 1 to 3 m from the surface of the ground, the natural frequency of the model decreases. The decrease in the natural frequency is approximately 11%. Meanwhile, when the cavity is positioned at 4 to 6 m from the surface of the ground. the natural frequency of the model increases. The increase in the natural frequency is approximately 10%. From the results of the second simulation where the cavity on the tree model is varied in diameter, it can be seen from Figure 5, when the diameter of the cavity is increased, the natural frequency of the tree model is decreases. Furthermore, on the 3rd simulation result where the cavity height is varied, it can be seen from Figure 5 when the height of the cavity is increased, the frequency of the tree model decreases.

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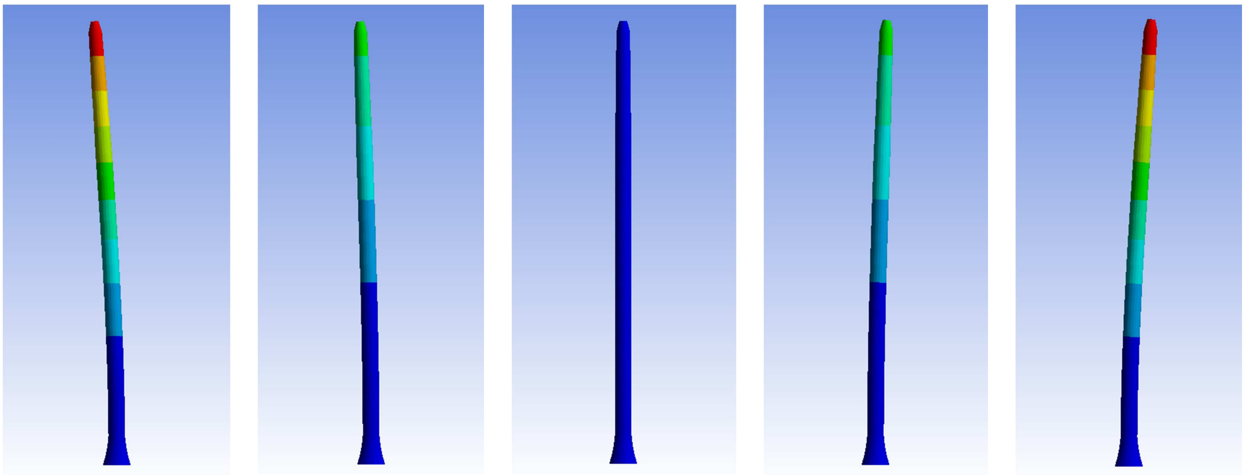


Figure 2: First mode vibration of the tree model

Table 3: (a) Simulation results of cavity position variation in tree model (b) Simulation results of cavity diameter variation in tree model (c) The simulation results of cavity height variation in the tree model

Tabel 3: (a)

Position (m)	First Mode Frequency (Hz)
1	1.7477
2	1.8266
3	1.9242
4	1.9934
5	2.0759
6	2.1662

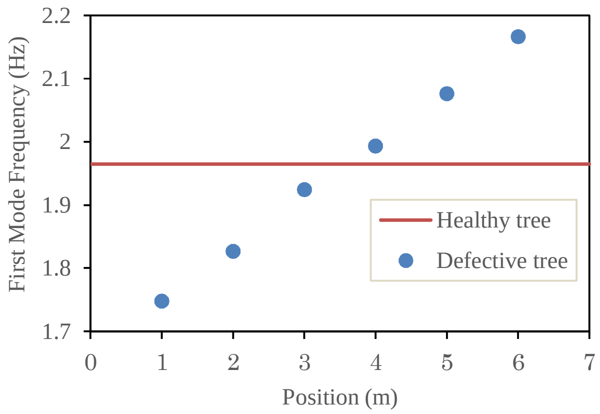
Tabel 3: (b)

Diameter (mm)	First Mode Frequency (Hz)
30	1.9642
50	1.9615
70	1.952
90	1.9292
110	1.8732
130	1.7477

Tabel 3: (c)

Cavity Height (mm)	First Mode Frequency (Hz)
100	1.8976
200	1.8549
300	1.8542
400	1.8076
500	1.7858
600	1.7477

(a)



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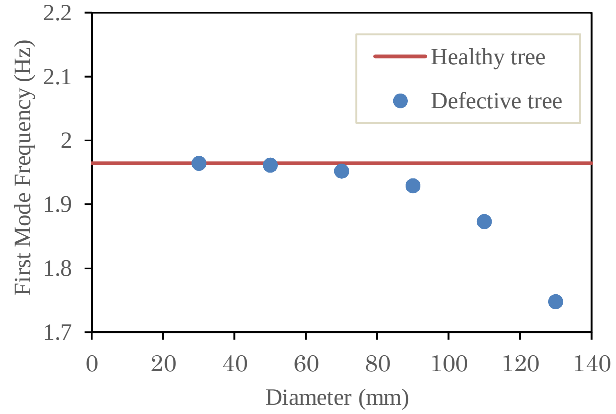

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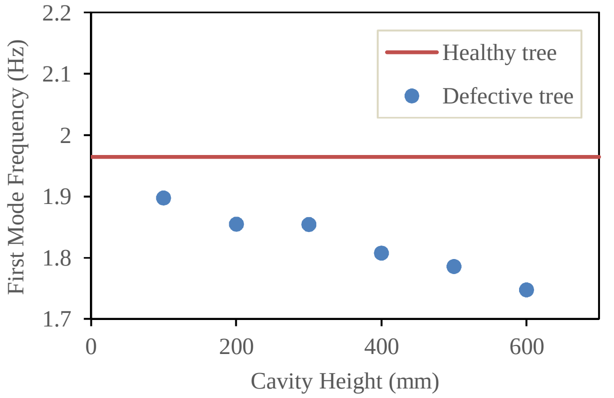

(c)

Figure 3: (a) Graph of relationship between the cavity position in the tree model and the first mode frequency (b) Graph of relationship between the diameter of the cavity in the tree model and the first mode frequency (c) Graph of relationship between the cavity height in the tree model with the first mode frequency

5.0 CONCLUSION

The natural frequency of the simulated palm tree model changes as some geometric parameters are varied. The natural frequency of the tree model decreases when the tree height increased. The decrease in natural frequency that occurs, is as expected from theory of the oscillation on cantilever beam. When the palm tree model is given a defect, the natural frequency also appears to be changing. However, the magnitude of the change is not significant only about 10% to 11%. Due to the insignificant change in natural frequencies it can be difficult to identify the condition of the tree. Therefore, further research is needed.

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