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Design and Optimizing Top Cover Feeding Unit Modular Production System and Pick & Place Station

Perancangan dan Optimalisasi *Top Cover Feeding* Unit *Modular Production System* dan *Pick & Place Station*

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Abstract

Modular Production System is a station unit consisting of industrial components in the form of pneumatic and electrical components controlled by a Programmable Logic Controller which is directed for industry-oriented vocational training. In a Modular Production System, there are several types of stations, one of which is the pick and place station which consists of two modules, namely the pick and place module and the conveyor module. This design discusses the optimization of the design of the top cover feeding unit at the pick and place station because the top cover is dislocated every time there is a change in position when the vacuum sucks the top cover. This design optimization is done by redesigning the feeding unit slider. By doing this optimization, it can make the feeding unit accommodate the top cover where it should be and improve the process capability of the system. The results of this optimization are determined based on the process capability values, before optimization the resulting values were 1.0417 for Capabiity Process and 0.77 for the index. Then after design optimization, the values are 3.402 for Capabilty Process and 6.396 for the index and produce a total force of 0.205 N by using a slider feeding unit tilt angle of 14o. This tilt angle was determined as the most optimal angle because it resulted in the least system failure.

Keywords: modular production system, pick and place station, capability process, tilt angle, total force.

***SDGs*:**

Abstrak

Modular Production System adalah suatu unit stasiun yang terdiri dari komponen-komponen industri berupa komponen pneumatik dan elektrik yang dikontrol oleh *Programmable Logic Controller* yang diarahkan untuk pelatihan vokasi yang berorientasi pada industri. Pada *Modular Production System* terdapat beberapa jenis stasiun, salah satunya adalah stasiun *pick & place* yang terdiri dari dua modul, yaitu modul *pick & place* dan modul konveyor. Perancangan ini membahas tentang optimasi desain unit pengumpan top cover pada stasiun *pick & place* karena *top* cover mengalami dislokasi setiap kali terjadi perubahan posisi pada saat vacuum menghisap *top* cover. Optimasi desain ini dilakukan dengan mendesain ulang *slider feeding* unit. Dengan melakukan optimasi ini, dapat membuat *feeding* unit dapat mengakomodasi *top* cover pada tempat yang seharusnya dan meningkatkan kemampuan proses dari sistem. Hasil dari optimasi ini ditentukan berdasarkan nilai kapabilitas proses, sebelum dilakukan optimasi nilai yang dihasilkan adalah 1,0417 untuk kapabilitas proses dan 0,77 untuk indeks. Kemudian setelah dilakukan optimasi desain, nilai yang dihasilkan adalah 3,402 untuk Capabilty Process dan 6,396 untuk index dan menghasilkan total gaya sebesar 0,205 N dengan menggunakan sudut kemiringan slider feeding unit sebesar 14°. Sudut kemiringan ini ditentukan sebagai sudut yang paling optimal karena menghasilkan kegagalan sistem yang paling kecil.

Kata Kunci: sistem produksi modular, *pick & place station*, kapabilitas proses, sudut kemiringan, total gaya.

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1. INTRODUCTION

Automation in the industrial era 5.0 is currently a technology that is very helpful in increasing production. With the automation applied to the industrial field, there are several improvements, namely, improving product quality, time efficiency, and reducing costs (Darto, 2015; Ricky and Habibullah, 2022). Therefore, many industry players need automation design to be applied to their industry.

Modular Production System is one type of several existing automation systems, which is a station unit consisting of industrial components in the form of pneumatic and electrical components controlled by a Programmable Logic Controller which is directed for vocational training oriented to the industrial field (Tanojo, 2015; Rimantho and Athiyah, 2019). In a Modular Production System there are several types of stations, one of which is a pick and place station which consists of two modules, namely the pick and place module and the conveyor module. The way the first pick and place station works are that the workpiece is placed on the conveyor and detected by a diffuse sensor or light barrier sensor. The workpiece is transported to the electric separator on the conveyor belt and detected by the second diffuse sensor. The cylinder takes the top cover by being sucked on the feeding unit to be united to the workpiece on the conveyor (Siva, Irawan and Utama, 2023).

In this design, it discusses the optimization of the design of the top cover feeding unit at the pick and place station which makes the workpiece dislocated every time there is movement, where the top cover dislocation occurs every time, there is a change in position when the vacuum sucks the top cover. Optimization of this design is done by redesigning the slider feeding unit. By doing this optimization, it can make the feeding unit accommodate the top cover where it should be and increase the process capability of this pick and place station system.

Modular Production System is a station unit consisting of industrial components in the form of pneumatic and electrical components controlled by a Programmable Logic Controller which is directed for industry-oriented vocational training (Jenaro and Suprianto, 2020). In a Modular Production System there are several stations, namely, distribution stations and Pick and Place stations (FESTO, 2023). The operation of Modular Production System also has several processes consisting of input, process, output. The input received by the Modular Production System comes from sensors, limit switches, push buttons and selection switches (Tuapetel and Narwalutama, 2022). While the process carried out by the Modular Production System is in accordance with the program entered into the Modular Production System (see Figure 1). The output of the Modular Production System is in the form of movement in accordance with the program that has been entered (Taufiq, 2017).

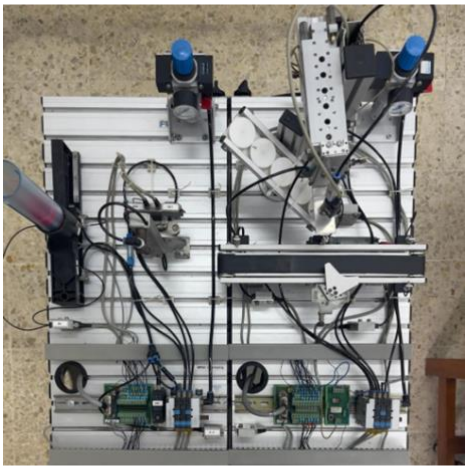

Figure 1. Modular production system (Siva, Irawan and Utama, 2023).

Figure 2. Pick and place station (Siva, Irawan and Utama, 2023).

The Pick & Place Station consists of two modules, namely the Pick & Place module and the Conveyor Module (see Figure 2). How the Pick and Place Station works, first the workpiece is placed on the conveyor and detected by a diffuse sensor or light barrier sensor.

The workpiece is transported to the electric separator by the conveyor belt and detected by a second diffuse sensor. Then, this station puts the workpieces on the feeding unit into the housing. The finished workpiece is released by the electric separator and carried to the end by the conveyor and stops when the diffuse sensor reads the presence of the workpiece at the end of the conveyor (Siva, Irawan and Utama, 2023).

In the pick and place station as shown in Figure 3, there is a pick and place module, in this module there is a slider feeding unit, a double-acting cylinder and a vacuum. Top cover is the workpiece that used in this module.

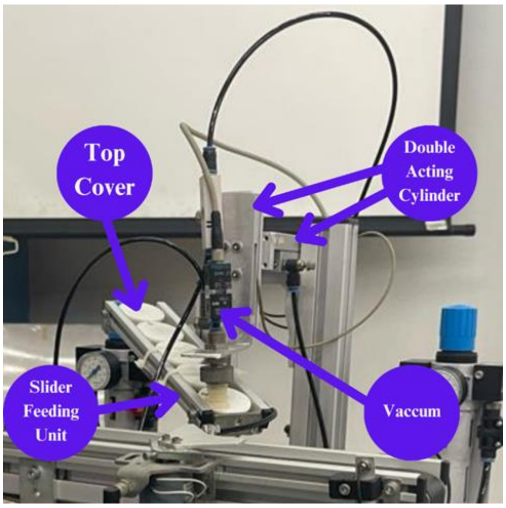

Figure 3. Pick and place module (Siva, Irawan and Utama, 2023).

2. METHODOLOGY

Optimization carried out at the pick and place station will be related to the design of the slider feeding unit and to the top cover. The data that will be taken in this design is the design of the slider feeding unit and the tilt angle of the slider feeding unit so that the pick and place station can run optimally by finding the best design. The method used in data collection is the experimental method. Experiments were conducted under the specified conditions, the difference in the slope angle of the slider feeding unit. The flow chart shown in Figure 4 is the steps taken in doing this design and research.

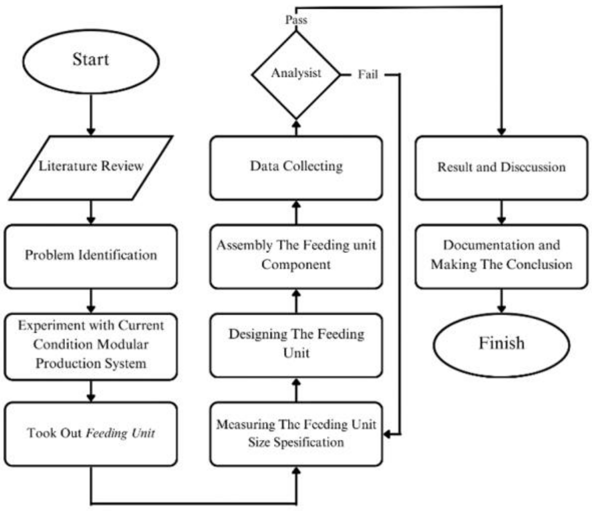

Figure 4. Designing and research flowchart.

in this design, several equations are also used, including:

- Equation for determine the capability process value (Rahmawati *et al.*, 2020):

$$Cp = \frac{USL-LSL}{6\sigma} \quad (1)$$

where:
Cp : Capability Process Value
USL : Upper Specification Level
LSL : Lower Specification Level
σ : Deviation Standard

- Equation for determine the centered capability process value (Hayati and Hasanah, 2022):

$$Cpk = min\left(\frac{USL-\bar{X}}{3\sigma}, \frac{\bar{X}-LSL}{3\sigma}\right) \quad (2)$$

where:
Cpk : Capability Process Value
$\bar{X}$: Mean of Data
USL : Upper Specification Level
LSL : Lower Specification Level
σ : Deviation Standard

- Equation for determine the Total Force (Astro, Amirudin and Mufida, 2017; Prastyo *et al.*, 2021):

$$\sum F = ma \quad (3)$$

$$mg \sin\theta - F_f = ma \quad (4)$$

$$mg \sin\theta - \mu_f mg \cos\theta = ma \quad (5)$$

$$g(\sin\theta - \mu_f \cos\theta) = a \quad (6)$$

where:

$\sum F$: Total Force (N)

F_f : Friction Force (N)

m : Mass (Kg)

g : Gravity (m/s^2)

μ_f : Friction Coefficient

a : Acceleration (m/s^2)

3. RESULTS AND DISCUSSION

3.1. Design Optimization

In this design, the changes made for design optimization are to remake the design of the slider holder on the feeding unit and the addition of the top stopper and the front stopper. As for the replacement of the top cover to get more organized specifications. Figure 5 as shown the design of the slider holder and top cover before design optimization.

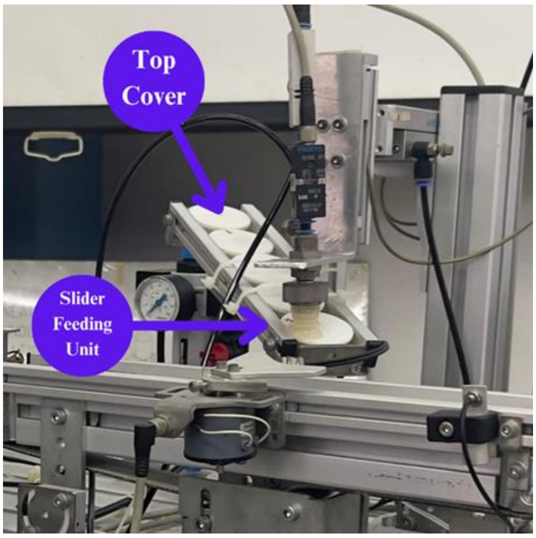

Figure 5. Feeding unit slider before optimization (Siva, Irawan and Utama, 2023).

As seen in Figure 5, the top cover on the slider is not well supported, where only the outermost part of the top cover touches the slider, and the weight of the top cover is too light. Therefore, dislocation often occurs when using this design. Meanwhile, in Figure 6, there are more stoppers that keep the top cover always in a predetermined place. The slider wall is also made tighter so that more parts of the top cover are suspended so that the top cover can be more stable (Siva, Irawan and Utama, 2023). Then, the top cover is also replaced using more regular specifications and weights.

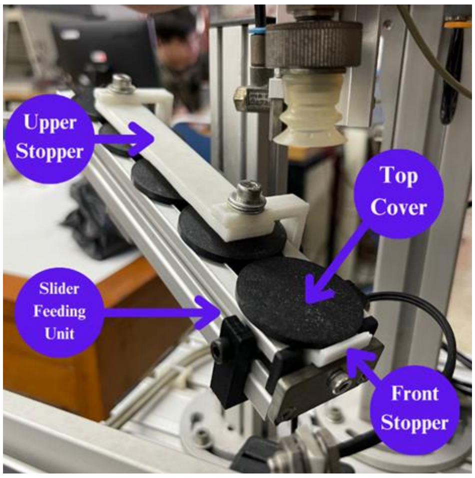

Figure 6. Feeding unit slider after optimization.

3.2. Design Optimization Assessment using Cp and Cpk Values

This calculation is based on data on the number of successes and failures that occur when running the pick & place station cycle 40 times in one loop using a maximum limit of 40 and a minimum limit of 20.

Table 1. Data on the number of successful cycles before optimization.

Loop	Number of Succesful Cycle
1	26/40
2	31/40
3	30/40
4	28/40
5	22/40

The data in Table 1 is used to calculate the Cp and Cpk values when no design optimization has been done.

- Mean of Data ($\bar{x}$): 27.4
- Deviation Standard (σ): 3.2

Cp and Cpk values can be found by:

$$Cp = \frac{USL - LSL}{6\sigma} = \frac{40 - 20}{6 \times 3.2} = \frac{20}{19.2} = 1.0417$$

$$Cpk = min\left(\frac{USL - \bar{x}}{3\sigma}, \frac{\bar{x} - LSL}{3\sigma}\right)$$

$$= min\left(\frac{40 - 27.4}{3 \times 3.2}, \frac{27.4 - 20}{3 \times 3.2}\right)$$

$$= min\left(\frac{12.6}{9.6}, \frac{7.4}{9.6}\right)$$

$$= \min(1.3125;\ 0.77) = 0.77$$

Table 2. Data on the number of successful cycles after optimization with variety of tilt angle.

Loop	Number of Succesful Cycle			
	14°	15°	16°	17°
1	39/40	40/40	35/40	35/40
2	40/40	38/40	36/40	35/40
3	39/40	39/40	37/40	33/40
4	39/40	37/40	33/40	32/40
5	37/40	38/40	37/40	34/40

The data in Table 2 is used to calculate the Cp and Cpk values when design optimization has been done. The equation below is one of the examples using the 14° tilt angle.

- Mean of Data ($\bar{x}$): 38,8
- Deviation Standard (σ): 0,979

Cp and Cpk values at 14° tilt angle can be found by:

$$Cp = \frac{USL - LSL}{6\sigma} = \frac{40 - 20}{6 \times 0.979} = \frac{20}{5.878}$$
$$= 3.402$$

$$Cpk = min\left(\frac{USL - \bar{x}}{3\sigma}, \frac{\bar{x} - LSL}{3\sigma}\right)$$
$$= min\left(\frac{40 - 38.8}{3 \times 0.979}, \frac{38.8 - 20}{3 \times 0.979}\right)$$
$$= min\left(\frac{1.2}{6.462}, \frac{18.8}{6.462}\right)$$
$$= \min(0.41; 6.396) = 6.396$$

Table 3. Result of the Cp and Cpk values.

	Before	After			
		14°	15°	16°	17°
Cp Value	1.0417	3.402	3.268	2.227	2.858
Cpk Value	0.77	6.396	6.014	3.474	3.944

From the calculation of the Cp and Cpk values in Table 3, it is found that the process capability values of Cp and Cpk vary due to the different angles at the time of data collection. However, the process capability values of Cp and Cpk when after design optimization has been much improved compared to before design optimization. Where, before design optimization, the resulting Cp and Cpk process capability values were 1.0417 and 0.77, respectively. Then, after optimizing the design with variations in the angle of inclination, the lowest Cp and Cpk process capability values produced were 1.497 and 2.275 respectively using an angle of 16° and the highest Cp and Cpk values using an angle of 14°, namely 3.402 and 6.396 respectively. Based on these results, it can be concluded that the design and optimization of the design of the slider feeding unit and top cover make the process capability of the pick & place station better (Siva, Irawan and Utama, 2023).

3.3. Analysist

The Table 4 is the result of all the discussion that have been carried out.

Table 4. Result of all data collected.

Tilt Angle (θ)	Cp Value	Cpk Value	Total Force (N)
14°	3,402	6,396	0,205
15°	3,268	6,014	0,221
16°	2,227	3,474	0,235
17°	2,858	3,944	0,248

Referring to the discussion and calculations that have been carried out, it is found that the process capability values Cp and Cpk before design optimization produce Cp and Cpk values of 1.042 and 0.77. Then, when after design optimization, it produces the highest Cp and Cpk values of 3.402 and 6.396 with a tilt angle of 14°. However, in the calculation of the force acting at an angle of inclination of 14° is the lowest total force value of 0.205 N while the highest total force value is obtained at an angle of inclination of 17° which is 0.248 N. It can be concluded that in this optimization the total force generated by the top cover is not required to be too large because based on direct experiments with a large total force resulting in the top cover hitting the front stopper too tightly so that the top cover is lifted from the slider which results in dislocation still occurs. Therefore, although the total force at the 14° tilt angle is the lowest, it has the highest capability value compared to other angles, so this 14° tilt angle is used because it is the condition that makes the system run with the least failure.

4. CONCLUSION

Based on the results of the design and optimization that has been carried out at the pick & place station, it can be concluded that, the way that can be done to minimize the dislocation that occurs on the top cover is to close the position of the slider wall so that more of the top cover surface is supported by the slider and also add a front stopper and top stopper to keep the top cover in the specified position. also obtained Cp and Cpk process capability values before design optimization are 1.0417 and 0.77, respectively. Then after design optimization, it increased to 3.402 and 6.396 by using a tilt angle of 14o. In the calculation of the total force acting on the slider and top cover, the highest total force is obtained when the tilt angle is 17° with a result of 0.248 N and the lowest total force is obtained at an angle of inclination of 14° with a result of 0.205 N. In this optimization, the slider tilt angle is set at 14° because in this condition the system can run optimally. Optimization of the slider feeding unit and top cover can be said to be successful because after optimization based on the process capability values Cp and Cpk, the results obtained are above the minimum standard.

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