Journal of Applied Sciences 15 (3): 456-464, 2015
ISSN 1812-5654

ansinet
Asian Network for Scientific Information

RESEARCH ARTICLE OPEN ACCESS

DOI: 10.3923/jas.2015.456.464

Enhancing Efficiency of Die Exchange Process Through Single Minute of Exchanging Die at a Textile Manufacturing Company in Malaysia

[1]Mohamad Amran Ibrahim, [2]Effendi Mohamad, [2]Muhammad Hazwan Arzmi, [2]Muhamad Arfauz A. Rahman, [2]Adi Saptari, [3]Abdul Samad Shibghatullah, [2]Mohd Amri Sulaiman and [2]Mohd Amran Md Ali
[1]Center of Graduate Studies, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100, Melaka Malaysia
[2]Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 75450, Melaka, Malaysia
[3]Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 75450, Melaka, Malaysia

ARTICLE INFO
Article History:
Received: November 18, 2014
Accepted: January 08, 2015

Corresponding Author:
Effendi Mohamad,
Faculty of Manufacturing Engineering,
Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 75450, Melaka,
Malaysia Tel: +063316450
Fax: +606-331 6411

ABSTRACT

The main idea of this research work is to demonstrate the benefit of the Single Minute Exchange of Die (SMED) tool in waste elimination. An initiative involving a selected textile manufacturing company in Malaysia and Universiti Teknikal Malaysia Melaka (UTeM) has been undertaken to support the study. Throughout this initiative, SMED was introduced to improve the time-consuming changeover process at the stamping machine of the chosen textile manufacturing company. This study was conducted based on the SMED's framework introduced by Shigeo Shingo through the process of data collection, analysis and evaluation. It involves conversion of some internal activities to external activities, usage of a jig in mold alignment as well as the creation of a new system to assist pressure settings at the stamping machine. Prior to the implementation, the initial recorded average changeover time of the stamping machine was 300 min. After implementation of SMED, the changeover time of the stamping machine had been significantly reduced to 223.15 min which represent a changeover time saving of 25.62%. In conclusion, the initiative appears to be feasible in demonstrating the benefit of SMED implementation especially in the textile manufacturing company.

Key words: SMED, waste reduction, lean manufacturing, changeover time

INTRODUCTION

According to the 2013 Annual Report of Bank Negara Malaysia (BNM), the manufacturing sector has positively contributed to the growth of the Malaysian economy (BNM., 2013). Its 3.4% growth was attributed to the continued strength of domestic-oriented industries and better performance of export-oriented industries in the second half of 2013. Manufacturing companies have continuously strived to find solutions to assure the survival of their companies and increase their profit (Mohamad *et al.*, 2008). Such efforts are to ensure that they remain competitive in the ever-dynamic Malaysian economy. Holweg (2007) and Mohamad and Ito (2013) have similar views of the common obstacles to success in the manufacturing sector. This includes the increasing number of inventories, lengthy cycle time, prolonged downtime, bottlenecks, high number of operators and low productivity.

In order to overcome these obstacles and improve the industries' capability, a smart, collaborative approach between industry and university must be created (Mohamad *et al.*, 2014). Pecas and Henriques (2006) believe that this approach can help the industries and provide a significant impact on the productivity and competitiveness of companies; Mohamad and Ito (2011) are confident that this approach may undoubtedly benefit the university. The university will afford its students the opportunity to experience real life situations including dealing with the manufacturing problems that usually occur in the industry.

Another method of improving the industry's capability is by reducing the waste produced. Ghosh (2013) defined waste as anything that does not add value to a product or a service to the customer. Abdulmalek and Rajgopal (2007) analyzed the benefits of the concept of lean manufacturing which is employed by companies to minimize or eliminate waste. Lean manufacturing serves its purpose in minimizing production costs and maximizing revenues and as a result improves the company's reputation. According to Dahlgaard and Dahlgaard-Park (2006), there are seven types of waste listed under lean manufacturing: over-production, waiting time, unnecessary motion, defect, transportation, unnecessary inventory and inappropriate processing. Pettersen (2009) listed various tools used to eliminate these wastes in lean manufacturing including Total Preventive Maintenance (TPM), Kanban, Heijunka (Production leveling), First In First Out (FIFO), Value Stream Value (VSM), Jidoka, Poka-Yoke, Andon, 5S, Kaizen, Single Minute Exchange of Die (SMED) and Standardized study.

To solve this problem, one initiative has been successfully undertaken by ABC Sdn. Bhd. one of the most prominent textile companies in Malaysia and Universiti Teknikal Malaysia Melaka (UTeM), both situated in Melaka, Malaysia. Initial observations show that the company's waste emanated from the downtime changeover process of a stamping machine.

During the observation study, there are two activities involved during the changeover process at this machine: (1) Changing the mold and (2) Setting the machine. The focus of this study is to improve the die exchange process of the observed stamping machine. This machine performs the most critical task as compared to other machines. As only one machine is available to produce the required products, any delay due to the changeover cannot be backed by any other machine. Consequently, the company experiences low machine utilization and low cost-effectiveness during production.

In this study, SMED was selected to reduce non-value added activities and improve the die set-up efficiency in the textile manufacturing company. The objective of SMED-introduced by Shingo (1985) is to accomplish machine set-up times that are less than 10 min. This is usually done by optimizing activities related to the changeover procedure and eliminating the waste related to the change of the die (Moreira and Pais, 2011; Shingo, 1985; Ferradas and Salonitis, 2013). SMED groups set-up activities into two: The internal set-up usually performed while the machine is turned off (inside the machine) and the external set-up performed while the machine is running (outside the machine). Figure 1 illustrates the changeover process in terms of time during the changing of the product while the four stages in SMED technique are shown in Fig. 2 (Kumar and Abuthakeer, 2012).

The first stage involves identifying the internal and external activities in changing die operation, the second involves separating the internal and external set-ups and the third involves converting activities from internal to external set-up while the final step involves streamlining all aspects of the set-up operation.

MATERIALS AND METHODS

In order to implement SMED, three valuable stages are proposed as shown in Fig. 3.

The first stage refers to data collection and it involves two steps. During the first step of obtaining the data, time study was conducted to obtain real-time activities. Based on the data collected, each changeover activity was identified as internal or external processes. Initial observations and time study were conducted to gather useful information regarding the stamping

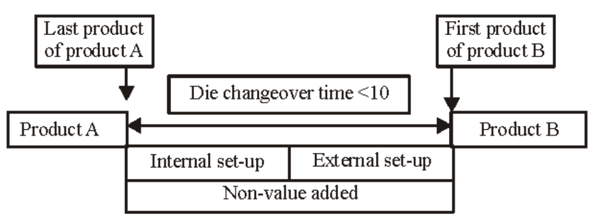

Fig. 1: Changeover time

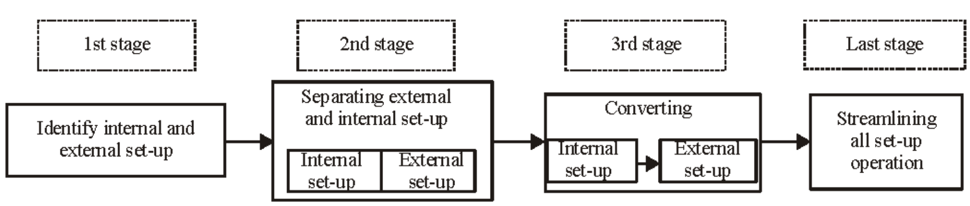

Fig. 2: SMED conceptual technique

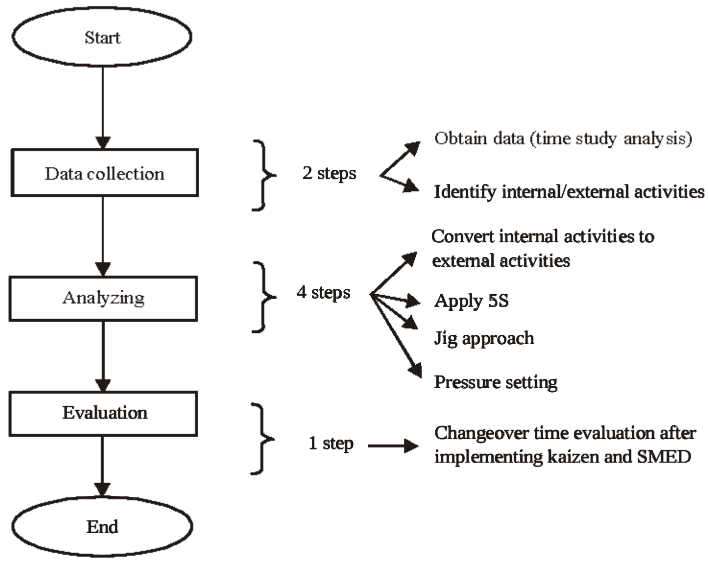

Fig. 3: Proposed SMED stages

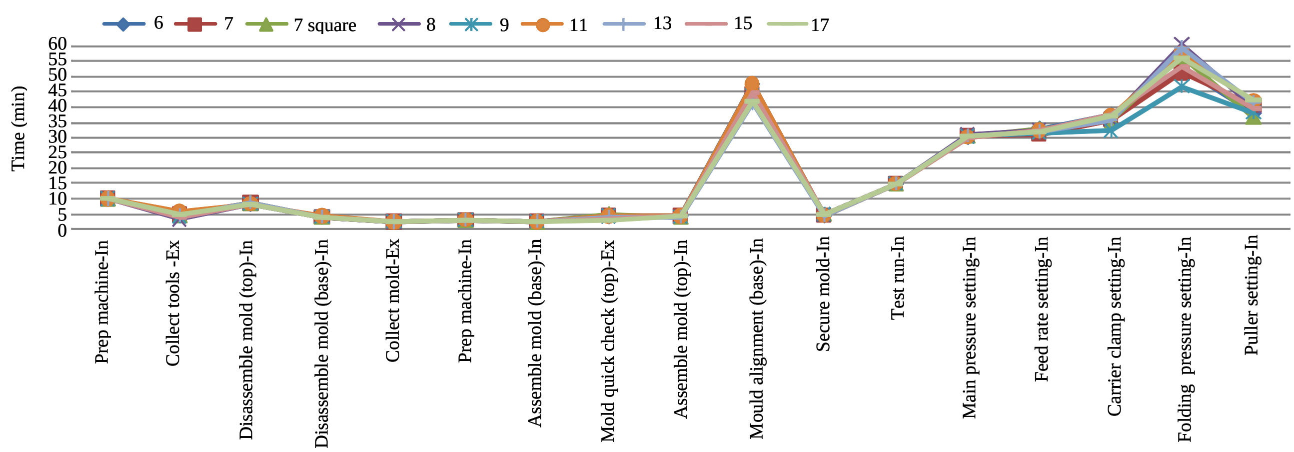

Fig. 4: Graph time versus changeover procedure, In = Internal, Ex: External

machine which is used to produce nine different sizes of snap fastener buttons. The production indicates that the mold must be changed according to the production preferences.

Since the products are small, higher precision is critical. Table 1 shows the time (min) each changeover activity needed to complete during changeover procedures for each mold used on the machine. The changeover process involves two main activities, namely the mold changing and machine setting and there are 17 steps in total for completing the changeover procedures. Three of them are external processes while the others are classified as internal. The study shows that a lot of time is spent during mold alignment and pressure setting. This activity will be analyzed and improved for the next changeover.

Based on the output of the study shown in Table 1 and Fig. 4, the changeover process took average 301 min to complete one session but may take longer if the settings are not done correctly in the first setting procedure. The situation may force the machine to reset again until an accurate setting is obtained.

The second stage is the analysis, during which a brief interview was conducted with the person in-charge of the machine. The interview was to get a clearer picture of the situation from a knowledgeable expert. Following that, any possible internal activity will be converted to external activity. Next, simplifying the steps; in terms of changeover procedure, individual improvement or tool required. The improvement or tools that need to be designed depend on the changeover activities. Applying 5S into the working area is the easiest of all, followed by the jig approach. Once the activity has been identified, the jig will be created and the dimensions of each mold taken.

As for activities that did not require any jig, a standard was created such as using marking to make the changeover

Table 1: Stamping machine changeover time (min)

			Type of mold								
Step No.	Type	Changeover procedure	6	7	7 square	8	9	11	13	15	17
1	In	Prep machine-In	10.00	10.00	10.00	10.00	10.00	1000	10.00	10.00	10.00
2	In	Collect tools-Ex	4.67	4.83	4.60	3.43	4.30	5.97	4.40	3.97	5.13
3	In	Disassemble mold (top)-In	8.38	8.60	8.57	8.47	8.47	8.33	8.87	8.32	8.37
4	In	Disassemble mold (base)-In	4.10	4.03	3.97	4.13	4.00	4.23	4.00	3.95	3.97
5	In	Collect mold-Ex	2.47	2.47	2.53	2.43	2.50	2.47	2.47	2.51	2.47
6	In	Prep machine-In	3.13	3.03	3.13	3.03	3.03	3.17	3.00	3.03	3.00
7	In	Assemble mold (base)-In	2.57	2.50	2.47	2.53	2.57	2.47	2.60	2.55	2.53
8	In	Mold quick check (top)-Ex	4.27	4.43	4.73	4.27	4.23	4.30	4.03	3.60	3.10
9	In	Assemble mold (top)-In	4.28	4.30	4.10	4.12	4.17	4.33	4.07	4.46	4.27
10	In	Mold alignment (base)-In	47.63	44.17	44.70	42.67	43.63	47.47	41.20	44.90	42.07
11	In	Secure mold-In	4.40	4.53	4.93	4.73	4.87	4.67	4.57	4.97	4.73
12	In	Test run-In	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
13	In	Main pressure setting-In	30.08	30.53	30.73	30.80	30.40	30.03	30.63	30.13	30.63
14	In	Feed rate setting-In	32.64	31.13	33.00	32.57	31.60	32.17	31.93	32.37	31.73
15	In	Carrier clamp setting-In	37.58	35.93	35.60	36.00	32.30	37.30	35.67	37.43	36.97
16	In	Folding pressure setting-In	52.53	51.23	56.37	60.37	46.80	56.70	59.23	53.07	56.30
17	In	Puller setting-In	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
		Grand total	301.69	297.17	301.17	304.45	285.93	311.60	303.24	299.55	302.57

activity easier; alternatively correctly setting the pressure can reduce the time spent. The final stage is the evaluation process, during which the application of the jig will be implemented into the changeover activities. From the experiment, the new changeover time was recorded and compared to the original changeover time. At the end of the stages, all the improvements will be documented for further improvement.

Applying 5S: Ho *et al*. (1995), Ho (1997) and Pheng (2001) have defined 5S as Seiri (Organization), Seiton (Neatness), Seiso (Cleanliness), Seiketsu (Standardization) and Shitsuke (Discipline). The 5S practice is a systematic approach to organizing and managing a working environment in order to improve efficiency, quality environmental performance, health and safety (Rahman *et al*., 2010).

Prior to its introduction, tools were strewn all over and not properly stored due to the unavailability of space. As a result, it is very time-consuming to find the necessary tool for changeover procedures when required. In order to improve the process, the tools are stored in a particular location (a rack) close to the stamping machine therefore making it easier for the technician to locate the tools. Figure 5 shows the rack that stores the mold for the stamping machine.

In addition, organizing the tools will positively impact the first step of the conversion activity preparation of the machine which also requires the same tools. Besides the tools, the rack that stored the mold was also improved. Earlier, the molds were stored randomly on the rack thus creating confusion while selecting the right mold to be used.

Jig approach: Mold alignment was done to synchronize the mold location between the top and bottom part of the mold and the machine itself. Aligning the mold is a very delicate process and any mistake can cause significant damage to the mold and the machine.

Fig. 5: Mold rack (improved)

Previously, mold alignment was done manually which was time-consuming as each alignment activity took nearly 40-45 min. The adjustment activities were time-consuming due to the complicated nature of tasks that required repetitive movements. It is therefore important to simplify this task and eliminate unnecessary repetitive movements that are time consuming. Jig is created to assist in mold alignment. The stamping machine uses the adjustable feature of the jig that facilitates its use in aligning all die molds.

Jig is also used to reduce the time and increase the productivity of production operations such as machining, assembling and inspection. The mass production of work-pieces is based on the concept of interchangeability according to which every part is produced within an established tolerance. Once the jig is correctly set up, any number of duplicate parts may be readily produced without additional set-up (Muniappan and Thiagarajan, 2014). For this improvement, the essential requirement of the jig is flexible, meaning that it is adjustable and can fit in and be used for all type of mold. Besides that, the jig must not be permanently attached to the machine but only when needed. This is to ensure that the jig does not interrupt machine operations later on.

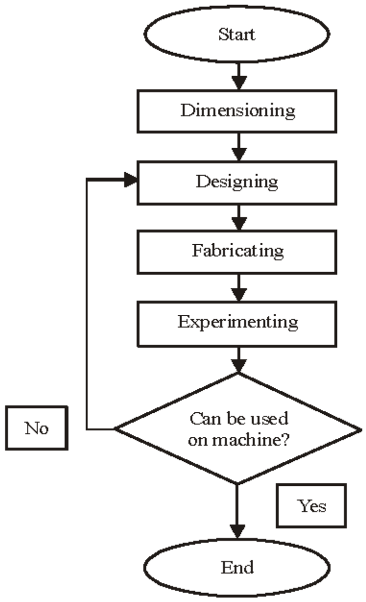

Fig. 6: Flowchart of jig development

Figure 6 shows the framework for developing the jig required in this study. In the first stage, the dimensions of the machine to be studied were obtained. Based on these dimensions, the exact shape of the jig that can be used on the press machine can then be created. In designing the jig, certain aspects and limitations must be considered such as flexibility and suitability of the jig to the machine.

Thereafter, the jig is created through two main processes: Laser cutting to shape jig parts and MIG (Metal Inert Gas) welding to attach all the parts. Lastly, the jig is tested on the machine and if it works as it is supposed to, that jig will later on be used in the mold alignment process. However, if the jig cannot be used on the machine, it must be redesigned to avoid any problem during the changeover procedures.

Technical drawing: In designing the jig, SolidWorks software was used. Figure 7a-f show the technical drawings of the jig.

Jig application: This jig is made of mild steel that is fashioned into the desired jig shape using a laser cutter and then certain parts are permanently joined together using the MIG welding processes. In order to use the jig, it needs to be attached onto the control panel of the machine as shown in Fig. 8.

Figure 8 shows the jig that is created to assist the mold alignment process during the changeover procedure. The jig

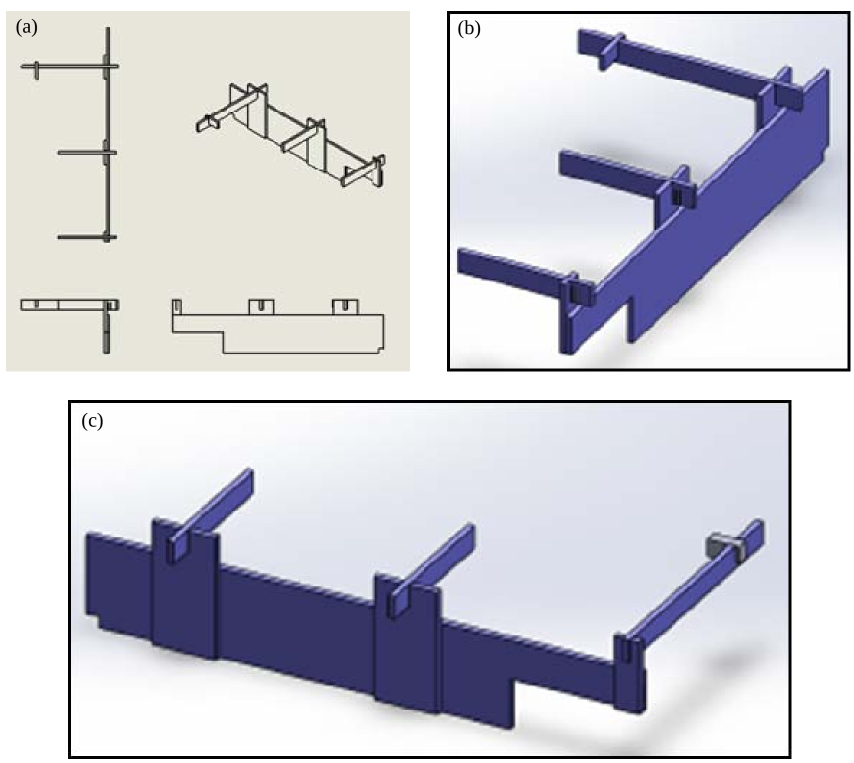

Fig. 7(a-f): Continue

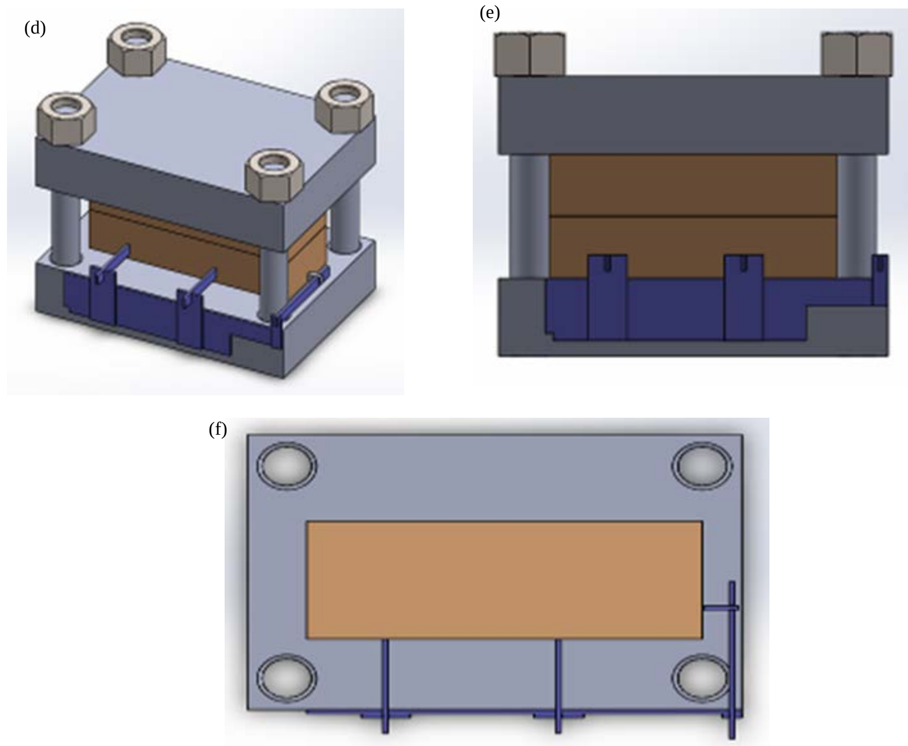

Fig. 7(a-f): Technical drawing of jig, (a) Jig drawing, (b, c) Jig assembly, (d) 3D, (e) Front and (f) Top view of jig application

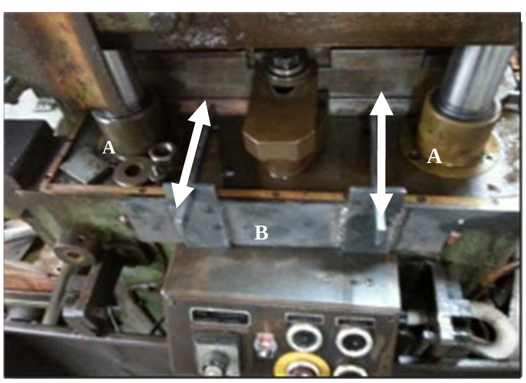

Fig. 8: Application of jig

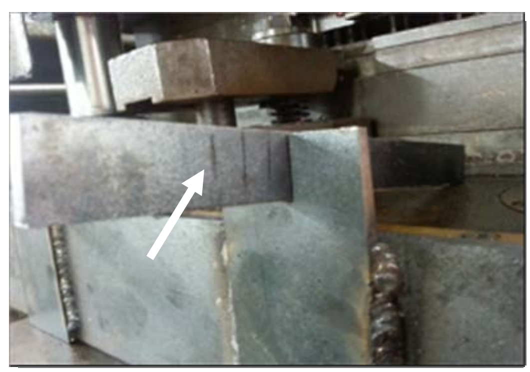

Fig. 9: Jig marking

part labeled (A) shows the adjustable part of the jig while part (B) is the base of the jig that will be fitted onto the machine. Parts (A) can slide forwards and backwards depending on the required mold to be aligned. On these parts, there will be markings indicating the location of the part where it is supposed to be based on the mold to be aligned. Figure 9 shows the markings on the jig that represent the length required for the jig to be extended.

The bar can be extended in line with the markings as shown in Fig. 9. Each marking represents different molds. It is important to ensure the bar extends according to the marking representing the current mold to be aligned.

Pressure-setting: The final improvements made are setting off the machine pressure. Previously, the setting was done based on trial and error. Pressure setting is the first step in resetting the stamping machine. Pressure was set by slowly turning a bolt located in the machine. During pressure setting, in order to obtain the right pressure, the technician would first use current pressure to press the raw material, creating a hole that would be compared to a previous production batch.

After determining the difference by measuring the depth of the hole using a vernier caliper, the bolt would be turned gradually until the pressed raw material was similar to a previous production batch. Nevertheless, the number of turns was undefined and usually done by trial and error, thereby necessitating the development of a system to eliminate the trial and error method. The trial and error method was particularly time consuming when the first try was unsuccessful; this step took 30.44 min before improvements were implemented. The improvement was a system created to remove trial and error by reducing the time needed to set the pressure by 92.34% (28.11 min). With this, the next phase of the changeover (i.e., setting the machine) is done in a total reduced time of 28.11 min (14.54%) compared to the previous 193.31 min it took to completely set the machine.

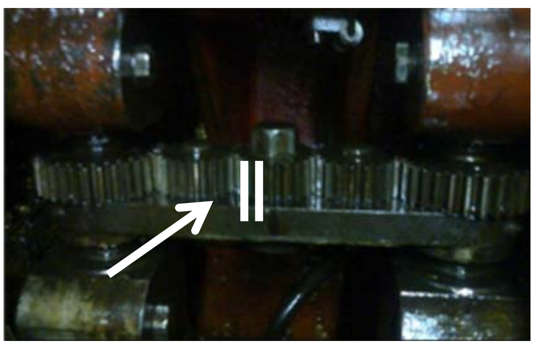

Fig. 10: Pressure-setting gap

Figure 10 shows the system that helps in simplifying the process of mold pressure setting. The gap between the two gear teeth will be used as the measurement tool. Each gap represents constant change of pressure, hence will provide the technician a better view of how much pressure change will occur with every degree the nut is turned. Based on the trial on setting the pressure, it was found that one tooth gap represents a difference of one millimeter of press depth. In other words, whenever the bolt turns every gap of the gear tooth, the hole depth on raw material will be increased by one millimeter.

RESULTS

In the early stages of SMED, an observation study was conducted to examine the changeover procedures in order to determine the activities involved in the changeover procedures and their sequence. In addition, stopwatch time study was conducted to determine the time taken by each activity during the changeover procedures. In obtaining the data, the changeover time was taken three times for each mold and the average used as a benchmark, since according to Shaw (1971) if the studied cycle time is above 40 min, the cycle needs to be recorded three times for current changeover time.

In finding the effectiveness of the proposed improvement, a new observation was conducted during the changeover procedures. This time, all the improvements have been included during the changeovers. Simultaneously, the time study was also conducted to determine the time taken by each changeover activity and had been recorded in Table 2. From the table SMED tool has eliminated three steps of changeover procedure i.e. collecting tools, collect mold from the store

Table 2: Stamping machine changeover time (minute) before and after SMED[1] implementation

			Mold type																	
			6		7		7 Square		8		9		11		13		15		17	
Step No.	Type	Changeover procedure	Before	After	Before	After	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	5.50	10.00	5.80	10.00	5.70
2	Ex	Collect tools	4.67	0.00	4.83	0.00	4.60	0.00	3.43	0.00	4.30	0.00	5.97	0.00	4.40	0.00	3.97	0.00	5.13	0.00
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	8.87	8.87	8.32	8.32	8.37	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	4.00	4.00	3.95	3.95	3.97	3.97
5	Ex	Collect mold	2.47	0.00	2.47	0.00	2.53	0.00	2.43	0.00	2.50	0.00	2.47	0.00	2.47	0.00	2.51	0.00	2.47	0.00
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	3.03	3.03	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	2.60	2.60	2.55	2.55	2.53	2.53
8	Ex	Mold quick check (top)	4.27	0.00	4.43	0.00	4.73	0.00	4.27	0.00	4.23	0.00	4.30	0.00	4.03	0.00	3.60	0.00	3.10	0.00
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	4.07	4.07	4.46	4.46	4.27	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	41.20	8.80	44.90	9.60	42.07	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	4.57	4.57	4.97	4.97	4.73	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	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	104.20	62.83	107.25	63.67	104.63	63.47
Machine setting																				
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	1.80	30.13	2.20	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	31.93	31.93	32.37	32.37	31.73	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	35.67	35.67	37.43	37.43	36.97	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	59.23	59.23	53.07	53.07	56.30	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	41.57	41.57	39.30	39.30	42.30	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	199.03	170.20	192.30	164.37	197.93	169.80
		Grand total	301.69	220.68	297.17	218.23	301.17	222.77	304.45	231.75	285.93	209.97	311.60	228.87	303.24	226.60	299.55	222.04	302.57	227.47
		Time reduction	81.02		78.93		78.40		72.70		75.97		82.73		76.64		77.51		75.10	
		Percentage reduction(%)	26.85		26.56		26.03		23.88		26.57		26.55		25.27		25.88		24.82	

[1]Single minute of exchanging die

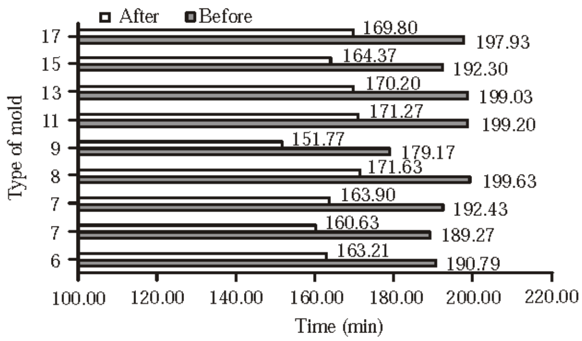

Fig. 11: Changeover reduction time graph

and check top mold. Another improvement is reduce time to preparing the machine before the changeover and increases the efficiency of mold alignment; examples, type six of mold; preparing the machine reduce from 47.63-10 min and mold alignments reduce from 47.63-10 min.

DISCUSSION

The result show that four activities have been improved following SMED implementation. With regards to overall time reduction, it shows that on average (for all mold), 25.62% time had been reduced which is nearly 223.15 min. From the study, the activities which contribute to the increment of changeover time are machine preparation, tools collection, mold collection, mold quick check, mold alignment and pressure setting. By this finding, the first complications are more to the set-up job identification and the second more to the lack of jig application. That's why, after the identifying and converting some procedures, some procedure had been eliminated and after the proposed jig; some procedure time had been reduced. Figure 11 graphically portrays a comparison of the improvements for each mold type before (blue) and after (red) the implementation of lean tools.

According to Fig. 11 the highest reduction is mold type 11 (82.73 min) and the lowest is mold type 8 (72.70 min). By referring to the previous research, SMED is the one of a powerful lean tool in enhancing the success of LM implementation by 61% setup time reduction 50% reduction of work in progress, 99% reduction of human movement (Costa *et al*., 2013), 5.32% increment of overall equipment effectiveness, increase 12% increment of on-time-delivery (Mulla *et al*., 2014) and 65.28% reduction in change over time (Sayem *et al*., 2014).

CONCLUSION

In conclusion, SMED has been successfully implemented on the stamping machine. Prior to the implementation, the initial recorded average changeover time of the machine was 300 min. Following the implementation of SMED, the average changeover time was reduced to 223.15 min which represents a 25.65% reduction from the previous changeover time. A number of improvements have been made including the application of 5S, the use of jig in mold alignment and the creation of a new system to assist pressure settings. However, further improvements still need to be made e.g., implementation of other LM tools or optimization of the newly implemented SMED to achieve shorter changeover time and higher flexibility.

ACKNOWLEDGMENT

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).

REFERENCES

Abdulmalek, F.A. and J. Rajgopal, 2007. Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study. Int. J. Prod. Econ., 107: 223-236.

BNM., 2013. Annual report 2013. Bank Negara Malaysia, Kuala Lumpur, Malaysia. http://www.bnm.gov. my/files /publication/ar/en/2013/ar2013_book.pdf.

Costa, E., S. Braganca, R. Sousa and A. Alves, 2013. Benefits from a SMED application in a punching machine. Int. J. Mech. Ind. Sci. Eng., 7: 373-379.

Dahlgaard, J.J. and S.M. Dahlgaard-Park, 2006. Lean production, six sigma quality, TQM and company culture. TQM Mag., 18: 263-281.

Ferradas, P.G. and K. Salonitis, 2013. Improving changeover time: A tailored SMED approach for welding cells. Proc. CIRP, 7: 598-603.

Ghosh, M., 2013. Lean manufacturing performance in Indian manufacturing plants. J. Manuf. Technol. Manage., 24: 113-122.

Ho, S.K., S. Cicmil and C.K. Fung, 1995. The Japanese 5-S practice and TQM training. Training Qual., 3: 19-24.

Ho, S.K.M., 1997. Workplace learning: The 5-S way. J. Workplace Learn., 19: 185-191.

Holweg, M., 2007. The genealogy of lean production. J. Oper. Manage., 25: 420-437.

Kumar, B.S. and S.S. Abuthakeer, 2012. Implementation of lean tools and techniques in an automotive industry. J. Applied Sci., 12: 1032-3037.

Mohamad, E., M.R. Mohd and R. Abdullah, 2008. Lean manufacturing implementation: A study on the development of Key Performance Indicators (KPIS) at aerospace manufacturing company. Proceedings of the International Conference on Mechanical and Manufacturing Engineering, May 21-23, 2008, Johor Bharu, Malaysia.

Mohamad, E. and T. Ito, 2011. University-industry collaboration in lean manufacturing implementation. Proceedings of 2nd Asian Conference on Engineering Education, October 7-9, 2011, Tokushima, Japan, pp: SS3-6:1-SS3-6:6.

Mohamad, E., M.H. Arzmi, T. Ito, M.S. Kasim, T. Sahroni and M.WA. Rashid, 2014. Improving die exchange process in textile manufacturing company with SMED. Proceedings of the 24th Design Engineering Systems Division JSME Conference Japan Society of Mechanical Engineers, September 17-19, 2004, Tokoshima, Japan.

Mohamad, E.B. and T. Ito, 2013. Integration of e-learning and simulation to user training programme of SMED. Int. J. Internet Manuf. Serv., 3: 121-136.

Moreira, A.C. and G.C.S. Pais, 2011. Single minute exchange of die: A case study implementation. J. Technol. Manage. Innov., 6: 129-146.

Mulla, M.L., S.G. Bhatwadekar and S.V. Pandit, 2014. Implementation of lean manufacturing through the technique of Single Minute Exchange of Die (SMED) to reduce change over time. Int. J. Innovative Res. Sci. Eng. Technol., 3: 13069-13076.

Muniappan, A. and C. Thiagarajan, 2014. Design and fabrication of stab arm weldment for drilling jig. Int. J. Applied Res. Stud., 3: 1-6.

Pecas, P. and E. Henriques, 2006. Best practices of collaboration between university and industrial SMEs. Benchmarking: Int. J., 13: 54-67.

Pettersen, J., 2009. Defining lean production: Some conceptual and practical issues. TQM J., 21: 127-142.

Pheng, L.S., 2001. Towards TQM-integrating Japanese 5-S principles with ISO 9001:2000 requirements. TQM Mag., 13: 334-341.

Rahman, M.N.A., N.K. Khamis, R.M. Zain, B.M. Deros and W.H.W. Mahmood, 2010. Implementation of 5S practices in the manufacturing companies: A case study. Am. J. Applied Sci., 7: 1182-1189.

Sayem, A., M.A. Islam and M.M.A. Khan, 2014. Productivity enhancement through reduction of changeover time by implementing SMED technique-in furniture industry. Int. J. Ind. Syst. Eng., 17: 15-33.

Shaw, A.E., 1971. Stop-Watch Time Study. In: Industrial Engineering Handbook, Maynard, H.B. (Ed.). 3rd Edn., McGraw-Hill, New York, pp: 294.

Shingo, S., 1985. A Revolution in Manufacturing: The SMED System. Productivity Press, New York, ISBN-13: 978-0915299034, Pages: 361.