DESIGN AND OPTIMIZATION OF MODULAR PRODUCTION SYSTEM PICK & PLACE STATION

Farrell Aristo Siva[1)], Agustinus Purna Irawan[2)], Agus Halim[3)], Didi Widya Utama[4)]
Program Studi Sarjana Teknik Mesin, Universitas Tarumanagara
e-mail: [1)]farrell.515190014@stu.untar.ac.id, [2)]agustinus@untar.ac.id, [3)]agush@ft.untar.ac.id, [4)]didiu@ft.untar.ac.id

Abstract: *In the industrial era 4.0 where the development of sophisticated technology, the development of technology has been increasingly rapid. The industry itself began to use this sophisticated technology with the aim of seeking maximum profit with minimum capital, so for that reason the industry began to switch to "Industrial Automation". With the aim of understanding the complicated production process, MPS (Modular Production System) is made with the aim of facilitating understanding of the related production process where the MPS to be studied is Pick & Place Station. The method to be used is an experimental method where what will be studied is the effect of flowcontrol openings on cycle time, the effect of flowcontrol openings on flowsensor data, vacuum lift force, vacuum force using the venturi principle. Where the greater the flowcontrol opening, the faster the cycle time will be with the risk of cylinder damage where the first entry group produces a slower cycle time than the cycle time produced by the second entry group. The flowcontrol opening itself also affects the data in the flowsensor where the data for average mass flowrate, average flow velocity, average volumetric flowrate, average temperature, and average pressure shown by data entry 1 is smaller than data entry 2. The vacuum lift force for entry 1 and entry 2 has the same value or there is a very small change for both the distribution station and the pick & place station. For vacuum force with the venturi principle, data entry group 1 produces a smaller force than data entry group 2.*

Keywords*: Flowcontrol, Industrial Automation, Modular Production System, Venturi*

INTRODUCTION

In this day and age where technological advancements are no longer foreign to humans, the presence of automated systems is also not new to the aspects of human life. Even with the existence of Industry 4.0, the use of technology is increasingly widespread. So it can be said that Industry 4.0 is a time when the role of humans is very minimal where this is due to human work that has begun to be replaced by robots or automatic machines. Not only one aspect of human life has experienced this where the industry itself, especially in the field of production, has begun to replace the role of humans into automatic machines. Based on this incident, the term "Industrial Automation" emerged.

Industrial automation itself utilizes advanced control systems and information technology to strengthen, accelerate, and improve manual and machining processes [1]. There are many factors that cause an industry to switch to automation. These things include saving production time, saving production costs, and so on with the aim that the company that oversees the industry. PLC or which stands for Programmable Logic Controller is an electronic circuit that can perform various control functions at a complex level [2]. PLC has almost the same working principle as a microcontroller except that PLC can work on more difficult and complex commands. So that PLC is widely used in the industrial field. MPS (Modular Production System) is a series of simulations of several production machines, where MPS itself does not only refer to 1 machine, but several machines which can be combined into one to form 1 complete production process [3]. Examples of existing MPS such as Distribution Station, Pick & Place Station, Processing Station, and others. Where the function of the station itself is in accordance with the name given.

Modular Production System or commonly abbreviated as MPS is a station unit consisting of industrial components in the form of pneumatic and electrical components with a Programmable Logic Controller (PLC) controller used for industry-oriented vocational training. Each MPS consists of one type of station, controller, control panel and trolley. Each station consists of several actuator modules equipped with sensors and solenoid valves. MPS itself uses PLC as its control unit. Commands to the PLC use a control panel consisting of START, RESET, STOP buttons and AUTO-MAN switches. There are several lights that complement the control board, these lights are found on START, RESET, and 2 sign lights [4]. MPS usually has 4 stations which consist of Distribution Station, Testing Station, Processing Station, and Handling Station where each station has different functions and programs to run it. MPS has an arrangement consisting of Station Mechanics, Profile Plate, Mobile Base Frame, PLC Board [5]. PLC itself has several functions which are divided into programmable (storing a program), logic (managing commands), controller (regulating and controlling programs) [6].

Figure 1. Modular Production System [7]

The Pick & Place station is equipped with a Pick & Place module and also a Conveyor module. The workpiece housing placed on the conveyor is detected by a diffuse sensor or light barrier. The workpiece is transported to the electric separator on the conveyor belt and detected by a second diffusion sensor. You could say that this station places the workpiece into its housing. The finished workpiece, released by the separator and sent to the end of the conveyor, then the barrier will detect the workpiece at the end of the conveyor. Pick & Place Station can also be said to be an Assembly machine, this is due to the working concept of this station which puts the "Workpiece Insert" into its Housing. This station also has several functions including [8]:

a. To carry/deliver the workpiece housing.
b. To insert the workpiece insert.
c. To insert the finished or complete workpiece.

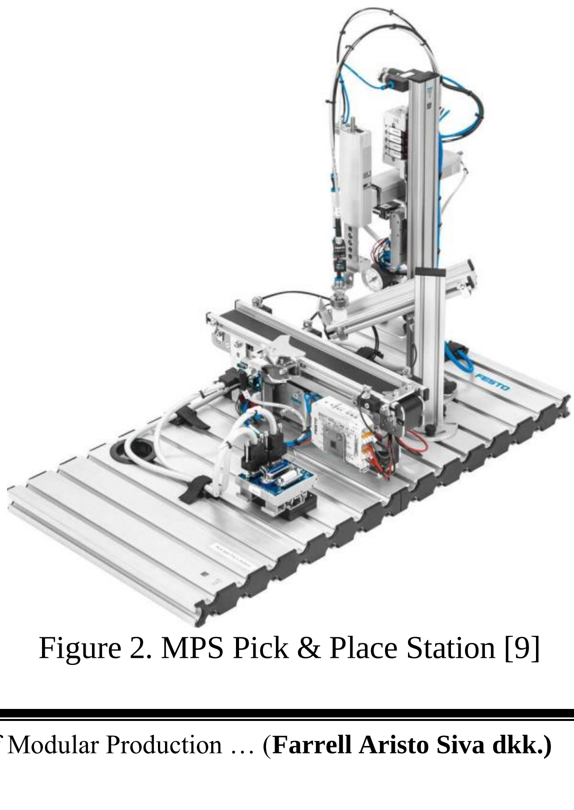

Figure 2. MPS Pick & Place Station [9]

The word Pneumatics is taken from Greek which means air or wind. Pneumatics is basically almost the same as hydraulics where if hydraulics use fluid flow then pneumatics use compressed air. In its own application, pneumatic systems are often used in automated systems. The Pneumatic system itself is assisted by several other components. The compressor that supplies pressurized air to the system where the pressure itself will be adjusted to the needs of the system to be run and the capabilities of the compressor itself. This pressure regulation can be assisted by regulators and valves, while the movement itself relies on actuators [10].

METHODS

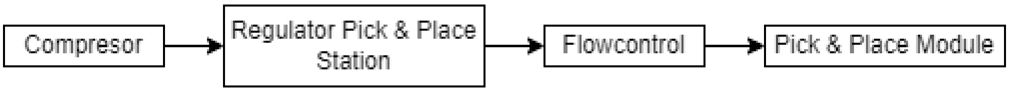

Figure 3. Flowchart

The data collection method carried out is an experimental method where the data to be taken consists of cycle time, flow control data (Mass flowrate, Flow velocity, Temperature, volumetric flowrate, pressure). While from the data taken, the average cycle time, average flow control data, vacuum lift force, and vacuum suction force will be calculated. Where data collection and calculation will be carried out in two conditions where the condition in question is the condition of the flow control opening.

Equipment Used

The equipment used in the research itself is not much this is because the existing equipment is already part of the MPS itself such as regulators, pick & place modules, valves, etc. So the equipment used consists of the MPS itself, compressor, flowcontrol, and also pneumatic hoses.

RESULTS AND DISCUSSION

Effect of Flow Control Opening on Cycle Time

The following is a table of existing experimental results where data collection is carried out 3 times where data collection is divided based on the time the process starts or is called the entry term. With the flowcontrol opening conditions as follows: Pick & place station up and down cylinder is at 5% opening and Pick & place station back and forth cylinder is at 48% aperture.

Table 1. *Cycle Time Modular Production System* (*entry* 1)

No.	***Pick & Place Station***
1	07.13 s
2	07.12 s
3	10.22 s
4	05.84 s
5	05.92 s

Total process time of pick & place station: 36.23 s
With 5 specimens, the average time required for 1 specimen pass through the process can be found by:

$$\bar{t} = \frac{\text{total process time}}{5} = \frac{36.23\ \text{s}}{5} = 7.246\ \text{s}$$

Table 2. *Cycle Time Modular Production System* (*entry 2*)

No.	*Pick & Place Station*
1	05.85 s
2	05.53 s
3	06.04 s
4	06.06 s
5	06.07 s

Total process time of pick & place station: 29.55 s
With 5 specimens, the average time required for 1 specimen to pass through the process can be found by:

$$\bar{t} = \frac{\text{total process time}}{5} = \frac{29.55 \text{ s}}{5} = 5.91 \text{ s}$$

Table 3. *Cycle Time Modular Production System* (*entry* 3)

No.	*Pick & Place Station*
1	05.82 s
2	06.06 s
3	05.83 s
4	05.89 s
5	05.92 s

Total process time of pick & place station: 29.52 s
With 5 specimens, the average time required for 1 specimen to pass through the process can be found by:

$$\bar{t} = \frac{\text{total process time}}{5} = \frac{29.52 \text{ s}}{5} = 5.9 \text{ s}$$

With the average time found for the three entries, the next step is to find the average time of all entries:

$$\bar{t}_{\text{total}} = \frac{\bar{t}_1 + \bar{t}_2 + \bar{t}_3}{3}$$

$$= \frac{7.426\text{s}+5.91 \text{ s}+5.9 \text{ s}}{3}$$

$$= 6.412 \text{ s}$$

In addition to the above data, data collection was also carried out to find the relationship between flow control openings and the cycle time of the two stations. With different opening conditions where these conditions include: The cylinder up and down the pick & place station is at an opening of 14%. Initially, data will be collected with openings of 15%-60%, but the movement of the cylinder becomes too rough.

Cylinder back and forth pick & place station is at 48% opening. Initially the experiment will be carried out with a cylinder opening state of 60%, but the cylinder movement becomes too rough which makes the pick & place module jerked so that the opening is not changed to reduce cylinder damage.

Table 4. *Cycle Time Modular Production System* (*entry* 4)

No.	*Pick & Place Station*
1	05.88 s
2	05.87 s
3	05.87 s
4	05.95 s
5	05.82 s

Total process time of pick & place station: 29.39 s
With 5 specimens, the average time required for 1 specimen to pass through the process can be found by:

$$\bar{t} = \frac{\text{total process time}}{5} = \frac{29.39\ \text{s}}{5} = 5.878\ \text{s}$$

Table 5. *Cycle Time Modular Production System* (*entry* 5)

No.	*Pick & Place Station*
1	05.90 s
2	05.71 s
3	05.78 s
4	05.92 s
5	05.76 s

Total process time of pick & place station: 29.07 s
With 5 specimens, the average time required for 1 specimen to pass through the process can be found by:

$$\bar{t} = \frac{\text{total process time}}{5} = \frac{29.07\ \text{s}}{5} = 5.814\ \text{s}$$

Table 6. *Cycle Time Modular Production System* (*entry* 6)

No.	*Pick & Place Station*
1	05.93 s
2	05.80 s
3	06.04 s
4	05.85 s
5	05.93 s

Total process time of pick & place station: 29.55 s
With 5 specimens, the average time required for 1 specimen to pass through the process can be found by:

$$\bar{t} = \frac{\text{total waktu proses}}{5} = \frac{29.55\ \text{s}}{5} = 5.91\ \text{s}$$

With the average time found for the three entries, the next step is to find the average time of all entries:

$$\bar{t}_{total} = \frac{\bar{t}_1 + \bar{t}_2 + \bar{t}_3}{3}$$
$$= \frac{5.878\ s + 5.814\ s + 5.91\ s}{3}$$
$$= 5.867\ s$$

Analysis:

In the overall average time or average cycle time, it can be seen that the average time of the 2nd entry group is faster than the average time of the 1st entry group, where the 2nd entry group has an average time of 5.867 s while the 1st entry group has an average time of 6.412 s. This is due to the enlarged flowcontrol opening where if further observed the total time required by pick & place station in the 1st entry group is longer than the 2nd entry group. The flowcontrol itself is tasked with regulating how much fluid can enter a cylinder.

Therefore, it can be said that the larger the flowcontrol opening, the faster the cycle time. But keep in mind that the larger the opening, the higher the risk of damage to the cylinder fitted with the flowcontrol. If there is no flowcontrol or the opening is too large, it is feared that the force pushing the cylinder will exceed the maximum force that can be received by the cylinder or there is an impact force that can cause damage to the cylinder. So it is important to find the optimal flowcontrol opening which makes the cylinder move quickly but does not damage it and the opening in the 2nd entry group is recommended. Although both do not damage the cylinder, the 2nd entry group opening condition has a faster cycle time.

Before and After MPS Process

Table 7. Pressure before and after the process

	Mass Flow rate	**Flow Velocity**	**Temperature**	**Volumetric Flowrate**	**Pressure**
Before Process	0 $^{kg}/_{h}$	0 $^{m}/_{s}$	24.4°C	0 $^{m^3}/_{min}$	6.07 bar
After Process	0.19 $^{kg}/_{h}$	0.2 $^{m}/_{s}$	24.2°C	0.002 $^{m^3}/_{min}$	5.99 bar

Table 8. Pressure before and after the process

	Mass Flow rate	**Flow Velocity**	**Temperature**	**Volumetric Flowrate**	**Pressure**
Before Process	0 $^{kg}/_{h}$	0 $^{m}/_{s}$	24.9°C	0 $^{m^3}/_{min}$	6.30 bar
After Process	0.13 $^{kg}/_{h}$	0.2 $^{m}/_{s}$	24.5°C	0.002 $^{m^3}/_{min}$	6.22 bar

Table 9. Pressure before and after the process

	Mass Flow rate	**Flow Velocity**	**Temperature**	**Volumetric Flowrate**	**Pressure**
Before Process	0.5 $^{kg}/_{h}$	0.6 $^{m}/_{s}$	24.6°C	0.006 $^{m^3}/_{min}$	6.85 bar
After Process	0.81 $^{kg}/_{h}$	1 $^{m}/_{s}$	24.3°C	0.01 $^{m^3}/_{min}$	6.7 bar

With the data above, the average data can be found, among others:

a. Average Mass Flowrate ($\overline{\dot{m}}$)

$$\overline{\dot{m}} = \frac{\left(0.19\ ^{kg}/_{h}\right) + \left(0.13\ ^{kg}/_{h}\right) + \left(0.31\ ^{kg}/_{h}\right)}{3}$$

$$\overline{\dot{m}} = 0.21\ ^{kg}/_{h}$$

b. Average Flow velocity ($\overline{v}$)

$$\overline{v} = \frac{0.2\ ^{m}/_{s} + 0.2\ ^{m}/_{s} + 0.4\ ^{m}/_{s}}{3}$$

$$\overline{v} = 0.27\ ^{m}/_{s}$$

c. Average Volumetric Flowrate ($\overline{\dot{V}}$)

$$\overline{Q} = \frac{0.002\ ^{m^3}/_{min} + 0.002\ ^{m^3}/_{min} + 0.004\ ^{m^3}/_{min}}{3}$$

$$\overline{Q} = 0.0027\ ^{m^3}/_{min}$$

d. Average Temperature ($\overline{T}$)

$$\overline{T} = \frac{(-0.2°C) + (-0.4°C) + (-0.3°C)}{3}$$

$\overline{T} = -0.3°C$

e. Average Pressure ($\overline{P}$)

$$\overline{P} = \frac{(-0.08\ bar) + (-0.08\ bar) + (-0.15\ bar)}{3}$$

$$\overline{P} = -0.103\ bar$$

Table 10. Pressure before and after the process

	Mass Flow rate	**Flow Velocity**	**Temperature**	**Volumetric Flowrate**	**Pressure**
Before Process	0 $^{kg}/_{h}$	0 $^{m}/_{s}$	23.3°C	0 $^{m^3}/_{min}$	5.72 bar
After Process	1.63 $^{kg}/_{h}$	2 $^{m}/_{s}$	24.3°C	0.021 $^{m^3}/_{min}$	6.92 bar

Table 11. Pressure before and after the process

	Mass Flow rate	**Flow Velocity**	**Temperature**	**Volumetric Flowrate**	**Pressure**
Before Process	0 $^{kg}/_{h}$	0 $^{m}/_{s}$	24.7°C	0 $^{m^3}/_{min}$	7.03 bar
After Process	1.04 $^{kg}/_{h}$	1.3 $^{m}/_{s}$	23.7°C	0.013 $^{m^3}/_{min}$	6.73 bar

Table 12. Pressure before and after the process

	Mass Flow rate	**Flow Velocity**	**Temperature**	**Volumetric Flowrate**	**Pressure**
Before Process	0.04 $^{kg}/_{h}$	0 $^{m}/_{s}$	23.6°C	0.001 $^{m^3}/_{min}$	6.51 bar
After Process	1.33 $^{kg}/_{h}$	1.6 $^{m}/_{s}$	23.4°C	0.017 $^{m^3}/_{min}$	6.28 bar

With the data above, the average data can be found, among others:

a. Average Mass Flowrate ($\overline{\dot{m}}$)

$$\overline{\dot{m}} = \frac{\left(1.63\ ^{kg}/_{h}\right) + \left(1.04\ ^{kg}/_{h}\right) + \left(1.29\ ^{kg}/_{h}\right)}{3}$$

$$\overline{\dot{m}} = 1.32\ ^{kg}/_{h}$$

b. Average Flow velocity ($\overline{v}$)

$$\overline{v} = \frac{2\ ^{m}/_{s} + 1.3\ ^{m}/_{s} + 1.6\ ^{m}/_{s}}{3}$$

$$\overline{v} = 1.63\ ^{m}/_{s}$$

c. Average Volumetric Flowrate ($\overline{Q}$)

$$\overline{Q} = \frac{0.021\ ^{m^3}/_{min} + 0.013\ ^{m^3}/_{min} + 0.016\ ^{m^3}/_{min}}{3}$$

$$\overline{Q} = 0.017\ ^{m^3}/_{min}$$

d. Average Temperature ($\overline{T}$)

$$\overline{T} = \frac{(1.3°C) + (-1°C) + (0.2°C)}{3}$$

$$\overline{T} = 0.17°C$$

e. Average Pressure ($\overline{P}$)

$$\overline{P} = \frac{(1.2\ bar) + (-0.3\ bar) + (-0.23\ bar)}{3}$$

$$\overline{P} = 0.223\ bar$$

Analysis:

Due to changes in the flow control opening, there are also changes in the five existing data including pressure, temperature, volumetric flowrate, flow velocity, and mass flowrate. Where by changing the flow control to be larger, the five existing data, namely mass flowrate, flow velocity, volumetric flowrate, temperature, and pressure. Mass Flowrate and Volumetric Flowrate are 2 things that are almost the same where the difference is the dependence of these two things on the existing temperature and pressure. These two things will increase along with the size of the flow control opening because more air can enter the cylinder so that the mass and volume that enters will be greater. The temperature in question is the cylinder stroke temperature where with the larger flowcontrol opening, the cylinder work will be faster and heavier as a result the temperature will rise even though it is not significant. As for pressure, the pressure itself is directly proportional to the discharge or volumetric flowrate so that if the volumetric flowrate increases, the pressure will also increase. This can cause differences in production costs when viewed in terms of industry. Indeed, the process will change to be much faster, but it will require expensive costs.

Vacuum Lifting Force

During the MPS process, whether it occurs at the pick & place station, the vacuum will experience a dynamic force where the vacuum must carry the specimen from one place to another. Where the vacuum lifting force becomes:

The first thing to look for is the angular velocity generated by the cylinder back and forth so the linear velocity of the cylinder must be found first.

$$v = 0.05\ {}^{m}/_{s}$$

$$a = \frac{v_t - v_0}{t}$$

$$a = 4.258 \times 10^{-3}\ {}^{m}/_{s^2}$$

With the linear velocity of the cylinder found, by referring to equations 2 and 3, the horizontal and vertical vacuum lift forces can be found:

$$F_v = 2.944 \times 10^{-3} N$$

$$F_H = 2.95 \times 10^{-3} N$$

$$F = \sqrt{(2.944 \times 10^{-3})^2 + (2.95 \times 10^{-3})^2}$$

$$F = 4.168 \times 10^{-3} N$$

With a change in the opening of the cylinder, the lifting power of the vacuum also changes, where the calculation will be:

The first thing to look for is the angular velocity generated by the cylinder back and forth so the linear velocity of the cylinder must be found first.

$$v = 0.05\ {}^{m}/_{s}$$

$$a = \frac{v_t - v_0}{t}$$

$$a = 4.826 \times 10^{-3}\ {}^{m}/_{s^2}$$

With the linear velocity of the cylinder found, by referring to equations 2 and 3, the horizontal and vertical vacuum lift forces can be found:

$$F_v = 2.944 \times 10^{-3} N$$
$$F_H = 2.95 \times 10^{-3} N$$
$$F = \sqrt{(2.944 \times 10^{-3})^2 + (2.95 \times 10^{-3})^2}$$
$$F = 4.168 \times 10^{-3} N$$

Analysis:
At the pick & place station, the vacuum lift force is influenced by the stroke of the cylinder back and forth which is 0.05 m. In both existing openings, it can be seen that there is a change in linear velocity but the existing changes have not been able to make significant changes to the final result of the existing lift force. So it can be said that the lift force is constant not because there is no change but the changes are too small to cause significant changes.

Venturi Calculation

Venturi calculations are carried out to find the pressure that occurs in vacuum. The process starts from the compressor to the regulator connected using an 8 mm PU hose, then continues to the terminal valve using a 6 mm PU hose, and from the terminal valve it is flowed using a 4 mm PU hose. Assuming that the vacuum diameter is the same as the diameter of the 4 mm PU hose, so the pressure becomes:
8 mm hose will be numbered 1
6 mm hose will be numbered 2
4 mm hose will be numbered 3

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$
$$6.35 = 5\ bar + \frac{1}{2}(v_2)^2 \left(1.293\ {}^{kg}/_{m^3}\right)$$
$$v_2 = 1{,}44\ {}^{m}/_{s}$$
$$P_2 - P_3 = \frac{1}{2}\rho v_2^2(\left(\frac{A_2^2}{A_3^2}\right) - 1)$$
$$5\ bar - P_3 = 0.446\ bar$$
$$P_3 = -0.446\ bar$$

Since the vacuum is equipped with a suction cup, the pressure can be converted into force which becomes:

$$P = \frac{F}{A}$$
$$-0.446\ bar = \frac{F}{2.19 \times 10^{-4}}$$
$$F = -9{,}767 \times 10^{-5}\ N$$

As a comparison, it is better to do calculations based on data from the 2nd entry group, resulting in:

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$6.59 = 5.2\ bar + \frac{1}{2}(v_2)^2 \left(1.293\ {}^{kg}/_{m^3}\right)$$

$$v_2 = 1.47\ {}^{m}/_{s}$$

$$P_2 - P_3 = \frac{1}{2}\rho v_2^2 (\left(\frac{A_2^2}{A_3^2}\right) - 1)$$

$$P_3 = -0.675\ bar$$

Since the vacuum is equipped with a suction cup, the pressure can be converted into force which becomes:

$$P = \frac{F}{A}$$

$$-0.675\ bar = \frac{F}{2.19 \times 10^{-4}}$$

$$F = -2.21 \times 10^{-3}\ N$$

Analysis:

The force referred to here is the suction force of the vacuum where this is influenced by the pressure and also the surface area of the existing hose where the size of the hose diameter used is 3 sizes, namely 8 mm, 6 mm, and 4 mm. Where based on the venturi principle when there is a difference in diameter that the fluid passes through, it will also experience a change in pressure. In fact, not only pressure, but fluid flow speed can also change. The pressure itself will experience 3 changes which adjust the size of the hose used. For air flow from the compressor to the regulator, it is connected with an 8 mm hose where 7 bar pressurized air will be flowed, then from the regulator to the terminal valve it is connected with a 6 mm hose and flowed with 5 bar pressurized air that has been adjusted by the regulator. From the terminal valve to the existing MPS parts will pass through a hose with a size of 4 mm. So that the suction pressure can be found, namely -0.446 bar (for data entry group 1) and -0.675 bar (for data entry group 2). The pressure that occurs in vacuum can be seen to have a negative value, this is due to the sucking nature of vacuum so it can be said that the minus sign acts as a direction marker only. When viewed, the pressure that occurs in both existing opening conditions, the pressure that occurs in vacuum becomes greater so that the suction from vacuum becomes stronger, so this affects the magnitude of the suction force on the MPS.

CONCLUSION

Based on the data above, it can be concluded that the aspects of the MPS are strongly influenced by the flowcontrol opening where the larger the flowcontrol opening, the faster the cycle time obtained where in condition 1 results in a time of 6.412 s and in condition 2 results in a time of 5.867 s, the greater the air demand, the greater the lift force generated although it is so small that it does not appear to change where in condition 1 and condition 2 results in a force of $4.168 \times 10^{-3} N$, and the vacuum suction force is also getting bigger where in condition 1 it is $-9{,}767 \times 10^{-5}\ N$ and in condition 2 it is $-2.21 \times 10^{-3}\ N$. So it can be concluded that the flowcontrol opening condition 2 produces more optimal results than the flowcontrol opening condition 1.

ACKNOWLEDGEMNET

The authors would like to thank the LPPM (Institute of Research and Community Service), Pneumatic & Hydraulic lab at Mechanical Engineering Department of

Tarumanagara University as institutions that helped facilitate the research and other parties who helped in the research until the preparation of the paper.

REFERENCES

[1] "Otomasi Industri: Pengertian, Cara Menghitung, dan Keuntungannya," Jurnal.id, 11 12 2018. [Online]. Available: https://www.jurnal.id/id/blog/otomasi-industri-adalah-sbc/. [Accessed 21 03 2023].

[2] "Kuliah Pemrograman Programmable Logic Controller (PLC)," Universitas Surabaya, 01 03 2020. [Online]. Available: http://te.ubaya.ac.id/kuliah-pemrograman-programmable-logic-controller-plc/. [Accessed 21 03 2023].

[3] Fernando, "Pengendalian Processing Station MPS (Modular Production System) Menggunakan PLC Twido," 2006.

[4] S. Taufiq, MODULAR PRODUCTION SYSTEM (MPS) STASIUN, Jakarta: Direktorat Pembinaan Sekolah Menengah Kejuruan Komplek Kementerian Pendidikan dan Kebudayaan, 2017.

[5] N. Arifin, "Rancang Bangun Protokol Komunikasi Antar PLC (Programmable Logic Controller) Menggunakan Metode Serial Asinkron," STIKOM SURABAYA, Surabaya, 2012

[6] "Apa itu PLC (Programmable Logic Controller)? Berikut Fungsi dan Cara Kerjanya," PROXSIS, 02 06 2022. [Online]. Available: https://surabaya.proxsisgroup.com/apa-itu-programmable-logic-controller/. [Accessed 24 03 2023].

[7] F. W. Bruns, "Remote Control of Real and Virtual Welding Robots for Learning," Research Gate, 01 2005. [Online]. Available: https://www.researchgate.net/figure/Modular-Production-System-in-Reality_fig5_241549109. [Accessed 20 03 2023].

[8] Festo, "Festo Didactic," [Online]. Available: https://ip.festo-didactic.com/InfoPortal/MPS/PickandPlaceStation/EN/index.html.

[9] Festo, "Pick&Place Station MPS D," 2023. [Online]. Available: https://www.festo.com/us/en/p/pick-place-station-id_PROD_DID_8034567/?page=0. [Accessed 20 03 2023].

[10] "Sistem Pneumatic : Pengertian, Bagian, dan kegunaannya," Inaparts, 26 08 2021. [Online]. Available: https://inaparts.com/mechanical-parts/hydraulic-pneumatic/sistem-pneumatic/. [Accessed 22 03 2023].