Experimental Examination on the Pneumatic Lifting Method of Deformable Object

Rabiatul A. Jaafar, Muhammad A. Ayub

Abstract*: Industries such as agriculture and food have used polypropylene bag widely used as it is cheap and easy to find. Fertilizers industry especially needed to use the polypropylene bag that have high protection barrier against the high-level humidity especially we living in Malaysia that have high humidity in the air. By layering the polypropylene bag with another polypropylene bag, the moisture problem can be overcome. The polypropylene bag for fertilizers consists of 2 layers which is the woven polypropylene bag and the clear polypropylene bag. However, when assembling this two-polypropylene bag, worker needed to manually insert the clear polypropylene bag into the woven bag. This increases the time process in production, high labour force needed and also higher cost for mass production. Furthermore, repetitive works can cause strain to the worker and increases the number of errors. To overcome this issue, the automated polypropylene bag assembly system is proposed. For this paper, we only focus on the lifting method of the automated polypropylene bag assembly system. With the used of the automated polypropylene bag assembly system, the repetitive works and labour force can be reduced. This will also give out cleaner and consistent last product.

***Keywords*: Fertilizers industry, Lifting method, Labour force, Polypropylene Bag, Repetitive works.**

I. INTRODUCTION

This project focuses on the lifting of deformable object which in this case is the clear polypropylene bag. The uses of polypropylene bag are crucial in order to prevent moisture from seeping in into the fertilizers thus will contaminate the fertilizers. As polypropylene is used in packaging, the industry is demanding to seek ways to enhance the capacity of the manufacturing and packaging as industries are still relying on labour force.

Growing demand of the consumer have cause companies to seek ways to enhance their capacity to provide a sustainable, safe, flexible and standardized technology for packaging [1]. Previous ways in manufacturing and packaging industries only relied on the labour force which contributes to the increase of processing time for mass production and labour cost. Repetitive tasks such as packaging can cause injuries and also psychologically effect to the worker consequently increases the number of incident and also error by workers [2]. The need for goods such as foods, fertilisers, and etc to be stored and transported without being damaged and contaminated have given rise on the interest of the technology and the art of packaging [3].

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Rabiatul A. Jaafar, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, adawiyah.92@gmail.com.

Muhammad A. Ayub, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia, muhammadayub@uitm.edu.my.

In the fertilizer industry, packaging plays an important role in order to deliver a safe and uncontaminated fertilizer to the consumers. Fertilizers are often packing in the polypropylene bag and usually consist of 2 layers which is the outer and the inner layer. The outer layer is the woven polypropylene bag and it is lined with the inner layer which is the clear polypropylene bag. Fig. 1 and Fig. 2 show the outer and the inner polypropylene bag for fertilizers packaging. The aim of this works is to design an opening system where the inner bag of the fertilizers can be automatically inserted into the woven polypropylene bag using a suction cup.

(a) (b)

Fig 1: (a) Woven polypropylene bag (outer layer) (b) clear polypropylene bag.

According to [4] the pick and place operation are suitable in the agriculture and fertilizer industries and have a great opportunity in this industry. Due to the physical properties of the agriculture properties such as the fruits and vegetables that are soft and easily deform and need to avoid damage to the goods makes it crucial to try to find the fit solution in handling deformable or flexible object for wide range of product.

II. DESIGN CONCEPT

The Automated Polypropylene Bag assembly system consists of 5 stages which are:

a) Stage 1: Bag Feeding Stage

In this stage, the polypropylene bags are stacked under the lifting system.

b) Stage 2: Lifting Stage

The lifting system consists of the linear actuator and also 4 suction cups. The linear actuator will move downward towards the polypropylene bag while the suction cups will simultaneously operate. Once the suction cup is in contact with the polypropylene and have gripped the workpiece, the actuator will move upward to its original position.

c) Stage 3: Opening Stage

In this stage, it consists of two main parts. The first part of this stage is the opening by using the suction cup and the second part is the opening by using the flipper. The mouth of the polypropylene bag will automatically open due to the gravitational force when the polypropylene is being lifted using the suction cup in the upward movement. This opening at the mouth of the bag will easily help to assist the bag opener to widely open the polypropylene bag. The bag opener consists of 2 rotary actuators, each mounted with a flipper that will move in a 90-degree rotation in a opposite direction to each other.

d) Stage 4: Assembly Stage

The wide opened polypropylene bag is moved using the automated guided vehicle (AGV). The AGV are mounted with a hanger will moves to enter the first bag (clear polypropylene bag) then to the second bag which is the woven polypropylene bag.

e) Stage 5: Ejection Stage

The already assembled bag on the hanger is then continued moves forward towards the clamp that are equipped with a receiver and obtain a signal from the transmitter that are attach with the hanger. The assemble bag are clamped and then are release to the ground after the AGV and the flipper are return to its original position. Fig 2 shows the design concept of the Automated Polypropylene Bag Assembly System.

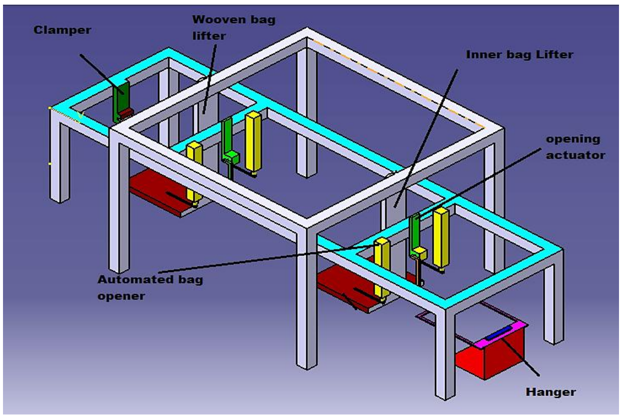

Fig 2: Isometric view of the desing concept for Automated Polypropylene Bag Assembly System.

However, this paper only concentrated on the opening stage where the polypropylene bag is being lifted using the vacuum cup.

III. LIFTING MECHANISM

Lifting mechanism includes linear actuator, suction cups, vacuum generator, pressure regulator, solenoid control valve and compressor. Fig 4 shows the pneumatic circuit for the experimental lifting mechanism.

This mechanism uses pneumatic actuator equipped with suction cup to extend and retract the piston to and from the workpiece. D. Saravanakumar et al [7] come out with a dynamics motion of pneumatic cylinder. There are four forces that create the net force of the pneumatic actuator, which has been discuss by D. Saravanakumar et al in his paper. The four net forces are as follow [7].

a) The pressure difference inside the chamber Fp, causing the resultant pneumatic force.
b) Frictional force opposite from the movement of piston and rod, Ffric.
c) External force acting on the load Fext.
d) Gravitational force due to inclination of cylinder.

The various of forces acting on the cylinder is shown in the Fig. 3. Equation of motion of the piston and slide of the rodless cylinder are formed by resolving the forces acting inside the cylinder [8], [9], [10].

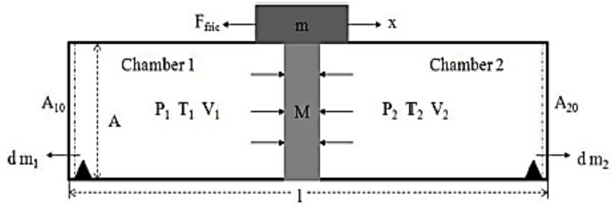

Fig 3: Free Body Diagram of a Pneumatic Cylinder and The Forces Acting Inside the Chambers [11].

The equation of motion for the motion of the piston rod can be stated as below

$$F = ma \quad (1)$$

$$F = (M_L + M_P)\,\ddot{x} = F_P - F_{fric} - F_{ext} + M_L g \sin \Theta \quad (2)$$

Where F_p is the results of the pneumatic force that acting on the piston that are caused by the pressure difference on the both sides of the piston (P_1 and P_2). F_{fric} in this equation represent the frictional force acting on the piston and $\ddot{x}$ is the acceleration. M_L is the mass of the external load while M_P is the mass of the piston-rod assembly of cylinder. Θ is the angle of tilting of the cylinder. From the equation (2), the resultant force, F_p is obtained using the below equation.

$$F_p = P_1 A_1 - P_2 A_2 - P_a A_{rod} \quad (3)$$

Where $_1$ and P_2 are the air pressure in the chambers 1 and chambers 2 respectively. A_1 and A_2 is the cross-sectional area of the cylinder chambers. P_a represent atmospheric pressure and A_{rod} represent the cross-sectional area of the piston rod. For this equation the cross-sectional area of the cylinder chamber is assume the same.

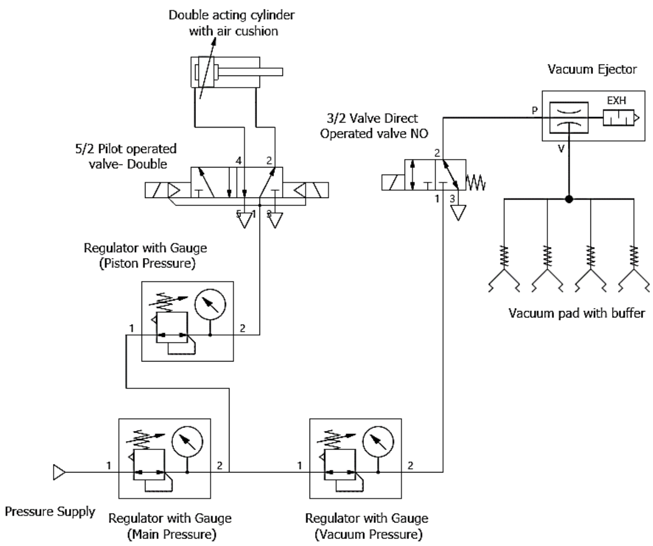

Fig 4: Pneumatic circuit diagram for lifting system.

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The system consists of three parts which is the main pressure where the pressure is supply form the compressor and control using the regulator with gauge. The second part is the cylinder part where it consists of double acting cylinder, 5/2 solenoid control valve and a regulator with gauge. The regulator with gauge for the cylinder part is mainly to control the speed of the cylinder by controlling the air pressure. The third part is the suction parts. This part consists of 1 regulator with gauge, 3/2 solenoid control valve, vacuum ejector and 4 suction cups. The vacuum generator operates when the compressed air flows into the ejector [5][6]. The vacuum ejector will produce negative pressure which will generate vacuum.

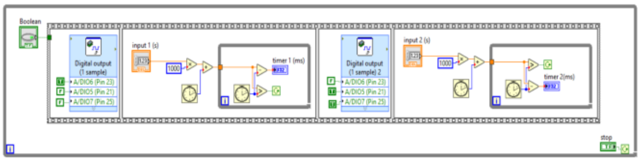

Fig 5: Labview programming for lifting system.

The switch will be turned on when press and the digital output will transfer signal to the A/DIO6 (pin 23) and A/DIO5 (pin 21) on the myRIO by turning the solenoid off at A/DIO6 (pin 23) and solenoid on at A/DIO5 (pin 21). Meanwhile, user can give input value for the time needed to wait. After the timer finish counting, it will reset automatically. The solenoid valve will activate again and this time the A/DIO6 (pin 23) is turned on while the A/DIO5 (pin 21) will turned off. There are two pins on the solenoid as there are 2-way solenoid valve. A/DIO6 (pin 23) and A/DIO5 (pin 21) represent the solenoid valve used for the double acting cylinder. A/DIO7 (pin 25) represent the solenoid valve for the vacuum ejector.

IV. RESULT AND DISCUSSION

A. Linear Actuator Result

The linear actuator result is taken. The time taken for the piston to moves downward (extend) and upward (retract) at different working pressure are taken in the experiment. Then with the time taken, the velocity of the actuator was calculated and plotted into a graph. The working pressure are from 0 kPa to 700 kPa without any load attached on the actuator

Fig 6 shows the graph for pressure against time in taken when the linear actuator moving upward (retract). The time for the linear actuator increases as the pressure increases. The relation of the time and the operating pressure is inversely proportional to each other. The lowest time for the piston to move upward (retract) is 4.09 seconds when operated at 100 kPa while the highest when operated at 700 kPa with timing of 0.92 seconds.

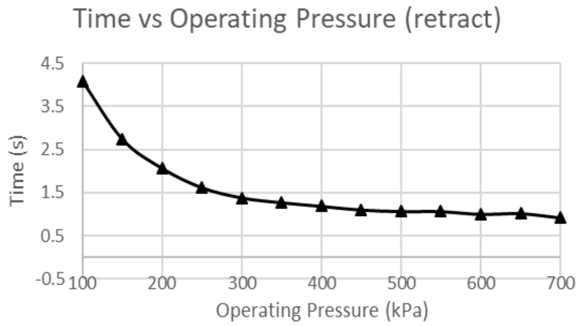

Fig 6: Graph Pressure against time for upward motion (retract) for cylinder.

Fig 7 shows the relation of time with the operating pressure when the linear actuator moves downward (extend) from the original position. The highest operating pressure is at 700 kPa with downward time of 0.84 seconds while the lowest time recorded is at 2.26 seconds when operated at 100 kPa pressure. The time taken while the linear actuator is moving downward (extend) is shorter than when the linear actuator is moving upward (extend). This is due to the gravitational force that always acting in the downward motion (extend). The linear actuator that moves upward (retract) are against the gravitational force thus longer time needed to retract the piston.

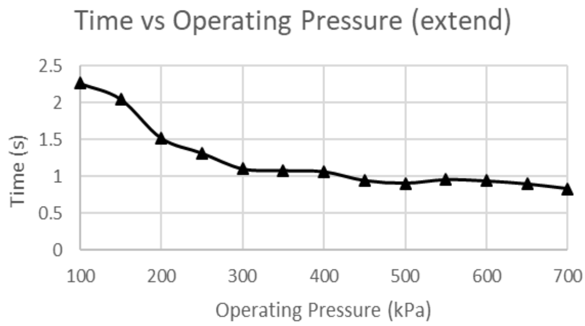

Fig 7: Graph pressure against time for downward motion (extend) for cylinder.

Assuming the load on the linear actuator is 5 kg (plastic bag and vacuum holder), the velocity of the linear actuator is calculated using the (2) and (3). Fig 8 shows the highest velocity when the actuator extend is at 5.48 m/s while for highest velocity when the actuator retract is at 5.18 m/s. The lowest velocity recorded with the operating pressure of 0 kPa for both cases. The lowest velocity for downward motion (extends) is 1.27 m/s while for the upward motion (retract) is at 1.27 m/s moving in the opposite direction. In order for the linear actuator to moves upward with load attach to it, the pressure must higher than 100 kPa.

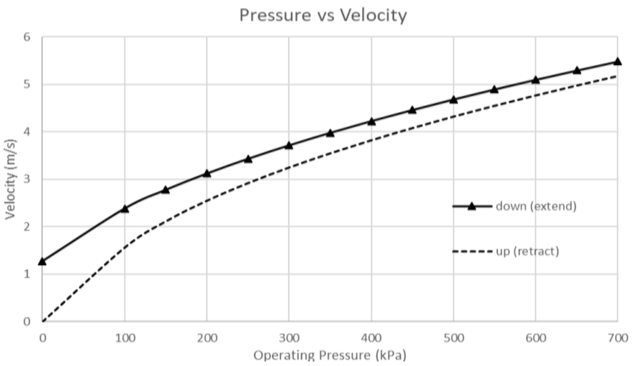

Fig 8: Graph operating pressure against velocity for downward and upward motion.

Table I shows the variation due to the pressure drop in the cylinder for the retract motion and the extend motion is 89.66% and 89.02% respectively. The high difference in the value of velocity between theoretical and the experimental is due to the air in the chamber 2 in the pneumatic cylinder is not fully dispose out from the cylinder. Due to this problem, there is a high variation due to the pressure drop. The air will flow into chamber 1 and will push the rod to extend. In reality, the air in chamber 2 needed some times to expel the air completely. However, in theoretical, we consider the chamber 2 of the pneumatic cylinder is zero thus causing in the high variation of the pressure drop in the cylinder.

Table I: Variation due to pressure drop at 300 kPa (retract and extend) motion

Motion	Description	Velocity (m/s)	Variation due to different air pressure drop (%)
Retract	Theoretical	3.25	89.66
	Horizontal	0.34	
Extend	Theoretical	3.71	89.02
	Horizontal	0.41	

B. Holding Force

Force for horizontal and vertical force are observed and identified by calibrating the gripping actuator. Data of the force are taken by manipulating the use of pressure and the calibration are made by using the force gauge. The reading of pressure is taken in unit bar while unit for force is in Newton, N. holding force that are parallel to the surface of the suction cup are called the horizontal force meanwhile the holding force that are perpendicular to the suction cup are called the vertical force.

Fig 9 shows the pressure are manipulated and the vertical force varies as the pressure are manipulated. The graph shows that the pressure and the vertical force are directly proportional to each other. The pressure increased as the force also increased. From the graph in Fig 9, 0 kPa up to 100 kPa, the normal force is zero and the highest normal force obtain when the pressure is at 300 kPa with the average vertical force of 1.72N

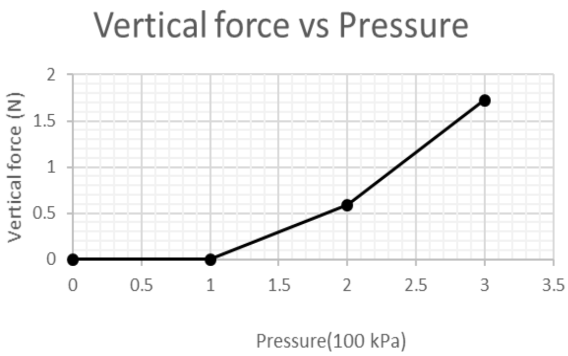

Fig 9: Graph pressure against vertical force.

Fig 10 shows that the pressure and the horizontal force are directly proportional. As the pressure increased, the horizontal force also increased. The shear force appears to be zero from 0 kPa to 100 kPa. At the highest shear force recorded which is 400 kPa, the average shear force is at 2.14N.

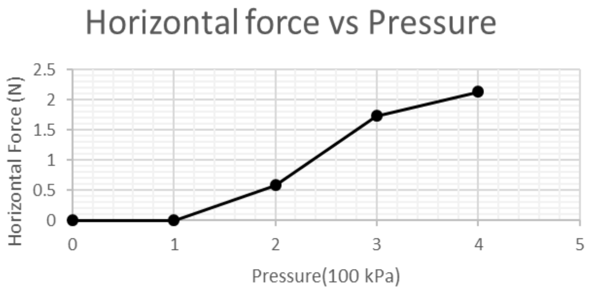

Fig 10: Graph pressure against horizontal force.

Both of the graph shows that the horizontal holding force that acts parallel to the surface of the suction cup can withstand more pressure than the vertical holding force.

The holding force of the suction cup are calculated theoretically. From the experimental and the theoretical the percentage error for the horizontal and the vertical force acting on the polypropylene bag is as Table II.

Table 2: Table of The Percentage Error Between Theoretical and Experimental for Vertical and Horizontal Force.

Type of force	Theoretical (N)	Experimental (N)	Percentage Error (%)
Horizontal	1.1886	2.14	44.46
Vertical	0.8886	1.723	48.43

For the holding force, we assume the coefficient of friction that are used in the theoretical calculation is flat and smooth surface. But in reality, the plastic is not smooth and will wrinkle as the suction cup grips the polypropylene bag. Due to the wrinkle, air leaks from the suction cup thus decreases the effectiveness of the suction cup and thus the high percentage error between the theoretical and the experimental.

V. CONCLUSION

The lifting method is one of the stages that needed to complete the Automated polypropylene bag assembly system. Several considerations have been made for the lifting method for the polypropylene bag such as the design proposed and the fabrication and the system suitability. The prototype for the lifting method is fabricated based on the drawing that have been made. The calibration has been verified by a theoretical calculation with some error when compared with the experimental data but it is in the tolerable range. Hence, the project objectives are accomplished in the arranged timeframe where the design, fabrication and calibrations are done in the time.

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AUTHORS PROFILE

Rabiatul A. Jaafar currently a Msc in Mechanical Engineering student in Universiti Teknologi MARA (UiTM). She received her B.Hons in Mechanical Engineering from Univerisiti Teknologi MARA (UiTM).

Muhammad A. Ayub Professor for Mechatronics at the Faculty of Mechanical Engineering, Universiti Teknologi MARA, Malaysia. He received his B. degree of Engineering (Mechanical) from UNSW Australia in 1989, and MSc and PhD from Loughborough University, UK in 1996 and 2004, respectively. Currently, he is the Dean of the faculty of mechanical engineering. His research interests include mechatronics, visual feedback and control of mechanical systems. Muhammad A. Ayub is the corresponding author and can be contacted at: muhdazmiayub@gmail.com.