Improving Die Exchange Process in Textile Manufacturing Company with SMEDEffendi MOHAMAD¹ Muhammad Hazwan ARZMI² Teruaki ITO³Mohd Shahir KASIM⁴ Taufik Roni SAHRONI⁵ Mohd Warikh ABD RASHID⁶^{1,2,4,5,6} Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya, 76100, Melaka, Malaysia³The University of Tokushima, Institute of Technology and Science
Minami-Josanjima 2-1, Tokushima-shi, Tokushima, 770-8506 Japan

This study presents collaboration between a textile manufacturing company in Malaysia and Universiti Teknikal Malaysia Melaka. In this Company-University Collaboration (CUC), Single Minute Exchange of Die (SMED) was introduced in the company to improve the time-consuming changeover process of its stamping machine. The framework of this study involves data collection stage, analysing stage and evaluation stage which are steps required to be fulfilled in SMED implementation. Previously, the changeover time of the stamping machine in average is 5.19 hours. After the implementation of SMED, the changeover time of the stamping machine was reduced to 3.83 hours in average or 23.59% reduction from previous changeover time. The improvements made are 5S, using jig in mould alignment and creating a new system in assisting pressure settings. In conclusion, the collaboration is shown to be feasible in supporting SMED implementation in the textile manufacturing company.

Key Words: Single Minute Exchange of Die, Waste reduction, Collaboration

1. Introduction

A variety of product exists in the current market. The importance of having high flexibility is emphasized to be one of the specialities in companies. Flexibility can be seen in many aspects i.e. process, product, volume, operation or routine [1]. Basically, flexibility are mostly related to the ability of producing many different products in a small time frame without sacrificing too much machine utilization rates while having a longer downtime [2]. By achieving high flexibility, production in an organization could be customized, have shorter lead times, able to cope with high uncertainty and also changing customer preferences from time to time without having issues regarding cost ineffectiveness in production [3].

In order to achieve high flexibility, one of the alternatives that could be adopted by companies is implementing lean manufacturing teaching in their organization. One of lean methods in reducing waste, the Single Minute Exchange of Die (SMED) is designed for the purpose of optimizing machine utilization by reducing downtime due to changeover processes. There are ample of companies that have already been practising SMED since the effectiveness of this method is already proven [4]. In addition, Ferradás and Salonitis [4] also stated that the ability of this method to be adapted in many different fields makes it even more useful and beneficial to the companies.

This study involves collaboration between university and industry. It is executed as part of collaboration between Universiti Teknikal Malaysia Melaka (UTeM) and one of manufacturing company in Malaysia in solving any issues that exist within the collaborated company. The purpose of this collaboration is two-pronged. From the university perspectives, the collaboration could provide students with real life knowledge regarding the actual situation in

^{2,4,5,6}Non-member, Universiti Teknikal Malaysia Melaka (Hang Tuah Jaya, 76100, Melaka, Malaysia)

¹Member, Universiti Teknikal Malaysia Melaka

³Member, The University of Tokushima

E-mail: effendi@utem.edu.my

industries and at the same time enabling them to experience the true nature of manufacturing problems that usually occur in the industry [5]. Besides that, this collaboration could enable students to build their technical skills and improve the growth of entrepreneurial factors [6]. Students from universities are required to propose solution to several issues in a particular industry. Via this collaboration, university can gain benefit in terms of knowledge and experience.

From the industries perspectives, this collaboration may assist them in defining and solving manufacturing problems with the help from academicians and the problems could be tackled in more effective ways. Besides problem solving, the collaboration would help the company in terms of their innovation process [6] since university tends to explore new technology from time to time. Related to that, according to Mohammad and Ito [5], there is a need of expertise in the rapid evolving technology which forces industry to perform collaboration with universities hence keeping them in the loop of surrounding technologies.

Nonetheless, in university-industry collaboration, certain aspects need to be considered such as the culture, organization and management characteristics between the two joined partners [7]. In order to have an effective relationship, both parties must have a same goal and at the same time working together to achieve it. Furthermore, certain aspect can be improved such as company efficiency, reducing waste, process capabilities and so on.

In this study, problem detected in the textile manufacturing company is the time consuming process of changeover procedure involving a stamping machine. The changeover procedure of this machine can be divided into two sections i.e. changing the mould and resetting the machine. The reason which leads to studying this particular machine is because this machine performs critical task compared to other machines. Currently, the company owns only one of this machines which could produce the required products. Hence, any delay due to changeover cannot be backed up by any other machines. Consequently, the company experiences low machine utilization and low cost-effectiveness in their production.

The stamping machine produces nine different sizes of snap fastener buttons. Each time different sizes need to be produced, the mould will be changed according to the production schedule. Since the products produced involve small size parts, higher precision is extremely important. Roughly, more than five hours is taken to complete one session of changeover process which includes changing the mould and resetting them properly. However, it may consume more time if the settings are not done correctly in the first setting procedure. This will force the machine to be resetting again until an accurate setting is obtained. Hence making the changeover process lasts for weeks.

2. Methodology

This study is mainly focuses on reducing the changeover time of a stamping machine in a textile manufacturing company. Two operations involved in this machine are pressing and folding. The pressing part is done first in order to get the shape of the snap fastener button, followed by the second operation whereby the side of the snap fastener button were folded inside to form a round shape. Figure 1.0 shows the snap fastener button produced by the machine while the red circle indicates the folded part around the button.

Figure 1.0: Product produced by stamping machine

Figure 2.0 shows the framework of this study. The first stage refers to the data collection stage. Second stage is the analysing stage and the last stage is the evaluation stage. Overall, these three stages are steps required to be fulfilled in SMED implementation.

In the data collection stage, there are 4 steps involved. The first step is obtaining the data. In this step, observation of changeover procedure was done, followed by recording the changeover procedure. Simultaneously, times for each changeover activity were recorded. The machine produces nine different sizes of products hence there will be nine different moulds. In order to obtain precise data, three readings were taken for each mould sizes. The average value of those three readings will be used to represent time requirement for each changeover procedures. Following that, literatures from various sources regarding reducing changeover time were collected and studied. Based on the collected data, observation and studied literature, each changeover activities were classified into internal and external processes.

From this point, it will be the beginning of the analysing stage. In order to obtain the picture of real-life situation at the production line, an expert knowledge is required. Therefore a brief interview was conducted with the person in-charge of the stamping machine. Following that, any suitable internal activity will be converted to external activity. In this study, there is no suitable internal activity to be converted. Hence, this study proceeded to simplifying the activities. In order to simplify the activities, certain attachments are required to be used. This attachment need to be designed first in order for them to fit the machine. Hence, dimensions of each part of machine and mould are required. From the dimension obtained before, the jig was created. As for certain activity that would not require any jig, a standard was created such as using marking to make the changeover activity easier.

At this point, evaluation stage starts. In order to find the effectiveness of the improvement done, an experiment using the standard and jig created were done. From that experimentation, new changeover time was recorded and compared to existing changeover time. Lastly, all of the improvements were documented for further improvement of the machine.

Figure 2.0: Methodology of study

3. Analysis and Results

In the early stage of SMED, an observation study is done to study the changeover procedures. A stopwatch time study was implemented to determine the time consumption of each activity during changeover procedures. In obtaining the data, the changeover time were taken thrice for each mould and the average were used as a benchmark for current changeover time. Table 1.0 shows the time required for each changeover activities to be completed during changeover procedures for each mould used on the machine in minutes. The changeover procedures were divided in to two main steps which is mould changing and machine settings. There are 17 steps in total for completing each changeover procedures. Only three of them are external processes while the others are classified as an internal process. Based on the total time, it shows that most of the times are consumed by setting the machine rather than changing the mould. Furthermore, it shows that the highest changeover time is 311.60 minutes equivalent to 5.19 hours.

Table 1.0: Stamping machine changeover time

Step No.	Type	Changeover Procedure	Mould Sizes (minutes)								
			6	7	7 Square	8	9	11	13	15	17
1	In	Prep machine	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
2	Ex	Collect tools	4.67	4.83	4.60	3.43	4.30	5.97	4.40	3.97	5.13
3	In	Disassemble mold (top)	8.38	8.60	8.57	8.47	8.47	8.33	8.87	8.32	8.37
4	In	Disassemble mold (base)	4.10	4.03	3.97	4.13	4.00	4.23	4.00	3.95	3.97
5	Ex	Collect mold	2.47	2.47	2.53	2.43	2.50	2.47	2.47	2.51	2.47
6	In	Prep machine	3.13	3.03	3.13	3.03	3.03	3.17	3.00	3.03	3.00
7	In	Assemble mold (base)	2.57	2.50	2.47	2.53	2.57	2.47	2.60	2.55	2.53
8	Ex	Mold quick check (top)	4.27	4.43	4.73	4.27	4.23	4.30	4.03	3.60	3.10
9	In	Assemble mold (top)	4.28	4.30	4.10	4.12	4.17	4.33	4.07	4.46	4.27
10	In	Mold alignment (base)	47.63	44.17	44.70	42.67	43.63	47.47	41.20	44.90	42.07
11	In	Secure mold	4.40	4.53	4.93	4.73	4.87	4.67	4.57	4.97	4.73
12	In	Test run	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
		Sum	110.90	107.90	108.73	104.82	106.77	112.40	104.20	107.25	104.63
		Machine Setting									
13	In	Main pressure setting	30.08	30.53	30.73	30.80	30.40	30.03	30.63	30.13	30.63
14	In	Feed rate setting	32.64	31.13	33.00	32.57	31.60	32.17	31.93	32.37	31.73
15	In	Carrier clamp setting	37.58	35.93	35.60	36.00	32.30	37.30	35.67	37.43	36.97
16	In	Folding pressure setting	52.53	51.23	56.37	60.37	46.80	57.70	59.23	53.07	56.30
17	In	Puller setting	37.95	40.43	36.73	39.90	38.07	42.00	41.57	39.30	42.30
		Sum	190.79	189.27	192.43	199.63	179.17	199.20	199.03	192.30	197.93

In: Internal Changeover Type

Ext: External Changeover Type

3.1 Improvement

5's was implemented in the tool stores of the textile manufacturing company. Before improvement, the tools were scattered on the floor. This is due to in availability of a place for tools to be stored. Hence time-consuming when technician are required to find the necessary tool for changeover procedures. In order to improve the process, the tools were stored in a specific location close to the stamping machine. Therefore, it is easier for the technician to locate the tools. In addition, by organizing the tools, this will give positive impact towards the first step of conversion activity which is preparation of the machine which also requires the same tools. Besides the tools, the rack which stored the mould was also improved by labelling all the mould. Before this, the moulds were stored randomly on the rack which later on creates confusion in selecting the right mould to be used. Figure 3.0 shows the rack which stores the mould for the stamping machine.

Figure 3.0: Mould rack

Mould alignment was done in order to synchronize the mould location between the top and bottom part of the mould and the machine itself. Aligning the mould is a very delicate process and any mistake can cause major damage to the mould and the machine. Previously, mould alignment processes were done manually which consume nearly 40 to 45 minute for each alignment activity. The time consuming alignment activities results from complicated task which require repetitive movement. Hence it is important to simplify this task and eliminate unnecessary repetitive movement which consume a lot of time. Jig is created to assist in mould alignment. The adjustable feature of jig make it possible to be used for aligning all die moulds is used by the stamping machine.

Figure 4.0 shows the jig which is created to assist the mould alignment process during the changeover procedure. The jig part labelled as (a) shows the adjustable part of the jig. These parts can slide forward and backward depending on the required mould to be aligned. On these parts, there will be a marking which indicates location of the part where it is supposed to be based on the mould to be aligned. Part (b) is the base of the jig that will be fitted on to the machine. Figure 5.0 shows the marking on the jig which represents the length required for the jig to be extended. This marking were created on the different moulds used by this machine. The materials used for creating this jig are mild steel. In designing the jig, AutoCad2014 software were used. In creating the jig, laser cutting process were used in shaping the raw material into desired shape. Following that, the MIG welding processes were used to join certain parts together permanently. To use this jig, simply attach the jig on the control panel of the machine as shown in Figure 4.0. Referring to Figure 5.0, the bar was extended based on the marking. Each marking represents different moulds. Hence it is important to make sure the bar was extended according to the marking which represent the current mould to be aligned.

Figure 4.0: Jig

Figure 5.0: Jig marking

Pressure setting is the first step in resetting the stamping machine. Pressure was set by gradually turning a bolt located in the machine. During pressure setting, in order to obtain the right pressure, technician will first use current pressure to press raw material. Then hole on raw material created from the press will be compared to previous production batch. After determining the difference by measuring the depth of hole using Vernier calliper, the bolt will be turned gradually until the pressed raw material is similar to previous production batch. Nevertheless, the amounts of turns are ambiguous and usually done by trial and error. Hence a system is needed to eliminate the trial and error method used before.

Figure 5.0 shows the system which helps in simplifying the process of mould pressure setting. Gap between two gear tooth will be used as the measurement tools. Each gap represents constant change of pressure, hence will provide the technician a better view on how much pressure change will occur with every degree the nut were turned. Based on the trial regarding setting the pressure, it is found that one tooth gap represent the different of one millimetres of press depth. In other words, whenever the bolt turns every one gap of gear tooth, the hole depth on raw material will be increased by one millimetre (Figure 6.0).

Figure 6.0: Pressure setting

3.2 Results

In finding the effectiveness of the proposed improvement, a new observation is held during the changeover procedures. This time, all the improvements were included during the changeovers. Simultaneously, stop watch time study was also done to determine the time consumed for each changeover activities. Table 2.0 shows the difference of changeover time between before and after the improvements were implemented. Based on the table, it shows that there are four activities have been improved after the SMED implementation.

Table 2.0:Stamping machine changeover time before and after SMED

Step No.	Type	Changeover Procedure	Mould Sizes (minutes)													
			6		7		7 Square		8		9		11		13	
			Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1	In	Prep machine	10.00	5.60	10.00	5.80	10.00	5.50	10.00	5.60	10.00	5.60	10.00	5.60	10.00	5.70
2	Ex	Collect tools	4.67	0.50	4.83	0.50	4.60	0.50	3.43	0.50	4.30	0.50	5.97	0.50	3.97	0.50
3	In	Disassemble mold (top)	8.38	8.38	8.60	8.60	8.57	8.57	8.47	8.47	8.47	8.47	8.33	8.33	8.32	8.37
4	In	Disassemble mold (base)	4.10	4.10	4.03	4.03	3.97	3.97	4.13	4.13	4.00	4.00	4.23	4.23	3.95	3.97
5	Ex	Collect mold	2.47	2.30	2.47	2.35	2.53	2.20	2.43	2.10	2.50	2.00	2.47	2.10	2.51	2.20
6	In	Prep machine	3.13	3.13	3.03	3.03	3.13	3.13	3.03	3.03	3.03	3.03	3.17	3.17	3.00	3.00
7	In	Assemble mold (base)	2.57	2.57	2.50	2.50	2.47	2.47	2.53	2.53	2.57	2.57	2.47	2.47	2.55	2.53
8	Ex	Mold quick check (top)	4.27	4.27	4.43	4.43	4.73	4.73	4.27	4.27	4.23	4.23	4.30	4.30	3.60	3.10
9	In	Assemble mold (top)	4.28	4.28	4.30	4.30	4.10	4.10	4.12	4.12	4.17	4.17	4.33	4.33	4.46	4.27
10	In	Mold alignment (base)	47.63	10.00	44.17	9.80	44.70	11.20	42.67	12.50	43.63	10.50	47.47	9.80	44.90	10.10
11	In	Secure mold	4.40	4.40	4.53	4.53	4.93	4.93	4.73	4.73	4.87	4.87	4.67	4.67	4.97	4.73
12	In	Test run	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
		Sum	110.90	64.53	107.90	64.88	108.73	66.30	104.82	66.98	106.77	64.93	112.40	64.50	107.25	63.47
13	In	Main pressure setting	30.08	2.50	30.53	1.90	30.73	2.20	30.80	2.80	30.40	3.00	30.03	2.10	30.63	2.50
14	In	Feed rate setting	32.64	32.64	31.13	31.13	33.00	33.00	32.57	32.57	31.60	31.60	32.17	32.17	32.37	31.73
15	In	Carrier clamp setting	37.58	37.58	35.93	35.93	35.60	35.60	36.00	36.00	32.30	32.30	37.30	37.30	37.43	36.97
16	In	Folding pressure setting	52.53	52.53	51.23	51.23	56.37	56.37	60.37	60.37	46.80	46.80	57.70	57.70	53.07	56.30
17	In	Puller setting	37.95	37.95	40.43	40.43	36.73	36.73	39.90	39.90	38.07	38.07	42.00	42.00	39.30	42.30
		Sum	190.79	163.21	189.27	160.63	192.43	163.90	199.63	171.63	179.17	151.77	199.20	171.27	192.30	169.80
		Sum (main run)	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30
		Sum (main run top)	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30	69.30

By implementing 5's, two activities of changeover procedure are affected. They are the first machine preparation and tool collection. By creating a specific location contain to arrange the necessary tools, time of locating and collecting needed tools is shortened. Based on Table 2.0, before 5's implementation ten minutes is required to complete the first machine preparation and at the same time 4.59 minutes to collect tools. After 5's implementation the time reduces by 43.67% (4.37 minutes) for the first machine preparation and 89.10% (4.09 minutes) for collecting tools.

Besides creating proper location for tools, the rack that stores the mould were also labelled based on mould names. Before this, the time taken to collect mould is 2.48 minutes due to unlabelled rack which frequently result in confusion regarding obtaining the right mould. After labelling the mould rack, time taken to collect mould has reduced by 14.64% (0.36 minutes) from before.

As for using designed jig in assisting mould alignment, it has reduced time by 76.83% (34.01 minutes) which previously require 44.27 minutes to complete. This is because to the jig has eliminate certain repetitive and unnecessary movement of the worker in aligning the mould. The jig has two parts which is stationary and adjustable. Stationary part are placed firmly on the machine control panel while adjustable parts are used as a guide showing the exact location where the mould should have positioned. In using it, simply adjust the adjustable part of the jig until it fit with the marking. Then slide the mould until it touches all edge of the jig. The adjustable parts can be sets with different length based on which mould would need to be aligned. Hence, it is suitable to be used for any mould for that particular machine. By implementing 5's and using designed jig during changeover, the time for first phase of changeover which is mould changing is reduced by 39.84% (42.83 minutes) compared to previous time which is 107.51 minutes.

In machine settings procedures, the improvement are made towards main pressure setting. Previously, the setting are done based on trial and error. To set the pressure, one of the bolt in the machine were turned gradually to achieve desired pressure. This would consume a lot of time especially when the first try are not successful. This steps has consume 30.44 minutes before improvements were implemented. As for the improvement, a system were created in order to remove trial and error method used before. After the improvement, the time to set the pressure are reduced by 92.34% (28.11 minutes). Hence the next phase of changeover which is setting the machine are done with the total reduction time of 14.54% (28.11 minutes) compared to 193.31 minutes to previously completely sets the machine.

In overall changeover time reduction, it shows that, in average, the changeover time has been reduced by 23.59% which is equivalent to 1 hour and 15 minutes. The activities which are effected in this study are the first machine preparation, tool collections, mould alignments and pressure setting. This is due to the relation that exist between these four activities with the improvements made.

4. Conclusion

SMED is implemented on the stamping machine due to high changeover time. Previously, the changeover time of the machine in average is 5.19 hours. After the implementation of SMED, the changeover time was reduced to 3.83 hours in average (23.59% reduction from previous changeover time). The improvements made are 5S, using jig in mould alignment and creating a new system in assisting pressure settings. Nevertheless, further improvements are required e.g. implementation of other LM tools or optimization of the newly-implemented SMED to achieve shorter changeover time and higher flexibility.

5. Acknowledgement

The authors would like to thank the textile manufacturing company for their cooperation and involvement in this study. The authors are also grateful to the Malaysian Government and Universiti Teknikal Malaysia Melaka (UTeM) for funding this research via Grant (PJP/2014/FKP/ (9C)/S013262).

6. References

- (1) Parker, R. P., and Wirth, A. (1999). Manufacturing flexibility: measures and relationships. European journal of operational research, Vol. 11 Issue 8(3), pp. 429-449.

- (2) Goyal, M., and Netessine, S. (2011). Volume flexibility, product flexibility, or both: The role of demand correlation and product substitution. *Manufacturing and service operations management*. Vol. 13 Issue 2, pp. 180-193.
- (3) Ngamsirijit, W. (2008). *Manufacturing Flexibility Improvement: Case studies and survey of Thai automotive industry*. Doctoral dissertation, University of Nottingham.
- (4) Ferradás, G. P. and Salonitis, K. (2013). Improving changeover time: a tailored SMED approach for welding cells. *Forty Sixth CIRP Conference on Manufacturing Systems*. Vol. 7, pp. 598-603
- (5) Mohamad, E., and Ito, T. (2011). University-Industry Collaboration in Lean Manufacturing Implementation. *ACEE TOKUSHIMA*.
- (6) Pecas, P., and Henriques, E. (2006). Best practices of collaboration between university and industrial SMEs. *Benchmarking: An International Journal*, 13(1/2), pp. 54-67
- (7) Liyanage, S. and Mitchell, H. (1994). Strategic Management of Interaction at the Academic-Industry Interface, *Technovation*, Vol. 14 No. 10, pp. 641-55