Automatic Pick-and-Place Packaging System with Vacuum Lifter

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Abstract. Flexible packaging manufacturing is one of the most essential industry of the world nowadays. This research aims to develop an economical & ergonomically designed pick-and-place sorting system for bag-making machines in the packaging industry. It provides a standard universal setup that is feasible to adapt with any type of bag-making machine as a pick-and-place attachment. This automated system can be installed at pickup location of the bag-making machine for the operation of pick-and-place of packaging bags, which is able to distribute packaging bags into the accepted bags platform without the supervision of a physical operator. This pick-and-place sorting system is able differentiate between two coloured bags while accepting the correct dimension of it to place it at a location of ‘accepted bag’ else at a location of ‘rejected bag’. The proposed machine system can sort-out three different dimensions of test samples by accepting bags with a fiducial mark and correct dimension only, while rejecting the bags without fiducial mark and of incorrect dimensions. A standalone mechanical structure based on stepper motors, electronics design and embedded control system was developed that includes an IR-proximity sensor, as a fiducial mark/colour detector and a loadcell based dimension analyser, to differentiate between different dimensions of the test samples.

1. Introduction
In every industry pick and place applications are commonly used for different type of products. Usually this pick and place process is mostly done by packaging operator at small industries therefore due to operator errors most of the times those products are being packed into the boxes for delivery which are faulty and do not match to the standards of the desired client or the required designs. This research document focuses on the development of an ergonomically designed application of a pick-and-place system for flexible packaging plastic film bags that is able to save time and wastage of material during bag making process, by the setup of bags dimension and other parameters into the control system of the machine. The miss-alignments errors are folded bags, wrongly or irregular bags packed by the operator without being noticed for delivery. An invention of a system, that is able to pack bags automatically while reducing these errors is needed. Automatic Pick & Place Packaging System with Vacuum Lifter is able to pick and place the plastic bags; at a same time rejects or separates these bags in accordance with their difference of colours and correct dimension (i.e. the bag length and width comparison is focused in this research paper only).
The vacuum suction end-effector(lifter) picks the plastic bag and move towards the location for placing the bag by following two degree of freedom (DOF) in a linear motion i.e. left and right & forward and backward (X-axis and Y-axis Motion). The vacuum suction pickup action is at the Z-Direction (axis), which is additional ½ degree of freedom to the system. The control system algorithm is able to categorize the bags by differentiating the two colours of bags and correct dimensions at pickup location and place the correct colour of bag with selected dimension to the area of accepted bags whereas it is also able to place various colored bags or of wrong dimensioned bags to the area of rejected bags.

The flexible packaging film reel which is placed in the bag making machine has already passed through the printing process and it is testified by printing machine automatically in contrast to its colour depth and quality. But still there are chances of errors in the bag design pattern and alignments most probably during the bag making process of the running machine. In the bag making machine (see Figure 1) process, the bags might be folded wrongly or irregularly and manually packed by the operator without noticing errors. Therefore, a novel application is needed to beneficial the company by incorporating this machine invention with the current setup of bag making machine. It adds-up a further investigation stage to minimize the errors for customer satisfaction with the improvement in serviced quality of the manufactured material and process sustainability by reducing the raw material wastage. These bags are of plastic poly-ethane/PVC material produced for the following products such as packaging material for tea, cooking oil, ice creams, biscuits, toffees, noodles etc.

In past few decades, not much research has been noticed in similar application of bag making machine industry, but the most relevant related application used for pick-and-place machines are highlighted in this paper.

However, in every industry a pick and place applications are commonly used for different type of products. In recent years many researchers have studied the pick-and-place mechanisms for different applications such as RFID tags and smart card pick-and-place operations, in which the main task is to run the system at high speed while the pick-and-place die keeps on fabricating the RFID tags and smart card. In it the main factors controlled during the process of picking includes tape adhesion, wafer back side condition, machine hardware and programming [2].

Whereby another research on vacuum suction cup units for pick and place of aircraft flexible assembly design suggests a sufficient idea for vacuum suction pick-and-place module that can be achieved by introducing high flexibility to the end-effector (gripper), which can be obtained by three parallel used principles i.e. human and computer based analysis of the gripping object as well as mechanical adaptation of the gripper to the object with the help of servomotors and vacuum suction cups. It can be designed according to required specification, for example introducing three gripping vacuum suctions at the end-effector of the gripper [3]

The latest technology used to pick-up small items is used in Surface Mount Technology (SMT), it is a technology commonly used in electronic assembly. It is a method where components are mounted
directly onto the surface of printed circuit board [4]. SMT uses visual location technology in its pick-and-place process, which offers a high speed and precision of component placement. Vision-Pro based system have been developed for SMT machine techniques; one of it is to solve the accurate image location by pattern-based location algorithms and the other is the calibration of camera, which is achieved by image wrapping technology through the checkerboard plate method [5], [6].

However, food is high-growth industry all over the globe. International food trading is demanding more raw materials every day. The current market demands more shelf life, improved quality, environmentally friendly materials and innovative packaging technology. The world’s packaging machinery demands is increasing 5% per year. Many companies are adapting agile manufacturing practices. Agile manufacturing refers to the capability to quickly go from a set of novel customer requirements to a quality, finished product therefore to meet the market demand of packaging, companies are trying to work fast to increase their efficiency with their consumers to deliver the packaging material with in the time limit [7]. The main aims of this project are to develop an economical, fast, accurate and automated pick-and-place system, and to reduce the raw material wastage induced by manual workers during bag making machine process.

The main objectives achieved in this project are to, (i) differentiate between two colours of bags using pick-and-place system, (ii) distinguish the correct dimension of the bags, and (iii) pick-and-place the bag at defined positions.

2. Highlights on the technology for the development of pick-and-place equipment
The most difficult part in pick-and-place packaging of bags is the overlapping of the bags to other bags while pick-and-place process. The pick-and-place of plastic packaging bag system can be designed in a way that each plastic bag is picked and placed at one time only; meaning one bag per lift. The mechanism of such machine may possess a sensing technology that is able to recognize the presence of the plastic bag underneath the pickup lifter and sends the signals to the control system which is programmed to send signals further to various components of the packaging system. This system may also consists of number of servomotors, which are used for transmit signals at precise movement at a specific time to control the variables such as package placement and displacement points [8].

In order to detect the image underneath the pickup lifter image processing is a good option to be used at this stage to differentiate the colour difference between two packages and the correct size detection. A CCD camera with 32-bit microcontroller operated by computer software can be installed at a point of Image processing unit, which is low cost and suitable for small research [9]. An image processing method “Hue Histogram Algorithm” can be used in this invention to detect the plastic bag placed under pickup lifter which will determine the number of objects in a column by identifying the location of object by the difference in its length and width i.e. the plastic bag placed under it is on the right path to be picked up or not and the main aim of this technique is to calculate the time which is suitable for the pickup lifter to determine the distance between the object (plastic bag) and the pickup lifter [10]. But the restrictions in this method is that the target light interference with object colour i.e. the position of each object in the column cannot be identified correctly [9].

The limitations of detecting an image with a camera are always influenced by environmental illumination changes. It can be modified by using HSV (Hue, Saturation and Value), which is somehow similar to “Hue Histogram Algorithm” method. However due to illuminations effects on camera, the image processing unit cannot adapt sudden changes frequently. The illumination changes can be minimized by RGB colour space method which is very weak to adapt illumination and brightness changes of an image. The advantage of using HSV is that the illumination changes the value of the detected image only, whereas this value change does not affect the HS-Histogram colour of the image [11]. A MATLAB M-file script can be written to process the image automatically to be used as an image processing computer interference software to detect the size of the image by ruler and colour techniques [12].

Pneumatic system of actuator can be used at lift arm to create a push force at the vacuum suction end-effector. A novel pneumatic control system can be implemented as multiplex pneumatic control system which consists of an oscillator, a resonant valve and air tube; where the oscillator causes the air
vibrations in air supply tube which is connected with the resonant valves. Therefore, the resonant valves are selectively controlled by air vibrations from the oscillator [13]. Limitations in pneumatic system are in compressor and many electrical wires forming the control valves, would complicates the entire pneumatic control system and the leaking of the valves.

A high-speed pick and place of the plastic film can be achieved by providing high adhesion strength and extremely low peel strength at the end-effector of the pick-and-place arm. For this reason, the plastic film roughness verses smoothness conditions can be measured to understand the critical properties required by the pick-and-place process [2]. The pick-and-place mechanism can be controlled by the number of servomotors which requires a perfect intelligent servomechanism of precise point-to-point positioning system. The idea suggested by [14] is that it can be used in pick-and-place control process by Flip-Chip technology and Iterative learning control (ILC) system, which can be used to enhance the point-to-point positioning accuracy of the control circuit.

Surface Mount Technology (SMT) pick & place machine designed by Autoronik (a German company) is a kind of machine that performs the pick-and-placing of electronic ICs on the electronic chip board. Mechanically machine is designed in such a way to provide high speed, repeatability and stability of the pick and place process which is achieved by using preloaded ball screws with AC-Servo motors. Such kind of mechanical system can be used in the development of any pick-an-place invention. The Autoronik pick-and-place machine uses Cognex Alignment Vision-Pro system to run its image processing capabilities which are synchronized with its control mechanism of pick-and-place. The machine also uses a bottom vision system to assure high-precision placement of pickup components. The machine also possesses flip-chip technology for point-to-point placement of the components over the electronic chip [15].

Another SMT pick-and-place machine by Manncorp, an America company, uses preloaded ball screws system to move the pick-up lifter at an accurate point with the use of closed-loop servo control system to achieve high performance of the machine but this machine has a dual gantry four heads which performs a pick-and-place task in two directions such as if one head is placing a component another will be picking up a component from other side, and the cycle continues hence increasing the reliability and speed of the machine. Perhaps all kind of SMT machines nowadays are using Cognex Alignment system “Vision on Fly” to achieve the image processing process with a bottom reference camera or vision system to achieve much easier and reliable fast performance tasks by the machine [16].

3. Concept Development and Evaluation

3.1. Concept of Process & System

The development of the mechanism for this invention is inspired by the SMTmax QM-2100 PCB pick & place machine which is operated by Cognex Visual-Pro Image processing software [17]. This invention system must identify the difference of two coloured bags and their dimensions during pick-and-place process while placing the correct bag into correct area.

The context diagram of pick-and-place processing system is given in Figure 2, in which the proposed setup for system idea is illustrated. In the process flow, the plastic bag dimensions, and colour is detected by the system meanwhile sending signals to the control system to adjust the lifter arm position before its pickup. The control system differentiates between two colours and the selected size of plastic bag by sensors, it further sends the signals to the actuator of the vacuum sucker at pickup arm to perform pickup function of the machine. After the bag is picked-up, the motion-control system is initiated, the decision processing system differentiates between the differences in colours and dimensions of the lifted bag and decides the placements position.
3.2. Design and System Development

The working area of Automatic Pick & Place Packaging System with Vacuum Lifter machine is set to be of approximately 45 cm x 45 cm, it is selected due to the small size of plastic bags which would be of about maximum 10 cm x 10 cm (length x width). Due to the testing of machine at its initial stage, the machine speed for pick-and-place is predicted to be set at five bags per minute.

Two belt driven stepper motor linear guides at perpendicular to each other are attached in order to achieve the two-way linear motion at X-direction and at Y-direction. And the Z-direction pickup task is controlled by a small DC motor. All the motion together would provide degree of freedoms to the vacuum actuator end-effector. An IR sensor mounted with a load cell to an external-baseplate is be used for Fiducial-mark recognition on the test sample of plastic film and its dimensions, respectively. The load cell is used to inspect the size of the bag during its pickup period. The placement flow chart with IR sensor and load cell for the concept of location training process can be given as in Figure 3.

![Figure 2. Process of Pick & Place System.](image_url)

![Figure 3. The Flow Chart of the Machine System with Location.](image_url)
4. Methodology

4.1. Design and System Development

In the X and Y axis motion, the stepper-motor control system is selected due to its accuracy and precision of perfection in motion and they are inexpensive as compared to servomotors. The Microchip PIC16F877A is used to program the selected objectives of the project due to its best feature in the industrial research and development and inspection in the field of Automation.

To get a successful pickup by vacuum suction more studies and research are required to develop the model of pick-and-place end-effector to have an exact pressure of vacuum and the pressing power of pickup-actuator when the plastic bag is lifted. If the pressing power of vacuum lifter is exceeded, it might cause the lifter to brake or damage the material of the bag.

Fiducial Marks are coloured blocks presented at the edge of printed plastic film and by the use of optic, ultrasonic, colour and piezoelectric sensors the bag making machine detects for cutting edge or for punching. These coloured marks on each bag are sampled to help the film in the printed frame to be aligned and to detect the size or position of each bag on a printed film during running machine process. As far as there are no cameras attached into the bag making machine to understand the complete image whiles there are several sensors used in the machine during the bag making process to keep the running film aligned.

For example, an IR sensor attached to the machine at a set value to turn ON the next motor when plastic bag bypass across its wave-light, the changes in its voltage generates a signal to turn-on the next motor. But this phenomenon of mechanism is not suitable for this invention because a colour sensor itself cost about US$300 or above. And fast speed camera technology is even much more expensive then these sensors.

Therefore, after careful analysis, a simple IR-proximity sensor (of range 2cm) is used in the development process of this invention to detect the difference between the two colours of plastic film bags.

To achieve the dimension analysis of the plastic bag film, a sample is weighted by the use of load cell to achieve the different voltage output ratings of each sample weight and the changes in the range of micro voltages is programmed into the memory of microprocessor, that is, each sample voltage reading represents the specific Length and Width of the sample, for example a 6 cm x 6 cm sample gives a voltage difference of 0.03mV (as shown in Figure 4). This value range is fed into the microprocessor control algorithm to understand that each time this film is placed over the load cell.

![Figure 4](image_url)  
**Figure 4.** a) Load Cell Voltage output without Sample, b) Load Cell Voltage output with Sample.

4.2. Working Process

To meet the objectives of this project test samples used are of two colours. To specify the difference in two types of sample bags, a transparent plastic film sample is used. Each sample is introduced with a Fiducial Mark on its corner (see Figure 5). Therefore, the system will accept the bags of correct dimension and a bag with a Fiducial-mark only to consider it as an Accepted Bag. In case if the fiducial mark is missing and the sample bag is transparent, the system understands it as rejected bag operation.
There are three samples used in our test. The dimensions used are of (length x width) cm = (6 x 6) cm, (8 x 8) cm & (10 x 10) cm. These three different dimensions are made as ‘Mode Selection’ input parameter of the embedded system design.

Figure 5. Test Samples of Transparent Plastic Films of various dimensions with Fiducial-Mark.

4.3. System Block Diagram
The system block diagram is illustrated in Figure 6, showing the hardware architecture. On the block diagram, the inputs to the microcontroller are named by the hardware function of the input. It clearly describes how each type of measurement is taken and what kind of the microcontroller is required. It is noticed from the drive unit block diagram that there are total 26 input/output ports (I/O) connections to the microcontroller, and due to many input/output connections PIC16F877A is selected to be used in this project [18]. The others most obvious points are the A/D converters, two PWMs, LCD Interference, enough discrete I/O for switches and other digital signal requirements, the embedded
system references for hardware development can be found in [19], [20], [10]. And The system flow chart is given in the Figure 7.
5. Simulation and Data Analysis

5.1. Experimental Setup
In this section the experimental setup is shown in both firmware and hardware forms of prototype to demonstrate the working of the project.

5.1.1. Dimension Analysis Monitoring System with the use of a Load Cell. The load cell used in this project is taken out from a precision weighing scale of resolution 0.01 grams and can measure up to maximum of 200 grams. INA125 IC [21] is used as operational amplifier for loadcell system, as the output voltage change of a precision (milligram) load cell is in micro (µ) volts therefore a voltage amplification bridge connection is used to increase the gain of the change in voltage from µ volts to millivolts. Load cell used in this project have a cable with four wires; having +/- excitation and +/- signal lines. The basic wire construction of a load cell is given in Figure 8.

![Figure 8. Four Wire Load Cell Compensated Diagram [22], [23]](image)

The hardware design of load cell to measuring output voltage range, block diagram is shown in Figure 9, where it states that on what stage the A/D conversion is required while programming the complete setup process.

![Figure 9. Block diagram of PIC16F877A-based weight monitoring system](image)
5.1.2. Colour Difference Monitoring System with the use of IR-Proximity Sensor. The task of proximity sensor in this project is to differentiate between an opaque material and a transparent material (i.e. plastic bag film). The output quantity of this sensor is analog voltage, and the output voltage range in its setup is measured as voltage change which is set in range from 0v to 5v for microchip input pin. In general, the direct output voltage of this sensor is 3v. To trigger digital input signal of microcontroller LM324 operational amplifier is used. The amplification is set to achieve maximum output of 4 volts from 3 volts output of the proximity sensor. However, the gain Av, of 1.33 is set by using the non-inverting amplifier configuration.

5.2. System Hardware Circuit
The complete system circuit schematic of drive unit & display units is given in Figure 10, and the hardware setup in shown in Figure 11.

![Complete System Circuit Schematic](image)

**Figure 10.** Complete System Circuit Schematic.

![Complete System Mechanical Design Setup](image)

**Figure 11.** Complete System Mechanical Design Setup.
5.3. Data Collection

The main code of implementation of this project involves the analogue-to-digital conversion of load cell voltage to a readable voltage in microcontroller by ADC to set the values of desired selected dimension or size of the plastic film samples. Table 1 shows the dimensions of selected test samples and their weights in grams and change in voltage by load cell, tested by a voltmeter.

| No. Samples | Sample Dimension \([w \times l]\) (cm) | Weight in grams (g) | Voltage Output Volts (V) |
|-------------|----------------------------------|---------------------|------------------------|
| 0           | -                                | 0.00                | 1.56                   |
| 1           | 6 x 6                            | 1.65                | 1.61                   |
| 2           | 8 x 8                            | 3.31                | 1.66                   |
| 3           | 10 x 10                          | 4.97                | 1.71                   |

While testing the sample, are placed on the load cell test pan, before the mode selection button. The pickup arm is at home position that is above the loading pan. Once the mode selection button is pressed, for example, mode M-1 is selected to test sample of dimension (6 x 6) cm, and the bag is supposed to be accepted so that the pickup arm drops the accepted bag at location of accepted material or else if the bag is rejected it drops it at a location of rejected material, as shown in Figure 12.

![Figure 12. Test Samples Experimental Placement Position of Locations.](image)

5.4. Data Analysis

Referring to the chart in Figure 13, output voltage versus distance of proximity sensor graph is achieved by keeping a refractive object across it. But if a transparent material is kept at 0 - 1 cm across the sensor, its output voltage does not change. And if an opaque object is kept at 0 - 1 cm, the voltage drops from 1.45v to 0.11v - 0.13v at 0cm to 5cm.

![Figure 13. Proximity Sensor Voltage vs. Distance Characteristic.](image)
5.5. Test Results
The main facts of the experiments are reported in Table 2 & 3. A total of three samples were tested for dimension analysis and colour difference to inspect all the modes of the system for pick-and-place process. The tick marks show the successful results achieved in testing. Nearly 87.5% correct samples were analyzed by the system. The average cycle time of the machine was much closer to the expected (i.e. the speed of machine during pick-and-place cycle).

### Table 2. Summary of Test Results of Accepted Bags.

| (l x w) cm | T_{a1} | T_{a2} | T_{a3} | T_{a4} | t_1 | t_2 | t_3 | t_4 | T_{a,avg} |
|------------|--------|--------|--------|--------|-----|-----|-----|-----|----------|
| 6 x6       | ✓      | ✓      | ✓      | ✓      | 17.0| 16.4| 15.0| 16.1| 16.1     |
| 8 x 8      | ✓      | ✓      | ✓      | ✓      | 16.1| 16.1| 16.3| 16.2| 16.2     |
| 10 x 10    | ✓      | ✓      | ✓      | ✓      | 16.3| 16.8| 16.1| 16.4| 16.4     |
| Total Average time of Machine to Pick-and-Place | 16.2 |

| (l x w) cm | T_{a,h1} | T_{a,h2} | T_{a,h3} | T_{a,h4} | t_1 | t_2 | t_3 | t_4 | T_{a,h,avg} |
|------------|----------|----------|----------|----------|-----|-----|-----|-----|-------------|
| 6 x6       | ✓        | ✓        | ✓        | ✓        | 11.8| 11.4| 11.9| 11.9| 11.8       |
| 8 x 8      | ✓        | ✓        | ✓        | ✓        | 11.0| 12.3| 12.1| 12.4| 12.0       |
| 10 x 10    | ✓        | ✓        | ✓        | ✓        | 12.1| 12.4| 12.0| 12.2| 12.2       |
| Total Average time of Machine to Return Back to Home Position | 12.0 |

### Table 3. Summary of Test Results of Rejected Bags.

| (l x w) cm | T_{r1} | T_{r2} | T_{r3} | T_{r4} | t_1 | t_2 | t_3 | t_4 | T_{r,avg} |
|------------|--------|--------|--------|--------|-----|-----|-----|-----|-----------|
| 6 x6       | ✓      | ✓      | ✓      | ✓      | 16.6| 16.4| 16.0| 16.1| 16.3     |
| 8 x 8      | ✓      | ✓      | ✓      | ✓      | 16.2| 16.1| 16.3| 16.2| 16.2     |
| 10 x 10    | ✓      | ✓      | ✓      | ✓      | 16.4| 16.6| 16.2| 16.4| 16.4     |
| Total Average time of Machine to Pick-and-Place | 16.3 |

| (l x w) cm | T_{r,h1} | T_{r,h2} | T_{r,h3} | T_{r,h4} | t_1 | t_2 | t_3 | t_4 | T_{r,h,avg} |
|------------|----------|----------|----------|----------|-----|-----|-----|-----|-------------|
| 6 x6       | ✓        | ✓        | ✓        | ✓        | 12.1| 12.4| 11.9| 12.4| 12.2     |
| 8 x 8      | ✓        | ✓        | ✓        | ✓        | 12.1| 12.3| 12.1| 12.4| 12.2     |
| 10 x 10    | ✓        | ✓        | ✓        | ✓        | 12.0| 12.0| 12.0| 12.1| 12.0     |
| Total Average time of Machine to Return Back to Home Position | 12.1 |
From Table 2 and Table 3:
The average time taken by machine to perform a random pick-and-place, \( T_{\text{avg}} \) is:
\[
T_{\text{avg}} = \frac{T_{a,\text{avg}} + T_{r,\text{avg}}}{2}
\]
(1)
\[
T_{\text{avg}} = 16.25\text{s} \approx 16.3\text{s}
\]
The average time taken by machine to return to its Home Position after successful pick-and-place process, \( T_{\text{Home,avg}} \) is:
\[
T_{\text{Home,avg}} = \frac{T_{a,\text{h,avg}} + T_{r,\text{h,avg}}}{2}
\]
(2)
\[
T_{\text{Home,avg}} = 12.05\text{s} \approx 12.1\text{s}
\]
There were three jams occurred during the test running of the machine. The achieved 87.5% of successful results can be calculated as:
Total number of tests conducted on samples from Table 2 & 3 are;
\[
T_{\text{test}} = 24
\]
Total Number of Jams Occurred during Test Running Cycle, \( J_{\text{test}} = 3 \)
Percentage of unsuccessful results, \( \alpha \)
\[
\alpha = \frac{J_{\text{test}}}{T_{\text{test}}} \times 100
\]
(3)
\[
\alpha = 12.5\%
\]
Percentage of successful results, \( R_s \);
\[
R_s = 100 - \alpha
\]
(4)
\[
R_s = 87.5\%
\]
5.6. Machine Test
Random test running of machine process was conducted to investigate the distribution of recovery time (i.e. idle time to fix the jam and restart the system completely). The first 3 jams occurred while random testing of machine is recorded; the time of recovery was noted as shown in Table 4 and the graphical distribution of recovery time is given in Figure 14.

**Table 4.** The counted Recovery Time of the Machine when it was Jammed.

| No. Samples Running During Jam (l x w) cm | Total Number of Jams occurred during Random Test Phase | Time (in seconds) of Machine Recover after Reset Button is Pressed, T(s) | \( T_1 \) | \( T_2 \) | \( T_3 \) | \( T_{\text{average}} \) |
|------------------------------------------|--------------------------------------------------------|---------------------------------------------------------------|------|------|------|-----------------|
| 6 x 6                                    | 3                                                      | 12.4 17.6 19.5 16.5                                           |      |      |      | 16.5            |
| 8 x 8                                    | 3                                                      | 10.0 15.4 20.4 22.9                                           |      |      |      | 22.9            |
| 10 x 10                                  | 3                                                      | 13.4 15.9 16.8 15.4                                           |      |      |      | 15.4            |
| Maximum Average Time of Recovery for Machine | 18.3                                                   |                                                              |      |      |      | 18.3            |

Based on the results achieved, the machine time of operation for each pick-and-place task is tremendously accurate as expected. The average time taken by the machine to perform one pick-and-place operation is about 16.3 seconds and if added the time of machine to return to home position, which is about 12.1 second, a total of about 28.4 seconds are achieved for one complete pick-and-place process.

Therefore, as tested that one complete pick-and-place cycle with machine returning to its home position would take about 28.4 second, the pick-and-place (of bag) speed of machine can be calculated as:

One complete cycle of pick-and-place, \( X = 16.3 \text{ sec} \)
Time for machine to return to its home position, \( Y = 12.1 \text{ sec} \)
For each bag pick-and-place operation: Total performance time, \( T_p \):
\[
T_p = X + Y
\]
\[
T_p = 28.4\text{ s}
\]
(5)
Figure 14 Measured Recovery Histogram.

Speed of machine to pick-and-place numbers of Bags per minutes (60 Seconds), $S_{Bags}$:

$$S_{Bags} = \frac{60s}{T_p}$$

(6)

Therefore, practically the machine can perform about 2 bags pick-and-place operations per minute, however the expected speed of machine was about 5 bags/minutes. The achieved speed of machine is vastly lesser than the actual bag making machine in the factory, which makes about 70 bags/minutes. The current invention speed is about 97% lesser than the actual bag making machine, but it is 60% accurate to the expected speed of the machine, given as:

Actual speed of Bag making Machine, $S_{Actual} = 70$ bags/min Expected Speed of the current system to pick-an-place, $S_{Expected} = 5$ bags/min

Achieved speed of pick-and-place, $S_{Bags} = 2$ bags/min

Percentage of Limitation in the current speed of system from reality, $S_{Lim, from reality}$:

$$S_{Lim, from reality} = 100 - \left[ \left( \frac{S_{Bags}}{S_{Actual}} \right) \times 100 \right]$$

(7)

Percentage of Limitation in the current speed of system from expected speed, $S_{Lim, from expected}$:

$$S_{Lim, from expected} = 100 - \left[ \left( \frac{S_{Bags}}{S_{Expected}} \right) \times 100 \right]$$

(8)

6. Conclusion and Recommendation

This project presents a pick-and-place process of plastic film bags after their bag making process to be picked up and placed at a desired location by the method of vacuum suction and the dimension analysis by a newly developed concept of load cell to monitor the dimensions of the film.

According to the experiments carried out on the prototype of the presented project, the approach allows the pick-and-place of plastic bags by a method of using vacuum suction with lower cycle of time as compared to the manual process, and required the presence of the only one human operator to only look after the each pick-and-place process performed by this machine and troubleshoot the machine jamming, if occurred during machine running cycles. Jams in pick-up end-effector do not affect the machine running cycle time significantly, as system can be restored shortly.

The only important factor that can be considered as the basis of this project is the costing related to the manufacturing and operation of this system. And such automation system can be predicted to be
used widely by industries and consumers are willing to compromise the quality of the product in lower ratios and big profits. Therefore, in order to increase the accuracy of this project a better vacuum suction with the pressure sensor can be used with a digital pressure controller by the interference of microchip (of 32-bit or higher). To improve the accurate position sensing of the system a visual aid can be used, but all of these sensors are of high cost and need extra income to build them but once the system is built using perfect sensors to achieve more accurate results more the demand of the system will be increased in the market.

By using programmable logic controllers (PLCs) to the proposed system it can easily reduce the use of many sensors, especially used in the positioning of the system. Also, a PLC based system reduces the use of many other electronic components and reduces the size of the circuitry and makes the system reliable and more cost effective. PLC’s are easy to be programed then a microchip and is user friendly plug-and-play device to control the automation of a system with lesser errors and more accurate and precise in its time delays for its functions and intrusions [24].

The project Automatic Pick & Place Packaging System with Vacuum Lifter can also be made to able to differentiate between not only two colours but various coloured bags of various dimensions to locate them accordingly to their desired location of more than two points of location as described in this project, which will benefit the industry to minimize the work load. The different sizes and colours of bags can be stored in the visual memory of system to demonstrate different bags accordingly and keep them in their desire set locations. Whereas, this picks-and-place project machines can be built in the bigger scale to support the pick-and-place purpose not only in food packaging as well as in heavy industries like, automobile parts, shipping industries and aircraft manufacturing plants.

7. References
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