Implementation of Continuous Improvement to Increase the Efficiency of the Production Process through Press Dies Design

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ABSTRACT

In the manufacturing industry, there are companies that operate in the metal forming sector. Many products are produced by the metal forming process, one of which is the packaging box lock hook. The key hook is a component part of the packaging box which functions as a hook so that the packaging box can be closed and locked. In the production of key hooks there is waste, namely over processing, which reduces the efficiency of production time. To reduce this problem, improvement efforts were made by implementing continuous improvement using the DMAIC method. Continuous improvement steps are carried out by direct observation in the field to find problems. After that, measurements and analysis are carried out to determine improvements that will be implemented. Then the improvement stage was carried out as an implementation of continuous improvement. Continuous improvement resulted in a press dies design for the key hook piercing process. By designing new press dies, production time efficiency will be achieved. After carrying out Continuous Improvement, it resulted in an increase in the efficiency of the number of processes from 6 processes to 5 processes and the total production time in 1 cycle from 13.3 hours to 11.4 hours or 1.9 hours faster or an increase in efficiency of 13.3 % of the total time before Continuous Improvement. And 50% increase in sub piercing process.

Keywords: continuous improvement, efficiency, press dies

INTRODUCTION

Manufacturing companies must have strategies that continue to develop in order to be able to compete and remain able to withstand the pressures that exist in the industrial world. In the manufacturing production process, there is a combination of two production times, namely the time where the production process is related to value added activities and the time where the production process does not have added value (non value added time). These two things cannot be separated in a series of manufacturing production processes where this will influence business competition. The more activities that occur in a production process, the more costs a company incurs. Consumers do not feel the direct impact of activities, but consumers can feel the increase in product selling prices. According to (Ramadhani et al, 2023) the cost of production determines the selling price of a product. When the selling price of a product is high, the product's competitiveness in the market will also decrease because consumers will automatically choose the same product at a lower price.

In a manufacturing company engaged in metal forming . In its production activities, converts steel plate sheet raw materials into products that have sales value. Many products are produced by manufacturing companies, one of which is the packaging box lock hook. The key hook is a component part of the packaging box which functions as a hook so that the packaging box can be closed and locked. The key hook uses SPCC steel plate material with a thickness of 1.5 mm. Looking at the production process, making key hooks consists of several work sequences, namely: cutting, blanking, piercing 1, piercing 2, bending, finishing paint. Judging from the existing processes, there are two identical processes, namely piercing process 1 and piercing 2. Looking at several existing processes, the author sees opportunities for continuous improvement.

Continuous improvement in manufacturing system processes is important (Akter et al, 2015), in all production process activities it is something that needs to be considered because consumers do not want waste which results in the high value of a product and want the product purchased to be free of defects. Kaizen is continuous process improvement, often considered the most important cornerstone of some production methods (Bond, 1999). Continuous improvement can be carried out by eliminating obstacles in the process flow, increasing process capabilities so that they can produce products that are of high quality and can compete in the market. Therefore, factors that can hinder process flow and capability must be identified and minimized so that process flow can run smoothly, process capability increases, and effectiveness and efficiency are achieved (Cahyanti et al, 2012). In the production process Continuous improvement can also be used to minimize waste . Waste is a situation where the implementation of production uses time, materials, energy or costs that exceed the appropriate amount (Sinulingga, 2009: 63). Waste contained in the product manufacturing process must be eliminated. Eliminating waste with the aim of minimizing human effort, minimizing inventory, minimizing time to develop products, minimizing time to fulfill customer requests with quality products, and minimizing defective or damaged products. Apart from this, eliminating waste will be able to stimulate or stimulate the company's competitive advantage, especially on increasing productivity and quality (Cahyanti et al, 2012). Efforts to reduce waste or activities can be carried out in activities that provide added value, for example by carrying out continuous improvements in the efficiency of the traffic of materials, operators, tools and machines which give rise to redundant processes.

According to Shigeo Shingo (Kato and Smalley, 2011: 34) there are 7 types of waste, namely over production, excess inventory, scrap and rework, waiting time, transportation. excessive, excessive movement and excessive processing. From the explanation above, in the process of making key hooks there is waste in the form of excessive processing. Excessive waste in the process certainly has a negative impact on the company, especially on production time efficiency. Likewise, what happens in the production process that there is production process waste. For this reason, it is necessary to carry out Continuous Improvement steps with the aim of reducing existing waste.

METHOD

The research method used in this research is design. The design of a press die is obtained from the development of continuous improvement carried out on the key hook production process. The research was conducted at a manufacturing company located in Malang district. This company is a manufacturing company that operates in the metal forming sector. The research was carried out from March 6 2024 to March 30 2024. The research was carried out at the Supporting Production Unit where the Unit produces product packaging facilities.

In the research process there are several stages starting with a field study where direct observations are made of the research object, namely the key hook production process. After observations are made, the problem within the research object is formulated. From the existing problem, proceed with looking for references related to the research object. The next stage is data collection and measurement analysis. After the data and analysis have been obtained, the press dies are designed. From the results of the design, potential improvements or increases in efficiency will be analyzed. If there is no increase in efficiency then it is repeated until the press die design results in an increase in efficiency. After increasing efficiency has been achieved, conclusions are drawn from the research.

RESULTS AND DISCUSSION

Production process sequence

In making the key hook, it consists of several processes and several machines are used. The sequence of the manufacturing process and the time required to manufacture 1000pcs of key hooks can be seen in the table below:

Table 1. Working time for each process

Process number	Activity Elements	Time Required for 1000 pcs (hour)									
		X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**
1	Material cutting	0,7	0,6	0,7	0,7	0,7	0,7	0,7	0,6	0,7	0,6

2	*Blanking*	2,1	2,3	2,0	2,8	2,1	2,3	2,4	2,1	2,1	2,3
3	*Piercing 1*	1,1	1,1	1,1	1,1	1,1	1,1	1,2	1,8	1,6	1,1
4	*Piercing 2*	1,1	1,1	1,1	1,1	1,1	1,1	1,2	1,8	1,6	1,1
5	Bending	2,2	3,0	2,8	2,2	2,3	2,4	2,5	2,2	2	2,2
6	Painting	0,8	1,0	0,9	0,9	0,8	0,8	0,4	0,8	1,1	0,8

Continuous Improvement

a. Define

In the key hook production process there are several steps or elements of activity that are carried out. Elements of these activities can be seen in table 1 above. In this activity process there are processes that have added value (value added) and processes that do not provide added value (non value added). In the value added process there are 2 identical processes that are carried out twice, namely piercing process 1 and piercing 2. This process also uses the same machine, so improvements need to be made that will eliminate identical processes so that they are not carried out twice.

b. Measurement

The next stage is to measure the efficiency of the production process time. This is necessary to determine the level of production efficiency currently underway so that a comparison can be obtained if the continuous improvement process has been carried out.

Calculation of average cycle time. From the calculation results, the following data is obtained:

Table 3. Key Hasp Process Average Cycle Time

Process number	Activity Elements	Time Required for 1000 pcs (hour)									
		X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**
1	Material cutting	0,7	0,6	0,7	0,7	0,7	0,7	0,7	0,6	0,7	0,6
2	*Blanking*	2,1	2,3	2,0	2,8	2,1	2,3	2,4	2,1	2,1	2,3
3	*Piercing 1*	1,1	1,1	1,1	1,1	1,1	1,1	1,2	1,8	1,6	1,1
4	*Piercing 2*	1,1	1,1	1,1	1,1	1,1	1,1	1,2	1,8	1,6	1,1
5	Bending	2,2	3,0	2,8	2,2	2,3	2,4	2,5	2,2	2	2,2
6	Painting	0,8	1,0	0,9	0,9	0,8	0,8	0,4	0,8	1,1	0,8

From the table above, the average cycle time in the process of making 1000 pcs of key hooks is:

Material cutting process : 0.7 hours

Blanking Process : 2.3 Hours

Process 1 : 1.2 Hours

Process 2 : 1.2 Hours

Bending Process : 2.4 hours

Painting : 0.8 Hours

Normal time calculation.

To calculate the normal time adjustment factor. In the key hook production process, adjustment factors are obtained as in the table below:

Table 4. Adjustment Factors in the Key Hasp Production Process

Process number	**Activity Elements**	**Skill**		**Effort**		**Condition**		**Consistency**		**P (1+total)**
		Adjustment		Adjustment		Adjustment		Adjustment		
1	Material cutting	C1	0,06	D	0	D	0	C	0,01	1,07
2	*Blanking*	B1	0,11	C1	0,05	D	0	D	0	1,16
3	*Piercing* 1	C1	0,06	C1	0,05	D	0	C	0,01	1,12
4	*Piercing* 2	C1	0,06	C1	0,05	D	0	C	0,01	1,12
5	*Bending*	C1	0,06	B1	0,1	D	0	E	-0,02	1,14
6	Painting	C1	0,06	D	0	D	0	C	0,01	1,07

From the adjustment factors above, the normal time for each activity element is obtained as follows:

Table 5. Normal Time in the Key Hasp production process

Process number	Activity Elements	Ws	P (1+Total)	Wn (WsxP)
1	Material cutting	0,7	1,07	0,7
2	*Blanking*	*2,3*	1,16	2,6
3	*Piercing* 1	*1,2*	1,12	1,4
4	*Piercing* 2	*1,2*	1,12	1,4
5	*Bending*	*2,4*	1,14	2,7
6	Painting	0,8	1,07	0,9

Standard time calculation

The next stage is calculating the standard time. To calculate the standard time, data is needed about the slack factor. After conducting research on conditions in the field, the following allowance factors were obtained:

Table 6. Looseness factors in the Key Hasp Production Process

Allowance factor	Conditions in the production unit	Allowance %	
		reference	taken
Energy Released	Very Light	6,0 – 7,5	6,5
work position	Sit	0 – 1,0	1
Work Movement	Normal	0	0

Eye Fatigue	almost continuous view	6,0 – 7,5	7
Working Temperature Conditions	Normal	0-8	4
Atmospheric Conditions	Enough	5,0 - 10	7
Personal Needs	male	0 – 2,5	2,5
Total			38

Because all processes are carried out in the same location, the level of difficulty is relatively the same and all are carried out by male operators, the standard time is obtained as follows:

Table 7. Standard Time for Key Hasp Production Process

Process number	Activity Elements	Normal Time (Wn)	Allowance (α)	Standard Time Wn + (Wn x α)
1	Material cutting	0,7	0,38	1,0
2	*Blanking*	2,6	0,38	3,6
3	*Piercing* 1	1,4	0,38	1,9
4	*Piercing* 2	1,4	0,38	1,9
5	*Bending*	2,7	0,38	3,7
6	Painting	0,9	0,38	1,2

Time Efficiency Calculations

The calculations above are summarized in the production time table below:

Table 8. Key Hasp Production Time

Process number	Activity Elements	Average Time (Ws)	Normal Time (Wn)	Standard Time (Wb)
1	Material cutting	0,7	0,7	1,0
2	*Blanking*	2,3	2,6	3,6
3	*Piercing* 1	1,2	1,4	1,9
4	*Piercing* 2	1,2	1,4	1,9
5	*Bending*	2,4	2,7	3,7
6	Painting	0,8	0,9	1,2
	Total	8,6	9,6	13,3

From the table above, it is known that before continuous improvement was carried out, the production process for key hooks per 1000 pcs required 6 process steps, 13.3 hours of total production time.

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c. Analyze

Looking at the key hook production process, there is an identical process and is carried out twice, namely the piercing process. The piercing process is a process that aims to make holes in key hook products. The resulting hole can be seen in the image below:

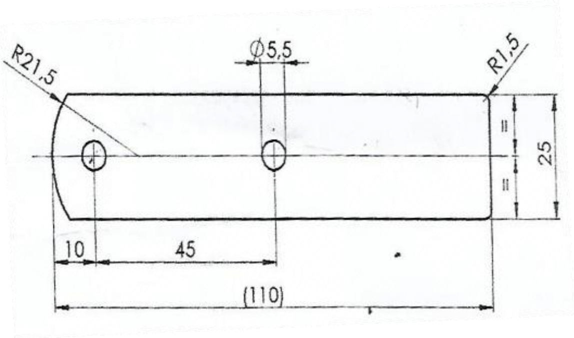

Figure 1. Keychain Piercing Hole

In the picture above you can see 2 holes with Ø 5.5 mm. To produce the hole, the process is carried out 2 times. Each process only produces 1 hole. The tools or tools used are dies which are operated with a mechanical press machine. The following is a picture of the dies used for piercing processes 1 and 2. From the picture above, it can be seen that there is only one tool for making holes, so innovation is needed so that in one work step you can produce 2 holes at once.

d. Improve

The improvement that will be made is to make new press dies so that it can increase process efficiency. When designing a press die, there are many things that must be considered. Starting from product analysis, determining the design, determining the materials used as well as technical analysis. This is necessary to obtain a good press die so that it will produce a quality product.

The design step includes several stages that must be calculated precisely and thoroughly so that maximum results will be obtained and in accordance with the desired function.

Punch

The punch is planned to use SKD 11 steel, which is steel for tools with a hardness of Hrc 58-62. In the design, the maximum allowable punch length must be known. The first calculation that must be known is the moment of inertia of the cutting plane.

If Ø is 5.5 mm, the moment of inertia is:

$$I = \frac{3,14 \times 5,5^4}{64}$$

$$= \frac{2873,29}{64}$$

$$= 44.89 \text{ mm}^4$$

The cross-sectional area is:

$$A = 3,14 \times 2,75^2$$

$$A = 23,7 \text{ mm}^2$$

So the radius of gyration is obtained by the value:

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$$Rg = \sqrt{\frac{44,89}{23,7}}$$

$$= 1,374 \text{ mm}$$

Next, look for the critical punch stress . To find out the critical punch stress , you need to first find the punch slenderness value. The length of the punch is planned to be 50 mm, so the slenderness value of the punch

$$\lambda = \frac{50}{1,374}$$

$$= 36,39 \text{mmm}$$

For SKD 11 material the price

E = 2.0.105 N/mm2

Sy= 550 N/mm2

So the comparative slenderness value is:

$$\lambda_1 = \sqrt{\frac{2 \text{ x } 3,14^2 \text{ x } 1,2 \text{ x } 200000}{550}}$$

$$= \sqrt{\frac{19,72 \text{ x } 1,2.200000}{550}}$$

$$= \sqrt{\frac{4732608}{550}}$$

$$= \sqrt{8604,74}$$

$$= 92,76 \text{mmm}$$

After each slenderness value, the critical stress value of the punch can be found , then the critical stress value of the punch

$$= 550 - \left(\frac{550}{2 \text{ x } 3,14}\right)^2 \text{ x } \frac{1}{1,2.200000} \text{ x } 36,39^2$$

$$= 550 - 7670,19 \text{ x } 0,005$$

$$= 507 \text{ N/mm}^2$$

After the critical stress of the punch is known, the next step is to check the stress that occurs due to the cutting force of the punch on the material. This inspection is to determine how much stress occurs due to the punch cutting force on the material which will later be compared with the critical stress of the punch . It is known that the thickness of the product material is SPCC steel with a thickness of 1.5 mm and has a fracture stress of 274.59 N/mm2, so the calculation voltage as follows:

U = 2 x 3.14 x 2.75

= 17.27 mm

F = 0.8 x 274.59 x 17.27 x 1.5

= 5690.6 N

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$$\sigma = \frac{5690,6}{23,75}$$

$= 239.604\ N/mm^2$

After carrying out the analysis, it is known that the stress that occurs due to the cutting force is smaller than the critical stress of the punch, so from this analysis it can be concluded that the punch is safe.

Punch Holder

used for the punch holder is St.52 steel. Install the punch holder on the top plate using M6 inbus bolts.

Top plate

The top plate is where the punch holder is attached and is the punch holder. The surface of the top plate must be even on both sides. The material used is SS41 steel because it has damping properties and toughness.

Holder Stalk

The handle is usually located at the center of gravity of the total force. This aims to avoid uneven pressure on the top plate. Since the design of the press dies this time has a rectangular shape with the same amount of force on both sides, the placement of the handle is right in the middle position. The material used for the holder is standard DIN 9859. Fastening to the top plate is done by welding.

Die

The die is the part of the press die that is attached to the punch. For press dies in the piercing process, the clearance is located on the dies. To find out the clearance value, use the calculation:

Us = 4% x 1.5

= 0.06mm

Next, look for the minimum die thickness.

F is known to be 5690.6 N. because there are 2 punches then:

$$F_t = 5690,6 \times 2$$

$$= 11381,2\ N$$

$$F_{sp} = 0,6\ \%\ \times\ 11381,2$$

$$= 682.872\ N$$

$$H = \sqrt[3]{\frac{11381,2 + 682,872}{9,81}}$$

= 10.713 mm

In the design, it was planned that the die thickness was 15 mm, which was in accordance with the minimum allowable thickness.

Bottom Plate

The bottom plate is the die support part. The bottom plate also functions as a part that is attached to the machine table. The material used is the same as the material used on the top plate. The thickness of the bottom plate is the same as the thickness of the die.

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Goods Releaser / Stripper

The stripper functions to remove items stuck to the punch. Apart from that, in this design the stripper also functions as a mall when the item is inserted so that it is in the appropriate position during the piercing process. This also aims to minimize product rejects. The stripper attaches to the die using M8 inbus bolts as a fastener. The material used is SS41 steel without hardening.

Machine Capacity Calculation

After designing the press dies, it is necessary to calculate what machine capacity is suitable for use in the process. This is necessary because less machine capacity will affect product quality, while excess machine capacity can reduce efficiency. To calculate the required machine capacity.

It is known that the cutting force for 2 punches is 11381.2 N = 1160.56 kgf

So :

$F_{st} = 15\% \times 1160.56$

$= 174.1$ kgf

$$P = \left(\frac{11381{,}2+174{,}1}{1000}\right) x\ 1{,}5$$

$= 2$ Tonf

So the required machine capacity is a minimum of 2 tons

e. Control

Because it is a design, the control stage is carried out by calculating efficiency estimates after continuous improvement. With the new Pess dies design, the piercing process is only carried out once and 2 holes are formed. So the estimated efficiency can be calculated as follows:

Table 9. Key Hook Production Time After Continuous Improvement

Process number	Activity Elements	Average Time (Ws)	Normal Time (Wn)	Standard Time (Wb)
1	Material cutting	0,7	0,7	1,0
2	*Blanking*	2,3	2,6	3,6
3	*Piercing* 1 & 2	1,2	1,4	1,9
4	*Bending*	2,4	2,7	3,7
5	Painting	0,8	0,9	1,2
	Total	**7,3**	**8,3**	**11,4**

After carrying out Continuous Improvement, the number of key hook production processes from 6 processes became 5 processes and the total production in 1 cycle went from 13.3 hours to 11.4 hours or 1.9 hours faster. So the efficiency percentage is calculated as follows:

$$= \frac{13{,}3-11{,}4}{13{,}3}$$

Efficiency x 100 % = 13.3 %

So after continuous improvement there was a total time efficiency of 13.3% compared to the time before continuous improvement. Meanwhile, for the piercing sub process, the efficiency is as follows:

$$= \frac{3,8 - 1,9}{3,8}$$

Efficiency x 100 % = 50 %

so that the piercing process occurs with a time efficiency of 50%.

Based on the results of the analysis above, it can be emphasized that implementing continuous improvement is a very effective approach in increasing the level of efficiency in various operational aspects of an organization as well as reducing product defects (Akter, et al, 2015). By focusing on gradual and continuous process improvement, companies can identify areas that need improvement and implement changes that can increase productivity, reduce waste, and improve output quality (Blaga, 2019), (Ron, 1998). Continuous improvement involves all employees in this process, which not only helps create a collaborative work culture but also ensures that every step taken is relevant and contributes directly to increased efficiency (Dejager, 2004). Increased efficiency through continuous improvement can also have a significant impact on operational costs. By minimizing waste, whether in the form of time, resources, or energy, companies can achieve better results at lower costs (Zimwara et al, 2013)

CONCLUSION

The application of Continuous Improvement in the key hook production process was carried out using the DMAIC method and resulted in a press die design consisting of 7 components. The following are details of the press die components for the key hook piercing process: Handle holder, Punch, Die, Top plate, Bottom plate, Punch holder, Stripper. After carrying out Continuous Improvement, the previous 6 processes became 5 processes and total production in 1 cycle from 13.3 hours to 11.4 hours or 1.9 hours faster. So there is a total production time efficiency of 13.3% of the total time before Continuous Improvement, while the piercing process produces an efficiency of 50% compared to the piercing process time before Continuous Improvement. Apart from efficiency in production time, the new press die design results, especially in the stripper section which was previously open, has become closed. This design will reduce the potential for product defects so that it can reduce the percentage of product rejects.

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