USING THE VIBRATION SENSORS TO DETECT ELEPHANTS

Pisit Phokharatkul[1] and Danai Liswadiratanakul[2]

[1]Lecturer, Department of Electronics and Telecommunications Engineering, Faculty of Engineering, Kasem Bundit University, 1761 Pattanakarn Rd., Suanluang, Bangkok 10250, Thailand

[2]Lecturer, Department of Science and Mathematics, Faculty of Engineering, Kasem Bundit University, 1761 Pattanakarn Rd., Suanluang Bangkok 10250, Thailand

ABSTRACT

This research proposed the development of vibration sensors to detect the elephants. A method based on the detection of vibration caused by footfalls. The purpose of the detection system have been try to reduce the confrontation between humans and elephants by warning. The elephant presence detection, consisted of the vibration sensor, was installed at a circular plate. The circular plates have different radii in the ranges 10 - 45 cm. These vibration modules were embedded into underground at 15 cm depth. The vibration sensor at a circular plate will convert motions of elephants into electrical signals when elephants enter the sensor areas, an early warning through SMS/Social Media is sent to the nearby forest officials and to owner of the crop field. In testing, the circular plate radii 20 - 45 cm. with the vibration sensor 801S can detect the motion of elephants, similar as the geophone seismic sensors. The experimental results are corresponding with the natural frequency of the circular plate 6 - 60 Hz which is the frequency range for the footfalls of elephants.

KEYWORDS: vibration sensor, geophone seismic sensor, circular plate, natural frequency, confrontation between humans and elephants

1. Introduction

Humans and elephants confrontation has been increased in the forest border areas with invade into human habitation. Thus, it is necessary to develop the sensors to detect the elephants. These sensors were used to detect the intrusion of wild elephants from the forests into human living areas and send an early warning through social media to the forest officials to take necessary actions. Intrusion data is used a decision method to avoid the confrontation between humans and elephants, and reduce the human-elephant conflict. If the people know the intrusion of elephants, it will save their lives from elephant attack. The confrontation may lead to loss human death, elephant death or both. The prototype sensors consisted of a vibration sensor 801s constructed inner at the upper circular plate as detail in Section 3.

2. Human-Elephant Confrontation

Human-Elephant confrontation occurs because humans and elephants have overlapping interests. Humans try to protect living area and their crops. These situations lead to the loss of humans and elephants. It is important to understand the elephants and the conflict of interests can be eliminated [1]. The causes of conflict or confrontation are often complex and difficult to resolve. Thus, physical barriers are designed to keep elephants out by making it as difficult as possible for them to enter an area [2]. The examples used barriers such as fences, and trenches, and combination of both. Electric fencing is considered by many areas as the most effective methods to protect the intrusion of elephants. An electric fence consists of wires carrying a pulsing electric charge support, and shocks to the elephants including humans and the other animals that come into touch of electrified wires. Disadvantages of electrified fence are heavy maintenance, expensive installation, and highly recommended from the animal protectors. Trenches have been used with success. Trench is wide and deep enough so that the elephants cannot step over it. Elephants cannot jump but trench has heavy maintenance, and expensive installation similar to the electrified fences. The trench is use in flat and dry areas. The other barriers have been employed including loose-stone, earth bunds, log barricades, and moats. However, elephants can break down these barriers and lead to the heavy maintenance cost. These solutions will affect the living of elephants directly. In this research proposes the development of vibration measurement technique for elephants to detect the vibration caused by footfalls as detail in section 3. The advantages of this method have no affect to elephants directly which is different from the physical barrier methods.

3. Design of Vibration Module

3.1 Vibration Measurement Module Structure

The vibration module consists of 801s vibration sensor which has very small size. In developing, it is necessary to install the sensors at a circular plate. The circular plate will vibrate when it receives the pressure forces from footfall of elephants. The plate is vibrated to correspond the natural frequency of it. The vibration sensors connect with Arduino board via LAN cable and send the vibration data via wireless networks as shown in Figure 1. The circular plate was embedded underground at 15 cm depth and responses the vibration at natural frequency of circular plate.

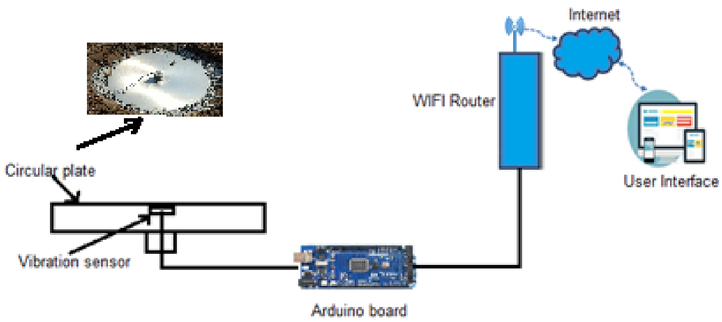


Figure 1 Vibration module structure.

3.2 Natural Frequency of Circular Plates

A Rayleigh method is used to compute the natural frequency of circular plates. [3] The strain energy (U) of thin circular plate in Polar coordinate can be written as follows:

$$U = \frac{D_e}{2}\int_0^{2\pi}\int_0^{R}\left[\left[\frac{\partial^2 z}{\partial r^2}+\frac{1}{r}\frac{\partial z}{\partial r}+\frac{1}{r^2}\frac{\partial^2 z}{\partial \theta^2}\right]^2 - 2(1-\mu)\frac{\partial^2 z}{\partial r^2}\left[\frac{1}{r}\frac{\partial z}{\partial r}+\frac{1}{r^2}\frac{\partial^2 z}{\partial \theta^2}\right] + 2(1-\mu)\left\{\frac{\partial}{\partial r}\left(\frac{1}{\partial r}\frac{\partial Z}{\partial \theta}\right)\right\}^2\right] r dr d\theta \quad (1)$$

$$D_e = \frac{Eh^3}{12(1-\mu^2)} \quad (2)$$

where E = elastic modulus

h = plate thickness, and

μ = Poisson's ratio

In the case of a displacement which is symmetric about the centre,

$$\frac{\partial}{\partial \theta} z(r,\theta) = 0 \tag{3}$$

$$\frac{\partial^2}{\partial \theta^2} z(r,\theta) = 0 \tag{4}$$

Substitute equation (3) and (4) into (1)

$$\begin{aligned} U &= \frac{D_e}{2}\int_0^{2\pi}\int_0^R \left[\left[\frac{\partial^2 z}{\partial r^2}+\frac{1}{r}\frac{\partial z}{\partial r}\right]^2 - 2(1-\mu)\frac{\partial^2 z}{\partial^2 r}\left[\frac{1}{r}\frac{\partial z}{\partial r}\right]\right] \mathrm{rdrd\theta} \\ &= \frac{D_e}{2}\int_0^{2\pi}\int_0^R \left[\left[\frac{\partial^2 z}{\partial r^2}\right]^2 + \left[\frac{1}{r}\frac{\partial z}{\partial r}\right]^2 + 2\mu\frac{\partial^2 z}{\partial^2 r}\left[\frac{1}{r}\frac{\partial z}{\partial r}\right]\right] rdrd\theta \end{aligned} \tag{5}$$

The total kinetic energy (T) of a plate bending can be written as:

$$\begin{aligned} T &= \frac{\rho h \Omega^2}{2}\int_A z^2 dA \\ &= \frac{\rho h \Omega^2}{2}\int_0^{2\pi}\int_0^a z^2 rdrd\theta \end{aligned} \tag{6}$$

where ρ = mass per volume

Ω = angular natural frequency

h = plate thickness

A = area over plate

Consider a circular plate has a radius a. The displacement perpendicular to a plate is z with an origin at the plate centre. If the plate centre is clamped at its edge r = a, the z =

0, and $\frac{\partial z}{\partial r} = 0$. Solve a displacement function which satisfies a geometric boundary condition as in Figure 2.

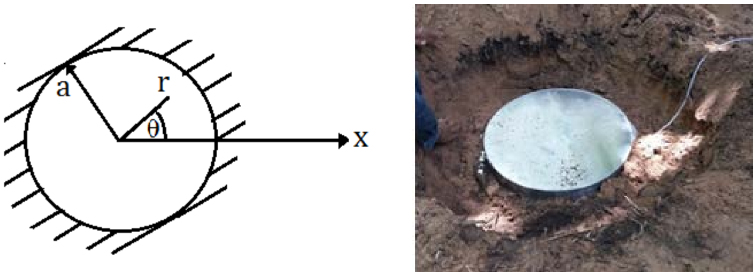
Let the outside of circular plate is clamped all around them. The boundary conditions are:

$$z(a, \theta) = 0 \tag{7}$$

$$\frac{\partial^2 z}{\partial r}|_{r=a} = 0 \tag{8}$$

But all modes of vibrations have symmetry respect with a diameter. The deflection function therefore becomes

$$z(r, \theta) = [AJ_n(kr) + BI_n(kr)]cosn\theta$$
$$z(r, \theta) = z_0 cos\left(\frac{\pi}{2}\frac{r}{a}\right) \tag{9}$$



a.) b.)

Figure 2 a.) Clamped circular plates, b.) Vibration Module was built in this research.

Substitute an equation (9) into the equation (6), the total kinetic energy (T) of the plate bending become

$$T = \frac{\rho h \Omega^2}{2} \int_0^{2\pi} \int_0^a \left[z_0 cos\left(\frac{\pi}{2}\frac{r}{a}\right)\right]^2 rdrd\theta$$
$$= \frac{\rho h \Omega^2 z_0 a^2}{4\pi}[\pi^2 - 4] \tag{10}$$

The total strain energy for symmetric case is

$$V=\frac{D_e}{2}\int_0^{2\pi}\int_0^{R}\left[\left(\frac{\partial^2 z}{\partial r^2}\right)^2+\left(\frac{1}{r}\frac{\partial z}{\partial r}\right)^2+2\mu\frac{\partial^2 z}{\partial^2 r}\left(\frac{1}{r}\frac{\partial z}{\partial r}\right)\right]rdrd\theta$$

$$=z_0^2 D_e\pi^3\frac{1}{a^2}(0.2978+0.25\mu) \tag{11}$$

Set the equation (10) equals the equation (11) as follows:

$$\frac{\rho h\Omega^2 z_0^2 a^2}{4\pi}[\pi^2-4]=z_0^2 D_e\pi^3\frac{1}{a^2}(0.2978+0.25\mu)$$

$$\Omega^2=D_e\pi^4\frac{1}{a^4}\left(\frac{1}{\rho h[\pi^2-4]}\right)(1.911+\mu) \tag{12}$$

Let μ =0.3,

$$\Omega=\frac{4.9744}{a^2}\sqrt{\frac{D_e}{\rho h}} \tag{13}$$

Since, the natural frequency f_n is

$$f_n=\frac{1}{2\pi}\Omega \tag{14}$$

Substitute Ω in the equation (13) into the equation (14). Therefore, the natural frequency is

$$f_n=\frac{4.9744}{2\pi a^2}\sqrt{\frac{D_e}{\rho h}} \tag{15}$$

3.3 Technical Methods

The vibration measurement module consists of 801S vibration sensor installed at the inner circular plate. The footfall of elephants can be done with the vibration waves in the range 4-80 Hz [4]. In designing, it is necessary to build the module responses corresponding with the natural frequency in the range 4-60 Hz follows the formula in equation (15). This research uses a stainless steel circular plate 1.0 mm. and 1.2 mm. thickness (h), mass per volume ρ = 7850 kg/m^3, and radius of circular plate in cm. various sizes. D_e in the formula in equation (15) is stiffness factor can be computed by formula in equation (2), where elastic modulus of stainless still E = 220x10^9 n/m^2, and Poisson ratio μ = 0.265.

The vibration measurement module is embedded underground at 15 cm depth. Let the elephants walk on the top or near the circular plate which the vibration sensor 801S is installed and collect the testing results.

4. Experimental results

The derived numerical results for determining the natural frequency were programmed in order to analyze different cases. Results of the numerical analysis for the present investigation were compared between the natural frequency and different circular radii as shown in Figure 3. Use data from the results of calculation to build the various different vibration modules. These vibration modules were embedded underground at 15 cm depth. and test with the footfall of elephants at Wangchang Ayudhya Laepaneit, Phranakhon Sri Ayudhya province as shown in Figure 4. The circular plate vibrates correspond the vibration waves from the footfall of elephants. The vibration sensor at circular plate converts the vibration into electrical signals and these signals are further processed via Arduino board. In testing, the researchers compared the performance of these vibration measurement modules with the geophone seismic sensors as the results in Table 1.

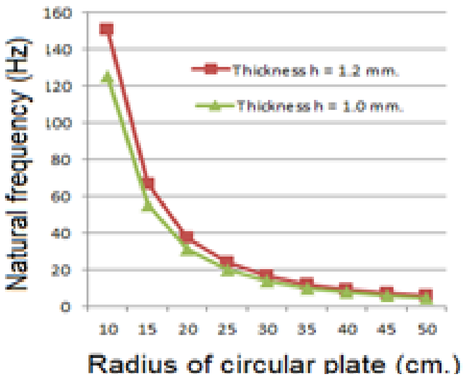
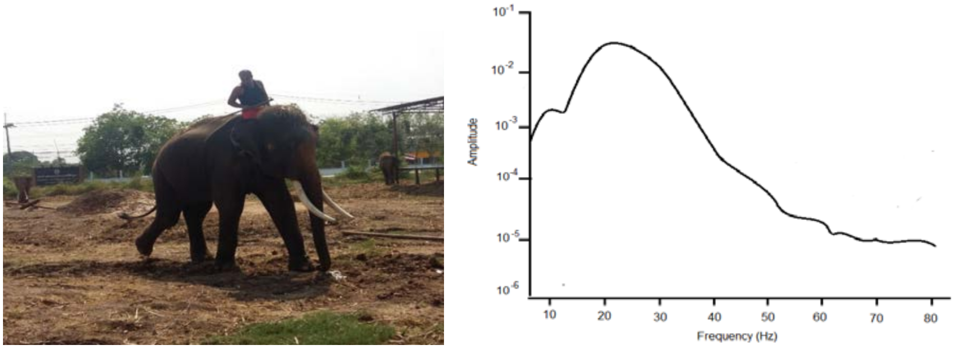


Figure 3 Natural frequency of circular plate with different circular radii.



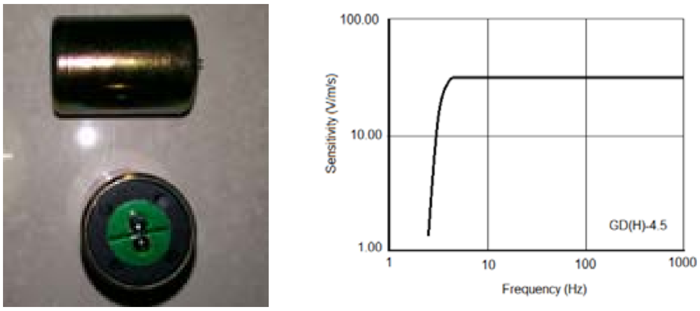
a.) b.)

Figure 4 a.) Testing carried out in elephant camp at Wangchang Ayudhya Laepaneit, Phranakhon Sri Ayudhya province, Thailand, b.) Power spectrum plots for the footfalls of elephants.

Table 1 Results of detecting vibration waves from footfall of elephants between the vibration modules and the geophone seismic sensors.

Radius of Circular plates (cm.)	Vibration Modules	geophone seismic sensors
10	✗	✗
15	✗	✓
20	✓	✓
25	✓	✓
30	✓	✓
35	✓	✓
40	✓	✓
45	✓	✓

Note: ✓ The vibration waves from footfall of elephants can be detected.
✗ The vibration waves from footfall of elephants cannot be detected.



a.) b.)

Figure 5 a.) Geophone seismic sensors GD-4.5, b.) Frequency versus sensitivity of geophone GD-4.5.

5. Conclusions and discussions

The human-elephant conflict situation should be monitored and find a method to solve or compromise disagreement. The elephant tracking information through the vibration modules will prevent the confrontation between humans and elephants, and reduce the loss of life and property. The study of elephant tracking path and time activities is the information to minimize confrontation. The development of vibration modules found that a frequency depends on the radius of circular plate as the graph in Figure 3. However, the thickness of the circular plate affects the natural frequency. In testing, the vibration modules with the radius at 10 and 15 cm. cannot detect the vibration waves from footfalls of elephants as in Table 1. Because the vibration waves from footfall of elephants have the natural frequency in the ranges 4.5 – 80 Hz (Figure 4) and the vibration waves at frequencies greater than 60 Hz have the low amplitudes until cannot be detected.

From Table 1, vibration module cannot detect the vibration waves of more than 60 Hz. Because the vibration waves have very low amplitude, similarly geophone seismic sensors cannot detect the vibration waves of more than 80 Hz for the same reason as the vibration modules. The different between vibration module and geophone seismic sensors are each vibration module measures a natural frequency in equation (15) only, But the geophone seismic sensors measure the frequency range 4.5-1,000 Hz follow the property of them as shown in Figure 5. Thus, the advantage of vibration module detects a peak of frequency 20 Hz (ignore the other frequencies) for footfalls of elephants using the circular plate radius 27.4 cm., 1.2 mm. thickness. In this research, the researchers measure the amplitude of vibration wave at the frequency 20 Hz from footfalls of elephants. It can distinguish the signals for footfalls of elephants from the footfalls of other species. However, disadvantage of vibration modules are the size of them, and inconvenient installation.

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Author's Profile

Pisit Phokharatkul D.Eng. He received the B.Ed. degree in Physics from Srinakharinwirot University, the B.Eng. degree in Electrical Engineering from Patumwan Institute of Technology, the M.Eng. degrees in Nuclear Technology from Chulalongkorn University, the M.Eng. degree in Electrical Engineering from King Mongkut's Institute of Technology North Bangkok, and the Doctor of Engineering degree in Electrical Engineering from King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand, respectively. Currently, he is an Associate Professor at Department of Electronics and

Telecommunications Engineering, Faculty of Engineering, Kasem Bundit University, Bangkok, Thailand. His research interests are in intelligent systems, embedded systems, wireless communication systems, and signal processing. E-Mail: pisit.pho@kbu.ac.th

Danai Liswadiratanakul, Ph.D. He received the B. Ed. Degree in Physics from Srinakharintarawirot University in 1980, M. Eng. Degree in Nuclear Technology from Chulalongkorn University in 1989, and Ph.D. in Educational Administration and Foundation from Illinois State University in 2002, respectively. He works at faculty of Engineering, Kasem Bundit University, Bangkok, Thailand in 1990 until now. His research interests are in Apply Physics, Electronics, intelligent electrical systems, and signal processing. E-Mail: danai.lis@kbu.ac.th