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Model design and simulation of automatic sorting machine using proximity sensor

Bankole I. Oladapo [a,*], V.A. Balogun [a], A.O.M. Adeoye [a], C.O. Ijagbemi [b], Afolabi S. Oluwole [a], I.A. Daniyan [a], A. Esoso Aghor [a], Asanta P. Simeon [a]

[a] Afe Babalola University, Ado-ekiti, Nigeria
[b] The Federal University of Technology, Akure, Nigeria

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ABSTRACT

The automatic sorting system has been reported to be complex and a global problem. This is because of the inability of sorting machines to incorporate flexibility in their design concept. This research therefore designed and developed an automated sorting object of a conveyor belt. The developed automated sorting machine is able to incorporate flexibility and separate species of non-ferrous metal objects and at the same time move objects automatically to the basket as defined by the regulation of the Programmable Logic Controllers (PLC) with a capacitive proximity sensor to detect a value range of objects. The result obtained shows that plastic, wood, and steel were sorted into their respective and correct position with an average, sorting, time of 9.903 s, 14.072 s and 18.648 s respectively. The proposed developed model of this research could be adopted at any institution or industries, whose practices are based on mechatronics engineering systems. This is to guide the industrial sector in sorting of object and teaching aid to institutions and hence produce the list of classified materials according to the enabled sorting program commands.

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1. Introduction

Materials handling involves the movement, storage, control, and protection of materials during their manufacturing, distribution, consumption, and disposal [1–5]. There are different material handling systems and equipment in industrial plants, which use conveyor system. It moves objects from the source to the terminal instead of moving objects with people due to its ability of continuity in the operation speed and consistency of objects in movement. Material handling systems ranges from simple pallet rack, shelving projects to complex overhead conveyor systems, automated storage, and retrieval systems. Material handling also consists of sorting and picking [1,2,6]. In recent times, various sorting systems have been developed. The applications of sorting varies from agricultural products, consumer manufactured products, books, etc. Constantin and Michael in 2002 reported that every sorting methodology can be classified based on the specification of two issues: (1) the form of the criteria aggregation model which is developed for sorting purposes, and (2) the methodology employed to define the parameters of the sorting model [7–14]. Few researches were also based on automatic sorting, manual sorting and online sorting methods. For example, few researchers proposed sorting system that can organize different material automatically without human aid, with the use of double acting pneumatic cylinder to push the material to its equivalent boxes on the conveyor belt [15–18]. Other methods are the dielectrophoresis [19,20], morphological transformation of labeling of materials [21], magnetophoresis [8,22], fluorescence activated image segmentation [23,24,26]. These proposed sorting methods however, have various problems attributed to them. For example, poor sorting efficiency, energy demand, multi-tasking and machine flexibility. In other to rise above the shortcomings of ever increasing sorting efficiency of materials, conserved energy and improve quality productivities, automatic sorting methods were proposed by various researchers [6,25–29]. This work proposed and based the model on the automatic sorting techniques. The aim of this research therefore is to design a model and simulate the functionalities of an automatic sorting machine using a capacitive

* Corresponding author.
E-mail addresses: bioladapo@abuad.edu.ng (B.I. Oladapo), balogunav@abuad.edu.ng (V.A. Balogun), aadeoye@abuad.edu.ng (A.O.M. Adeoye), tadeijagbemi@gmail.com (C.O. Ijagbemi), afowolesam@yahoo.com (A.S. Oluwole), afolabiilesanmi@yahoo.com (I.A. Daniyan), greatsosoliso@gmail.com (A. Esoso Aghor), engnrsimeon4real@yahoo.com (A.P. Simeon).

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proximity sensor. In order to achieve this developed automatic sorting methods, the images of the objects (i.e. plastics, wood and steel) were captured with the proximity sensor and the conveyer belt transports the material from one point to another. The conveyor system automatically sort objects in such a way as to increase product manufacturing, quality control and profit making enterprises. It is important to know that the conveyor belt could be automated by allowing the objects to move to the detection position through the dynamics of the running motors [30–32] using the sensor signal to control the Programmable Logic Controller PLC for processing. Subsequently, the program bird's logic control signal becomes the output to the motor driving the object into the computer window to be defined by the PLC. The crank motor adopts the principle of pneumatic cylinder and capacity optical sensors to push all the three object into their corresponding position. It is envisaged that this research could be used to enhance the teaching and learning of mechatronics system engineering at different institution across the globe and most especially in Nigeria. This would enhance knowledge and skills acquisition and also a better understanding of mechatronic systems both in theory and practical [33–35]. The foundation has the potential to lead to the development of high-tech materials analysis for counting which could be installed into the system [36–38].

Fig. 1. The wedge belt (V-Belt).

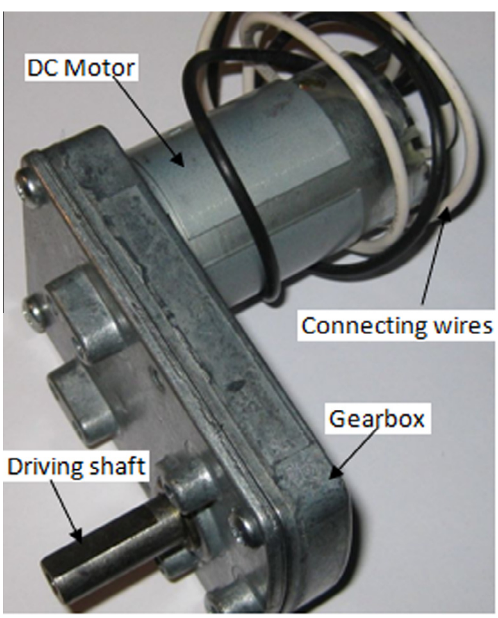

Fig. 2. DC motor with gearbox is for conveyor.

2. Theory and principles

2.1. Sorting machine belt assembly and movement

The sorting machine drive uses a conveyor belt and a 'Betel Coley' to transport objects from the origin to the destination. From literature, flat belts (Flat belt), conveyor wraps (Fold edge) and wedge belt (V-belt) [32,33] are some of the reported commonly used conveyor belts for automatic sorting machines. This work follow suit from commonly adopted belts from literature. Hence the wedge, flat and fiber (natural fiber) belts were adapted for this research. The wedge belt is made of the synthetic ring encased in

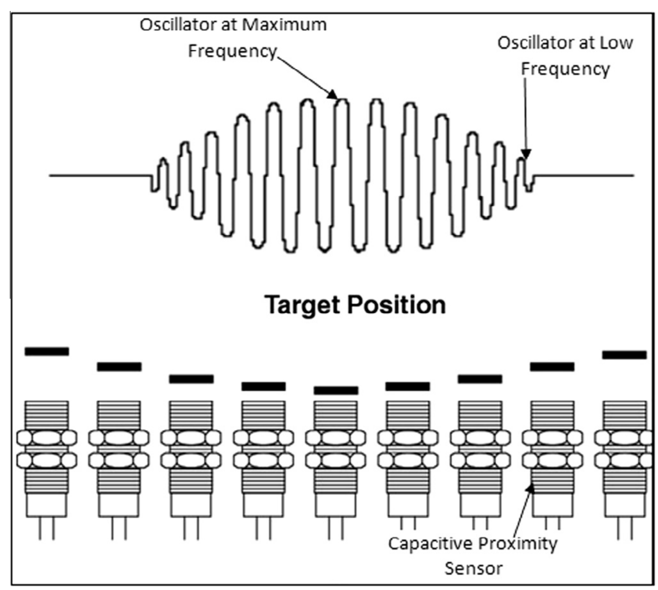

Fig. 4. Phase of an oscillator slater with detection by capacitive proximity sensor.

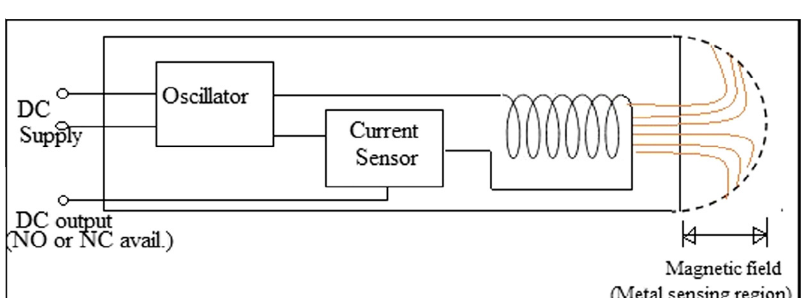

Fig. 3. Structural design and working principle of a capacitive proximity sensor.

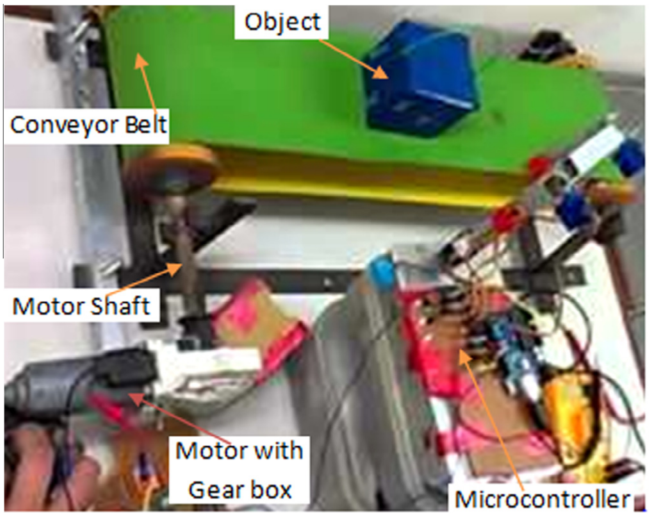

Fig. 5. Sets of automatic sorting objects on a conveyor belt.

rubber that gave the core the desired strength. The wedge-shaped belts are of a trapezoidal shape and size that shows both the corresponding teeth inclined at an angle of between 38° and 44° as shown in Fig. 1.

The drive of the automatic sorting machine uses a DC motor and gear reduction system to reduce the speed and increase the torque of the motor as indicated in Fig. 2. The load capacity of the DC motor is approximately 25 kg at the factory conveyor level. This load includes the gearbox assembled with DC motor as shown in Fig. 2.

2.2. Characteristics of the systems sensors to detect objects

The detection section of the automatic sorting machine has a detection device, which is made of the proximity capacitive sensor. This sensor changes the capacitance due to the distance and the type of object to detect. This equipment has many advantages. For example their ability to detect objects of all kinds of metals and non-metals. In addition, they are cheap, available and easy to configure over the other types of proximity sensors. The operations of the capacitive proximity sensors entails that the dielectric constant of the object changes in capacitance when the object moves closer to the sensor which depend mainly on the speed of the conveyor belt [29,33,34,40–43]. They sense fluid level, chemical concoctions etc. of any object within the range. They are generally used for industrial purposes [43,44]. The electrical circuit formed by the DC oscillator slater has the capacity to change the magnetic field induced due to the current sensor as shown in Fig. 3. The objects to be sorted moves in logical order in such a way that as it gets closer to the capacitive proximity sensor, it gives a maximum output oscillation frequency as depicted in Fig. 4. If however, the object moves further away from the sensor, a lower oscillation frequency is displayed.

3. Experiments

3.1. Experimental procedures

Fig. 5 shows the control system arrangement of the proposed operation of the belt conveyor system, which makes the sorting material to appear in series. The conveyor belt receives the signal from the capacitive proximity sensor in order to actuate and process the program logic and at the same time to run the conveyor to work as intended [23]. The conveyor belt actuates as soon as an object is placed on it. The object is then transported to the area of the detecting sensor activated by the PLC. It then sends a signal to the double acting cylinder to push the object into the appropriate compartment for storage.

The output of the system consists of two parts: (1) a metal and (2) non-metal. The behavior of the conveyor belt determines the output. The sensor sends the signal to the control system that eventually sorts the object into their different categories [39] based on the sensor positions. This is to get the desired position when the motor serves as the kickoff, and rotate objects or specimens to the belt and place it on a desired point on the conveyor for the double acting cylinder to push the object to the desired compartment.

This work adapted the PLC design concept of [44–46] to link the electronics connection of the sorting system together as shown in

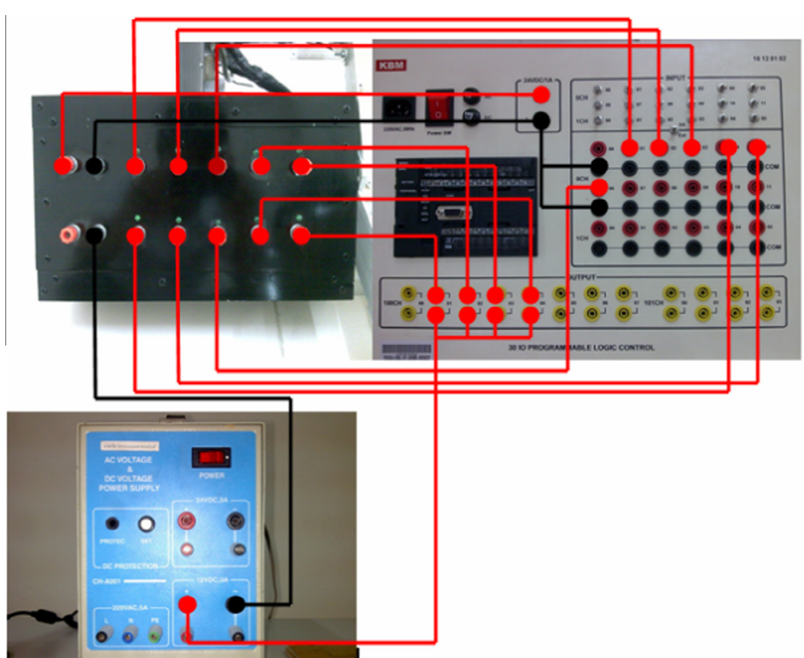

Fig. 6. The electronic connection of the sorting system to the PLC.

Table 1
Phase detection of capacitive proximity switch.

Object trial	Detecting distances (mm)
Steel	16.912
Wood	9.981
Plastic	0.3156

Fig. 6. The PLC is to serve as the distribution network to capacitive proximity sensor, double acting cylinder, conveyor drives, etc. this will ensure the proposed concept are well defined and in a logical flow.

In addition, the phase detection distances of capacitive proximity sensor for different materials are well documented and the extract for the three materials adapted for this work is as shown in Table 1 and Fig. 7. These distances are important to determine the proximity distances at which maximum oscillation frequency can be detected. The optimum detecting distances for different materials is as shown in Table 1. The choice of the type of proximity sensor depends solely on the object types and detecting distances as shown in Fig. 7.

During the experimental investigations, the materials were taking from the source and dropped into the conveyor system driven by the motor to be sorted. The test objects for sorting were designed in such a way that they have the same shape and size. Their weight could vary due to the chemical properties of the sorting material. The movements of the object to sort were kept at a pre-defined distance from each other. This is to enable the three capacitive proximity sensors to detect each of the objects based on their detecting distance and pushed by the electro-pneumatically operated double acting cylinder before sliding into the available compartment as shown in Fig. 8.

4. Results

The result obtained show that for the 15 trials of materials sorted using the capacitive proximity sensors for the different materials under investigations (i.e. steel, wood and plastics), each object were sorted correctly into the designated compartment however, each of the object varies in sorting time. It can be observed that it took 9.9, 14.1 and 18.5 s for plastic, wood and steel objects respectively as shown in Fig. 9.

The results of the three trials are the time trial at the distance from the object passes through the sensor. The object was pushed down to the basket by the cylinder. It was the same spot near the top of the plastic basket. A fruit basket is at the end of the iron fall of a distance of about 20 cm from the conveyor edge.

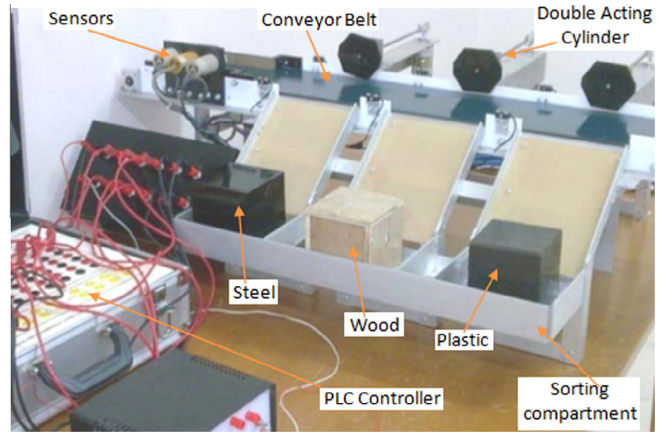

Fig. 8. Result of automatic sorting of objects on a conveyor belt on the complete model system.

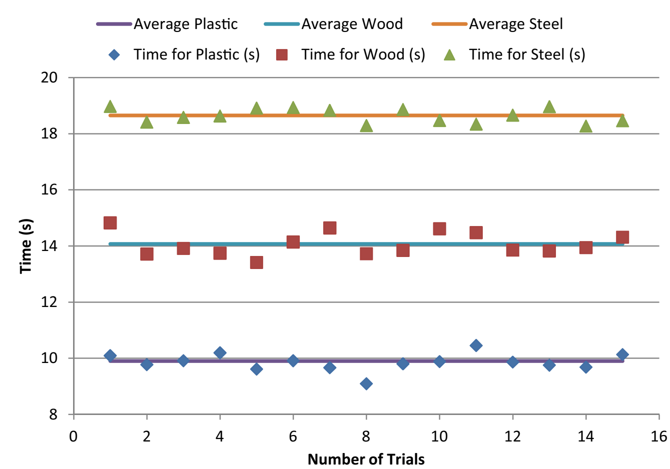

Fig. 9. The results of graphical representation of sorting trial.

5. Conclusion

The proposed methodology of modeling the sorting machine in this work can be adopted and extended to evaluate and model other types of sensors that could be applicable for sustainable sorting of different objects. This work is a fundamental approach to modeling a manufacturing and automated machines. It is observed that irrespective of the type of sensors used, the proximity distances of the sorting sensors plays a vital role in determining the

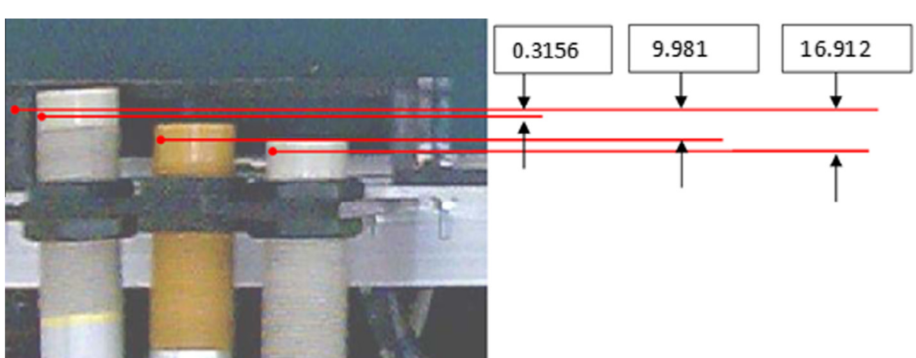

Fig. 7. Distance arm detection of individual specimen.

time it takes for sorting. In general, it is recommended that capacitive sensors be used for sorting of complex manufacturing of objects with different chemical properties. The following conclusion can be deduced from this work:

1. Since the trial objects were sorted successfully, the sorting sensors, conveyors and other accessories were proper for sorting machine modeling.
2. It is also observed that the PLC is necessary for the logic programming of the sorting machine. This is because it 'brain' of the sorting system to executes the programmed functions.
3. Each object were sorted correctly into the designated compartment with an average sorting time of 9.9, 14.1 and 18.5 s for plastic, wood and steel objects respectively.
4. Depending on the torgue of the DC gear motor, the weight of the sort material has little or no effect on the movement towards the conveyor belt and sort time however it is recommended that further analysis be carried to evaluate this hypothesis.
5. The driving range and the speed of the object depend mainly on the control of the PLC and the sensitivity of the sensor that could be adjusted to a suitable distance between object-sensor detection distance.
6. It is recommended that this model be extended to include other types of sensors and objects of different material (i.e. different chemical properties) to ensure repeatability and model consistency.

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