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Design of Rejection Subsystem for Abnormal Workpiece Condition Modular Production System at Distribution Station

Perancangan *Rejection Subsystem* Kondisi Benda Kerja Tidak Normal *Modular Production System* pada Stasiun Distribusi

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Abstract

In the industrial era 4.0, the automation system technology used is growing rapidly. Automation systems in the industry are very useful, especially in reducing production time. One of the tools that can be used to simulate production in an industry is the Modular Production System (MPS). MPS itself consists of several stations to simulate the production process on a small scale. In a production system, of course, a system is needed that can detect abnormal workpiece conditions. This system will be driven by a Programmable Logic Controller (PLC). This system will be placed at the distribution station. The rejection system in MPS is needed because, in MPS there is still a manual process, namely in the process of inserting workpieces into the stack magazine. with this manual process, it is likely that workpieces with abnormal conditions will be processed by MPS. This condition is unlikely to be processed further to the pick and place station. Therefore, objects with abnormal conditions must be separated by this rejection system. There are 2 methods used to conduct this research, namely using the 5/3 valve and the positive stop method. Data collection from both methods is done by experiment. From the experimental results of the two methods, it can be seen that the best method used for this system is the positive stop method. This method is the most appropriate method because it can produce a very accurate swivel arm stop position. From the data obtained, using the 5/3 valve method with a pressure of 4 bar the swivel arm stop position ranges from 22.4 cm to reach more than 25.8 cm, and at a pressure of 5 bar the swivel arm height ranges from 25.8 cm to more. By using the positive stop method the swivel arm stops exactly at the specified swivel arm height because the swivel arm is held by the pneumatic cylinder.

Keywords: industrial automation, modular production system, rejection system, distribution station.

***SDGs*:**

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Abstrak

Di era industri 4.0, teknologi sistem otomasi yang digunakan semakin berkembang pesat. Sistem otomasi yang terdapat pada industri sangat bermanfaat terutama untuk mengurangi waktu produksi. Salah satu alat yang dapat digunakan untuk mensimulasikan produksi di sebuah industri adalah *Modular Production System* (MPS). MPS sendiri terdiri dari beberapa stasiun untuk mensimulasikan proses produksi dalam skala kecil. Dalam sebuah sistem produksi, tentunya dibutuhkan sebuah sistem yang dapat mendeteksi kondisi benda kerja yang tidak normal. Sistem ini nantinya akan digerakkan oleh *Programable Logic Controller* (PLC). Sistem ini akan ditempatkan pada stasiun distribusi. Sistem penolakan pada MPS sangat diperlukan karena, pada MPS masih terdapat proses manual yaitu pada proses pemasukan benda kerja ke *stack magazine*. dengan adanya proses manual ini, kemungkinan benda kerja dengan kondisi tidak normal akan terproses oleh MPS. Kondisi ini tidak mungkin diproses lebih lanjut ke *pick and place station*. Oleh karena itu, benda dengan kondisi tidak normal harus dipisahkan dengan sistem penolakan ini. Terdapat 2 metode yang digunakan untuk melakukan penelitian ini, yaitu dengan menggunakan katup 5/3 dan metode positive stop. Pengambilan data dari kedua metode tersebut dilakukan dengan eksperimen. Dari hasil eksperimen kedua metode tersebut dapat diketahui bahwa metode yang pling baik digunakan untuk sistem ini adalah metode positive stop. Metode ini merupakan metode yang paling tepat, karena metode ini dapat menghasilkan posisi berhenti *swivel arm* yang sangat akurat. Dari data yang didapatkan, dengan mengunakkan metode katup 5/3 dengan tekanan 4 bar posisi berhenti *swivel arm* berkisar antara 22,4 cm hingga mencapai lebih dari 25,8 cm dan pada tekanan 5 bar tinggi swivel arm berkisar antara 25,8 cm hingga lebih. Dengan menggunakan metode *positive stop swivel arm* berhenti persis pada ketinggian *swivel arm* yang ditentukan, karena *swivel arm* ditahan oleh silinder pneumatik.

Kata Kunci: otomasi industri, *modular production system*, sistem *rejection*, stasiun distribusi.

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1. INTRODUCTION

In the industrial era 4.0 as it is today, the automation system technology used is developing more rapidly over time. Automation is a process in which there is no direct human activity (Rachman, 2023). Automation system technology that exists at this time is very useful, especially in increasing production time (Aldean and Rafli, 2022). With this automation system, various sectors can be improved, such as production time efficiency, efficiency in production costs, and can also increase production results with good quality and tend to be uniform. Therefore, many business actors in the industrial sector are utilizing and developing this automation system technology. This is due to the various advantages offered. In running automation, there are 4 main elements, namely the power source (used to run the automation process), the instruction program, the control system, and the controlled process (Fauziah, 2022).

Modular production system or MPS is a tool that can be used to simulate production using an automation system. MPS itself consists of various stations. Some of these stations function to simulate the production process on a small scale (Tanojo, 2015). In general, MPS consists of five stations where each station has different functions and programs to run it. The five stations that generally exist in MPS are distributing station, testing station, handling station, processing station, and sorting station (Badarudin, 2022).

In an automatic production process, a rejection system is also needed which functions to sort workpieces that have abnormal conditions which are often referred to as "Not Good" or NG products. This rejection system must also be carried out automatically which will be controlled by a Programmable Logic Controller or PLC using the help of sensors that will be placed on the distribution station. PLCs also have several important components, namely the Central Processing Unit (CPU), memory, input and output modules, and communication ports used for programming (Astuti, Arso and Wigati, 2015). The main function of the sensor is to respond to an input and then convert it into a current or electric potential difference which is the output (Aribowo *et al.*, 2021). Programmable Logic Controller or often referred to as PLC is a digital electronic device that uses programmable memory to store instructions such as logic, sequential, timer, and algorithms to perform and control a certain function or process (Kurniawan *et al.*, 2021). The command to the PLC uses a control panel consisting of several buttons, namely the start, reset, stop, and auto/man switches. In addition to using buttons, the control panel is also equipped with several indicator lights. This indicator light consists of a start light, reset and two sign lights (Taufiq, 2017). After the input signal is processed according to the program logic, the PLC will produce a signal in the form of an output signal which will then be used to control the MPS (Bittner and Spence, 2003; Attaran and Celik, 2023).

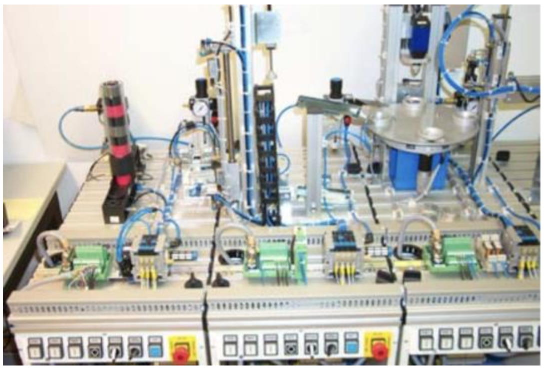

Figure 1. Modular production system in reality (Bruns and Schäfer, 2004).

This rejection system is very necessary in this MPS because in the work process of MPS there is still a manual work process that exists when inputting workpieces to the stack magazine component (see Figure 1). With this manual input process, the risk of errors occurring due to human factors, one of which occurs due to (Lande *et al.*, 2018). This research will discuss the design of the rejection subsystem for abnormal workpiece conditions of the modular production system at the distribution station which will be controlled using a PLC, so that the process can work automatically and create more accurate and effective and efficient results.

Distribution Station is one type of MPS which is a workpiece supply station. The Distribution

Station has the purpose of distributing the workpiece from its place (magazine) and transferring the workpiece available for the next process through a suction device (vacuum) (see Figure 2). Distribution Station is the beginning of an MPS where Distribution Station has 2 important parts which are Magazine Stack Module and Transfer Module (Siva, Irawan and Utama, 2023). The distributing station is composed of several electropneumatic modules which are then assembled into a single system and mechanically interconnected (Badarudin, 2022).

Figure 2. MPS distibution station (FESTO, 2007).

The purpose of this research is to create a simulation of a rejection system in the industrial world on a small scale. thus, this system can be used as a learning medium in the field of industrial automation systems.

2. METHODOLOGY

There are 2 methods used in this study, namely using the 5/3 valve method and using the positive stop method. This data collection is done by experimental tests using several variations of data collection. The variation of data collection that will be used is to use the size of the flow control opening on the cylinder.

2.1. 5/3 Valve Method

This 5/3 valve is used to move the swivel arm. The use of this 5/3 valve is intended to stop the air supply used to move the cylinder when the condition of the workpiece on the MPS is detected to be abnormal. The abnormal workpiece condition referred to in this study is a workpiece with an inverted position (Hendri *et al.*, 2023).

2.2. Positive Stop Method

In the positive stop method, there are 4 additional components, namely the 5/2 valve which is used to move the pneumatic cylinder, the pneumatic cylinder which functions as a stopper cylinder, the reed switch which functions to detect the position of the stopper cylinder, and the holder for the stopper cylinder. In addition to the addition of several necessary components, in this positive stop method there are several things that need to be considered, such as the weight and specifications of the rotary actuator so that the amount of force that will be received by the stopper cylinder is obtained. The formula for weight can be defined as (Saputra, 2018):

$$w = m \sin \theta \ . g \qquad (1)$$

where:
w = weight (N)
m = mass (kg)
ϴ = angle
g = gravitation ($^{m}/_{s^2}$)

The formula for torque can be defined as (Majedi and Puspitasari, 2017):

$$M = F \ . L \qquad (2)$$

where:
M = Torque or momen ($^{N}/_{m}$)
F = Force (N)
L = Length (m)

Spesification of rotary actuator (FESTO, 2023):

- Rotary actuator brand : Festo
- Rotary actuator type : DSR-16 180-P
- Operating pressure : 2-8 Bar
- Torque at 6 Bar : 2 Nm
- Radial Load : 75 N

2.3. Flowchart of MPS Works

Figure 3 is a flowchart of how the distribution station MPS works. When the operator presses the "start" button, the distribution station MPS will start working. This MPS will be controlled by PLC.

After the MPS starts working the PLC will check the position of the cylinder. If the cylinder position is at position X6 (initial), then the process will proceed to the next step. However, if the cylinder is not yet in position X4, the rotary actuator will retract. After the cylinder position is in the correct condition, the rotary actuator will extend and be in position X4. After that the PLC will check the position of the rotary actuator. If the rotary actuator is not in position X4 (end) within 2 seconds, the PLC will consider the workpiece as reject or NG.

If the rotary actuator position is in position X4, the vaccuum will lift the workpiece and the rotary actuator will retract to position X6, and the workpiece will proceed to the pick and place station. If within 2 seconds the rotary actuator is not in position X4, then the workpiece will be lifted, and the rotary actuator will retract to position X5 (middle). When the rotary actuator has reached position X5, the stopper cylinder will advance (extend) and then the rotary actuator will extend and be blocked by the stopper cylinder.

After the rotary actuator is completely blocked by the stopper cylinder, the vacuum will release the workpiece, and the workpiece will fall. Next, it will retract to position X6, and the stopper cylinder will retract.

3. RESULTS AND DISCUSSION

3.1. 5/3 Valve Method

The experiment is declared a failure if the height of the swivel arm has exceeded the maximum height of the swivel arm when the swivel arm rotates clockwise (see Figure 4). The following Figure 5, Figure 6, Figure 7, Figure 8, Figure 9 are existing experimental results where data collection is carried out 5 times where data collection is divided based on the magnitude of the opening in the flowcontrol and the pressure used in the rotary actuator. With the following flowcontrol opening conditions: at a pressure of 4 bar the flowcontrol opening is 8.47%, 17.1%, 25.64% and 34.19%. While at a pressure of 5 bar using a flowcontol opening of 8.47%. A value of 0 means failure.

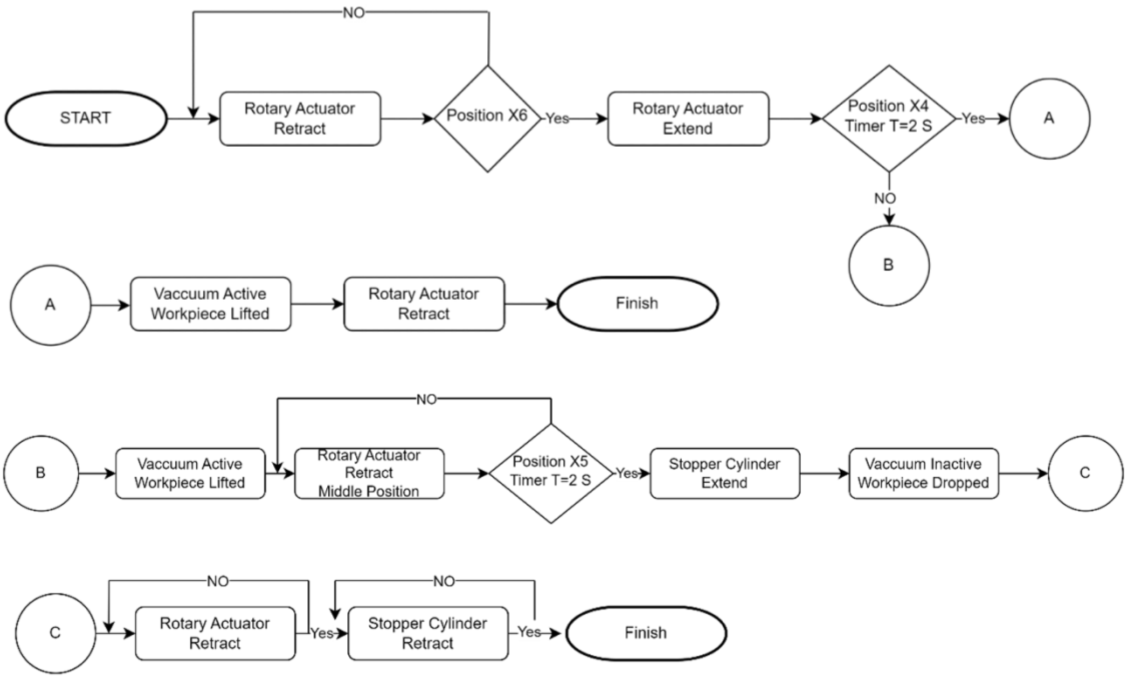

Figure 3. Flowchart of MPS works.

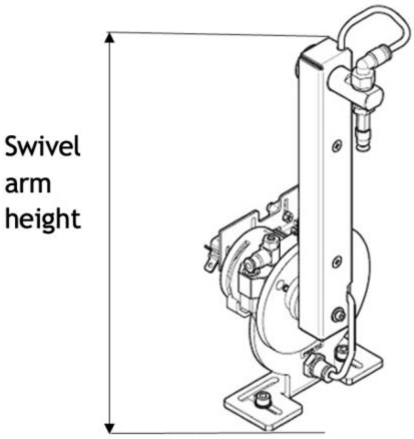

Figure 4. Swivel arm height (Schilling, 2023).

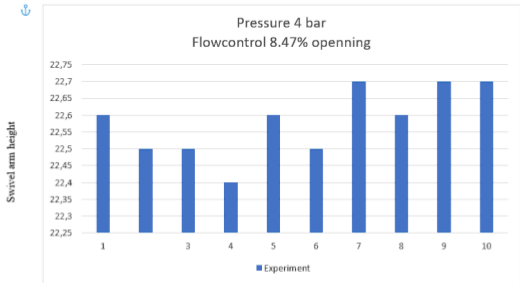

Figure 5. Valve 5/3 method data 8.47% pressure 4 bar.

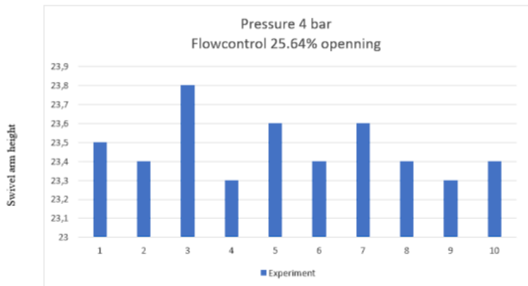

Figure 6. Valve 5/3 method data 17.1% pressure 4 bar.

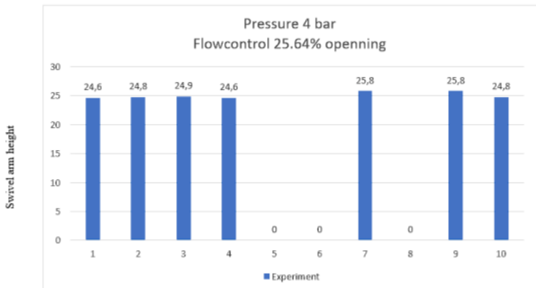

Figure 7. Valve 5/3 method data 25.64% pressure 4 bar.

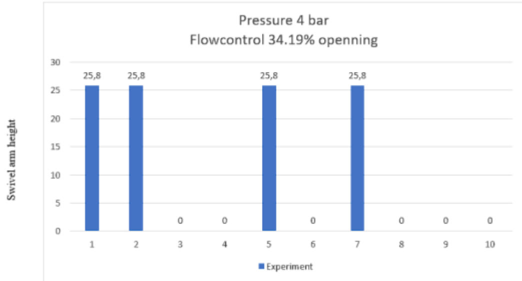

Figure 8. Valve 5/3 method data 34.19% pressure 4 bar.

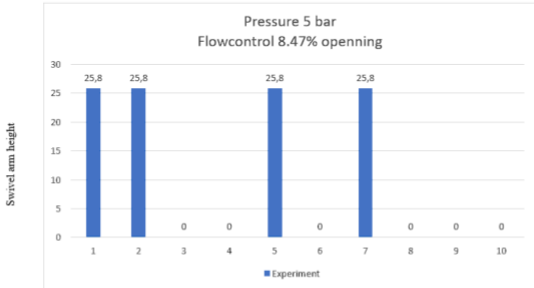

Figure 9. Valve 5/3 method data 8.47% pressure 5 bar.

From the experiments that have been carried out; by using the 5/3 high valve method the swivel arm will stop with a position that is always different, even experiencing failure (inaccurate). The swivel arm stop position has a small difference when using a small flow control opening. This small flow control opening will cause the swivel arm to move very slowly. therefore, the system will not work effectively.

3.2. Positive Stop Method

This positive stop method is done by using the addition of a pneumatic cylinder component that functions as a barrier (wedge) from the swivel arm movement, so that it can produce an accurate swivel arm stop position. Thus, before designing the rejection system on MPS, there are several things that need to be considered. Some of these things that need to be considered are:

a. Swivel arm mass : 156 gr → 0.156 kg
b. Inner swivel arm mass : 180 gr → 0.18 kg
c. Belt mass : 4 gr → 0.004 kg
d. Vaccuum and gear mass : 86 gr → 0.086 kg
e. Workpiece mass : 14 gr → 0.014 kg

Calculation of the weight and force that will be received by the wedge when the swivel arm moves:

a. Weight of swivel arm

$$W_{Swivel\ Arm} = m\ g\ \sin\theta$$
$$= 0{,}15\ kg\ 9{,}81\ {}^{m}/_{s^2}\ \sin 60$$
$$= 1{,}325\ N$$

b. Weight of inner swivel arm

$$W_{Inner\ Swivel\ Arm} = m\ g\ \sin\theta$$
$$= 0{,}18\ kg\ 9{,}81\ {}^{m}/_{s^2}\ \sin 60$$
$$= 1{,}529\ N$$

c. Weight of belt

$$W_{Belt} = m\ g\ \sin\theta$$
$$= 0{,}004\ kg\ 9{,}81\ {}^{m}/_{s^2}\ \sin 60$$
$$= 0{,}034\ N$$

d. Weight of vacuum and gear

$$W_{Vaccuum\ dan\ gear} = m\ g\ \sin\theta$$
$$= 0{,}086\ kg\ 9{,}81\ {}^{m}/_{s^2}\ \sin 60$$
$$= 0{,}731\ N$$

e. Weight or work piece

$$W_{Benda\ Kerja} = m\ g\ \sin\theta$$
$$= 0{,}014\ kg\ 9{,}81\ {}^{m}/_{s^2}\ \sin 60$$
$$= 0{,}3398\ N$$

f. Force when swivel arm moves

$$T_{at\ pressure\ 4\ bar} = \frac{2\ Nm}{6\ bar}\ x\ 4\ bar \quad (3)$$
$$= 1{,}333\ Nm$$

$$T_{at\ pressure\ 4\ bar} = F\ x\ r \quad (4)$$
$$1{,}333\ Nm = F\ x\ 0{,}08905m$$
$$F = 14{,}969\ \text{N}$$

g. Total force

$$\sum F = F + W_{Swivel\ Arm} + W_{Inner\ Swivel\ Arm} + W_{Belt} + W_{Vaccuum\ dan\ gear} + W_{Benda\ Kerja} \quad (5)$$

$$\sum F = 14{,}969\ N + 1{,}325\ N + 1{,}529\ + 0{,}731\ N + 0{,}3398\ N$$
$$\sum F = 18{,}894\ N$$

After the calculations above, the stopper cylinder to be used must be able to accept a minimum load of 19 N. Therefore, a cylinder by using the positive stop method, data collection is also carried out by experimentation.

Data collection is carried out with several variations of flow control openings. The flowcontrol openings used are 13.33%, 26.67%, 40% with a pressure of 4 bar with a size of Ø16 mm is selected.

Table 1. Positive stop method data 13.33% pressure 4 bar

Experiment	Swivel Arm Height (cm)
1	Fail
2	Fail
3	Fail
4	Fail
5	Fail
6	Fail
7	Fail
8	Fail
9	Fail
10	Fail

Failure occurs due to the stopper cylinder moving forward too slowly, so that when the swivel arm goes down the stopper cylinder is held by the swivel arm and causes the stopper cylinder to not be in the correct position (dislocation). The dislocation that occurs in the stopper cylinder can then provide several conditions that cause failure (see Table 1). One of the conditions that causes this failure is that the position of the swivel arm is not in the position it should be. This failure is shown in Figure 10.

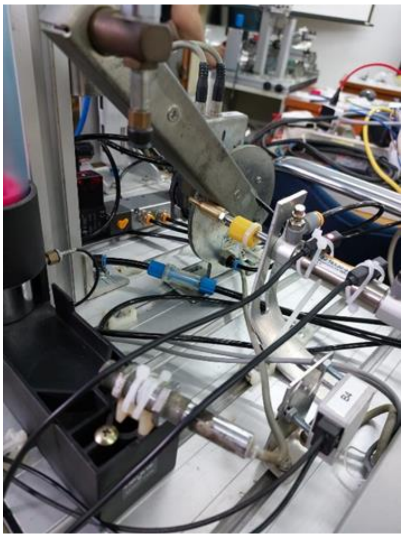

Figure 10. Failure condition of rejection system.

Table 2. Positive stop metod data 26,67% pressure 4 bar.

Experiment	Swivel Arm Height (cm)
1	Success
2	Success
3	Fail
4	Success
5	Fail
6	Fail
7	Success
8	Success
9	Fail
10	Success

In this second experiment (see Table 2), failures still occurred several times. The failure rate was 40%. This figure is still quite high. The occurrence of failure is also caused by the forward speed of the cylinder which is not too fast (Majedi and Puspitasari, 2017).

Table 3. Positive stop metod data 40% pressure 4 bar.

Experiment	Swivel Arm Height (cm)
1	Success
2	Success
3	Success
4	Success
5	Success
6	Success
7	Success
8	Success
9	Success
10	Success

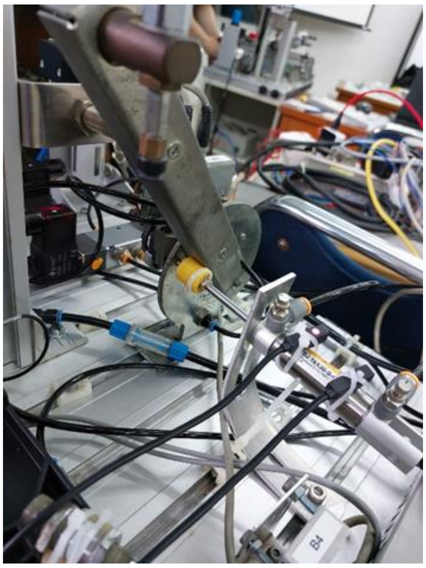

Figure 11. Success condition of rejection system.

In this third experiment, the failure was no longer seen in 10 experiments (see Table 3). The forward speed of the stopper cylinder has also been classified as the optimal speed for running this rejection system (Lande *et al.*, 2018). The rejection system can be declared successful if the position of the stopper cylinder and swivel arm is in a predetermined position. This success condition can be seen in Figure 11.

4. CONCLUSION

From the data that has been presented, it can be concluded that by using the 5/3 valve method, the position of the swivel arm can stop approaching the desired position when the maximum flow control opening is 17.1% using a pressure of 4 bar. However, the system movement becomes ineffective because the swivel arm moves very slowly. The swivel arm can stop at the desired position accurately with the positive stop method, where the swivel arm is forced to stop at the specified position. The success rate of performance is only measured by the magnitude of the flow control opening contained in the stopper cylinder.

REFERENCES

Aldean and Rafli, A.M. (2022) *Otomasi Industri : Pengertian, Cara Menghitung, dan Keuntungannya*, *Mekari Jurnal*. Available at: https://www.jurnal.id/id/blog/otomasi-industri-adalah-sbc/ (Accessed: 4 January 2023).

Aribowo, D. *et al.* (2021) 'Sistem Perancangan Conveyor Menggunakan Sensor Proximity PR18-8DN Pada Wood Sanding Machine', *EDUSAINTEK: Jurnal Pendidikan, Sains dan Teknologi*, 8(1), pp. 67–81.

Astuti, S.I., Arso, S.P. and Wigati, P.A. (2015) 'Analisis Standar Pelayanan Minimal Pada Instalasi Rawat Jalan Di RSUD Kota Semarang', *Jurnal Kesehatan Masyarakat*, 3(1), pp. 103–111.

Attaran, M. and Celik, B.G. (2023) 'Digital Twin: Benefits, Use Cases, Challenges, And Opportunities', *Decision Analytics Journal*, 6, p. 100165..

Badarudin, R. (2022) 'Virtual Distributing Station Sebagai Sarana Media Pemrograman PLC', *Jurnal Edukasi Elektro*, 6(2), pp. 75–84.

Bittner, K. and Spence, I. (2003) *Use Case Modeling*. Boston: Addison-Wesley Professional. [Print].

Bruns, W. and Schäfer, K. (2004) 'Remote Control of Real and Virtual Welding Robots for Learning', in *IFAC Proceedings Volumes. 7th IFAC Symposium on Cost-Oriented Automation (COA 2004)*, Gatineau, Québec, Canada: IFAC Community (7th IFAC Symposium on Cost-Oriented Automation (COA 2004), Gatineau, Québec, Canada, 6-9 June 2004), pp. 215–219.

Fauziah, G.N. (2022) *Rancangan Konveyor Pada Proses Perpindahan Material Pada Mesin Semi Otomasi Finger Joint Dari Pembuatan Produk Door Frame di PT. Interkayu Nusantara*. Skripsi. Universitas Trisakti. Available at: http://103.49.68.23/usaktiana/index.php/home/detail/detail_koleksi/0/SKR/th_terbit/00000000000000107254/0# (Accessed: 19 July 2023).

FESTO (2007) 'Learning Systems Modular Systems For Mechatronics Training'. FESTO. Available at: https://www.scribd.com/document/490765255/Modular-Learning-Systems-for-Mechatronics-Training (Accessed: 23 April 2027).

FESTO (2023) *Semi-rotary drives DSR/DSRL, Catalog*. Available at: https://www.festo.com/media/pim/160/D15000100122160.PDF (Accessed: 2 March 2023).

Hendri, A. *et al.* (2023) 'Sistem Kerja Buka Tutup Pintu Secara Automatis Menggunakan Foto Sensor dan Sistem Manual Pneumatik', *Marine Science and Technology Journal*, 3(2), pp. 39–44.

Kurniawan, A. *et al.* (2021) 'Pelatihan Dasar Programmable Logic Controller (PLC) Berbasis Daring Menggunakan PLC Fiddle Untuk Guru SMK di Surabaya', *Sewagati*, 5(3), pp. 278–285.

Lande, D. *et al.* (2018) 'Automated System for Rejection of Poor Quality Material', in *IOSR Journal of Engineering (IOSRJEN). 7th National conference on Recent Developments in Mechanical Engineering RDME-2018*, Pune, India: Department of Mechanical Engineering, College of Engineering, pp. 51-54.

Majedi, F. and Puspitasari, I. (2017) 'Optimasi Daya dan Torsi pada Motor 4 Tak dengan Modifikasi Crankshaft dan Porting pada Cylinder Head', *JTT (Jurnal Teknologi Terpadu)*, 5(1), pp. 82–89.

Rachman, T. (2023) 'Konsep Dasar Optimasi'. Universitas Esa Unggul. Available at: https://lms-paralel.esaunggul.ac.id/pluginfile.php?file=%2F174549%2Fmod_resource%2Fcontent%2F1%2F02_6623_TKT312_032019_pdf.pdf (Accessed: 7 February 2024).

Saputra, H. (2018) 'Analisis Konsepsi Siswa Konsep Dinamika Gerak', *GRAVITASI: Jurnal Pendidikan Fisika dan Sains*, 1(1), pp. 21–31.

Schilling, H. (2023) *The translation dilemma - Intended use vs. intended purpose*, *seleon GmbH*. Available at: https://www.seleon.com/en/the-translation-dilemma-intended-use-vs-intended-purpose/ (Accessed: 4 May 2024).

Siva, F.A., Irawan, A.P. and Utama, D.W. (2023) 'Design and Optimization of Modular Production System Distribution and Pick & Place Station', *International Journal of Innovative Science and Research Technology (IJISRT)*, 8(7), pp. 3057–3065.

Tanojo, D. (2015) 'Kontrol Modular Production System Berbasis PLC Siemens S7-300 Dengan Menggunakan HMI Touch Panel Damaris Tanojo', *CALYPTRA*, 4(1), pp. 1–8.

Taufiq (2017) *Modular Production System (MPS) Stasiun Distribusi Dengan Siemens S7300*. 1st edn. Jakarta, Indonesia: Direktorat Pembinaan Sekolah Menengah Kejuruan Kementerian Pendidikan dan Kebudayaan. [Print].