pISSN 2685-9386 eISSN 2685-1645

JESR

Volume 4 Issue 2, December 2022

JOURNAL OF ENGINEERING AND SCIENTIFIC RESEARCH

Publisher :

Faculty of Engineering, University of Lampung
Jl. Soemantri Brojonegoro No.1 Bandar Lampung – Indonesia
http://eng.unila.ac.id/

HALAMAN PENGESAHAN

Judul	: Rapidness Characteristics of Ultrasonic Wave Propagation on Eggs Using HC-SR04 Module
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Instansi	: Teknik Elektro Universitas Lampung
Publikasi	: JESR – Journal of Engineering and Scientific Research
ISBN	: 2685-1695
Volume	: 3
No	: 1
Tanggal Publikasi	: 30 Juni 2021
Penerbit	: Teknik Elektro Universitas Lampung
Website	: http://jesr.eng.unila.ac.id/index.php/ojs/article/view/72

Bandar Lampung, Juni 2023

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Rapidness Characteristics of Ultrasonic Wave Propagation on Eggs Using HC-SR04 Module

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Article Information:

Received:
6 March 2021

Received in revised form:
2 May 2021

Accepted:
5 May 2021

Volume 3, Issue 1, June 2021
pp. 25 – 30

http://doi.org/10.23960/jesr.v3i1.72

Abstract

Fertility rate is one of the main factors of the success of an egg in order to hatch properly. The process of egg fertility detection is currently visually based, using manual methods (by carrying eggs one by one). This takes time and cost so that it will affect the production of poultry cultivation. This study aims to find out the characteristics of rapid propagation of ultrasonic waves in eggs. Information regarding the characteristics of rapid wave propagation is very important in the process of evaluating and testing the quality of eggs because the rapid propagation of the wave reflects the quality of the eggs that are generally done destructively. This research is expected to be preliminary information in developing rapid and objective non-destructive technology for determining the fertility of poultry eggs using ultrasonic waves. The study reported the results of rapid measurements of ultrasonic wave propagation propagated on different types of eggs. This study used three types of eggs, namely poultry-chicken eggs, organic-chickens and ducks. Methods in the process of determining the characteristics of each egg using ultrasonic waves. Ultrasonic waves are waves that can propagate on certain objects, materials and components. The HC-SR04 module is used as an ultrasonic wave transmitter and receiver medium. Ultrasonic waves of 40 Khz are propagated to the surface of the egg and received by a receiver transducer placed facing each other. The distance between the egg and the HC-SR04 module is 5 cm and 10 cm. Distance and length of propagation time parameters are used as information to generate egg wave propagation speed values. The test process was carried out on 10 eggs, from each type. The observed age of the egg sample was 5 and 14 days. Based on the results of testing and calculations provide results that duck eggs have the highest speed value, while chicken eggs are the lowest.

Keywords: *rapidness, ultrasonic waves, HC-SR04, propagation speed.*

I. INTRODUCTION

Eggs are shelled objects that contain embryo, produced by poultry [1], [2]. Chicken eggs that incubate have temperatures. Eggs fertility is an indicator of the presence or absence embryo in the egg [3]. Fertility is a group of eggs indicates the number of eggs that develop from eggs that incubated number. if eggs are looked at with a lamp (candling process) it turns out that there are seeds inside, then the egg is fertile [4].

Non-destructive testing or NDT (Non Destructive Test) is one method of testing or assessment is technical, which can specifically provide information on objects, materials, and components without doing damage to the object examined. Various NDT methods are image processing, near infrared waves (NDI), X-ray waves, Gamma rays and ultrasonic waves. In this study, ultrasonic technology was used to perform non-destructive assessment of eggs. Ultrasonic technology is one of the non-destructive testing methods that are quite successful and an alternative choice to determine and know the inside of a particular material. Assessment of the quality of foodstuffs using ultrasonic-based techniques is often preferred, over other techniques. This is because it is cheaper, portability of the device, and does not damage nature. In addition, the low-energy ultrasonic signals used in non-destructive testing have no negative effect on the physical and mechanical properties of biomaterials. [5].

Ultrasonic waves are sound waves with a frequency of more than 20 kHz that can be used in object analysis. Currently there are various methods to assess the quality of a material, one of which is by using ultrasonic

waves. The use of ultrasonic waves in non-destructive testing has several advantages over other methods. Ultrasonic waves can take measurements quickly and can be used for the characterization of concentrated and opaque systems (not transparent light). Ultrasonic waves are sensitive to particle sizes of 10 to 1000 nm with concentrations between 10% to 50% depending on the nature of the system measured. [11].

Ultrasonic technology is an option in this study because it is known that translucent power is superior to infrared, and the investment cost is cheaper. The use of ultrasonic waves has been widely used in various fields, such as in the construction industry, to determine material defects in the production process of concrete and metal. In the field of medicine, to find out the condition of the fetus, organs, and body tissues as well as some applications in agriculture and military.

The incubation industry is one of the main industries in the production chain of poultry cultivation and plays a major role in poultry rearing. Egg hatching power is an important factor in the incubation industry. It is influenced by many factors such as egg handling, egg fertility, and other egg hatching problems. Fertile eggs are eggs that contain a lot of living embryonic tissue that develops while infertile eggs are eggs that have dead embryonic tissue and do not develop or have no living cells at all. In fertile eggs case, the hatching potential can only be maintained, if there is a mishandling then the hatching potential will be failed.

The most important factor is to make sure that the eggs placed in the incubator are actually fertile eggs. Detection of fertile and infertile eggs, will increase productivity and benefit, because it saves space, costs, and prevents bacterial contamination in the body. The success rate in egg hatching can be improved by knowing the condition of the egg in a fertile or infertile state. Fertile eggs are placed in incubators for incubation until hatching, while eggs known to be infertile can be immediately separated so as not to interfere and damage eggs that are in the incubation process.

In general, to find out fertile and infertile eggs are carried out the process of observation (candling). This process requires human resources and is inefficient. The fatigue factor and human vision error are major problems, as they have to check hundreds if not thousands of eggs per day. Therefore, usually only a few eggs are randomly selected based on the physical shape, color and condition of the egg shell. These parameters serve as determining egg fertility, which means most infertile eggs are likely to remain in incubators [6]. Therefore, the process of detecting fertile eggs before incubation using ultrasonic technology is expected to improve the efficiency and quality of production and bring better economic benefits in the future [7].

This study is a preliminary study to look for opportunities for the use of ultrasonic waves to conduct non-destructive tests on eggs. The goal of this study is to develop NDT in determining fertile and infertile eggs. When ultrasonic waves are propagated through the egg, there are various aspects that determine the characteristics of propagation, such as: geometry, egg dimensions, shell characteristics, egg whites and egg yolks [8]. The speed of propagacizing ultrasonic waves has a relationship with the physical magnitude of an object passed, including distance, porosity, cracks, and others [11].

This study learns about the characteristics of egg types (poultry-chicken / broilers, organic-chicken / domestic and ducks) on the parameters of ultrasonic velocity. It is very important to know the internal condition of thte eggs, while generally, the conventional method is used in this case. We need a new method that is using an ultrasound device. The vision of ultrasonic is to become an alternative method to find the condition of fertile eggs that are accurate and friendly use [9]. It is expected that the results obtained in this study, can be used as initial information for making and developing non-destructive egg identification systems using ultrasonic waves at a relatively cheaper cost and easy to use.

II. MATERIAL AND METHOD

The test was conducted using 3 types of eggs, namely poultry-chicken eggs, organic-chicken, and duck eggs. Each amounted to 10 items. Eggs used on average 5- 14 days old. The variables observed in this study are the distance, time, and speed of ultrasonic propagation in each egg with a different type. Ultrasonic waves emitted using a transducer. Fig 1 explain block diagram eggs testing system.

Ultrasonic parameter measurement methods is transmission distance and length of propagation time is done with signal transmission mode. Ultrasonic waves of 40Khz frequencies are repetitively generated with a transmitter transducer triggered from a microcontroller. The transmitter and receiver transducer is an HC-SR04 sensor with a working frequency of 40KHz. Testing begins with the signaling transmitted by an ultrasonic sensor to the object (egg). The test used HC-SR modules fired on the surface of the egg. HC-SR04 will emit a wave from the transmitter, when the wave hitting the surface of the egg then the buzzer will sound as a notification and then the reverse wave will be received by the receiver. The design of this egg testing device uses C language programming. Programming is

embedded in the Arduino Uno R3 microcontroller through the Arduino IDE software. The design of the test device starts from the initialization of the pin by Arduino Uno R3 for the HC-SR04 ultrasonic sensor module, buzzer, and LCD, after which the transmitter on the HC-SR04 sensor will emit waves towards the object (egg). When the wave hits the surface of the egg, the buzzer will light up as a notification. After that the distance value and the length of the reflection time will be displayed on the LCD. Here's a diagram of the system programming flow in Figure 2.

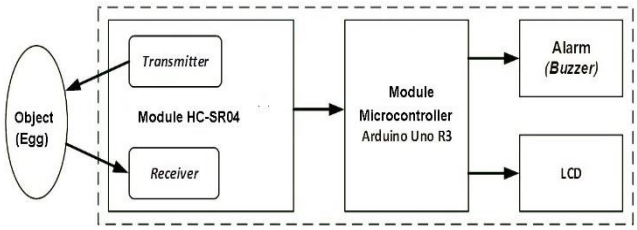

Figure 1. Block Diagram Eggs Testing System

Egg testing technique is done in 2 stages. The first stage of testing is to measure the distance value and length of the reflection time when the vertical egg positions. The second stage of testing is to measure the distance value and length of the reflection time when the position of the egg horizontally. After obtaining data distance and length of time propagation of feeding waves will be determined the fast value of each egg vine with the equation (1).

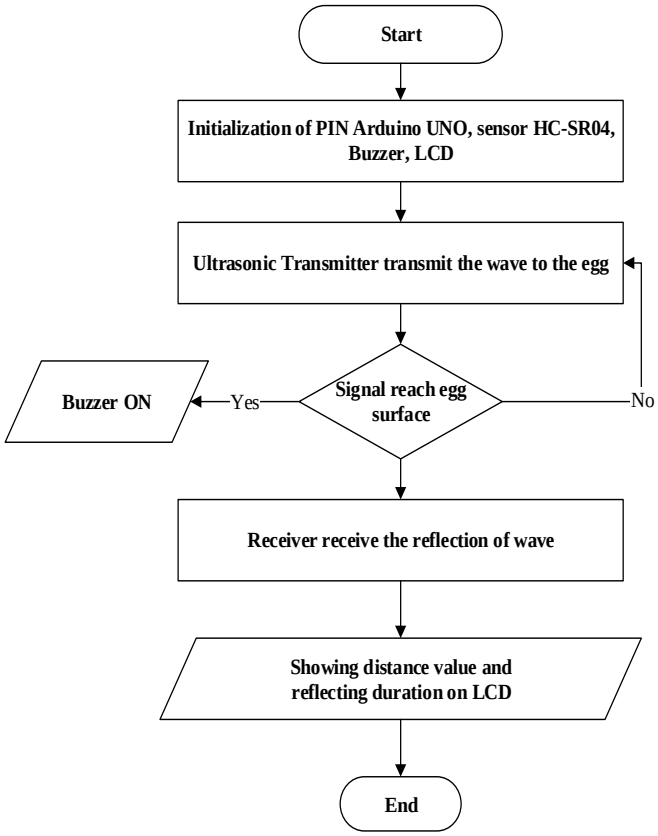

Figure 2. Flowchart Programming System

The flow chart, explaining some of the stages of the process in this study. The initialization of the PIN on the Arduino UNO module is used by sensors, buzzers and LCD. After the initialization process, the transmitter can emit ultrasonic waves to the surface of the egg. When the wave emitted by the transmitter touches the egg, the buzzer and ultrasonic wave will return to the receiver. The reverse wave received by the receiver is then processed by a microcontroller to produce a distance value and reflecting time.

By using the distance and time of reflection, the value of the speed of the wave propagation can be known. Equation (1) is used to calculate the fast value of ultrasonic wave propagation in each type of egg. The velocity of the wave propagation (V) is obtained by measuring the time it takes for the wave to traverse the medium. Calculations are done automatically through the program code on the Arduino IDE software.

$$\boldsymbol{V = \frac{S}{tof}} \tag{1}$$

Where:

$\boldsymbol{V}$ is the Velocity (m/s)
$\boldsymbol{s}$ is Distance (m)
$\boldsymbol{t_{of}}$ is Time (s)

The program code consists of several algorithms that researchers want to obtain wave propagation speed values. Some libraries are also used that the program can run properly. Therefore, in the end, it obtained the speed value of wave propagation from each type of egg.

III. Results and Discussions

Measurement of the distance and time of reflection of waves to eggs aims to find out the characteristics of the propagation speed of each egg. From the data obtained, each egg has a different wave reflecting time. It is known that changes in the speed of propagation can indicate a physical change that occurs in each egg. Eggs with an age of 1 day have a higher wave propagation rate compared to the age of 14. This is because eggs with a age of 1 day have a thicker albumin compared to eggs aged 14 days.

The process of evaporation of water and the entry of microorganisms through the pores in the egg shell causes dilution in the egg albumin. This causes as the egg ages, there will be dilution in the egg albumin [10]. During the storage period the egg will undergo a change in content so that its quality will experience changes. Evaporation of the water, can be reduced by several ways including storing eggs at low temperatures and covering the pores of eggs with vegetable oils or minerals. Table 1 and 2 show data on test results and calculations conducted on poultry-chicken eggs.

Table 1. Measurement and testing with a distance of 5 cm (Poultry-Chicken Eggs)

Trial No.	Distance (m)	Propagation Speed in the Vertical Position (m/s)	Propagation Speed in the Horizontal Position (m/s)
1	0,05	131,58	157,23
2	0,05	146,63	166,67
3	0,05	142,45	146,63
4	0,05	142,45	138,12
5	0,05	166,11	167,79
6	0,05	142,86	161,81
7	0,05	144,09	164,47
8	0,05	149,25	150,15
9	0,05	159,24	151,52
10	0,05	160,77	153,37
Average		148,54	155,78

Table 2. Measurement and testing with a distance of 10 cm (Poultry-Chicken Eggs)

Trial No.	Distance (m)	Propagation Speed in the Vertical Position (m/s)	Propagation Speed in the Horizontal Position (m/s)
1	153,8	162,60	164,20
2	165,8	150,60	168,63
3	147,4	164,20	168,35
4	160,5	145,35	167,50
5	152,2	147,93	168,07
6	150,3	155,04	175,13
7	163,1	163,67	176,99
8	151,7	167,22	170,65
9	155,2	166,67	166,67
10	157,9	159,24	159,24
Average		155,84	158,25

Table 1 is the result of testing chicken eggs with a distance of 5 cm. Average length of wave reflecting time when vertical and horizontal positions of 0.0003 s. The results of the calculation of wave propagation speed in vertical and horizontal positions of 148.58 m / s and 155.78 m / s, respectively. While in Table 2 with a distance of 10 cm, the average value of the length of the wave reflection time of 0.0006 s and the results of rapid calculation of vertical and horizontal wave propagation of 155.84 m / s and 158.25 m / s. Table 3 and 4 presented the results of the measurement and testing on organic-chicken eggs with the same distance and treatment as before.

Table 3. Measurement and testing with a distance of 5 cm (Organic-Chicken Eggs)

Trial No.	Distance (m)	Propagation Speed in the Vertical Position (m/s)	Propagation Speed in the Horizontal Position (m/s)
1	0,05	162,34	156,25
2	0,05	147,06	154,32
3	0,05	161,81	161,81
4	0,05	167,22	158,73
5	0,05	149,70	168,35
6	0,05	143,68	157,73
7	0,05	156,25	155,76
8	0,05	154,80	156,74
9	0,05	142,45	157,23
10	0,05	155,28	162,34
Average		154,06	158,93

Table 4. Measurement and testing with a distance of 10 cm (Organic-Chicken Eggs)

Trial No.	Distance (m)	Propagation Speed in the Vertical Position (m/s)	Propagation Speed in the Horizontal Position (m/s)
1	0,05	169,49	155,28
2	0,05	162,87	159,24
3	0,05	147,93	142,45
4	0,05	166,11	143,68
5	0,05	161,81	144,09
6	0,05	160,77	167,79
7	0,05	154,80	165,02
8	0,05	169,49	155,76
9	0,05	157,23	163,93
10	0,05	155,76	155,28
Average		160,63	155,25

Table 3 is the result of testing organic-chicken eggs with a distance of 5cm. The average length of wave reflecting time when vertical and horizontal positions are 0.0003 s. The results of rapid calculation of wave propagation in vertical and horizontal positions of 154.06 m /s and 158.93 m/s respectively. While in Table 4 with a distance of 10 cm, the average value of the length of wave reflection time of 0.0006 s and the results of rapid calculation of vertical and horizontal wave propagation of 160.05 m / s and 155.25 m /s.

Table 5. Measurement and testing with a distance of 5 cm (Duck Eggs)

Trial No.	Distance (m)	Propagation Speed in the Vertical Position (m/s)	Propagation Speed in the Horizontal Position (m/s)
1	0,1	168,07	167,50
2	0,1	166,67	157,73
3	0,1	166,67	161,29
4	0,1	161,81	163,67
5	0,1	160,00	165,02
6	0,1	161,29	161,81
7	0,1	169,49	156,74
8	0,1	161,81	156,25
9	0,1	168,07	155,28
10	0,1	166,67	155,04
Average		165,05	160,03

Table 6. Measurement and testing with a distance of 10 cm (Duck Eggs)

Trial No.	Distance (m)	Propagation Speed in the Vertical Position (m/s)	Propagation Speed in the Horizontal Position (m/s)
1	0,1	164,20	158,73
2	0,1	164,20	180,18
3	0,1	155,04	158,73
4	0,1	169,78	162,87
5	0,1	162,34	163,93
6	0,1	160,26	164,74
7	0,1	162,87	154,80
8	0,1	166,94	166,94
9	0,1	168,63	167,50
10	0,1	166,94	169,20
Average		164,12	164,76

Then in Tables 5 and 6, is the result of measurement and calculation of duck egg samples. Based on the data obtained, duck eggs have the highest ultrasonic wave propagation speed compared to other eggs. At a distance of 5 cm obtained the speed of propagation of 165.05 m / s and 160.03 m / s. For the measurement of duck eggs at a distance of 10 cm obtained the speed of propagation of 164.12 m / s and 164.76 m / s.

The entire table presented showed that the values of the measurements of poultry-chicken egg, organic-chicken and duck eggs are vary. Measurements are made from a distance of 5 cm and 10 cm against the egg. Measurements start from a distance of 5cm, this is because at that distance, the sensor can work effectively. The sensor module used in the study was only able to work from a distance of 3 cm to 400 cm. Based on several experiments conducted, at a distance of 5 cm and 10 cm resulting in a stable value and easy to observe. Therefore, the data at that distance is used as an analysis material to find out the characteristics of eggs.

From each measurement and test at a distance of 5 cm on each egg obtained the average value as follows. In poultry-chicken eggs rapid propagation waves of 148.54 m/s and 155.78 m/s, organic-chicken eggs of 154.06 m/s and 158.93 m/s, and duck eggs of 160.63 m/s and 155.25 m/s. Then at a distance of 10 cm; poultry-chicken eggs amounting to 167.61 m/s and 168.54 m/s; organic-chicken eggs of 165,0 m/s and 160,03 m/s, and duck eggs of 164,12 m/s and 164,76 m/s. Significant data changes occur when measurements are made at a distance of 5 cm.

Based on the results of measurements made on poultry-chicken and organic-chicken eggs, it is known that organic-chicken eggs has a higher wave propagation speed than poultry-chicken eggs. This can be influenced by one of the factors, which is the difference in the thickness of the cage/shell. The thickness of a normal poultry-chicken egg shell is 0.33 - 0.35 mm, while the organic-chicken is 0.34 - 0.40 mm. [12].

From the results of the analysis on this study, the shell thickness factor has a large influence on the value of the speed of the resulting wave propagation. The denser a medium of propagation, the faster the ultrasonic wave is reflected. Poultry-chicken eggs has the lowest fast-propagation while duck eggs have the highest fast-propagation. This is because the structure of the egg shell and the internal condition of the egg affect the rapid propagation of waves. In general, the denser a medium of propagation, the faster the wave is reflected.

IV. CONCLUSIONS

Based on the measurements, calculations and analysis that have been done, it can be concluded that the characteristics of rapid wave propagation in duck eggs are the fastest compared to organic-chicken eggs and poultry-chicken eggs, with values of 160.63 m / s and 155.25 m / s at a distance of 5 cm and 164.12 m / s and 164.76 m / s at a distance of 10 cm. The most effective measurement is done at the sensor distance with the egg by 5 cm. Although the measurements and calculations that have been done show a rapid difference in propagation in eggs, there needs to be further development and research using components and equipment that have a higher frequency and accuracy rate.

ACKNOWLEDGMENT

Thank you to the DIKTI who provided funding through The Master Thesis Research (PTM) 2020 scheme.
Thank you to the entire member of Laboratorium Elektronika Universitas Lampung, for being supporting and facilitating the necessary equipment in this research.

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