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A Preliminary Study for Simple Physics Models of Coconut Tree

Rahmawati[1], HD Rahmayanti[1], N Amalia[1], FD Utami[1], S Viridi[2] and M Abdullah[3,*]

[1] Doctoral Program, Physics Department, Faculty of Mathematics and Natural Sciences
[2] Nuclear Physics and Biophysics Research Division
[3] Electronic Materials Physics Research Division
[1,2,3] Institut Teknologi Bandung, Jalan Ganesha 10, Bandung 40132, Indonesia
[2] Research Center for Nanosciences and Nanotechnology, Jalan Ganesha 10, Bandung 40132, Indonesia
E-mail: *din@fi.itb.ac.id

Abstract. An investigation of how coconut palm tree withstands gale force winds has been performed. When observed carefully, the motion of the stalks and leaves affected the wind resistance. The stalks and leaves move randomly when the wind blows continously. Although this is such an interesting phenomenon, there is still no report on the physical modelling. This paper proposes a simple mathematical model to analyze the phenomenon. A simple tool was also designed to retrieve data using *Video Tracker*. The experiments were conducted on several types of springs. The model showed that the theoretical prediction accurately explained the phenomenon.

1. Introduction

The coconut tree (*Cocos nucifera*) is a member of the palm family which can be utilized for various purposes. This tree is often called tree of life due to the benefits of all its parts. Coconut trees are grown troughout along the coastwise in tropical country. Withstand gale force is an interesting physical phenomenon to be investigated. When observed carefully, the random motion of leaves and stalks make effect for the wind resistance. Previous studies had examined the dynamics of motion for various trees and their resistance to the wind. James reported the use of mass damping on two or more oscilating masses pairs[1]. There also several studies on trees and winds focused on forest trees[2-5]. According to Moore and Maguire, natural frequencies and damping ratio were main parameters in dynamic tree study to the wind [2]. Especially for tree branched, twigs get larger wind effect than braches. Hence, the influences of these two aspects must be considered in every tree movement process simulation [6]. This case studies focus on the phenomenon of natural frequency effect of coconut tree resistance agaٴints the wind. This research is expected to reveal the unique characteristics of coconut trees survival against wind gale force. Potential applications in the future is to be a reference of earthquake resistant building construction design.

2. Model

We assume the natural frequency (without interruption) of the coconut tree oscillation is ω_0. The changes (small deviation) of natural frequency occur due to change the location of central mass affected leaves and stalks sway. Accordingly, natural frequency becomes time dependent where a small change in natural frequency occur against the initial natural frequency (without central mass location displacement). Thus, the shortly natural frequency when the wind is blowing can be written:

$$\widetilde{\omega}_0 = \omega_0 + \omega(t) \tag{1}$$

With $|\Delta\omega(t) \ll \omega_0|$ and has an average value $\langle \Delta\omega(t) \rangle$ to ensure that the deviation is random. Thus, we can write the following expression of velocity

$$v(t) = v_0 \cos(\omega_0 t) \tag{2}$$

Then the kinetic energy of coconut tree can be written as follows:

$$E_k = \frac{1}{2} m v_0^2 \cos(\omega_0^2 t) \tag{3}$$

This study focused on the analysis of interesting phenomena in coconut trees blown by the wind. This phenomenon is related to the physical parameters of oscillation, resonance event and energy from the random movement of coconut's stalks and leaves. Physical model of the coconut's stalks and leaves designed using spring-mass system. The phenomenon of oscillation motion had been recorded using a digital camera then analyzed using a video tracker.

3. Experiment

We assumed that the coconut tree is elastic and has varying leaves mass along stalks. Based on this assumption, we made a simple model of coconut tree using elastic stem. The spring-mass system is representative of the coconut leaves are shown in figure 1.
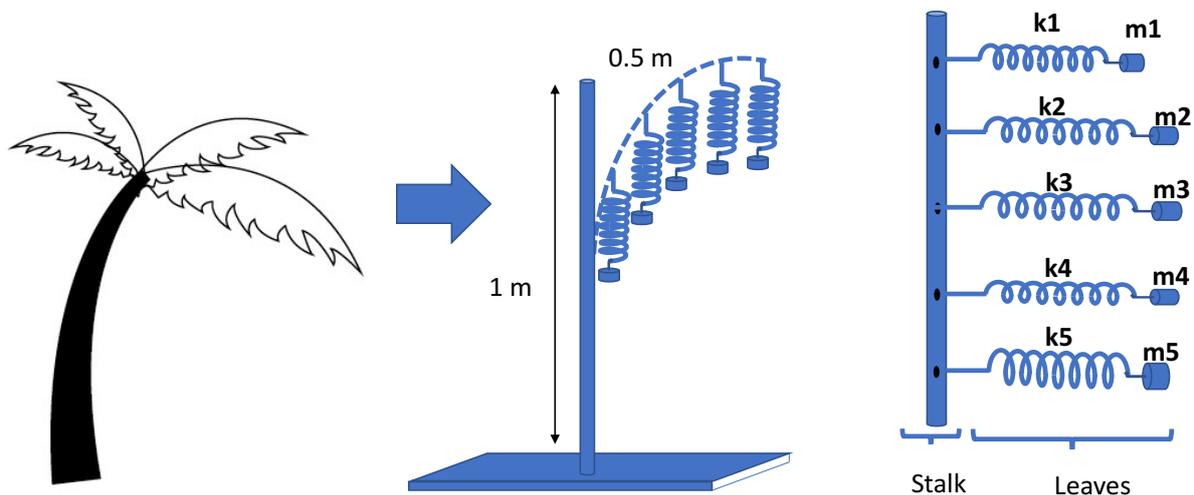
Figure 1. Simple model of palm coconut tree.

This experiments, we use four variations of spring-mass system model. First, we use five equal masses and five springs with the same constants. Secondly, we used five different masses and five springs with the same constants. Then, we used five equel masses and five springs with different constant. The last variation, spring-mass system used five different masses and five springs with different constants. Futhermore, external force treatment on each model representative of the wind gale force. Motions of

manually released objects were captured for 60 seconds by digital camera (Nikon L840, 16 megapixel and 30 fps) in a video mode. Every video tracked using video tracker then analyzing the results.

4. Results and Discussion

A simple experiment model to investigated coconut tree effect natural frequency against the wind gale force has successfully prepared using the spring-mass system, are shown in figure 2. Variations of spring-mass system model can be showen in Table 1.

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Figure 2. The result of pile driving tests at laboratory scale.

Table 1. Variations of spring-mass system.

Spring-mass System	Mass $\left(\times 10^{-3} kg\right)$	Spring Constanta $\left(N/m\right)$
Type-A	$m_1 = m_2 = m_3 = m_4 = m_5 = 5$	$k_1 = k_2 = k_3 = k_4 = k_5 = 26.15$
Type-B	$m_1 = 15; m_2 = 20; m_3 = 5;$ $m_4 = 50; m_5 = 50$	$k_1 = k_2 = k_3 = k_4 = k_5 = 26.15$
Type-C	$m_1 = m_2 = m_3 = m_4 = m_5 = 5$	$k_1 = 26.15; k_2 = 26.15; k_3 = 5;$ $k_4 = 138.75; k_5 = 27.75$
Type-D	$m_1 = 15; m_2 = 20; m_3 = 5;$ $m_4 = 50; m_5 = 50$	$k_1 = 26.15; k_2 = 26.15; k_3 = 5;$ $k_4 = 138.75; k_5 = 27.75$

Graph of angular frequency from video tracker analysis for all types of spring-mass system is shown in figure 3.
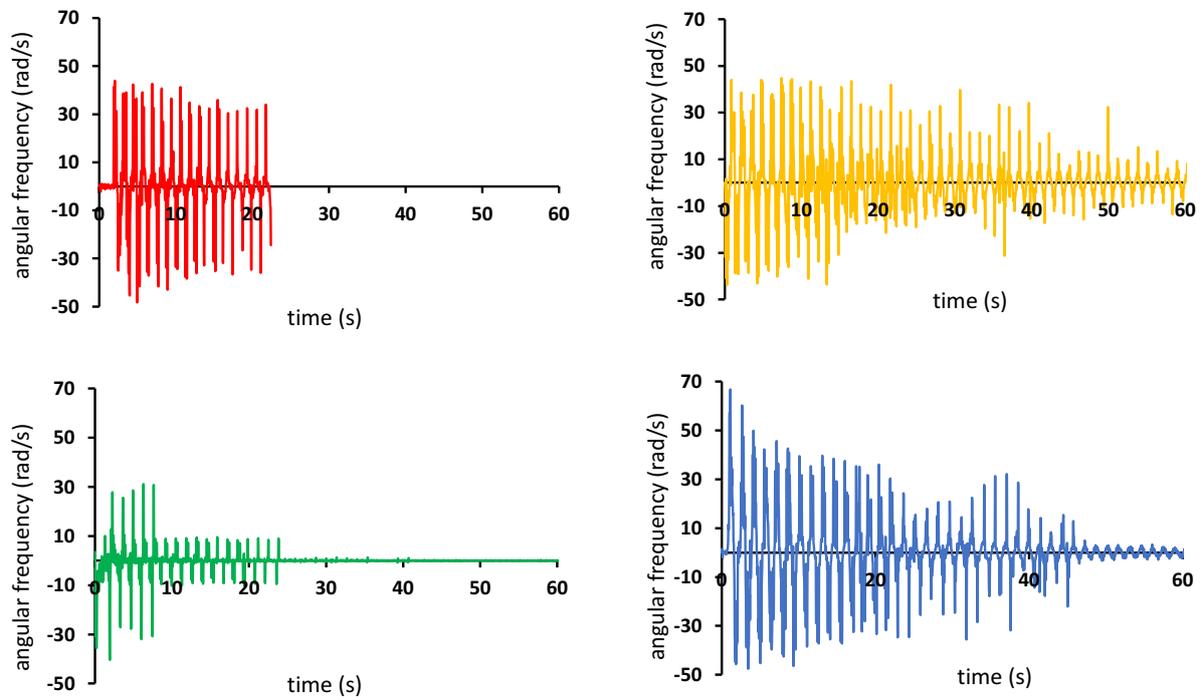
Figure 3. Graph of anguler frequency on several spring-mass system (a)Type-A; (b)Type-B; (c)Type-C and (d)Type-D

Based on figure 3, the angular frequency of spring mass system type-A; type-B; type-C and type-D decrease drastically at t = 24s; 52s; 25s and 44s. At certain time interval affects the oscillation behavior of the real physical system due to non-conservative friction force in the medium where the system damped. Hence, the amplitude of the oscillation decreases as energy is dissipated [7]. Therefore, this model can represent oscillation motion of the coconut tree movement.

The relationship between the period and frequency of oscillations in the spring-mass system has been studied extensively by researchers for a long time [8,9]. Kinetic energy is influenced by the mass of matter and its velocity. Energi kinetic graph for all types of spring-mass system is shown in figure 4.
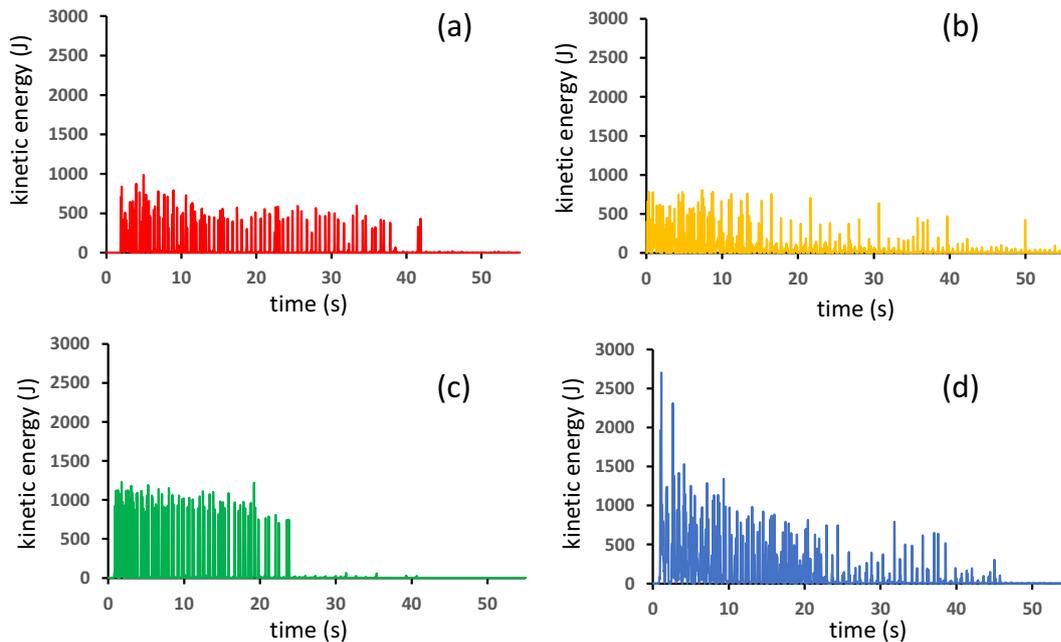
Figure 4. Graph of kinetic energy spring-mass system (a)Type-A; (b)Type-B; (c)Type-C and (d)Type-D

All spring systems were damping when received external forces. Refer to kinetic energy shown in Figure 4, the spring - mass system type-B has longest duration oscillation motion result. The initial hypothesis predicts that the spring-mass system type-B with different mass variations and equal constants springs indicate the most appropriate of natural frequency effect of coconut tree for the wind gale force.

5. Conclusions

The coconut tree's physical model has been designed. The models consist of dynamic masses represent the stalks and leaves. The phenomenon of stalks and leaves sway motion as resistance to the wind represented by spring-mass system B. Further study will be measure the natural frequency of the actual coconut tree compare the results of the experimental data of coconut tree's physical model. Furthermore, Monte Carlo simulations will be performed to predict the total energy of random motion of leaves and stalks. A simple tool also will be designed to retrieve data using Basic for Application (VBA) Excel.

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