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Data Acquisition System for Software Interfaced Material Handling System

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ABSTRACT:The Global automated material handling equipment market is estimated to grow with 7.32% CAGR during the forecast period to generate revenue of $60.11 billion by 2027 due to increase in demand in industrial automation. Flexibility in automation and monitoring are key issues in industries. Many researches are working on flexible material handling mechanisms to improve system efficiency. The objective of the work was to develop a data acquisition system using the microprocessor raspberry pi on a micro-controller Arduino controlled, automated material handling system to improve efficiency.The project objectives were to automate a material handling prototype system for a miniature component with a horizontal linear actuator consisting of a rack and pinion mechanism, a conveyer belt mechanism, an inclined actuator consisting of a conveyer belt mechanism and a vertical linear actuator consisting of a lead screw mechanism which are powered using Direct current motors and controlled by the inputs received from the Infrared Proximity sensors of the position of the material being handled which are controlled by Arduino micro-controller programming and Data monitoring, validation and reporting of the system efficiency as feedback to the system by validating the time taken for material handling operation using raspberry pi and creating reports for failure diagnosis and process improvement which were reported on email.The results obtained from monitoring the material handling system, reported the errors of the material handling process which were in the range of 10-15% for low motor actuation speed of 10–25 rpm and 15–25% for high motor actuation speed of 50–100 rpm re-calibrated by programming the micro-controller thereby continuously improving from the constant feedback received from the Data Acquisition system.

KEYWORDS: Flexibility, Arduino, Micro controller, Data Monitoring.

I. INTRODUCTION

It is estimated that the global market for automated material handling systems will expand at 7.32 percent CAGR over the forecast period to produce income of $60.11 billion by 2027 due to several contributing variables including increased need for automated solutions across sectors and increased efforts for a safe working setting. The study's foundation year is 2018, and the prediction period is 2019-2027. Furthermore, several technological advances in the industry and the fact that the implementation of these equipment lowers labor costs further enhance this market's development. The key driver of growing development in the worldwide market for automated material handling machinery is the growing demand for automated alternatives across sectors. The market discovers its applications in several industries such as chemical, automotive, semiconductors and electronics, e-commerce, aerospace, food and beverage, metal and equipment, and healthcare, whereas market activities include packaging, assembly, transportation, storage and waste processing and distribution [1]. In Europe, North America, Asia-Pacific and the rest of the world, the region-wise segmentation of the worldwide automated material handling machinery market takes place. By capturing the biggest market share of 32.12 percent in 2018, the European market dominated the worldwide automated material handling machinery market. Key variables that have a positive impact on the development of the European market for automated materials handling machinery are R&D investments in robots, increasing automotive sector, increasing e-commerce sector and numerous public projects. However, with the greatest CAGR development over the forecast period, the Asia-Pacific market is anticipated to move forward. It is anticipated that government projects and increasing spending in the region will drive the development of this market. During the 2019-2027 forecast era, the Asia-Pacific automated material handling machinery market is anticipated to catapult forward with the greatest CAGR of 8.85%. In the current situation, the automated material handling equipment market is motivated mainly by improved acceptance and increasing spending on drone robotics technologies and business and consumer purchases. The main market trend influencers are the economies of China, India, Japan, South Korea, Australia and the nations that jointly form the rest of APAC. Countries such as India, China, and Japan contribute significantly to the Asia-Pacific economy. Government projects in India and China focus on improving the manufacturing and manufacturing industry through multiple programs and campaigns such as ' Make in China ' and ' Make in India ' to promote market development. Over the previous several years, the Indian two-wheeler sector has grown tremendously. In terms of revenues, it even exceeded the Chinese two-wheeler market. Several e-commerce organizations like Amazon and Flipkart have created substantial investments in market growth and development. Because of all these variables, the Asia-Pacific automated material handling machinery market's future perspective looks very promising [3].

II. LITERATURE REVIEW

The use of sophisticated automation technology in manufacturing systems has improved the flexibility of manufacturing; however, this generates important stress for operators who have to cope with more choices than before and has an adverse effect on their job satisfaction or well-being. Research on how cognitive automation and mechanical automation impact flexibility of manufacturing in the material handling scheme. Cognitive automation is characterized as a computerized system that offers operators with appropriate data and reduces cognitive deliverables; mechanical automation relates to an automated system that reduces physical deliverables [4].In latest years, producers have been confronted with an increasingly uncertain market environment due to changes in customer demands, global competition and technological development [5]. Flexibility in manufacturing was suggested as the most significant alternative to address the uncertainty. The capacity of producers or production systems to deal with the demands of clients while facing uncertainties is the flexibility of manufacturing. The system level flexibility involves process, product, routing, quantity, and extension; program, manufacturing, and market flexibility are included in the aggregate level flexibility. Due to this multi-dimensional aspect of flexibility, measuring flexibility in manufacturing is fuzzy and complicated, thus indirect measurements are often used to assess flexibility in production rather than direct measurements. Indirect measurements do not directly determine flexibility in manufacturing; instead, they assess some of the impacts affected by flexibility in manufacturing. The number of parts (or part families), the changeover time, the downtime and the number of tasks often provide an indirect perspective on the degree of manufacturing flexibility [6][7].Parts or subassembly components between workstations are transported by material handling systems. Flexible material handling is essential as a fundamental element of a flexible production system in order to achieve flexibility in production [8][9]. Operators ' function is essential in enhancing a material handling system's flexibility. Even with today's advanced manufacturing technologies, individuals have not been completely substituted by automation because individuals (1) add flexibility; (2) perceive patterns better; (3) improvise processes when congestion happens; (4) inductively prevent deadlock and bottlenecks; and (5) making decisions of important deliverables. A material handling system operator conducts cognitive duties (e.g. monitoring, control, planning, and decision-making) as well as physical tasks (e.g. loading / unloading materials, moving components, packaging, etc.). Inappropriate data would therefore result in the operator using inappropriate controls in the material handling scheme, leading to an adverse impact on the flexibility of manufacturing. Furthermore, the presentation of appropriate data in the material handling scheme would be an effective way to enhance the efficiency of the scheme by decreasing downtime and cycle time, leading in greater flexibility in the handling of materials. [10 - 18].A DC motor's PWM control is used to drive a conveyor belt. An H-bridge was used to supply the DC engine, which enables the wise inversion of the engine rotation. An ARDUINO UNO board, fitted with an Atmega 328 microcontroller, generates the PWM signal. A program was published in the LabVIEW 2013 programming setting for managing the ARDUINO UNO board. Unlike other conveyor belt driving systems, this system enables their operating tasks to be optimized through tests. A conveyor belt's working duty can be altered by changing the duty-cycle value of the PWM signals that control the H-bridge transistors that supply the DC motor. The DC motor's PWM control offers the performance set at the design point [19].

Automation is a cost-effective manner of manufacturing discrete parts or manufacturing process industries. Automation increases the effective use of resources by partly or totally replacing employees with equipment. In the manufacturing context, automation often relates to the mechanization and integration of environmental factors [20]. Automation still needs the existence of another sort of employee, i.e. operators, who normally undertake cognitive job, such as data processing, information interpretation, and decision-making, to replace the physical job of workers. Automation has been researched from the view of the cognitive elements of employees in this respect. The focus was on cognitive automation and flexibility in relation to the cognitive variables of the operators in the material handling scheme and the cognitive automation effectiveness of material handling in an automated warehouse scheme. For the operator of a material handling system, cognitive automation, e.g. technical support, which provides information such as what sub-assembly part and how much of the part should be sent to each workstation, reduces the cognitive workload of the operator and improves awareness of the situation. We describe cognitive automation as a digital or computerized scheme that offers operators with appropriate data to handle material efficiently and effectively. We thought that well-designed cognitive automation in the material handling scheme would minimize the operator's mental workload and improve productivity, contributing to better situational awareness. [21 - 33].

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III. EXPERIMENTAL WORK

a) Selection of material handling control components

Table 1 displays all the design specifications and assumptions used to position the sensors optimally to get accurate results. Also, based on these specifications and assumptions the motor control is also determined. For data monitoring, validation and reporting expected values are required, to obtain the expected values these specifications and assumptions are necessary.The Component of volume of 2cm3 and weight 10gm was also layered with white sheet or white paint to reflect as much infrared light incident on it from the Proximity Infrared sensor for consistent and prompt detection. Figure 1 displays the CAD model of the linear actuation system which comprises of a rack and pinion mechanism. The pinion of this mechanism is driven by the DC Motor and has pitch circle diameter of 32.5mm.

Table 1. Design Specifications and initial requirements for the Material Handling System

Maximum Values for Design Assumptions and Recommendations	
Component Volume	2 X 1 X 1 cm3
Conveyer Pulley/Roller Diameter	7cm
Length of the Rack	25cm
Diameter of the pinion	4.5cm
Profile of the Teeth	Spur
No. of Teeth in pinion	45
Length of the Lead Screw linear Traverse	25cm
Length of the Lead Screw	30cm
Pitch of the Lead Screw	1.25mm
Screw Material	Mild Steel
Lead Screw Diameter	8mm(M8)
Width of the Conveyer Belt	2cm
Component Traverse Length on the Conveyer Belt 1 & 2	15cm
Length of the Lead Screw Traverse	30cm
Conveyer Belt 1 Inclination Angle with horizontal axis	0
Conveyer Belt 2 Inclination Angle with horizontal axis	45 Degrees
Length of the Rack	30cm
Rack and Pinion linear Traverse Length	25cm
Total Volume of space required for the Material Handling System	60 X 40 X20 cm3

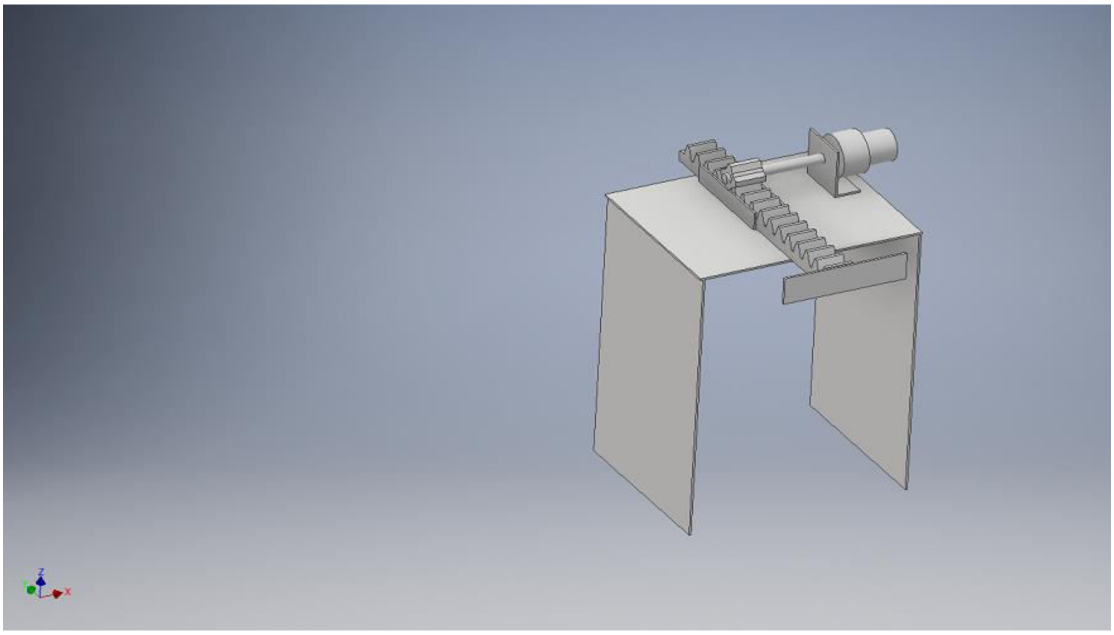

Figure1 Rack and Pinion mechanism used as Material Handling Actuation mechanism

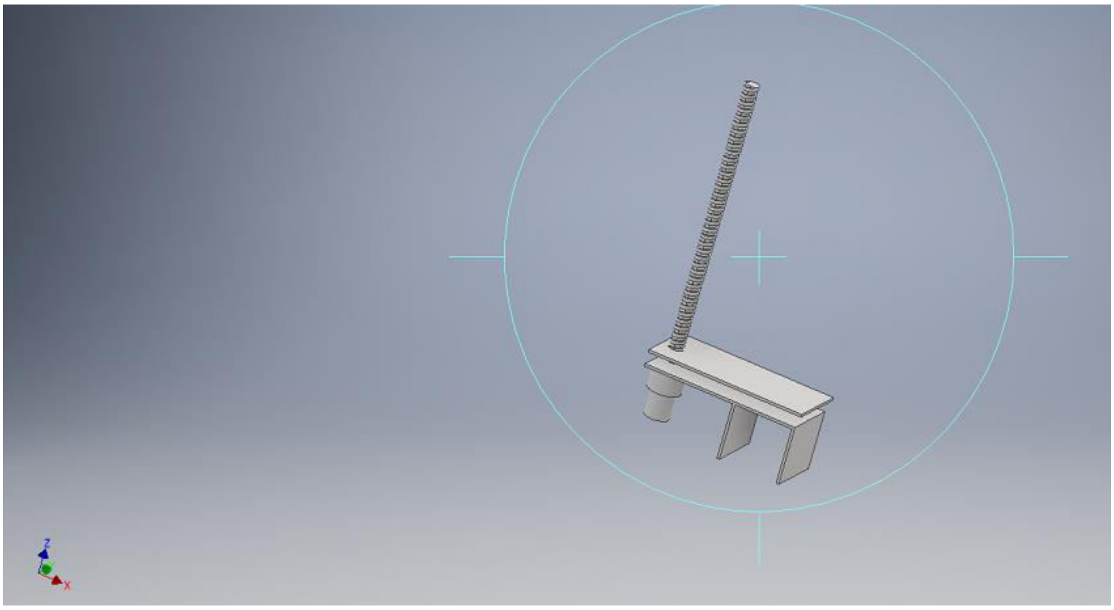

Figure 2 Lead Screw mechanism used as Material Handling Actuation mechanism

Figure 2 displays the CAD model of a vertical linear actuation mechanism using a lead screw of length 300mm which is fastened to the DC Motor at the base of the lead screw mechanism. The platform to lift the component is fastened to the nut and therefore traverses vertically along.

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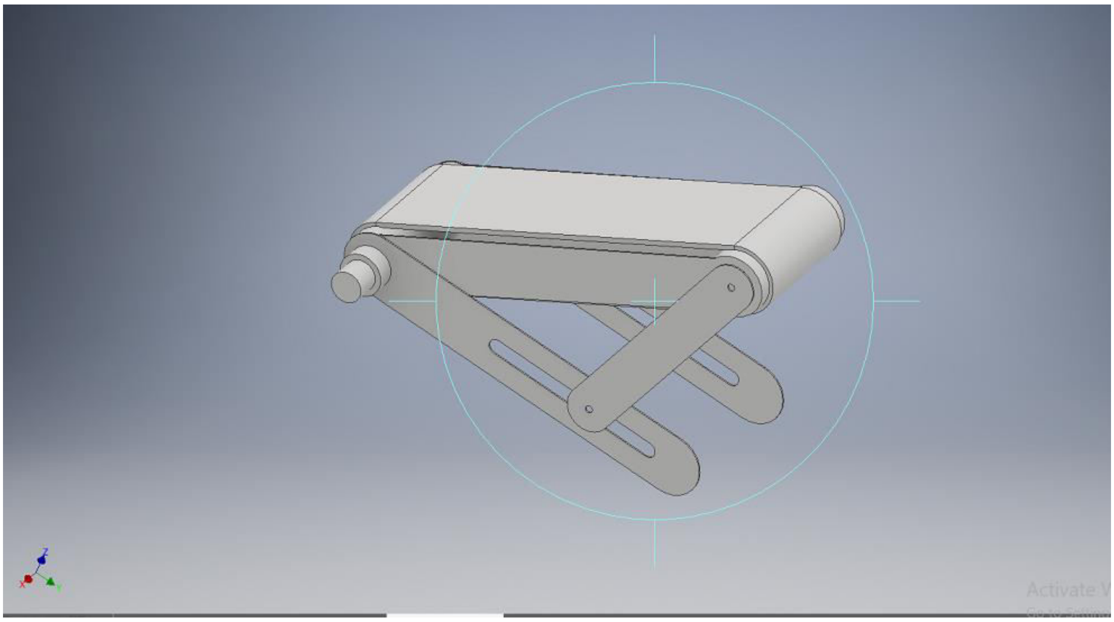

Figure 3 Inclined conveyer belt material handling mechanism

Figure 3 displays the CAD model of an inclined conveyer belt mechanism with the pulley diameter of 70mm and belt width of 20mm. The horizontal link is provided with a slot for the support link to be fastened and for the conveyer belt mechanism to be fastened to the frame of the material handling system. Figure 4 displays the assembled CAD model of the material handling system. The initial point for the material handling system is from the right side of the model from the horizontal conveyer belt mechanism and concludes at the end of the inclined conveyer belt mechanism.

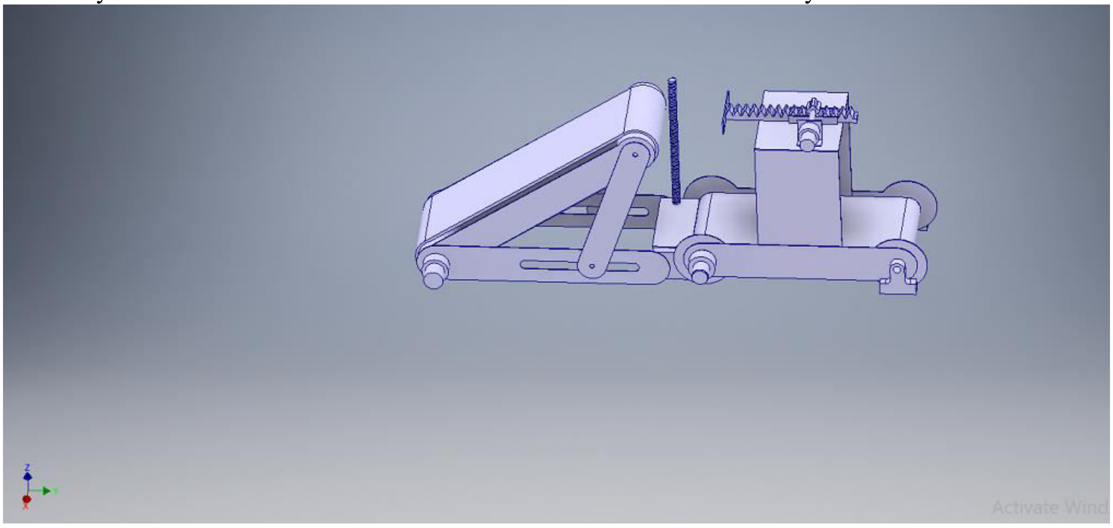

Figure 4CAD Model of the Material Handling System

b) Speed calculations of the material handling system:

Speed of conveyor Belt at Motor Speed 100 rpm
= 3.14(PI) x D (Drive Pulley OD) x RPM of Pulley
Suppose pulley Diameter- 0.3mtr
Pulley RPM- Motor RPM
Motor speed -100
Speed of conveyor belt- 3.14 x 0.07 x (100) =37.68 m/min
Speed of conveyor belt = 0.628 m/s
Time taken to traverse 0.15m = 0.15/0.628 = 0.24 s

Speed of the Lead screw at Motor speed 100 rpm = Pitch of the screw X Speed of Motor

= 1.25mm X 100 rpm
= 125 mm/min
= 2.08 mm/s
Time taken to traverse 0.25m or 250mm = 250/0.26 = 120 s

Circumference of the Pinion Pitch Diameter Circle = 3.14 * D; D is the pitch diameter
Linear distance traversed in a single rotation = 3.14 * Pitch Diameter
D = 32.5 mm
Linear distance traversed in a single rotation = 3.14 * 32.5 = 102.05mm
For, Motor speed = 100 rpm = 1.66 rps
Circumference of 1.66 times rotation = 1.66 X 102.05 = 169.4 mm
Therefore, the Rack traverses a linear distance of 16.94 cm per second

IV. RESULTS AND DISCUSSION

1) The Motor Shaft Diameter is 3mm and the pulley hole diameter is 3mm. Motor Clamp holders were to fix the motors in the horizontal alignment but for vertical alignment of the motors the frame has been used to support.The DC motor 2 as shown in Figure 5 is attached below the frame for controlling the vertical lead screw actuation

Figure 5Motor Conveyer Connection

The lifting plate for the component is welded to the nut of the lead screw, which when actuated lifts the component.

2) Sequence of events of the automated material handling system:
   1. As shown in Figure 6, the initial point of the material handling system is at point 1 labeled in the figure.
   2. Once the component is placed in the slotted belt and the AC source is provided to the material handling system, the conveyer belt controlled by DC Motor 1 as shown in Figure 7 rotation commences.
   3. The component reaches the other end of the conveyer to the plate of the lead screw. The Proximity sensor 1 senses the component as it reaches the other end of the conveyer belt.
   4. The Proximity sensor 1 initiates the actuation of the DC motor 2 controlling the lead screw and hence lifting the component.
   5. The component gets detected by the Proximity sensor 3 as it is lifted and initiates the actuation of DC motor 3 which controls the rack and pinion mechanism. The rack linearly actuates the component towards the conveyer belt being actuated by DC motor 4 as shown in Figure 7.
   6. The Proximity Sensor 4 detects the component and initiates the actuation of DC motor 4 which controls the inclined conveyer belt.
   7. The Proximity sensor 4 also initiates the reverse rotation of the Lead screw mechanism and the Rack and Pinion mechanism to get them to their initial position to be prepared for the next component.

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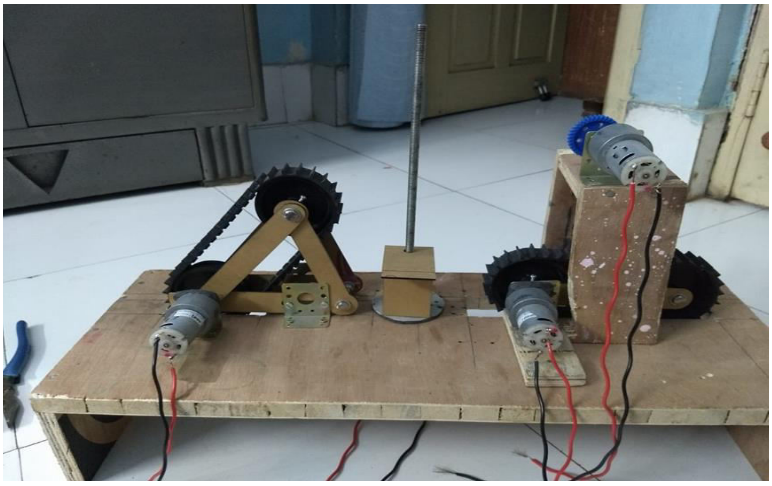

Figure 6 All Motor Connections

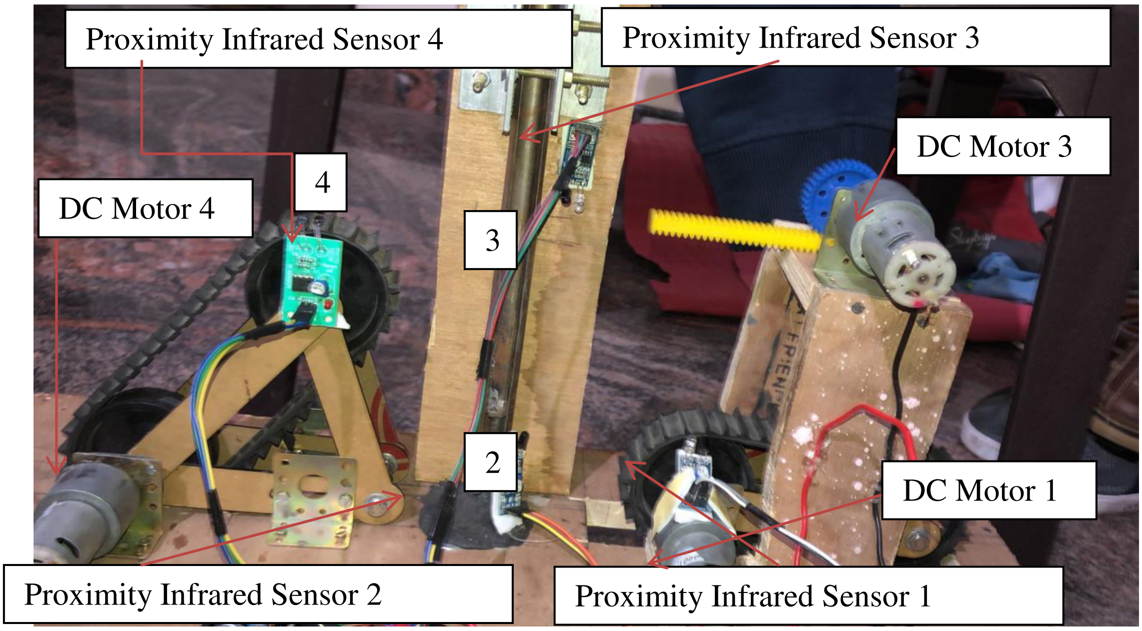

Figure 7 Motor Conveyer Connection with Proximity Sensor Connections

3) Data Monitoring and Reporting results obtained

As shown in Figure 8, the elapsed time reading for the Material Handling system at Motor Speed of 100 rpm with the conveyer belt speed of 0.628 m/s, lead screw traverse speed of 2.08 mm/s and rack and pinion linear actuation speed of 16.94 cm/s, has large divergence with the expected value, either due to the motor voltage control not being accurate and frictional losses, but there has been negligible divergence from the expected values in the conveyer belt traverse time and rack and pinion actuation time due to high speeds and short actuation distance.

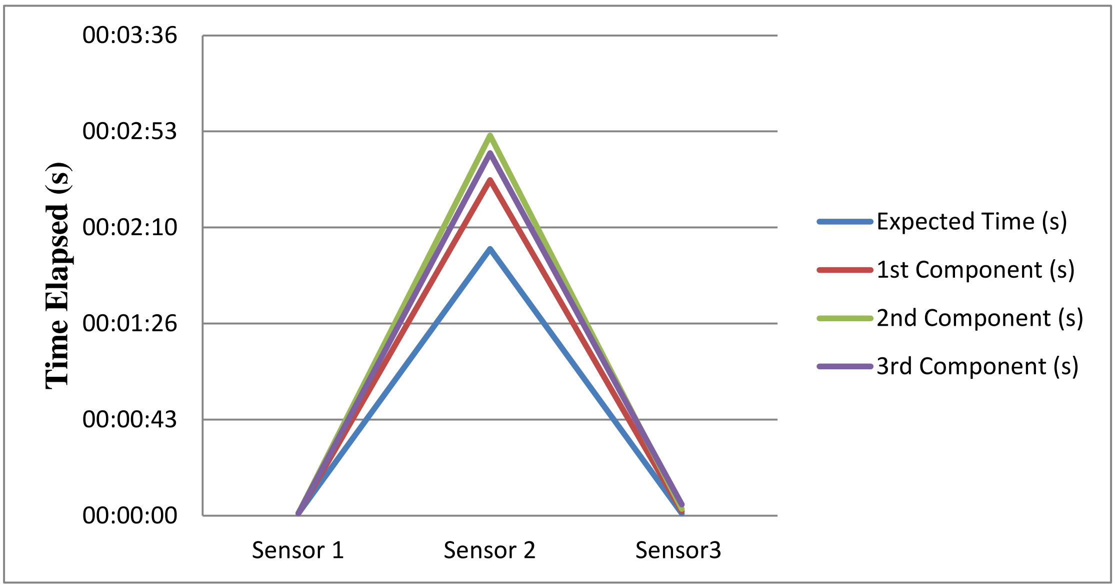

Figure 8Elapsed Time for material handling for motor speed of 100rpm

As shown in Figure 9, the elapsed time reading for the Material Handling system at Motor Speed of 50 rpm with the conveyer belt speed of 0.314 m/s, lead screw traverse speed of 1.04 mm/s and rack and pinion linear actuation speed of 8.47 cm/s, has lesser divergence with the expected value, either due to the motor voltage control not being accurate and frictional losses, but there has been negligible divergence from the expected values in the conveyer belt traverse time and rack and pinion actuation time due to high speeds and short actuation distance.

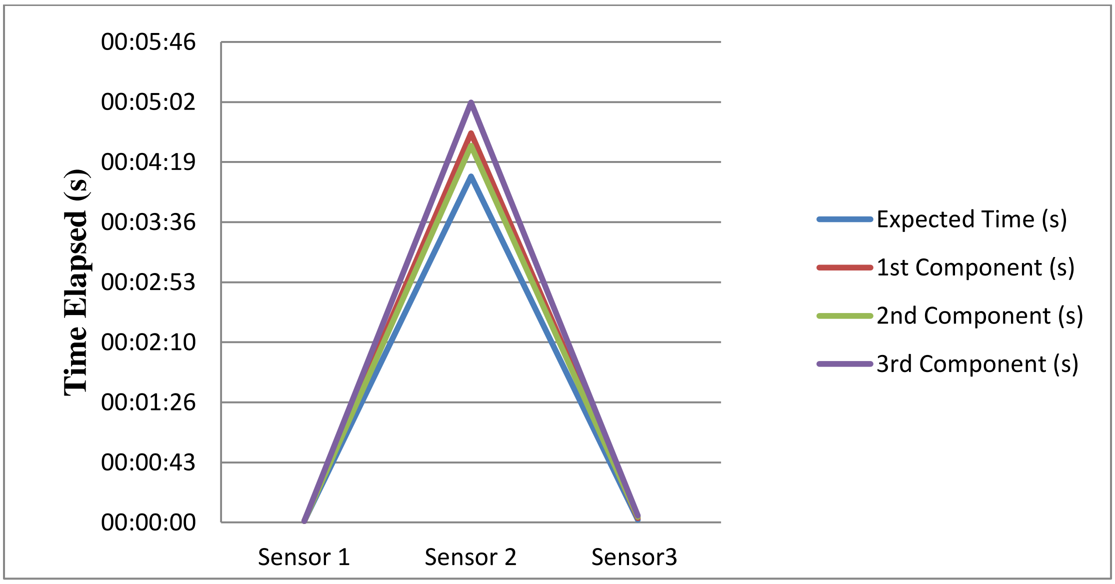

Figure 9Elapsed Time for material handling for motor speed of 50rpm

As shown in Figure 10, the elapsed time reading for the Material Handling system at Motor Speed of 25 rpm with the conveyer belt speed of 0.157 m/s, lead screw traverse speed of 0.52 mm/s and rack and pinion linear actuation speed of 4.25 cm/s, has large divergence with the expected value, either due to the motor voltage control not being accurate and frictional losses, but there has been negligible divergence from the expected values in the conveyer belt traverse time and rack and pinion actuation time due to high speeds and short actuation distance.

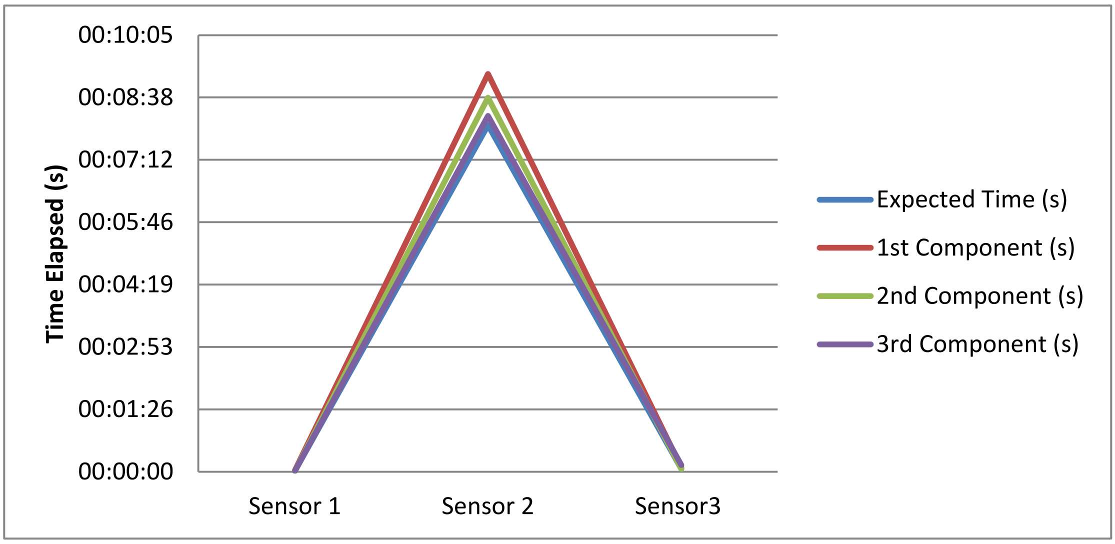

Figure 10Elapsed Time for material handling for motor speed of 25rpm

As shown in Figure 5.7 and Table 5.4, the elapsed time reading for the Material Handling system at Motor Speed of 10 rpm with the conveyer belt speed of 0.0628 m/s, lead screw traverse speed of 0.21 mm/s and rack and pinion linear actuation speed of 1.7 cm/s, has least divergence with the expected value, either due to the motor voltage control being accurate and least frictional losses, but there has been negligible divergence from the expected values in the conveyer belt traverse time and rack and pinion actuation time due to high speeds and short actuation distance.

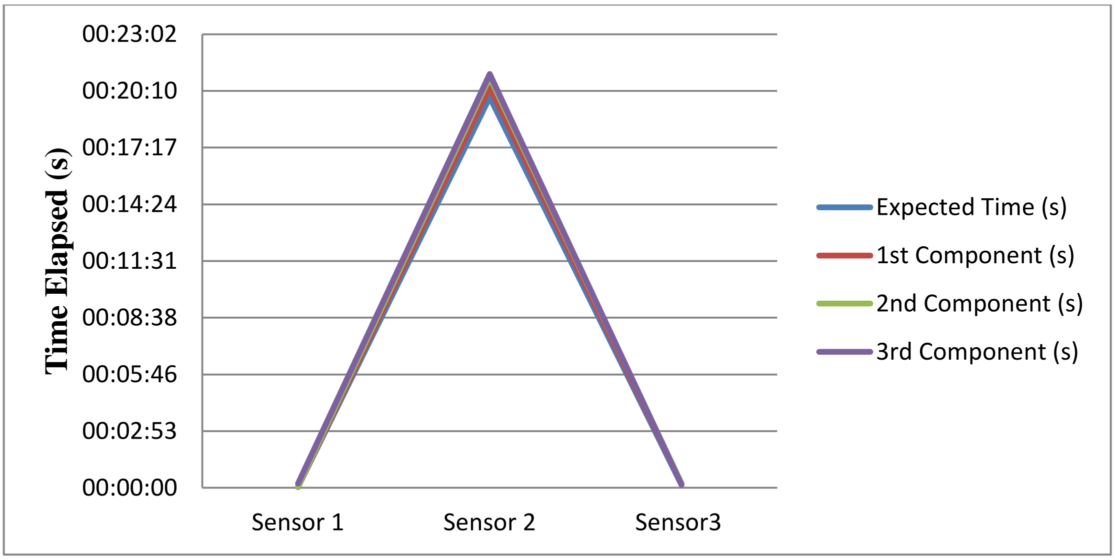

Figure 11Elapsed Time for material handling for motor speed of 10rpm

V. CONCLUSION

- A material handling prototype system for components of maximum volume of 2cm3 and maximum weight of 10g with universal actuating mechanisms was automated and controlled by micro controller Arduino to enhance flexibility in the material handling system to be as customizable as possible, this system has wide application in the electronic and semi-conductor industry due to its flexibility and automation. The effectiveness of automating the material handling system in allowing the system to be flexible is inherent as the parameters which vary based on customization requirement can be easily varied in the Arduino program.

- Monitoring and reporting of the elapsed time using microprocessor raspberry pi and the infrared sensor for each material handling mechanism helped us make the system more adaptive to changing requirements with ease and low cost and also make the system capable to diagnosis faults or maintenance of the material handling system.

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