Jurnal Kejuruteraan SI 1(5) 2018: 37-41
https://dx.doi.org/10.17576/jkukm-2018-si1(5)-06

An Application of Capacitance Proximity Sensor for Identification of Recyclable Materials

(Penggunaan Penderia Kapasitan Jarak dalam Mengesan Bahan Kitar Semula)

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ABSTRACT

Capacitive proximity sensor is often used in various industrial applications for contactless measurement of an object or target displacement and position. In this research, the capacitive proximity sensor is used for new alternatives in detecting recyclable materials specifically plastic and paper for aiding in the separation process. The detection of the sensor for this study is based on the permittivity values of each material where the sensor is adjusted according to the tested material permittivity. Several experiments have been conducted using different types of papers, plastics, and a combination of both materials for this study. At the end of the experiment, the sensor is able to detect a different type of paper and plastic. The sensor also able to detect the combination of both paper and plastic based on their difference in permittivity values. However, there are some limitations to this system such as the size, density, permittivity values, as well as the distance between both sensor and target are affecting the accuracy of the detection system causing the sensor to fail in identifying the samples.

Keywords: Capacitive proximity sensor; permittivity; detection; recyclable

ABSTRAK

Penderia kapasitan jarak biasaannya digunakan dalam pelbagai jenis industry yang melibatkan pengukuran sesuatu objek ataupun penentuan posisi objek tanpa melibatkan sentuhan. Dalam kajian ini, penderia kapasitan jarak ini telah digunakan sebagai alternatif baru dalam mengesan bahan kitar semula seperti plastik dan kertas dalam proses pengasingan. Pengesanan oleh penderia ini adalah berdasarkan nilai permitiviti bahan kitar semula di mana penderia yang digunakan akan diselaraskan kepada nilai permitiviti bahan yang diuji. Beberapa uji kaji telah dijalankan menggunakan kertas dan plastik yang berbeza-beza serta gabungan kedua dua jenis sampel tersebut. Hasil kajian menunjukkan penderia kapasitan jarak dapat mengesan kebanyakan kertas dan plastik yang digunakan. Penderia ini juga berjaya mengesan sampel gabungan kertas dan plastik berdasarkan perbezaan nilai permitiviti masing masing. Namun begitu, terdapat beberapa kekurangan dalam sistem pengesanan ini seperti saiz sampel, ketumpatan, nilai permitiviti serta jarak antara penderia dan sasaran mengganggu ketepatan pengesanan sistem ini menjurus kepada kegagalan dalam mengesan sampel yang diuji.

Kata kunci: Penderia kapasitan jarak; permitiviti; pengesanan; bahan kitar semula

INTRODUCTION

The fast-expanding economy in developed countries has been encouraging solid waste generation increase, especially in the capital. With economic growth, business activity and utilization rate that is increasingly developed in the capital city of Kuala Lumpur will accelerate generation rate and a total of municipal solid waste daily (Budhiarta et al. 2012). According Web is Official Chief Executive Officer Solid Waste Management Corporation & Public Cleaning (PPSPPA), solid waste generation in Peninsular Malaysia in the year 2005 and 2012 is 17,000 tons and 22,000 tons per day respectively. Meanwhile in the year 2013, solid waste generation increase drastically namely reach 30,000 to 33,000 tons one day. PPSPPA estimated the generation of solid waste in the year 2020 is 30,000 tons per day.

A solid waste management system used by developing country like Malaysia is by delivering all waste to dumping site including the waste that can be composted and recycled. Figure 1 shows the composition of solid waste UKM at the dumping site where the recyclable item like paper, polystyrene, plastic, drink box, aluminium and glass are 21, 16, 15, 5, 4 and 2% respectively (Zulhafizal et al. 2013). The problem is the dumping site in Malaysia are almost full. Therefore, the solution is to avoid the waste that can be composted and recycle from sending to the dumping site.

The initial step that needs to be done in the recycling process is to separate the solid waste. In Malaysia, the separation of solid waste is done manually by manpower. Actually, the separation by manually will give much negative impact to staff who did the separation. One of them is employee easy to fall into health problems such as

skin disease and so on. In this research, the effectiveness of the capacitive proximity sensor will be tested to identify the recyclable materials for waste sorting system and the research scope is in Universiti Kebangsaan Malaysia (UKM). Types recyclable plastics used in this study is packaging plastic (Polypropylene), black garbage plastic (high-density polyethylene), transparent plastic (vinyl) and food container (polystyrene) meanwhile, for recyclable paper, A4 plain paper and newspaper was chosen.

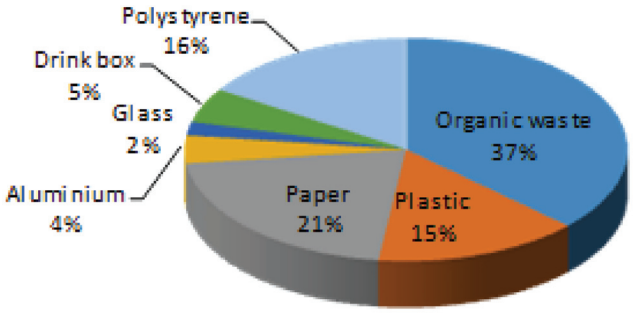


FIGURE 1. The composition of solid waste in UKM

CAPACITIVE PROXIMITY SENSOR

Capacitive proximity sensor used in this study is shown in Figure 2. It is a technological instrument that able to detect an object that near to the sensor without any physical contact (Nan et al. 2009). The types of proximity sensors used in this research were RIKO KC3030-KP2, which has a sensing range of about 2 to 30 mm with operating voltage between DC12 to 24V. This sensor function by measuring the capacitance between electrodes which affected by an object that close to the sensor (Benniu et al. 2007). Capacitive sensors operate by detecting the change in capacitance between the capacitive sensor and the intended target. Capacitance is an electrical property between two separate materials, and its strength varies with distance and the properties of the materials (Namco 2013). This capacitance sensor is ideal for this research because the sensor is able to detect the target and ignore the material of conveyor belt because of the acrylic and belt has a low value of permittivity or dielectric constant.

FIGURE 2. Capacitive proximity sensor (Udelhoven 2012)

Figure 3 shows the component of the capacitive proximity sensor. The sensing surface of a capacitive sensor is formed by two concentrically shaped metal electrodes of an unwound capacitor. When an object nears the sensing surface it enters the electrostatic field of the electrodes and changes the capacitance in an oscillator circuit. As a result, the oscillator begins oscillating. The trigger circuit reads the oscillator's amplitude and when it reaches a specific level the output state of the sensor changes. As the target moves away from the sensor the oscillator's amplitude decreases, switching the sensor output back to its original state.

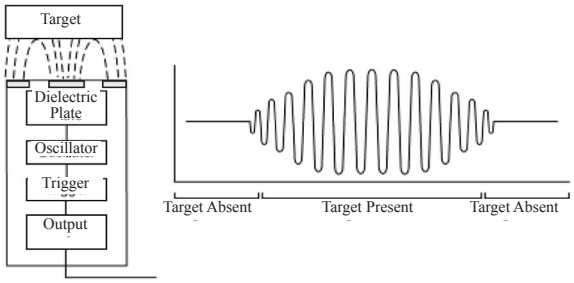


FIGURE 3. Component of the capacitive proximity sensor (Rockwell Automation 2014)

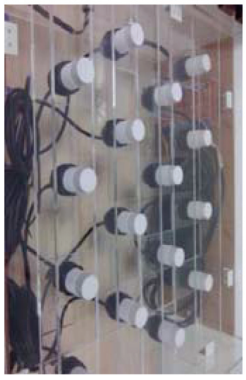
METHODOLOGY

The capacitive proximity sensors will be arranged by 4 x 4 lines as shown in Figure 4. The sensor was placed in two lines which is sensor number 2, 4, 6, 8,10, 12, 14 and 16 was adjusted with low dielectric of sample and another two lines of sensors which is sensor number 1, 3, 5, 7, 9, 11,13 and 15 was adjusted with high dielectric of sample. The estimated value of dielectric constants of paper and plastic according to Navy Electricity and Electronics Training Series (NEETS) is given in Table 1. Table 1 show the value of dielectric constant of paper is higher than plastic.

Figure 5 indicated the flow chart of a testing procedure for six recyclable materials using capacitive proximity sensor. Firstly, preparation of sample was carried out. Samples will be measured and weighed to get sample density value. In this research, samples are divided into two with two different densities which are 0.02 cm^3/g and 0.04 cm^3/g. Then, conveyor and all the capacitive proximity sensors will switch on. The conveyor was adjusted to minimum speed to avoid the inferring of the process detection and have enough time to detect the sample.

TABLE 1. Dielectric constant of recyclable material

Sample	Resin	Dielectric constant
Packaging plastic	*Polypropylene* (PP)	2.2
Heavy duty PE garbage plastic	*high-density polyethylene* (HDPE)	2.3
Transparent plastic	*vinyl* (V)	2.0
Polystyrene	*polystyrene* (PS)	2.7
Newspaper	-	3.85
A4	-	3.85



(a)

15	16
13	14
11	12
9	10
7	8
5	6
3	4
1	2

(b)

FIGURE 4. Capacitive proximity sensor (a) actual image of sensor (b) numbering of each sensor on the conveyor

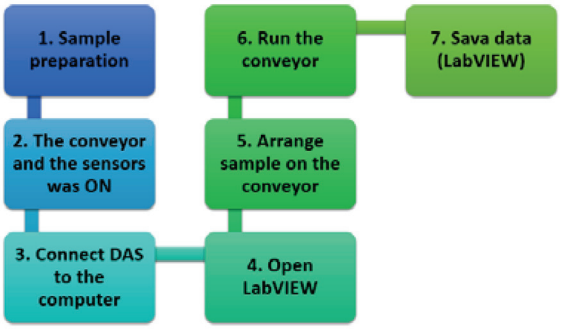


FIGURE 5. Flow chart of a testing procedure

LabVIEW software has been installed to the computer to clarified the result from the sensor. Data Acquisition System (DAS) were used to connect the sensor with the computer. Sensor will be adjusted with the constant value dielectric sample that is low and high like which indicated in Table 1. Figure 6 illustrated the top view of samples on the conveyor belt with the attachment of capacitive sensor. Samples are located at the top of the conveyor will go through the sensor with the lower speed so the capacitive sensor has enough time to detect and display results at the LabVIEW software.

RESULT AND ANALYSIS

The result and analysis of data for the experiment will show whether capacitive proximity sensor able or not to detection of materials recycling. Figure 7 illustrated the output data from LabVIEW software that shown the displays of capacitive sensor. The data 1 above is the sensors that adjusted with low dielectric while data 2 is the sensor that was adjusted with high dielectric.

Figure 8 are shown the result and analysis for the detection for density of 0.02 g/cm³. The results for the density 0.04 g/cm³ are presented the same as with detection in Figure 8. In these experiments, there are three cases which is detection on paper, detection of plastic and detection on both paper and plastic. Based on Table 2 and Table 3, for the detection towards newspaper and A4, the values of dielectric are same which is 3.85. This can be proved when sensors are adjusted to the dielectric of the newspaper, the LabVIEW software showed both sample is detected. Similar as when the samples are passed through the sensors that are adjusted to the dielectric of A4. Meanwhile, for the detection of plastic, the results displayed that the dielectric of packaging plastic, heavy duty PE garbage plastic, and transparent plastics are almost the same. This is because the sensors can detects all the samples even though the sensors only adjusted to the dielectric of transparent plastic. Based on the Figure 5, transparent plastic has the lowest dielectric which is 2.0 compared to packaging plastic and heavy duty PE garbage plastic which is 2.2 and 2.3. Besides that, for the detection towards paper and plastic, we can see on the Table 3 indicated the paper has the high dielectric than plastic. When the sensors are adjusted to the dielectric of transparent plastic, LabVIEW software showed the green button. Otherwise, when the sensors are adjusted to the dielectric of the newspaper, the LabVIEW software showed the grey button. Figure 10 showed the overall conclusion for this detection of recyclable material by using a capacitive proximity sensor.

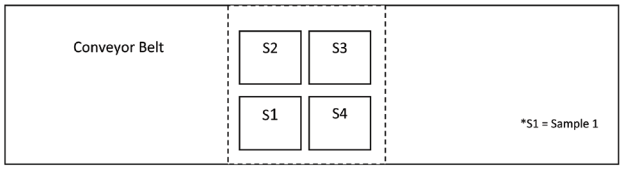


FIGURE 6. The top view of samples position on the capacitive proximity sensors system

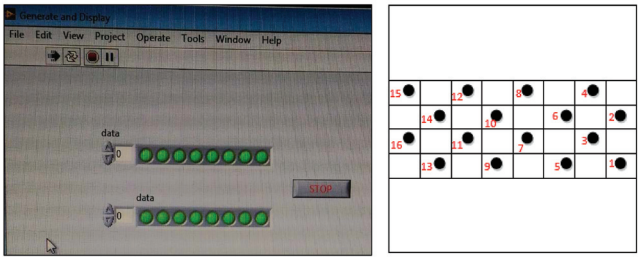
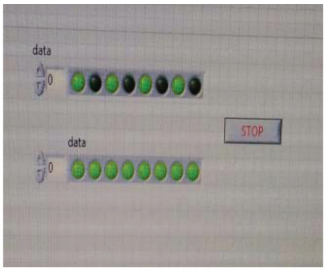
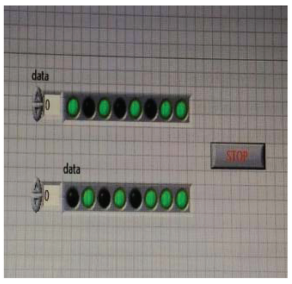
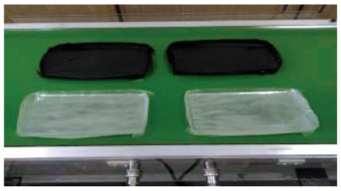
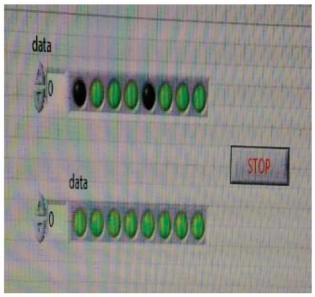
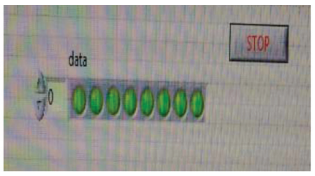
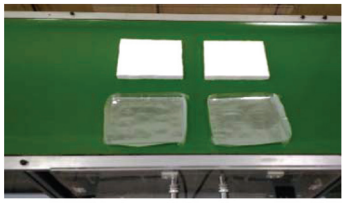
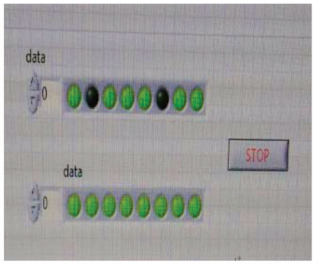


FIGURE 7. The output of LabVIEW displays of capacitive sensor

TABLE 3. The results for density 0.04 g/cm^3

Test	Sample	LabVIEW Image
Identification of A4 and newspaper		
Identification of heavy duty garbage plastic and transparent plastic.		
Identification of heavy duty garbage plastic and packaging plastic.		
Identification of packaging plastic and polystyrene.		
Identification of newspaper and transparent plastic.		

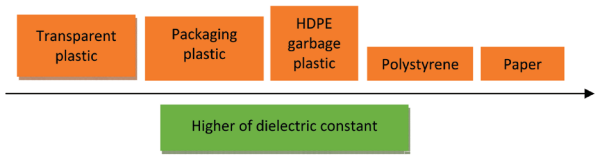


FIGURE 8. Detection of plastic and paper by using the capacitive proximity sensor

CONCLUSION

The results showed that the capacitive proximity sensor is reliable to identify the recyclable materials which are packaging plastic, heavy duty PE garbage plastic, transparent plastic, polystyrene, newspaper, and A4. This can be proved when the results obtain exactly the same with the theoretical value of dielectric constant. Paper has higher dielectric compared plastic. Meanwhile, for the plastic sample, the difference value of dielectric value for packaging plastic, heavy duty PE garbage plastic, and transparent plastic are very small that cause the capacitive proximity sensor can detect all three samples although sensor only adjusted with dielectric value for the one sample only. Based on this experiment, polystyrene sample has higher dielectric compared packaging plastic, heavy duty PE garbage plastic, and transparent plastic.

ACKNOWLEDGMENT

The author would like to express appreciation to all the individual for their cooperation and information in making this thesis successfully.

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Received date: 8th May 2018
Accepted date: 15th August 2018
Online First date: 1st October 2018
Published date: 30th November 2018