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Analytical approach for hot packing machine on electro-pneumatic circuit with on-delay timer

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Abstract
The supportability measure in the assembling ventures is basic, particularly in the vehicle enterprises. At present, endeavors are being made by the ventures to relieve CO_2 discharge by the absolute vehicle weight advancement, machine usage and asset proficiency. In lieu of this, it is imperative to understudy the assembling machines received in the auto ventures. One of such machine is the hot packing machine that is utilized for about 35% of the assembling activities inside the car enterprises. In this manner, the normalization and advancement of the hot packing interaction could decrease the carbon impression inside the vehicle ventures. This work understudied the on-postpone clock practical valve of the hot packing machine to decide different interaction boundaries influencing it. The point by point actual model of the pneumatic and electro-pneumatic chamber frameworks for the control is mimicked and advanced for both the pneumatic and electro-pneumatic chamber systems. Experimental and reproduction model thewere set up at the FESTO work station and FESTO FluidSIM®5.1 separately to assess the compelling speed, speed increases, removal, and stream rate for the pneumatic and electro-pneumatic actuator on the two frameworks. Correlations were made among pneumatic and electro-pneumatic cylinder frameworks on their trademark bend to improve the cycle factors. The outcome favors the electro-pneumatic circuit frameworks in security and in planning hot packing machines. The outcome acquired could clarify the comprehension of the squeezing arm of a hot packing machine.

Keywords: Electro-pneumatic system, Pneumatic actuator; Hot Packing machine; On-delay timer; Fluid SIM®

1. Introduction

It was recommended that CO_2 can be moderated with the creation of lighter weight vehicles to decrease fuel utilization, and lessen CO2 discharges to the climate (Hagenah, Merklein, Lechner, Schaub, and Lutz, 2015; Li, Chiang, Tseng, and Tsai, 2014a; Li *et al*., 2014b) [7, 12, 13]. Hot packing innovation is one of the critical approaches to enhance energy interest inside the auto assembling industry (Oldenburg, Steinhoff, and Prakash, 2008, 2009; Oldenburg *et al*., 2009; Karbasian and Tekkaya, 2010) [18, 19, 11]. Hot packing is a strategy that was utilized in applying gold tooling in book imprinting in the nineteenth century (Cambras, 2004) [4]. Hot packing was formally reported in Germany by Ernst (Benedek, 2005) [3] in 1892 as the printing technique utilized on cowhide and paper materials. Hot packing has additionally been received for making plastics and printing of safety cards since 1950s (Karbasian and Tekkaya, 2010; Wang and Lee, 2013) [11, 26]. Hot packing can be characterized as a dry printing interaction of lithographic material in which foil or dry paint of various tones are being superimposed on a surface at high temperatures (Benedek, 2005) [3]. This is regularly appropriate inside the plastic, paper and security ventures. It has an insignificant contamination impact on the climate. The misuse of hot packing machine (HPMs) in car body structure producing is developing yearly. Some car organizations utilize over 35% hot stepped parts for their models in the new years (Karbasian and Tekkaya, 2010; Wang and Lee, 2013) [11, 26]. Glob-partner, there has been an expanding pattern and fast turn of events and mechanical advancement in the creation of pneumatically and electro-pneumatically worked machines (Gamal, Sadek, Rizk, and Abou-el Saoud, 2016) [6]. This is likewise noticeable inside the innovative improvement of HPMs. Some HPMs makes use of packed air to create their packing outcome (Harper, 2005) [8]. As the packed air is passed to their frameworks, the chamber grows to start the machines' tasks. During hot packing activity, a warmed bite the dust of higher temperature is mounted on the chamber head and the item to stamp is set on a table bad habit underneath the packing head (Sugimoto, Sakai, Umemoto, Shimizu, and Ozawa, 2004) [22]. The printing is finished by driving the hot kick the bucket on the work piece.

This makes an impact on the outside of the item by the dry paint or foil bites the dust (Benedek, 2005) [3]. Bites the dust can be made of silicone elastic or metal to have a hard surface for an engraving; it tends to be projected straightforwardly or by packing; and it conveys undeniable degrees of subtleties decorated on the outside of both the ordinary and unpredictable shapes to frame a particular plan. Foils has complex coatings that move the outline to the outside of the item (Couchman, 1998) [5]. There are metallic and non-metallic foils, which comprise of a discharge layer, a shading layer and a cement base. In metallic foils, the shading layer is supplanted with a chrome or a vacuum metallic aluminum layer. Foil passes on are accessible in various metal shades for example copper, bronze, silver and gold. Distinctive HPMs can be utilized for various purposes, yet the most well-known HPMs are the basic here and there squeezes, which this exploration work depends on (Benedek, 2005; Couchman, 1998; Gamal *et al*., 2016) [3, 5, 6].

1.1 Advantage and system description of hotpacking machines model

Recently, Trajkovic, Milosavljevic, Tunestål, and Johansson (2006) [25] explored assorted kinds of valves and transfers (for example electromagnetic, electro-water powered, pressure driven, pneumatic, and electro-pneumatic actuators) for various machines. They investigated the difficulties between quick reaction valves, transfer and low stream rate. It was especially fascinating that pneumatic worked valve is more proficient and fit for the researched HPMs applications (Adeoye, Aderoba, and Oladapo, 2017; Watson and Wakeman, 2005) [2, 27]. The electro-pneumatic and electro-pressure driven actuators have similar working standards with the exception of the distinction in their resultant power age and working media (Abdel-Hamid, Sohair, and Ahmed, 2015; Minh, Tjahjowidodo, Ramon, and Van, 2009; Ruan, Burton, and Ukrainetz, 2002) [1, 14, 21]. The pneumatic actuators have quicker reaction time when contrasted and the pressure driven actuators. This is because of the low thickness of air received by the pneumatic actuators as its working medium (Abdel-Hamid *et al*., 2015; Oladapo, Balogun, Afolabi, Azeez, & Asanta, 2015; Minh *et al*., 2009) [1, 14, 16]. Apparently, because of the compressibility of air and its nonlinear conduct, the control arrangement of pneumatic actuators will in general be troublesome as far as activity capacity (Minh *et al*., 2009) [14]. The HPMs are worked on the standards of high temperature and high-pressure air as a fuel source. The electro-pneumatic valves (EPV) and time transfer valves can be further developed alternatives to electro-water powered or water powered arrangement of activity. To diminish the irregularity between the outward moving power forecast and the test estimation, examinations have been done widely on the exactness of the proposed model that assessed pneumatic and computerized electro-pneumatic plans (Minh *et al*., 2009; Mohamed and Shima, 2015; Oladapo *et al*., 2016) [14, 15, 17]. Packing or squeezing is the interaction whereby level material is embedded as a curl that goes through the bite the dust into a packing press to frame the ideal state of the material (Davis and Caldwell, 2006; Kalpakjian and Schmid, 2001) [10]. The HPMs has temperature ranges between 40 ˚C and 400 ˚C, input voltage of 220 V and a 600 W warming limit. The HPMs warming limit has a period defer control valve scope of 0.1 s–10 s. The most extreme stroke of the hot plate is 80 mm from the reference point and a greatest pressing factor of 60 bar on a one torque air blower. The HPMs can contain a hot plate of 140 mm × 170 mm at a time. The time postpone valve can be a regularly close as well as a typically open valve. A ordinarily close time defer valve has a lock changing screw that fills in as the valve clock. The valve is intended to meet the stream rate necessities. It is a combinational of a 3/2-way valve, an air supply and a choke help valve. The 3/2-way valve can be of typically open or regularly close position. The sort embraced in this work is the regularly open time postpone valve. The regularly open and typically close time defer valves are ordinarily intended to be impelled for a period somewhere in the range of 0 and 30 s. This can be reached out past 30 s with extra repository. During the hot packing activity, the pilot of the 3/2-way valve is activated when the air supply pressure is around 12 bar (Tokashiki, Fujita, Kagawa, and Pan, 1996) [24].

1.2 Aim and Objective

The point of this work is to understudy the useful valve of the HPMs and to decide the boundaries for its ideal execution. The predetermined goals are to:

1. Understudy the pneumatically and electro-pneumatically worked HPMs with the end goal of proposing unmistakable ends for its plan and tasks.
2. Design and mimic the HPMs 3/2 way valve regularly open spring return. The spring return is planned with anexpansion valve to frame a period postpone valve with three outlets as displayed in Figure 1 (a) and (c).
3. Recreate the HPMs time postpone valve with two outlets as displayed in Figure 1(d) to direct the hour of the forward and bring stroke back.
4. Reproduce the HPMs hand-off with switch-on delay for the time deferral of the electro-pneumatic system.

1.3 The construction of electro-pneumatic drive for HPMs

The set-up of the electro-pneumatic drive with Fluid SIM® framework is as displayed in Figure 2. A schematic graph of the electro-pneumatic control framework (EPCS) was received to check the situation with the stamp speed, defer time and smooth development of the cylinder.

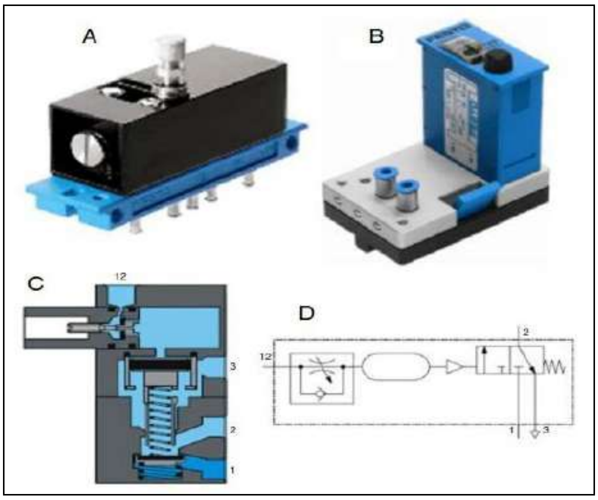

Fig 1: (a) Functional time delay valve with three outlets, (b) time delay valve with two outlets, (c) schematic representation of a time delay valve, (d) symbol of a time delay valve

2. Mathematical modeling of pneumatic system

To assess the exhibition of the air in the chamber what's more, the pneumatic conduct, the numerical examination of the air, the chamber and the cylinder should be analyzed. Air is known to be an incompressible multi segment liquid, which made out of dry air and water fume in warm balance. The pressing factor, speed, space of the chamber and cylinder and the stream pace of the twofold acting chamber is displayed in Figure 3. The accompanying suspicions are considered in the condition:

- The flow of compressed air is steady state and laminar
- The gravitational force is negligible on the flow
- Area of the connecting tube is stable in linearity
- The tempera ion of the arrangement is kept constant.

The overall model for nonstop progression of the framework linearity of the stream pace of air is given by the accompanying conditions:

$q_1 + q_2 + 2q_3 = c0\ P_l + (a_1 + a_2)\dot{}x$, (1)

$q_1 + q_2 = -kpPl$ (2)

$q_1 + q_2 = kiAi - kp0Pl$ (3)

Where

$a_1 = P_1A_1/RTs$; $a_2 = P_2A_2/RTs$; q_1, q_2 and q_3 address the stream the flow rate through each of the valves; x is controlling piston position; V_1 and V_2 are volumes of the double acting cylinder; P_1 also, P_2 are the input and output pressures applied individually to the system and Ai is the cross-sectional area of the double acting cylinder displayed in Figure 3. The dynamic equation of motion ofthe piston-rod is described as:

$Mr\ d/dt\ \dot{}x + \beta\dot{}x + Ff + FL = P_1A_1 - P_2A_2 - PaAr$ (4)

where, MP is the mass of the piston, x is the pistonlocation at a specific point on schedule, β is the coefficient of viscous friction, Ff is the Coulomb friction force, FL is the external force from thestamp, P1 and P2 are the absolute pressures in the cylinder, PAis the absolute pressure. A_1 and A_2 is the piston effective areas, Ar is the rod cross sectional area.

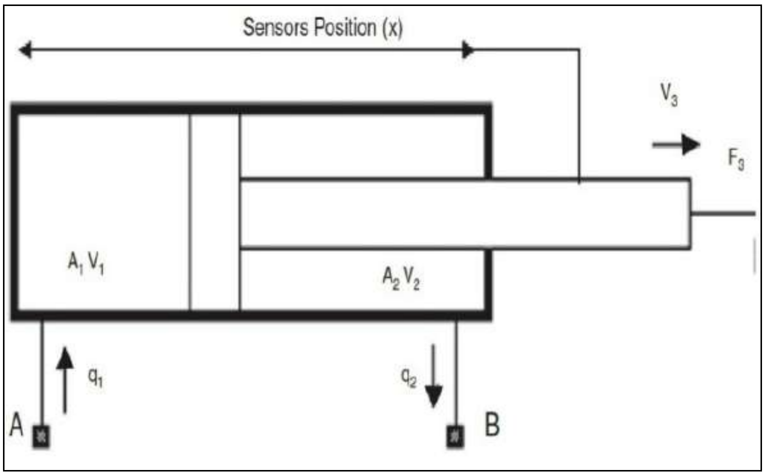

Fig 2: The schematic diagram of the electro-pneumatic circuit in the HPMs.

Some researchers for example (Beater, 2007; Ilyukhin and Arfikyan, 2011; Richer and Hurmuzlu, 2000; Takosoglu and Laski, 2011; Tokashiki *et al.*, 1996) [3, 20, 24] proposed the mathematical representation used to examine the electro-pneumatic control systems actuatinga double acting cylinder for HPMs. In their model, the time delay 5/2 pneumatic valve with double air pilot was simulated and controlled by the computer and workstation for both the forward and the backward strokes. The model is based onfour differential equations which explain the dynamics of the pneumatic cylinder pressures and identify the progressive movement of the mechanical control system, shown in Eq. (4). The equations consider the direction of the flow through the expansion valve.

$dx/dt=v$, (5)

$dv/dt= F/m$, (6)

$dP_1/dt=n.(R.T.G_1 - A_1.P_1.v) / (V0_2 - A_1.x)$ (7)

$dP_2/dt=n. (-R.T.G_2 - A_2.P_2.v) / (V0_2 - A_2.x)$ (8)

Where v is the speed of the piston, R is the universal gas constant, T is the working temperature of the compressed air; n is coefficient; F is the force on the output of the cylinder used to calculate the acting force on the piston.

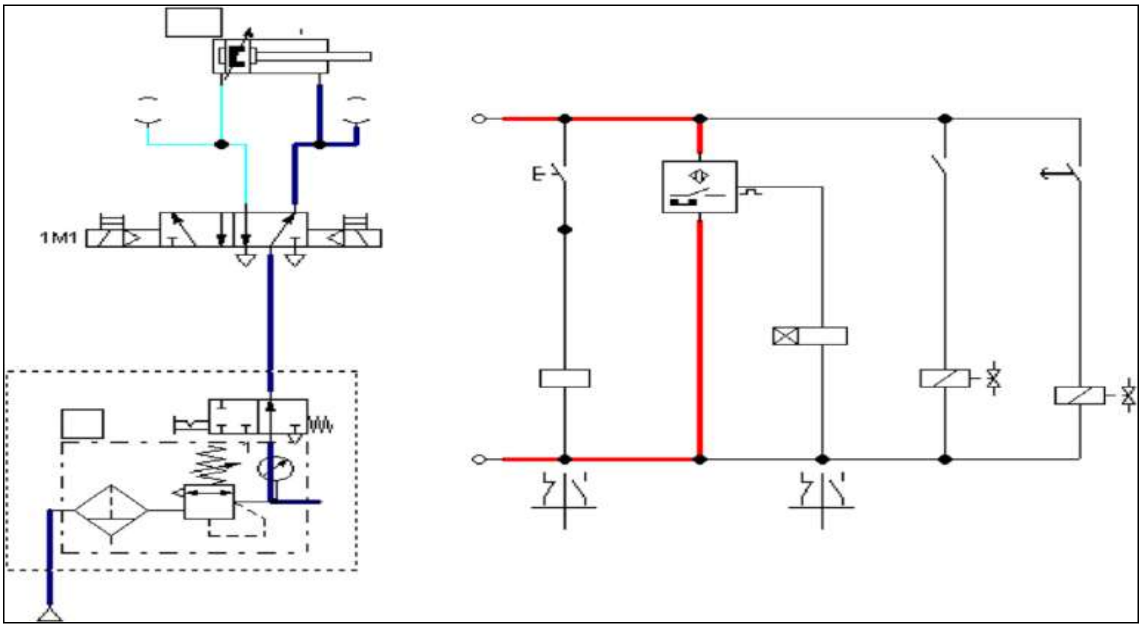

Fig 3: Schematic representation of the double-acting pneumatic actuating cylinder.

2.1. Developed model equation
From Eq. (1) substituting the value of a_1 and a_2, and if the temperature is kept constant, then the model equation is as shown in Eq. (9).

$$q_1 + q_2 = C0Pi + (P_1A_1 + P_1A_2)\dot{}x / R \quad (9)$$

If all the parameters of the arrangement are taken into consideration. Where A_1 = 0.0003142 m^2, A_2 = 0.000264 m^2, x = 0.1 m and R is the specific dry air constant = 287.05 J kg^{-1} K^{-1}.The working input pressures are P_1 = 5.0 bar and P_2 = 0.0 bar deduced from the result in Fig-7 &8. Thus, when there is an input pressure is on no output pressure occursand vice visa. Therefore substituting all parameters, the general model for continuous flow of the system is given by Eq. (10).

$$q_1 + q_2 = C0Pi + 0.00553d/dt(x) \quad (10)$$

3. Experimental set-up
The element part of the HPMs system mechanism is shown in Tables 1 &2 for the Electro-Pneumatic Control System and Pneumatic Control System respectively. This consists of.

1. Pneumatic double acting cylinders, which act as the mechanical stamping piston.
2. 5/2-way solenoid impulse valve pneumatically/electrically piloted with a manual over ride.
3. The compressed air supply and air service unit.
4. The push button switch that closes at the actuation of the system and opens immediately after released.
5. The relay, which immediately switches on when current is passed and switch off immediately current is removed from the circuit.
6. The magnetic proximity sensors which serve as the work piece in the experimental setup.
7. The relay, with switch-on delay that determines the time delay of the piston movement. The valve solenoid that switches on the 5/2-way solenoid impulse valve

Table 1: Description part list for Electro-Pneumatic Control System

Quantity of item	Symbol of item	Description of item
1	1A1	Double acting cylinder
1	0Z1	Air service unit, simplified representation 3/2-way valve, manually operated
1	1V1	5/2-way double solenoid impulse valve
2	K2	Relay with switch-on delay
1	K1	Relay
1	1M1	Valve solenoid
1	1M2	Valve solenoid
1	1S1	Pushbutton (make)
1	K1	Make switch
1	K2	Make switch
1	1B1	Inductive proximity sensor
1	1B1	Distance rule

Table 2: Description part list for Pneumatic Control System

Quantity of item	Symbol of item	Description of item
1	1A1	Double acting cylinder
1	0Z1	Air service unit, simplified representation
1	1V2	Time delay valve, normally closed
1	0V1	3/2-way valve, manually operated
1	1V1	5/2-way valve, manually operated
1	1S1	3/2-way valve with push button
1	1S2	3/2-way roller lever valve
1	1B1	Distance rule

The arrangement of the element parts that made up the HPMs system mechanism that is created to behave like the HPMs for the EPCS and PCS are as shown in Figures- 4 &5 respectively. From Figures 4 &5, it can be seen that the parts are systematically arranged to depict the sequential and logic flow of the HPMs process.

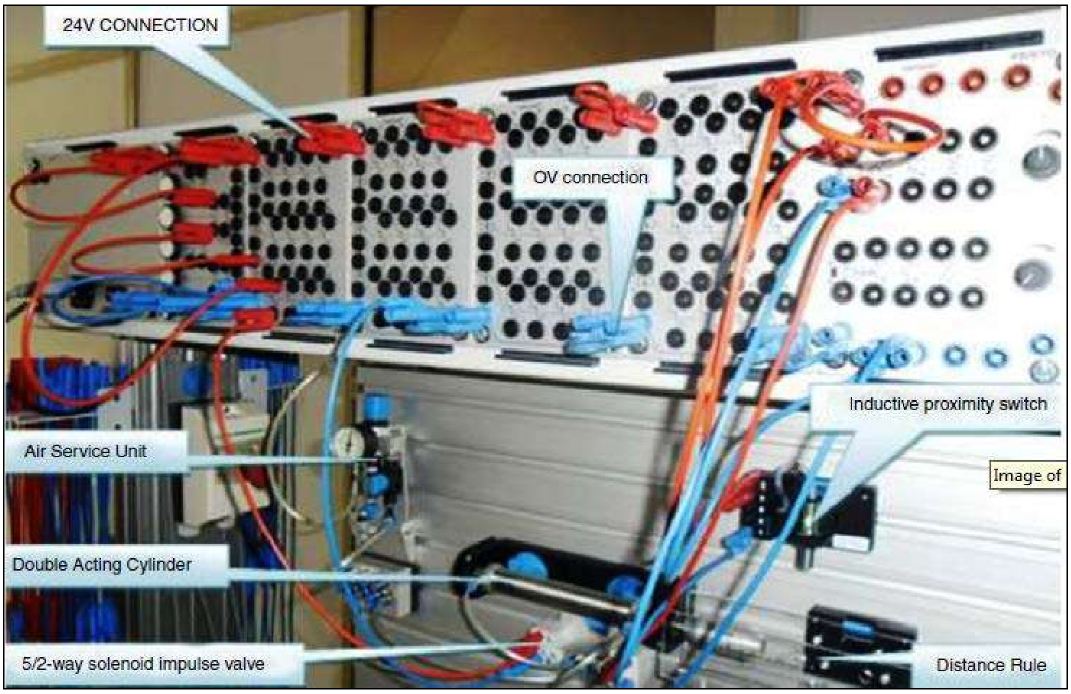

Fig 4: Experimental setup of Electro Pneumatic Control System.

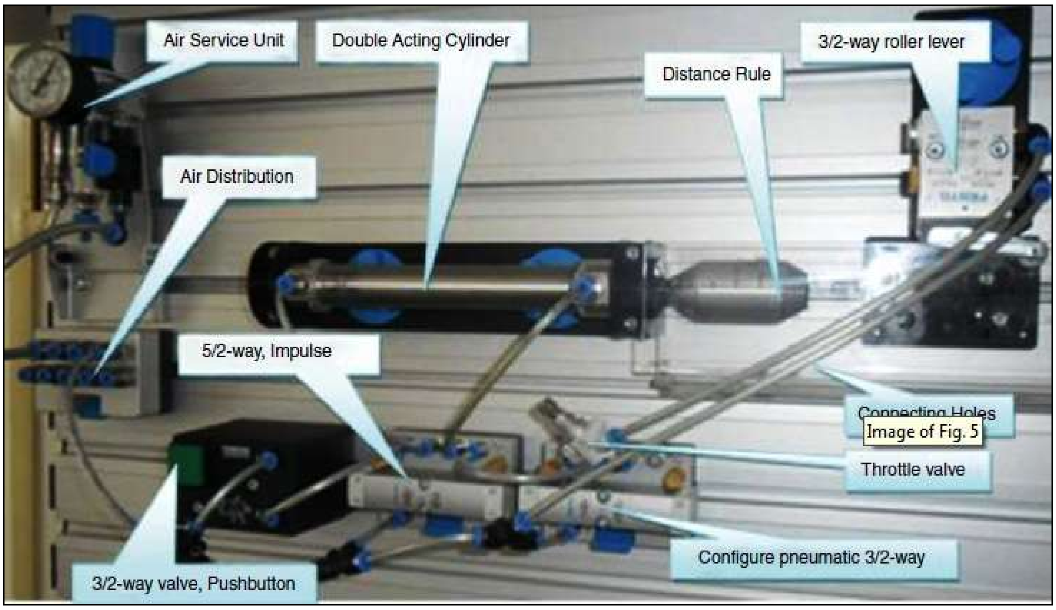

Fig 5: Picture of experimental setup for Pneumatic Control System

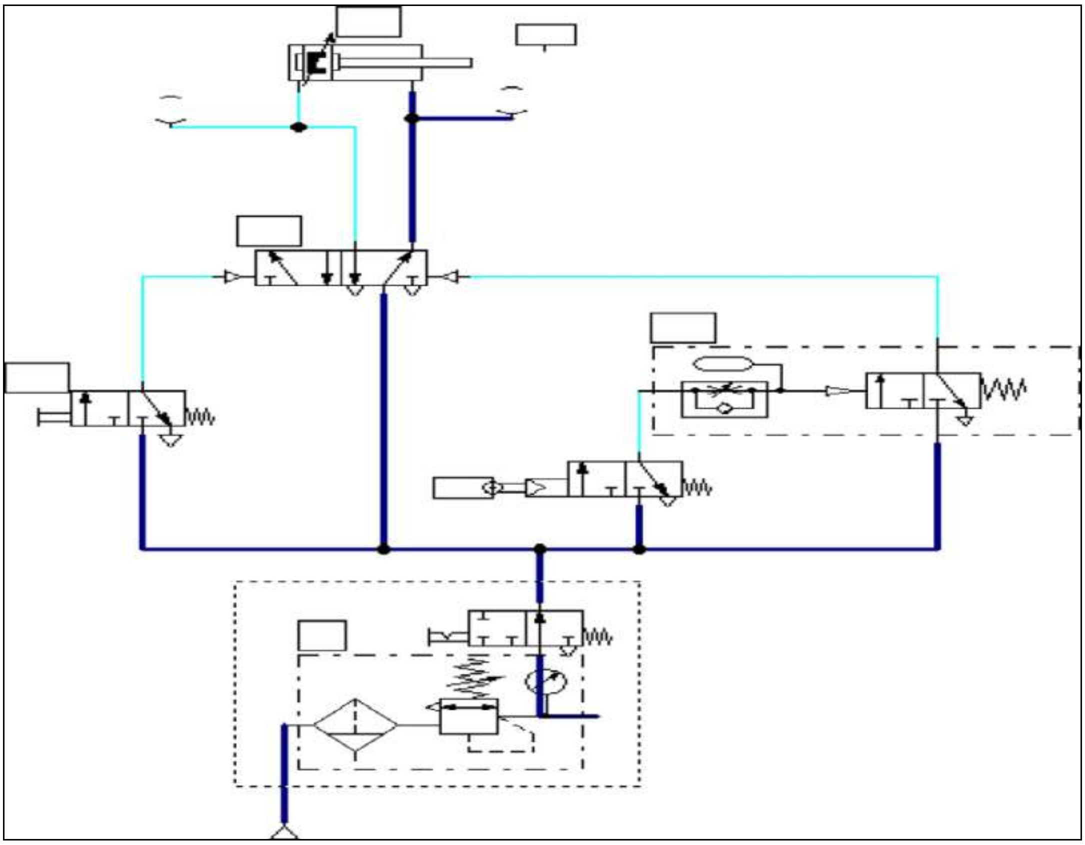

Fig 6: The schematic diagram of the pneumatic simulation of circuit in HPMs

The packing control framework was additionally planned with the pneumatic FluidSIM® programming as displayed in Figure 6. From Figure 6, the cylinder head is incited with a forward stroke by discouraging the pushbutton 1B1 as displayed in Figure 6 in the pneumatic circuit. It conveys messages to the 5/2-way drive pneumatically twofold guided valve regulator 1V1 and opens the inflow of high-pressure air coming straightforwardly from the compressor. The double acting cylinder is being incited by a joined signal sent from the 3/2 roller switch valve, ordinarily close and the 5/2-way valve. The wind currents from the blower through the 3/2 roller valve to the time delay ordinarily open useful valve. This makes the chamber push ahead and in reverse after a predefined time. The portrayal and the assignment of each piece of the segment in Figures 3 and 6 are separated in Tables 1 and 2. The stream pace of the framework that arrives at the double acting cylinder is controlled by the stream pace of the compressor, the air administration frameworks and the initial level of the time defer valve. The 5/2-way drive twofold pneumatically directed valve and the longitudinal slide valve have five ports and two positions. This is utilized as a last control component that connects the valves to the double acting cylinder and to the 3/2-way valve with typically shut pushbutton with a spring return. The control valve has three ports and a physically worked switch for incitation. A precisely guided spring return 3/2-way roller switch valve is used to initiate the development of the twofold acting chamber. The ordinarily shut time postpone valve is comprised of a pneumatically worked air steered 3/2-way valve, a single direction stream control valve (choke valve) and an air aggregator that controls the time deferral of the air inflow. The FESTO Fluid SIM® programming is embraced to reenact the HPMs control framework. The created FESTO FluidSIM® comprise of: the typically close time delay valve DSNU-20-100-PPV-A, the 5/2 single pilot arranged to a solitary guided spring return ordinarily shut 3/2 valve D:TPBG- VL-S/2-Q4, a throttle valve D:TP-PPV-GRLA for opening the compacted air, the time change valve D: TP-BG-PZVT- 3/2G-3OS-Q4 used to get the test information, the meter rule for distance estimation, an air administration with an air channel that manages the wind current states assigned D: TP-PVV-LFR-MICFQ also, the cylinder received which is assigned DSNU-20-100-PPVA as displayed in Figures 4 and 5. The cylinder bar, cylinder breadth what's more, the stroke length of the bar chamber were 8.0 mm, 20.omm, and 100.0 mm separately. A direct size of 200 mm since quite a while ago, estimated the dislodging of the chamber prior and then afterward excitation. The pneumatic stress is estimated with a 10 bar pressure check. The investigations were completed under a greatest tension of 6.0 bar for security and all together not to surpass the working pressing factor of the HPMs (Fig. 7).

4. Results and discussions

Diverse virtual experiences and test measure product completed through the created model displayed in Figures 8 &9. The accompanying outcomes were gotten to discover the functionality of the framework. In the first place, during the time spent the HPMs, speed development of the FESTO FluidSIM® stages was noticed. The situating distance, speed and speed increase of the actuator (the actuator is the principle packing arms of the chamber where the packing, cushion is appended to help the cycles) that is utilized for the packing arm of the machine were controlled. As the cycle advances and as the pressing factor level of the compressor arrives at 6 bar, it was seen that there was a variance on the development of the pressing factor dropping lower than the 6 bar prior to expanding further up to the 6 bar mark after about 0.06 sec of activity. This marvel was seen on the pressing factor measures for both pneumatic and electro-pneumatic test esteem. The reenacted examination likewise displayed the drop and high-pressure contrasts as displayed in Figure 8 however no huge distinction in.

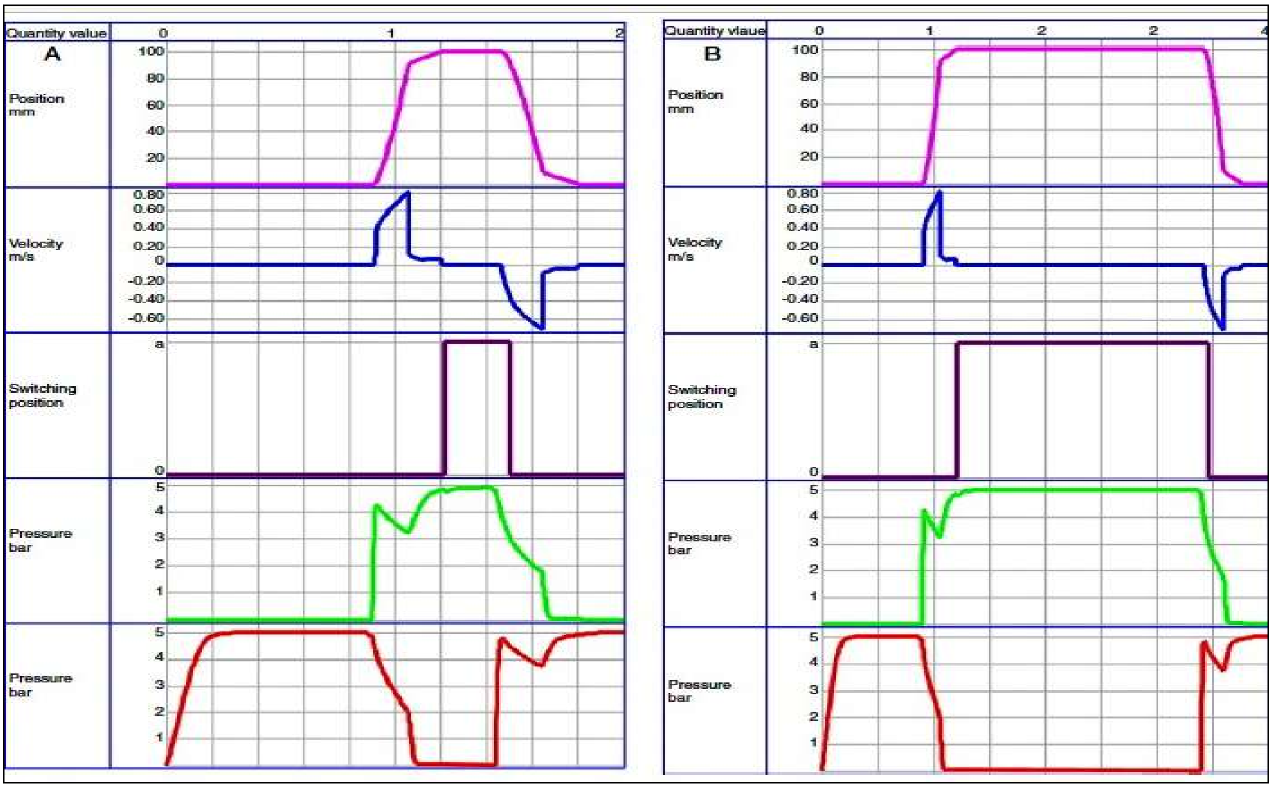

Fig 7: (A) The simulation diagram result of dependence of position and velocity on time of pneumatic system 10% opening of time delay valve. (B) The simulation diagram result of dependence of position and velocity on time of pneumatic system 80% opening of time delay valve.

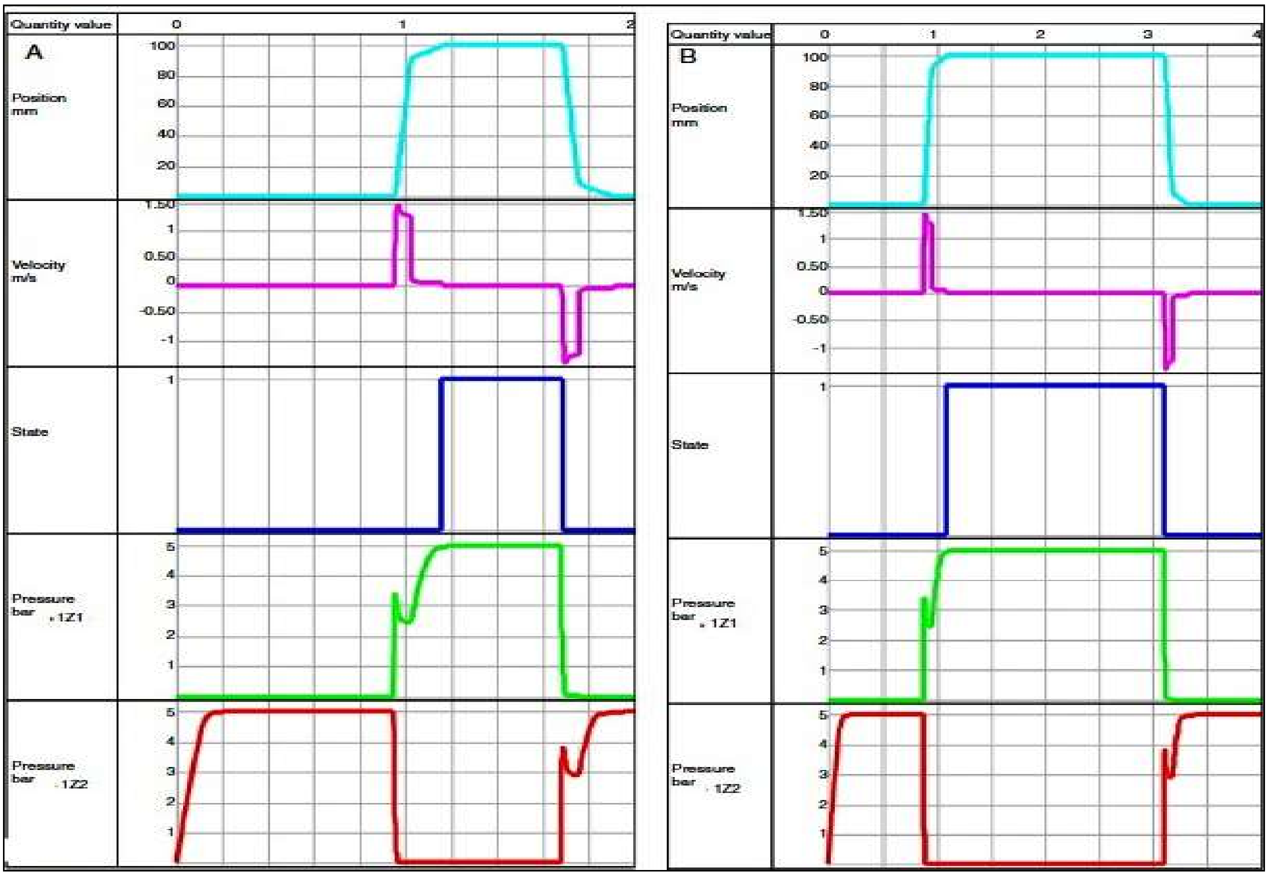

Fig 8: (A) Simulation result of electro-pneumatic system 2.0 sec relay with switch on-delay. (B) Simulation result of electro-pneumatic system 0.5 sec relay with switch on-delay.

The time delay for alloy material should be different from non-alloy material. From Figs. 7–9 it can be seen that the relay switch was only activated at the return stroke of the cylinder for all the test carry out which means it is the part of component that activate the return stroke. The inductive proximity sensor shows the position of the cylinder at a point in time
The outcome acquired. From the investigation of the actuator. The attractive pad of the double acting cylinder help to diminish the unexpected introductory dismiss from the framework from inside the time period of 0.4 s. This guide the full development of the actuator in request to have great and stable impression without the application of an indiscreet power which could make a mark and a default impact on the work piece. It has been proposed in the writing (Li *et al*., 2014; Li *et al*., 2014; Oldenburg *et al*., 2008, 2009) [12, 13, 18, 19] that a power applied by a pressing factor of 6.0 bar is sufficient to make an impact on the work piece when warmed. At the place of incitation there was a progression of air from the inventory unit through the air administration station to the control valve for 5/2-way solenoid motivation valve and 5/2-way drive twofold pneumatically directed valve for electro-pneumatic and pneumatic framework separately as displayed in Figure 7. Air is then, at that point provided with a 3/2 roller switch valve which filled in as the work piece in the framework and the on-defer clock valve that controls the hour of development of the cylinder. From Figure 5, on the electro-pneumatic framework, the electric sign is passed from the 24 v.

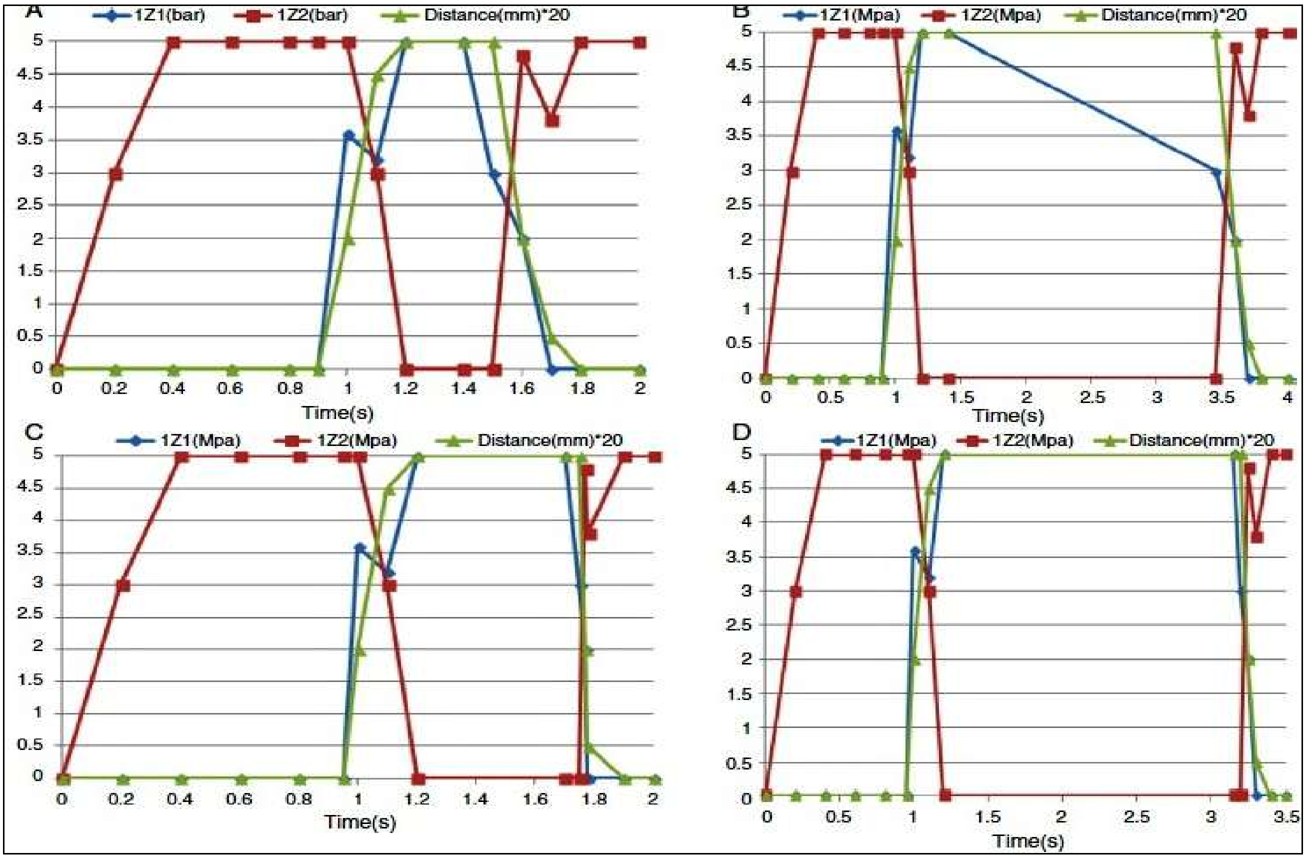

Fig 9: The experimental result of dependence of position and velocity on time of pneumatic system 10% opening of time delay valve. (B) Experimental result of dependence of position andvelocity on time of pneumatic system 80% opening of time delay valve. (C) Experimental result of electro-pneumatic system 2.0 sec relay to switch on-delay (D) Experimental result of electro-pneumatic system 0.5 sec relay to switch on-delay.

5. Conclusions

The electro-pneumatic and pneumatic system for the hot packing machine is introduced in this paper. The on-postpone clock valve was planned, created and designed on the FESTO instructive workbench to imitate and reenact the HPMs pneumatic system for practical execution. The reproduced HPMswas assembled utilizing the principle HPMs segments. The test furthermore, reenactment results show the qualities and conduct of the air development inside the framework. This outcome is likewise a proof that the defer season of the framework can be acquired all the more correctly and precisely with the on-postpone clock valve consolidated in the get together as displayed by the reproduction and exploratory examinations led in this work. This is useful to propel the presentation and advancement of the HPMs. The following end can additionally be drawn from this work:

- It tends to be seen that the chance of attractive pad framework at the two finishes of the embraced standard pneumatic chambers forestalled the abrupt packing of the work piece. Thus, to keep away from expansion in piece as well as improve rate due to abrupt packing in HPMs, it is suggested that attractive pad framework be fused into the HPMs. This framework can give the necessary shocks safeguard during the HPMs packing activities.
- In spite of the fact that, It can be concluded from both the recreations and test set up that the pneumatic worked framework for on-delay timing is flighty, the HPMs can be worked with both the pneumatic and

electro-pneumatic framework factors contingent upon the workpiece material. The applied power during a packing activity is calculate by the material property of work piece.

- It is additionally evident that the process duration differs relying upon the inflow of air from the inventory component. Henceforth for maintainability also, measure advancement, it is suggested that the HPMs be controlled with a 24 (DC) Volt info electrical energy under indicated time length for the defer time on the work pieces since the 24(DC) Volt input supply on the electro-pneumatic worked HPMs makes a difference to lessen the electrical energy utilization when HPMs is joined with electro-pneumatic and pneumatic framework. This could additionally make mindfulness on the electrical energy utilization of the mechanical based HPMs to further develop the asset waste and increment the financial goal for the HPMs use.
- The decrease in the utilization of electrical energy with the proposed 24 V for PCS and EPCS could additionally decrease the discharge of CO_2 to the climate which thusly decreases carbon impression of the Hot Packing Machine activities.

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