

An application of SMED Methodology

Berna Ulutas

Abstract—Single Minute Exchange of Dies (SMED) mainly focuses on recognition of internal and external activities. It is concerned particularly with transferring internal activities into external ones in as many numbers as possible, by also minimizing the internal ones. The validity of the method and procedures are verified by an application a Styrofoam manufacturing process where setup times are critical for time reduction. Significant time savings have been achieved with minimum investment. Further, the issues related with employer safety and ergonomics principles during die exchange are noted.

Keywords—die exchange, internal-external set-up, lean manufacturing, single minute die exchange.

I. INTRODUCTION

SMED was developed by Shigeo Shingo in 1950s Japan in response to the emerging needs of increasingly smaller production lot sizes required to meet the required flexibility for customer demand. The study was originally developed through the study of a die change process [1]. Generally, SMED aims to standardize and simplify the operations. By this means, the need for special skilled workers is also minimized. Since then, the ways to improve and support the SMED technique are considered in the literature. The SMED technique is used as an element of Total Productivity Maintenance (TPM) and “continuous improvement process” in various studies to reach lean manufacturing [2–5]. [6] describes lean enablers which is based on the principles of lean production. Incorporated into an appropriate methodology, lean enablers can be employed to design new factories or deduce measures to improve existing factories.[7] initially focus set on critical stations that have long setup times. With the application of SMED, improvements were substantial with initial data showing reduction of setup time ranging from 25% to as high as 85%. With the reduced setup time, production flexibility expanded as it was able to afford more frequent product mix changes. In addition, machine utilization and equipment went up with the reduced setup. Case studies about setup reduction at different manufacturing environments take place in some texts [8-10]. In addition, the technique is evaluated about its sequential implementation approach [11]. An important lack of the SMED was the consideration and motivation of human factor. This issue is discussed in the academic texts [11, 12]. Another important discussion about the SMED methodology in the literature is the impact of design on setup operations [11, 11-

15]. [16] addresses the effect of decreasing setups through learning, on the multi-item capacitated lot sizing problem and the results of transmission of learning between items that can result from the use of standardized fixtures. Research outcomes illustrate the opposite effects observed from setup time reduction depending on the capacity and learning levels. [17] present a case study and argue the sequential application of stages of the SMED methodology, including the sequential application of improvement techniques that are assigned to those stages, need not always represent an effective improvement route. [18] provide a review of the latest research on scheduling problems with setup times/costs. [19] utilize the Cpk index to provide a quantitative measurement of the equipment design by applying the SMED methodology in automobile manufacturing. It is indicated that SMED in other words “quick changeover” is still a suitable method not only for manufacturing improvement but also for equipment/die design development.[20] investigate the die casting process that uses high productive level machines. The changeover procedure during die casting process is studied as possible area for reducing time consumption.[21] focus on the SMED applications for process industry plants that produce materials like paints, paper products, foods, beverages, personal care items and fiber, and apparel rather than assembled products such as refrigerators, cell phones, or automobiles. It is noted that changeover complexity should be considered in addition to the mechanical and electrical changes when changing to a different product since these industries often need chemistry and physics changes during the process is reaching equilibrium on the new product and specified properties.[22] describes the improvement of the quick changeover process of a painting line in a wooden frames factory. The application presents the scheduling of the involved setup operations, considering their duration, precedence relations and resources' need, in order to achieve a reduced setup time.[23] develop a new structured methodology based on lean SMED to help Reconfigurable Manufacturing Systems reconfigure in a more efficient way, introduce various external and internal convertibility activities, and how to redesign these activities to make the convertibility process less timely. The aim of this study was to assess the die exchange activities and by following SMED methodology steps reduce inefficient times and consider human issues. For this purpose, this study is structured as follows. First, lean manufacturing concepts are summarized. Third section introduces main steps of SMED. Section four presents the application and results obtained. Finally, conclusions are provided in the last section along with further research directions.

Berna Ulutas is with the Department of Industrial Engineering, Eskisehir Osmangazi University, Eskisehir 26480 Turkey (phone: +90-222-2303972 (ext.3631); fax: +90-222-2393613; e-mail: bhaktan@ogu.edu.tr).

II. LEAN MANUFACTURING

Lean manufacturing is known as a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. For many, lean manufacturing is the set of "tools" that assist in the identification and steady elimination of waste (muda). The main tools of a manufacturing program are value stream mapping, 5S, TPM, SMED, and Six Sigma. There are also less used tools or subsets of the major tools, such as a Kaizen improvement culture, Hoshin Planning, mistake proofing, Jidoka, standardized work, and just in time inventories. These tools focus on certain aspects and areas of the manufacturing process to eliminate waste and improve quality while production time and cost are reduced. The waste reduction philosophy of considers the change over time as a non-value added activity. Change over time that is illustrated in Figure 1 is defined as a method of analyzing and reducing the time needed to change a process from producing one good part to producing the next good part.

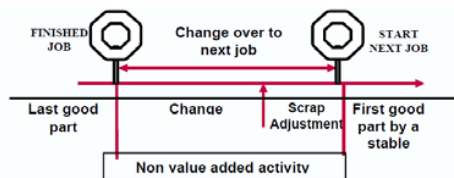


Fig. 1 Representation of change over time

[23] present a brief history of lean manufacturing and then discuss the different facets or tools that are components of an effective lean culture and program.

III. SMED

SMED is one of the many lean production methods for reducing waste in a manufacturing process. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product. This rapid change over is key to reducing production lot sizes and thereby improving flow. The phrase "single minute" does not mean that all changeovers and startups should take only one minute, but that they should take less than 10 minutes (in other words, "single-digit minute") [1]. Closely associated is a yet more difficult concept, One-Touch Exchange of Die, (OTED), states the change overs can and should take less than 100 seconds. SMED was originally developed to improve die press and machine tool setups, but its principles apply to changeovers in all type of processes. Setup operation is defined as the preparation or post adjustment that is performed once before and once after each lot is processed [1]. Shingo divides the setup operation into two parts: Internal setup: The setup operation that can be done only when the machine is shut down (attaching or removing the dies).

External setup: The setup operation that can be done when the machine is still running. These operations can be

performed either before or after the machine is shut down; for example, getting the equipment ready for the setup operation can be done before the machine is shut down. The three main steps of SMED, also given in Fig.2, can be summarized as follows:

- Step 1: Separating internal and external setup
- Step 2: Converting internal setup to external setup
- Step 3: Streamlining all aspects of the setup operation

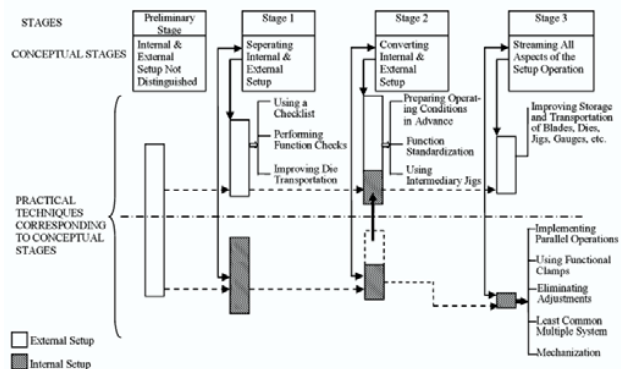


Fig. 2 SMED conceptual stages and practical techniques

IV. APPLICATION

This application aims to optimize machine utilization, enabling small lot sizes, reducing production times, reducing the time that machine does not operate. Also, shortening preparation and machine adjustment times and reducing stocks. The facility in concern manufactures Styrofoam products that are used to support mainly for refrigerators during packing and handling. The injection presses in the facility are also capable of producing other products by utilizing the dies that are designed for automotive parts and construction sites. High product variation forces the company to make changeovers frequently. Huge presses (5-meter high) are used. The dies that are mounted to the presses have dimensions around $2000 \times 1000 \times 500 \text{ mm}^3$. Setting up these machines takes a long time and the company had to reduce set-up times. Based on the initial observations, the changeover times are recorded up to 5-6 hour. Even for small sized presses that utilize smaller dies total setup times were 3-3.5 hours on the average. The records for the 155 dies are analyzed and their physical features (i.e., dimensions, weights, etc.), frequency of their use, and handling distances are identified. Considering the set up times and frequencies for the presses, a Pareto analysis was applied to determine the problematic machine that must be focused on first. Then the concepts of SMED are applied to reduce setup times.

4.1. Analyzing setup time

A video recorder was used to analyze how setup tasks are executed in the current case. Then, based on the activities, total time is analyzed. A pie chart is drawn where the percent of task times are stated in Fig. 3.

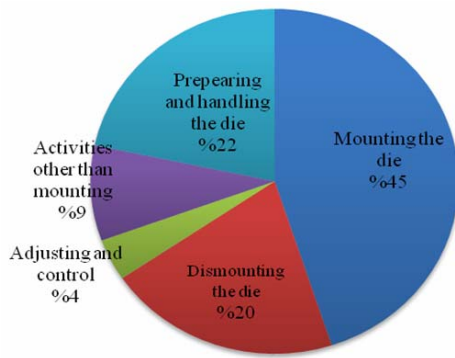


Fig. 3 Current percent of setup steps

4.2. Eliminating inefficient time

Eliminating the time that may be wasted during searching required equipments is important. Therefore, a list of materials and equipments that is being used during setup is made. Also, forms are designed to enable that they are available and properly working when needed.

4.3. Identifying internal and external setup

Considering the man-machine diagrams for the setup tasks, internal and external setups were assessed. In this step, task groups are formed and their total time was identified. Table 1 summarizes the type of setup and corresponding tasks.

TABLE I
IDENTIFYING INTERNAL AND EXTERNAL SETUPS

Type of setup	Tasks groups	Total Time
Internal setup	b, c, d, e, f, g, h, i, j, k	141min 8sec
External setup	a, l, m, n	14min 51sec

4.4. Converting internal setup to external setup

In order to convert internal setup times to external setup times, main focus was on the tasks related with product and material handling, information gathering, cleaning, maintenance, adjustment and control.

In the current state, the centering mechanisms of dies were being changed after the machine was stopped. The dies needed to be transported from the department where the dies were stored. On the other hand, changing the centering mechanism was really a hard operation, taking long time and so difficult to standardize. Therefore, this operation was suggested to be done as an external activity. Required centering mechanism could be prepared on a spare die at the die center before machine was stopped.

One of the problematic activities was identified as the handling of the dies. Therefore, transporting dies was defined as an external operation. Further, an available tow truck or forklift had to be get set before setup. Since the department where the dies were located to the far corner of the factory, the distanced to handle the dies were taking excessively long. Therefore, it is suggested that the most frequently used dies should be located nearby the presses.

Considering the weight of the dies, the handling and mounting the dies tasks being executed by the operators were noted as unsafe. Operators were centering the dies by trial-and-error approach, lifting the dies on the top of the pres by a manually operated jig, and skewing the nuts with lots of efforts. By using more automated material handling equipment, 11 minute and 21 seconds are expected to decrease. To reduce setup time and waste time using manual clamps as a cheap and fast alternative to bolts and screws; using quick fixtures, hydraulic, pneumatic, or electromagnetic fixtures may also be helpful. Further, inserting and removing screw tasks is expected for the operators. The use of these fixtures shortened the tasks 86 minute 26second. On the other hand, since the operator was using both hands, it was a dangerous operation that was executed on a tall machine and required extreme care. The assignment of internal and external tasks is assigned to operator 1 and 2. Some activities are suggested to be executed together, simultaneously, or alone. Table 2 and Table 3 provide these assignments along with their standard times.

TABLE II
INTERNAL AND EXTERNAL TASKS DEFINED FOR OPERATOR 1

Setup	Tasks	The way of doing	Standard time (sec)
External	a	Together	164
Internal	b	Together	94
Internal	c	Simultaneously	392
Internal	d	Together	640
Internal	e	Simultaneously	1540
Internal	f	Together	991
Internal	g	Together	1108
Internal	h	Simultaneously	1547
Internal	i	Together	1035
Internal	j	Simultaneously	537
Internal	k	Together	624
External	l	Alone	368

TABLE III
INTERNAL AND EXTERNAL TASKS DEFINED FOR OPERATOR 2

Setup	Tasks	The way of doing	Standard time (sec)
External	a	Together	164
Internal	b	Together	94
Internal	c	Simultaneously	392
Internal	d	Together	640
Internal	e	Simultaneously	1540
Internal	f	Together	991
Internal	g	Together	1108
Internal	h	Simultaneously	1547
Internal	i	Together	1035
Internal	j	Simultaneously	537
Internal	k	Together	624
External	m	Alone	120
External	n	Alone	239

4.5. Standardization

In the final step, the improvement studies were reported and checklists were formed. The causes for recursive activities were determined as much as possible and act plans to eliminate them were provided. Finally, the setup tasks will no longer be unpredictable time delays by use of the precise time

records. Therefore, better planning activities will lead to better customer satisfaction. The education and skill levels of the workers are also an important issue that needs to be considered during standardization.

V. CONCLUSION

In this study, SMED methodology was applied to prepare an optimal standard procedure for changeover operations on defined machine. Ergonomics and safety issues were also taken into consideration during setups. Since an ergonomic workplace makes operations easier for the operators, simple however crucial changes are suggested.

Further studies in the facility may include 5S and Kaizen studies for internal setup. Alternative ways to shorten internal setups can be searched in detail. In order to eliminate adjustment steps, trial and errors should be minimized. Settings must be used for changeover operations instead of adjustments. Therefore, a design of experiments study can be done to determine parameters of the machine.

It should be kept in mind that successful implementation of new production methods requires sustainability and permanent solutions and the key of sustainability is the standardization of that optimal solution.

REFERENCES

- [1] S. Shingo, "A revolution in manufacturing, the SMED system", 1985, Productivity Press.
- [2] M.C. Eti, S.O.T. Ogaji, S.D. Robert, "Implementing total productive maintenance in Nigerian manufacturing industries", *Appl Energy*, 2004, vol. 79, pp. 385–40.
- [3] G. Chand, B. Shirvani, "Implementation of TPM in cellular manufacture", *J Mater Process Technol*, 2000, vol. 103, pp. 149–154.
- [4] H. Sun, R. Yam, N.G. Wai-Keung, "The implementation and evaluation of Total Productive Maintenance (TPM) - an action case study in a Hong Kong manufacturing company", *Int J Adv Manuf Technol*, 2003, vol. 22, pp. 224–228.
- [5] L. Bamber, B.G. Dale, "Lean production: A study of application in a traditional manufacturing environment", *Prod Plan Control*, 2000, vol. 11, no. 3, pp. 291–298.
- [6] P. Nyhuis, C.P. Schulze, and T. Klemke, "Lean-Enablers – An Approach to Design Lean Factories", *The Business Review*, Cambridge, December 2010, vol. 16, no. 1, pp. 113–119.
- [7] R.O. Agustin and F. Santiago, "Single-minute exchange of die", *In Proceedings of Advanced Semiconductor Manufacturing Conference and Workshop - ASMC 96 - Theme - Innovative Approaches to Growth in the Semiconductor Industry*, 1996, pp.214–217.
- [8] M. Gilmore, D.J. Smith, "Set-up reduction in pharmaceutical manufacturing: an action research study", *Int J Oper Prod Man*, 1996, vol. 16, no. 3, pp. 4–17.
- [9] S. Tharisheneprem, "Achieving Full Fungibility and Quick Changeover By Turning Knobs In Tape and Reel Machine By Applying SMED Theory", *In Proceedings of 33rd International Electronics Manufacturing Technology Conference*, 2008, 5 pages.
- [10] C. Moxham, R. Greatbanks, "Prerequisites for the implementation of the SMED methodology: A study in a textile processing environment", *Int J Qual Reliab Man*, 2001, vol. 18, no. 4, pp. 404–414.
- [11] R. McIntosh, S. Culley, G. Gest, T. Mileham, G. Owen, "An assessment of the role of design in the improvement of changeover performance", *Int J Oper Prod Man*, 1996, vol. 16, no. 9, pp. 5–22.
- [12] D. Van Goubergen, H. Van Landeghem, "Reducing setup times of manufacturing lines", *In Proceeding of International Conference on Flexible Automation and Intelligent Manufacturing*, Dresden, Germany, 2002.
- [13] D. Van Goubergen, H. Van Landeghem, "Rules for integrating fast changeover capabilities into new equipment design", *Robot Comput Integr Manuf*, 2002, vol. 18, pp. 205–214.
- [14] A.R. Mileham, S.J. Culley, G.W. Owen, R.I. McIntosh, "Rapid Changeover– a pre-requisite for responsive manufacture", *Int J Prod Man*, 1999, vol. 19, no. 8, pp. 785–796.
- [15] [14] S. Patel, P. Shaw, B.G. Dale, "Set-up time reduction and mistake proofing methods: A study of application in a small company", *Bus Process Man J*, 2001, vol. 7, no. 1, pp. 65–75.
- [16] E. Pratsini, "Learning complementarity and set up time reduction", *Comp Oper Res*, vol. 25, no. 5, pp. 397–405, 1998.
- [17] R.I. McIntosh, S.J. Culley, A.R. Mileham, and G.W. Owen, "A critical evaluation of Shingo's 'SMED' (Single Minute Exchange of Die) methodology", *Int J Prod Res*, 2000, vol. 38, no. 11, pp. 2377–2395.
- [18] A. Allahverdi, H.M. Soroush, "The significance of reducing setup times/setup costs", *Eur J Oper Res*, 2008, 187, pp. 978–984.
- [19] M. Cakmakci, "Process improvement: performance analysis of the setup time reduction-SMED in the automobile industry", *Int J Adv Manuf Tech*, 2009, vol. 41, pp. 168–179.
- [20] M. Perinic, M. Ikonc, S. Maricic, "Die Casting Process Assessment Using Single Minute Exchange Of Dies (SMED) Method", *Metalurgija*, July-September 2009, vol. 48, no. 3, pp.199–202.
- [21] P.L. King, "SMED in the Process Industries", *IE*, September 2009, pp.30–35.
- [22] R.M. Sousa, R.M. Lima, J.D. Carvalho, A.C. Alves, "An Industrial Application of Resource Constrained Scheduling for Quick Changeover", *In Proceedings of IEEE International Conference on Industrial Engineering and Engineering Management (IEEM 2009)*, Hong Kong, December 08–11, 2009, vol. 1–4, pp. 189–193.
- [23] A.M. Deif, "A Lean Approach to Improve Reconfigurable Manufacturing Systems", *In Proceedings of the 2010 Industrial Engineering Research Conference*, A. Johnson and J. Miller, eds., 7 pages.
- [24] M.C. Kocakulah, J.F. Brown, J.W. Thomson, "Lean Manufacturing Principles and their Application", *Cost Management ABI/INFORM Global*, May/Jun 2008, vol. 22, no. 3, pp. 16–27.

Berna Ulutas was born in 1977. She received her Ph.D. in Industrial Engineering. She is an Assistant Professor of Industrial Engineering at Eskisehir Osmangazi University, Turkey. She worked as a post-doc fellow at Penn State Berks, USA. Her main researches include modeling and optimization of facility layout problems by use of bio-inspired heuristics. She also conducts research related with decision making methods (i.e., DEA, ANP) to solve real life problems. Dr. Ulutas is a member of Chamber of Turkish Mechanical Engineering.