UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electronic and Computer Engineering

ACOUSTIC WAVE SIGNAL ANALYSIS USING PIEZOELECTRIC COUPLING DEVICE FOR DISC COUNTING APPLICATION

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Bachelor of Electronic Engineering (Industrial Electronics) with Honours

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ABSTRACT

Part counting system is an essential system for packaging process in every industry. However, manual counting is not an efficient and precise way. Therefore, a new method is necessary to differentiate the quantity of disc by using the concept of changes of resonance frequency with the number of disc count. In this project, piezoelectric coupling device is used as actuator and sensor to measure the quantity of disc. Due to, the weak propagation of acoustic wave between disc, the piezoelectric sensor will pick up very low AC signal and contains noises. Therefore, the signals generated by piezoelectric sensor needs to be investigated and characterized first before designing the filter circuit and amplifier circuit in order to filter noises and amplify the signals to a level which can be measured by oscilloscope. Once the signals are conditioned, the resonance frequency of the discs at different frequency range is identified which representing the information of number of discs. For the experiment, piezoelectric coupling device is placed in parallel and sandwiching the discs in between. One of the piezoelectric plate is operating as a transducer which vibrate and generates acoustic wave signal. If there is any material in contact with acoustic wave, the added mass will cause the vibration frequency changes. At the opposite side, another piezoelectric is operating as a sensor to pick up the vibration signal to detect the pattern of changes of vibration frequencies in correlation with number of count for the disc. The signal is being measured with oscilloscope in the form of waveform patterns. The waveform is then being analyzed to determine the relationship between the quantity of the object and resonance frequency. Repeated experiment is done to verify the results. From the experiment results, it has shown that the more the quantity of disc, the higher the resonance frequency in the range from 8 kHz to 12 kHz.

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ABSTRAK

Sistem kiraan adalah sistem penting untuk proses pembungkusan dalam setiap industri. Walau bagaimanapun, pengiraan secara manual bukan cara yang cekap dan tepat. Oleh itu, satu kaedah baru diperlukan untuk membezakan kuantiti disk dengan menggunakan konsep perubahan frekuensi resonans dengan bilangan disk. Dalam projek ini, piezoelektrik digunakan sebagai transduser dan penderia untuk mengukur kuantiti disk. Disebabkan perambatan gelombang permukaan yang lemah antara kepingan disk yang isyarat ulang-alik (AC) yang dikesan oleh penderia piezoelektrik juga adalah sangat rendah dan mengandungi hingar. Oleh itu, isyarat yang dihasilkan oleh penderia piezoelektrik perlu disiasat dan mencirikannya terlebih dahulu sebelum merekabentuk litar penapis dan litar penguat untuk menapis hingar dan menguatkan isyarat ke tahap yang boleh diukur oleh osiloskop.Setelah isyarat yang dihasilkan telah disempurnakan setiap frekuensi resonans pada julat frekuensi yang berbeza akan ditentukan yang mana ianya mewakili maklumat bilangan disk yang dikira. Untuk menjanlankan ujukaji, piezoelektrik akan diletakkan secara selari dengan mengepit disk yang perlu dikira di antaranya. Salah satu keping piezoelektrik itu akan beroperasi sebagai transduser yang bergetar dan menjana isyarat gelombang akustik. Jika terdapat apa-apa bahan diletak antara piezoelektrik tersebut ianya akan menggubah gelombang akustik dan menyebabkan perubahan frekuensi resonannya. Pada sebelah muka yang bertengangan, penderia piezoelektrik akan memungut isyarat getaran untuk mengesan corak perubahan frekuensi getaran berdasarkan bilangan disk yang dikira. Isyarat ini kemudian diukur dengan osiloskop dan kemudiannya dianalisis untuk menentukan hubungan antara kuantiti objek dan resonans frequensinya. Ujian eksperimen ini diulang untuk mengesahkan keputusan dan didapati bahawa apabila bilangan disk meningkat, frekuensi resonans juga meningkat dari 8 kHz hingga 12 kHz.

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CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter consists of the basic information for this project. The first section of this chapter is background which describes the introduction to general area of study and the reason of choosing this project. After that, this chapter includes the problem statement and objectives which will describe the problem facing and going to be solved in this project. Besides, this chapter also discuss the project significant, scope and project outline.

1.1 Background

In every industry, part counting system is an essential system at packaging process. Most of the packaging process have to pack the product in a big amount for clients. For example, production of Wafer or Substrate Company have to pack the wafer in 100 pieces per stack. However, human counting is not an efficient and precise way. Besides, paper is needed to be placed in between two wafer to prevent scratches so that the paper might affect the counting result. Therefore, this analysis project shown a new method to differentiate the quantity of disc by using the concept of changes of resonance frequency.

All of the matter have bulk properties which affect their resonance frequency. In other words, the different resonance frequency can used to indicate the characteristic of the matter. The piezoelectric sensors utilize an energy source to excite an acoustic wave. Hence, the acoustic wave interacts actively with the measurement of interest and its properties such as frequency are used to monitor the measurement.

This project is an analysis project which aims to use the concept of acoustic wave and resonance frequency in measuring the quantity of disc. Besides, piezoelectric coupling device is placed in parallel, one of the piezoelectric plate is transducer which generate

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agitation in air and acoustic wave signal is generated. If there is any material contact with acoustic wave, the added mass will cause the vibration frequency changes. Then, another piezoelectric sensor picks up the vibration signal to detect the vibration frequency.

After that, the signal is being transferred to waveform pattern and showed in oscilloscope. The waveform is then analyzed to determine the relationship between the quantity of the object and resonance frequency. Repeated experiment testing can verify the result after data analysis.

1.2 Problem Statement

Piezoelectric coupling device used as piezoelectric actuator and piezoelectric sensor. However, the high sensitive of piezoelectric sensor will produce signal which contains many noise. Besides, the amplitude of signal produced by piezoelectric sensor is very low. Hence, the noise and the low amplitude of signal produced will affect the data collection and analysis process and hence influence the accuracy of result.

Besides, the signal produced from piezoelectric plate can only observed from oscilloscope. However, usage of oscilloscope will affect the efficiency of data analysis. Hence, usage of software to analyze the signal is necessary.

In addition, every resonance frequency at different frequency range will represent different information. The signal picked up by piezoelectric sensor might be changed in different condition.

1.3 Objectives

The objectives of this project is to characterize the piezoelectric sensor that used as actuator and sensor. After familiar with the characteristics of piezoelectric sensor, the next objective is to design an amplifier and filter circuit to increase the amplitude and reduce noise of signal produced which can improve the signal quality for analysis. Lastly, this project used to investigate the relationship between quantity of disc and resonance frequency and verify the result.

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1.4 Project significant

Acoustic wave analysis with Piezoelectric coupling sensor can used to determine the quantity of disc by changing of resonance frequency. An electrical signal is given to piezoelectric actuator, it will start vibrate and generate acoustic wave signal while the piezoelectric sensor will pick up the signal from actuator. When two piezoelectric plates place in parallel, any matter in between two plates will affect the acoustic wave signal. Therefore, the changes of acoustic wave signal will cause the changes of resonance frequency of that matter. By analyzing the changes of resonance frequency, some useful information can be investigated.

Other than that, this project has a lot of potential to go further to investigate the changes of resonant frequency by using piezoelectric technology which is useful in many industry such as automation machine. By doing analysis of signal that altered according to environment, effective monitoring system can be developed based on this concept also.

Lastly, this project can be implemented in counting system of industrial such as disc production and wafer production. This analysis shown that the quantity of disc can be determined by using changes of resonance frequency and the result is not affected by inserting paper in between two disc. Therefore, this method shown efficiency and accuracy. This project can be implemented in surface crack inspection for vehicles and machine such as air handling unit (AHU).

1.5 Scope

The piezoelectric coupling plate with round shape is used and characterize in this project but not to produce a new piezoelectric plate. The apparatus being used in this project is Microsoft Excel and oscilloscope which are used to collect and analyze signal. The quantity of CD counting in this project is limited to 4 CD due to the limitation of power supplied to actuator.

The scope of this project is to build an experimental sample for experimental testing instead of real product due to the constraint of time and cost. The result will be analyzed in Microsoft Excel and the result will be verified.

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1.6 Thesis Outline

The first chapter is introduction which is a general overview of the project. The problem statement in this part is to explain about the problem faced in market now. Besides, the problem faced in the project also explained in this session. The objective of the project is to provide the method of solving the problem statement and the reason of doing this project. The significant project is to emphasize the benefits and advantage of doing the project. Lastly, the last part in introduction is scope which is discussing the apparatus used and limitation of the projects.

The chapter named literature review is to provide the detail information about the theory of acoustic wave, and piezoelectric sensor. The information about analysis signal processing also provided in this chapter. This part will allow people to briefly understand about the newest technology and result from other research.

The next chapter is methodology which will provide the details procedure for completing the project. The procedure set is according to the step of solving the problem statement and achieve the objective of the project. The procedure including the step of designing circuit, investigate the piezoelectric coupling sensor, analyze signal and verify the result.

Next, the result and discussions part will provide all the final result in the project and present in formal and simple way. The result will be used to justify the achievement of the objective in the project.

Lastly, the conclusion and suggestion will provide the summary of the project. Suggestion for further research in the project will be given in this part also.

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CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter consist of the current state of knowledge which related to the keyword of this project title. Firstly, the background and principles of piezoelectric sensor will be discussed in first section. Next section describes about the introduction and theory of acoustic wave. The relationship of acoustic wave and piezoelectric sensor also discussed in this section. After that, the design of filter circuit and amplifier circuit are discussed in next section.

2.1 Introduction of measurement

’Measure what is measurable, and make measurable what is not so’ is a quote from an Italian physicist and astronomer, Galileo Galilei, 1564 – 1642. In this 21st century, high technology for measuring of physical quantity is very important for industry in process monitoring and control [1].

Measurement is an experimental determination which used to measure the magnitude of a physical quantity by comparing it with the corresponding unit of measurement. Basically, most of the measurements are determined by exploiting the physical effect in a measuring devices such as transducers or sensors. In a basic measuring process, it consists of an input energy, system and output energy. Input energy is any physical effect such as pressure which generates or controls a signal and transfers it to output energy such as electrical energy.

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Transducers are used to convert one kind of energy to another kind of energy. Transducer is a collective term for both actuator and sensor. Actuator can be used to move or control a mechanism or system. Sensor is used to detect some characteristic that changes in response to some excitation. There are two type of sensor, which are passive and active.

Passive sensor is a sensor which does not need any additional energy source and it can directly generate signals in response to external change. However, the disadvantage of the passive sensors is it may not function if any change happened on additional energy source. Besides, another type of sensor is an active sensor which requires an external power supply for operation, for example, battery is needed for active sensor to operate. An active sensor will reflect the external energy source and returned to sensor for measurement. The example of active sensor-based technologies is scanning electron microscopes.

2.2 Piezoelectric Sensors

Sensor is an essential component in measurement. Piezoelectric is one of the sensor that can convert the energy from mechanical to electrical or electrical to mechanical. The following sub-chapter will discuss the background, principle and basic knowledge about piezoelectric.

2.2.1 Background

Piezoelectricity is the meaning of electricity resulting from pressure. Piezoelectricity effect is a linear electromechanical interaction of certain crystal and ceramics. The interaction occurs between the mechanical and the electrical state in crystal without the center of symmetry. In addition, piezoelectric sensor is a device used to convert the physical change of pressure, strain or force to a signal of electric charge [1].

The Piezoelectric effect was discovered by the brothers Pierre and Jacques Curie in 1880. At that time, they were investigating about the relationship of pressure and electric charge in crystal. Those investigations also reported the first importance phase of the development of solid state physics of crystal. The first application of the piezoelectric

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sensor was used in World War I to measure the force, pressure and acceleration. After that, many researchers started to investigate more use of piezoelectric sensor and the development of piezoelectric sensor [2].

In year 1997, a new Monolithic Piezoelectric Sensors (MPS) was being verify that it can be used in both gaseous and liquid phase measurements. MPS is simple to use and yet stable, its oscillator circuits in relatively vicious media. Besides, the unique relationship of piezoelectric sensor with sound was found by researchers. Therefore, scientist started to implement piezoelectric sensor into electronic device as audio filters and buzzers.

Until this point, the only material used for piezoelectric is quartz because it was not expensive and common. However, researchers started to find alternatives and more effective manufacturing methods, but the technology was overshadowed by discovery of radiation and vacuum tubes,

Nowadays, the modern applications of Piezoelectric sensor are as piezoelectric motors, process control, inkjet ejectors, quality assurance, time standards in watches, and vibrational dampeners. Besides, personal electricity generation such as energy harvesting is a famous example of application of piezoelectric sensor.

2.2.2 Advantages

The reason of piezoelectric sensor been chosen for application is because of its many advantages. The main advantages of piezoelectric sensors are its high rigidity which produce a measurement of deflections typically in the range of micro-meter. Besides, it has also wide measuring rage which the span-to-threshold ratio is around 10^8. In the other hand, piezoelectric sensor also has the high natural frequency up to over 500 kHz. The transduction elements of piezoelectric sensor which made of single crystal has very high stability.

Since the piezoelectric sensor has a wide operating temperature range so it can be used in many situation with different temperature. In addition, piezoelectric sensor is not sensitive to electric field, magnetic field and radiation. This is a good characteristic that make piezoelectric sensor not easy to be effected by other elements. Moreover,

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piezoelectric sensor has high linearity of the dependence of the output on the measured [1].

Piezoelectric transducer can be used as actuator and sensor. One of the advantages of it that used as actuator and sensor is the capability of integration into existing structures and controlled by voltage easily. Besides, piezoelectric sensor has low weight, low power requirements, low-field linearity and high bandwidth. All these characteristics have an upper hand compared to other sensors [3].

2.2.3 Principles of Piezoelectricity

Direct Piezoelectric Effect

The direct piezoelectric effect is shown when the change of electric polarization proportional to the strain that applied to the material. A material is indicated as piezoelectric only when the application of an external mechanical stress gives rise to dielectric displacement in the material and the displacement is the internal electric polarization. The effect of piezoelectric is dependent on the symmetry of cell unit in a crystal.

Converse Piezoelectric Effect

Converse piezoelectric effect is the piezoelectric crystal becomes strained when an external electric field is applied [2].

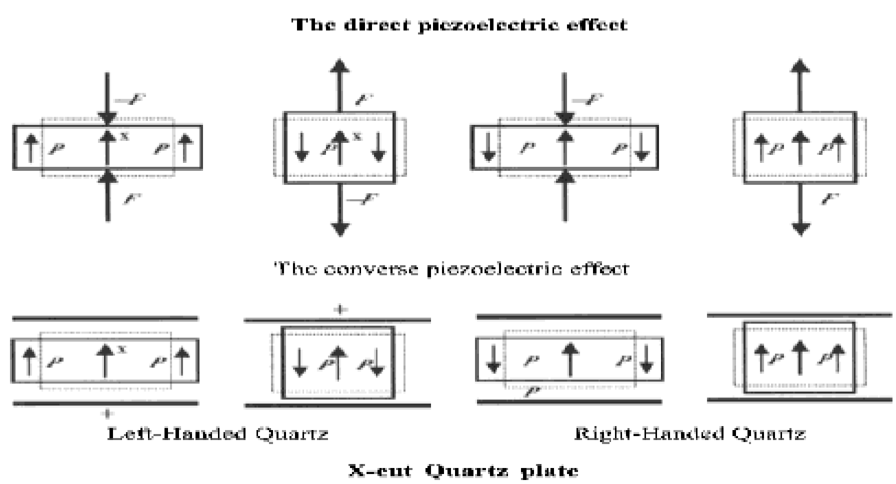

Figure 2.1: Direct and converse piezoelectric effects [2]

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Section 2.2.2 has shown the advantage of piezoelectric effect which is the reason why piezoelectric have been used in a wide range of application. By comparing to piezoelectric effect, the adaptive materials from other categories are more difficult to integrate into existing structures and they are lacking of consistent mathematics model [3].

When a piezoelectric transducer is mechanically stressed, it generates a voltage. This phenomenon is governed by the direct piezoelectric effect. This property makes piezoelectric transducers suitable for sensing applications. Compared to strain gauges, piezoelectric sensors offer superior signal to noise ratio, and better high-frequency noise rejection. Piezoelectric sensors are, therefore, quite suitable for applications that involve measuring low strain levels. They are compact, easy to be embedded and require moderate signal conditioning circuitry [4].

Consider a beam with a pair of collocated piezoelectric transducers bonded to it as shown in Figure 2.1. The purpose of actuators is to generate a bending effect in the beam by applying a moment to it. This is done by applying equal voltages, of 180◦ phase difference, to the two patches. Therefore, when one patch expands, the other contracts. Due to the phase difference between the voltages applied to the two actuators, only pure bending of the beam will occur, without any excitation of longitudinal waves [4].

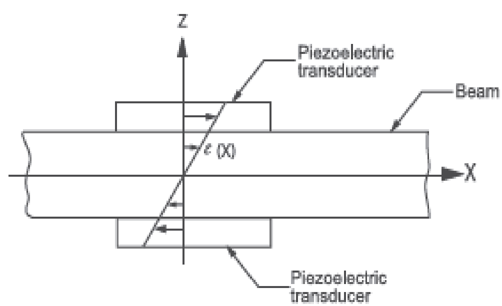

Figure 2.2: A beam with a pair of identical collocated piezoelectric actuators

Based on the assumption of total strain in a piezoelectric transducer is sum of mechanical strain induced by mechanical stress and the controllable actuation strain caused by applied electric voltage.

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