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PLC Based Automated Object Sorting System

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Abstract: In this advance era, automatic sorting is highly desirable in approximately every industry. Its main objective is to reduce human efforts and time which can ultimately raise its efficiency. However, perfect sorting machine is still in progress which should be flexible and compatible in design. In this work, the proposed sorting machine is able to corporate compatibility by using conveyer belt and proximity sensors to detect type of material i.e. wood, metal or plastic and also identifies size of material in three different ranges and finally sort the material separately in assigned basket by using pneumatic cylinder (controlled by Programmable Logic Controller (PLC)). The proposed multi sorting system is able to sort nine objects of nine different ranges are sorted with 100% accuracy within the time interval of 0.5 seconds. The proposed model could be implemented in any industry whose applications are mechatronics based engineering system. This model can also produce list of sorted objects through enabled sorting program commands.

Keywords: Material Management System (MMS), Pneumatic Cylinder, Proximity Sensor, Programmable Logic Controller (PLC).

I. INTRODUCTION

Material management system(MMS) is a major requirement of almost every manufacturing industry and it can be done through storage, controlling, protection and sorting with respect to their dimensions (height, length, weight), colors using machine vision (image processing), or material of an object. MMS ranges from simple to complex processes depend upon its applicability [1-4]. In this technological era, we have vast varieties of automatic sorting systems; their uses depend on its application like agriculture and consumer products etc.[5-10].

An automatic sorting machine performs task of sorting components according to their sizes and materials and it can be done individually as well as simultaneously with or without human interaction depending upon its application. Previously proposed sorting techniques were based mainly on machine vision [11-13], hyper spectral imaging [14, 15], PLC [16] and/or various sensors [17-19]. However, these proposed methods have several problems like less sorting efficiency [11, 12, 20], long time interval between inputs [17], inaccurate to identify varieties of objects [11], machine is limited for specific task [13], implement separate programming for each task (enhances machine complexity) [12, 21] and manually operated [20]. Our work presents an automatic sorting technique based on both hardware and software. There are three main objectives of this paper.

First task is to distinguish among the three types of material (wood, plastic and metal) by using proximity sensors.

Second task is to sort the objects with respect to their heights at three different levels and send it to their specific compartment by using pushing mechanism (conveyer belt, pneumatic cylinder PLC).

Third task is to maintain small time interval between input materials.

The remaining paper is organized as follows; Theory and principle is described in Section 2, proposed methodology in section 3, implementation in section 4 and Results are explained in Section 5. Finally, the paper is concluded in Section 6.

II. THEORY AND PRINCIPLES

A. Model Structure

Complete phenomenon of sorting and pushing mechanism by using conveyer belt, sensors and pneumatic cylinder is shown in fig 2. It works on the principle of detection of material type initially then identifies the size of material to push it to its destination by using sensor technology.

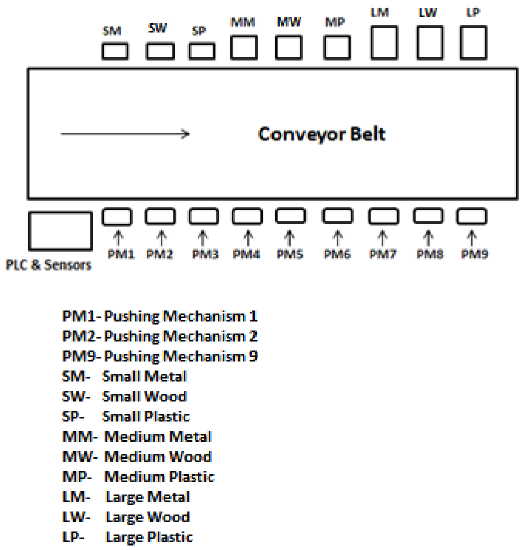

Fig.1 Physical Representation of Sorting Mechanism.

B. Sorting and Pushing Mechanism

The sorting mechanism customs the conveyer belt for the transportation of the objects from source to target. From the previous work we have noted that, flat belts, conveyor wraps and wedge belt i.e. V-belt [22], are few of the commonly used types of the conveyor belts utilized in automatic sorting machines. We have opted for wedge belt in our research. The required strength of the core of V-belt is achieved by wrapping the synthetic ring in the rubber. The trapezoid shaped, 4ft long and 9inch wide, conveyer belt is powered by 24V Switching Mode DC Power Supply. It is essential to note that the automated belt moves the object to detection position by dynamics of the running motors using sensor signals fed in PLC for processing.

C. Pneumatic Powered System

Pneumatic System is a classic method to utilize pressure pump for pushing and sorting the articles [23]. These mechanical devices utilize compressed gas power for the production of force. The double acting cylinder, used in our research, both extends and retracts its strokes. 5 by 2 control valves fundamentally direct the retraction and propelling of the pneumatic cylinder. This controlling of solenoid valve is done via PLC.

The force that was exerted by double acting pneumatic cylinder on target can be mathematically expressed as:

$$f = pa \tag{1}$$

$$p = r\,\pi \tag{2}$$

$$f = r\pi \frac{d^2}{4} \tag{3}$$

where,

$f = force\ exerted\ (N)$

$r = guage\ pressure(\frac{N}{m^2}, Pa)$

$a = full\ bore\ area(m^2)$

$d = full\ bore\ piston\ diameter(m)$

The force exerted on in stroke can be expressed as:

$$f = p(d_3^2 - d_4^2)/4 \tag{4}$$

where,

$d_{3=} full\ bore\ piston\ diameter\ (m)$

$d_{4=} piston\ rod\ diameter\ (m)$

D. Detection of Objects through Sensors

Detection of an object through proximity sensor may rely on light, sound, vision or electromagnetic field. The first sensor placed in our system in order to sense the presence of the arriving object is Inductive Sensor. It is a non-contact sensor, performing the task of differentiation of metallic and non-metallic objects. The inductive effect aids in the recognition of metals. The arrival of the metallic article on the belt causes the dampening in the amplitude of the oscillator present in inductive sensor. The rise and fall in the amplitude of the oscillator cause change in the output of the sensor. Next, capacitive sensors are placed. The capacitive proximity sensors are able to identify metallic as well as non-metallic objects irrespective of their form. Whether the article is solid, liquid or powdered, these sensors would be able to perceive them. This sensor is usually used in industries [23]. This sensor varies the capacitance due to the nature of the object. The oscillator has the capability to modify the magnetic field induced because of the current sensor. The fluctuation in the oscillation frequency is noted by the threshold circuit. Lastly, photoelectric sensors are used. These versatile sensors are widely used in agriculture industry

[24]. The photoelectric sensor comprises of a transmitter side and a receiver side. Transmitter branch is mainly a light emitter source; it can be a LED or a laser diode, the light radiated can either be visible or infrared light. The receiver end is used to identify the emitted light; it can be a photodiode or a phototransistor. The received signal is further amplified. Our photo-electric sensors are not only used for identifying the plastic material but also distinguishing 3 different height objects. The highest package will be identified by all three sensors. The medium sized by two sensors and the smallest will be sensed by only one photoelectric sensor. Following table shows comparison among all three sensors.

Table 1 Proximity Sensor Comparison. [24]

Technology	**Sensing Range**	**Applications**	**Target Material**
Inductive Sensor	<4-40 mm	Close Range detection of ferrous material	Iron, steel, copper, Aluminum
Capacitive Sensor	<3-60 mm	Close range detection of non-ferrous material	Liquid, wood, granulates glass.
Photoelectric Sensor	<1 mm-8 cm	Long range, small and large target detection	Metal, Plastic, Rubber, Paper, Wood

Table 1 shows complete sensing ranges for each sensor. Using these ranges small, medium and large objects can be detected up to 4 to 6 inch, 6 to 8 inch and greater than 8 inches respectively.

III. PROPOSED METHODOLOGY

The proposed methodology shows complete architecture of our proposed work. Firstly, the conveyer belt is switch on then the testing object is identified through proximity sensor moreover, object is sorted in specific box through PLC which controls position of pneumatic cylinder and purpose of DC gear motor is to control speed of conveyer belt.

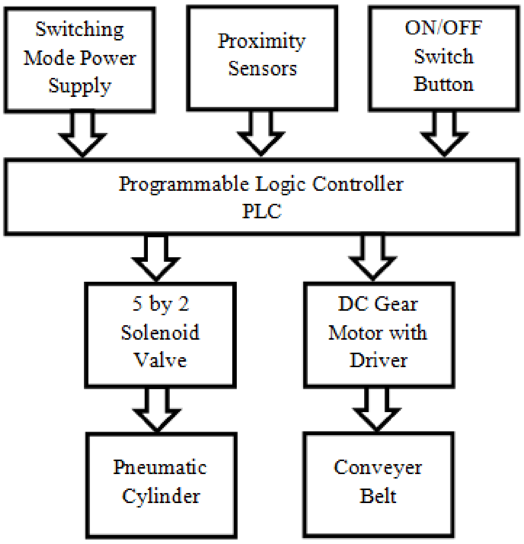

Fig. 2 Working phenomenon of the proposed system.

IV. IMPLEMENTATION

Our working mechanism comprises of objects passing through conveyer belt and their detection according to their size and material and sorted into assigned box through pneumatic system.

The methodology of proposed work is shown above, in figure 3:

- The system is powered ON and the items are fed on conveyer belt.
- Once an item arrives on the conveyer belt, proximity sensors i.e. inductive sensor, capacitive sensor and photo reflective sensors detect the article and differentiate among the construction material of the object (metal, wood and plastic).
- As the material is recognized, the object is then identified by photo reflective sensors placed on three different heights. The sensors' height facilitate in the recognition of small, medium or large sized object.
- If the object is small sized metal, it is pushed by solenoid valve 1(controlled by PLC) in to the concerned box. Similarly for medium sized metal valve 2 and for large sized metal valve 3 is functioned.

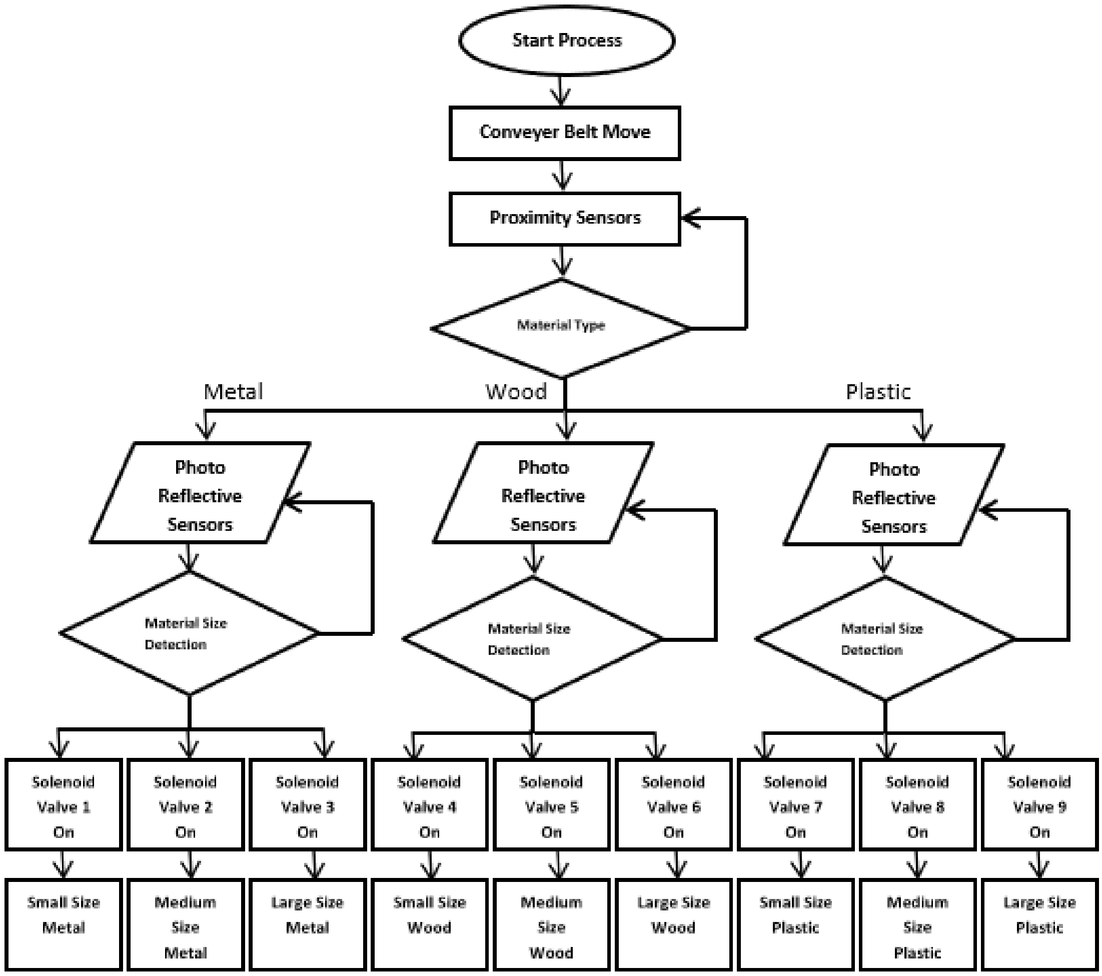

Fig. 3 Flow Chart of proposed system.

- If the article is small sized wood, it is pushed by solenoid valve 4 in to the related box. Likewise for medium sized wood valve 5 and for large sized wood valve 6 is operated.
- For the small sized plastic, solenoid valve 7 pushes it in to the regarded box. Also medium sized plastic is pushed by valve 8 and for large sized plastic valve 9 is functioned.

V. RESULTS AND DISCUSSIONS

Table 2 shows complete results of MMS by sorting through proximity sensors if,

- The material is detected by capacitive, inductive and one of the photo electric sensors placed at small height then it is small sized metal.
- The material is detected by capacitive, inductive and two photo electric sensors placed at small and medium height then it is medium sized metal.
- The material is detected by capacitive, inductive and all three photo electric sensor then it large sized metal.
- The material is detected by capacitive and one of the photo electric sensors placed at small height then it is small sized wood.
- The material is detected by capacitive and two photo electric sensors placed at small and medium height then it is medium sized wood.
- The material is detected by capacitive and all three photo electric sensors then it is large sized wood.
- The material is detected by only one photo electric sensors placed at small height then it is small sized plastic.
- The material is detected by two photo electric sensors placed at small and medium height then it is medium sized plastic.
- The material is detected all three photo electric sensors placed then it is large sized plastic.

Table 2 Experimental Summary.

S. No.	Capacitive Sensor I0.2	Inductive Sensor I0.3	Reflective Sensor 1 (Small Height) I0.4	Reflective Sensor 2 Medium Height) I0.5	Reflective Sensor 3 (Large Height) I0.6	PLC Output	Actuator	Material to be Sort
1	High	High	High	Low	Low	Q0.1	Actuator1	Small Metal
2	High	Low	High	Low	Low	Q0.2	Actuator2	Small Wood
3	Low	Low	High	Low	Low	Q0.3	Actuator3	Small Plastic
4	High	High	High	High	Low	Q0.4	Actuator4	Medium Metal
5	High	Low	High	High	Low	Q0.5	Actuator5	Medium Wood
6	Low	Low	High	High	Low	Q0.6	Actuator6	Medium Plastic
7	High	High	High	High	High	Q0.7	Actuator7	Large Metal
8	High	Low	High	High	High	Q1.0	Actuator8	Large Wood
9	Low	Low	High	High	High	Q1.1	Actuator9	Large Plastic

Finally, there are 9 double acting pneumatic powered 60psi air gas cylinder which is controlled by 5/2 valve through 24V PLC to push the sorted output in its specific compartment.

Figure 4 shows the results of 4 trials of material sorted. Each object was sorted correctly into the designated compartment however sorting time varies. It can be observed by following information

- 1.5, 2 and 2.5 sec for small plastic, small wood and small steel.
- 3, 3.5 and 4 sec for medium plastic, medium wood and medium steel.
- 4.5, 5 and 5.5 sec for large plastic, large wood and large steel objects respectively as shown in figure 4.

Figure 4 shows, as multiple objects are placed with a difference of 0.5 seconds, the system implemented shows that even if there is any delay in the sorting of one object it does not affect the identification of the second object. The experimental results portray that the system attained substantial performance compared to other published models. In [17] the objects were sorted i. 6-8 seconds which is much greater than the time interval of our proposed work (0.5 seconds). However, the proposed work only applicable for transparent plastic and not for colored plastic, and used individual sensor with less sensing range is assigned for each level of height.

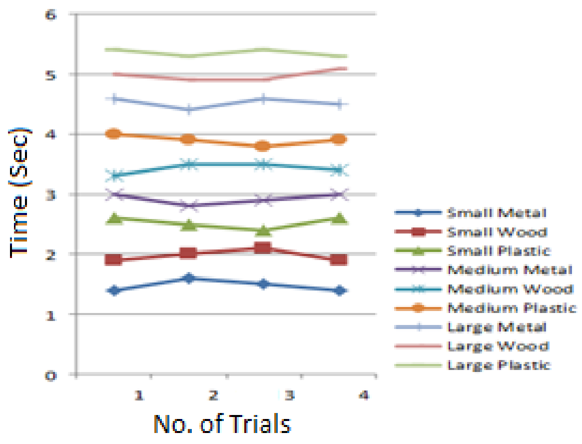

Fig.4 Graphical Representation of Sorting Trials.

VI. CONCLUSION AND FUTURE WORK

This work proposes an efficient MMS for multi sorting of three different objects (wood, plastic, metal) in three different sizes (small, medium and large) of material by using PLC and proximity sensors. The proposed algorithm shows 100% accuracy in identification of material with minimal time interval i.e. 0.5 seconds between testing objects. The proposed system can be implemented in brick manufacturing, luggage sorting, quality checking of solid objects and food processing industries.

The performance of proposed system can be enhanced by addressing or including more complex features like color, shape and texture of objects.

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