Shortening Changeover Time - An Industrial Study

Justyna Trojanowska, Krzysztof Żywicki
Chair of Management and Production Engineering
Poznan University of Technology
Line 3: Poznan, Poland
justyna.trojanowska@put.poznan.pl

[1]Maria Leonilde R. Varela, [2]José M. Machado
[1]Department of Production and Systems, [2]Mechanical Engineering Department
University of Minho, Guimarães, Portugal
leonilde@dps.uminho.pt, jmachado@dem.uminho.pt

Abstract— **This paper presents the results of the use of the Single Minute Exchange of Die method to shorten changeover time on machines in a polish production company. This project has been developed for a manufacturing company, whose products are fiberboard, hardboard and softboard products manufactured by a highly specialized industry using only pure wood fibers. Long changeover times used to conduct to bad results in timely delivery of orders. Therefore, in this work each element of the changeover time was analyzed to understand if it could be eliminated, moved or simplified. Implemented solutions significantly reduce setup time and improve the Company's competitiveness.**

Keywords- single minute exchange of die method, fiberboard manufacturing, lean manufacuring.

I. INTRODUCTION

Economic changes on the competitiveness of wood industry are forcing the producers willing to maintain position in the market to search for solutions designed to streamline production processes. Therefore, the application of appropriate management concepts or philosophies, aimed at reducing costs by eliminating waste and improving production processes are needed. Thereby obtaining competitive advantage leads often to the need of applying the Lean Manufacturing methodology, and this is derived from the Toyota Production System concept. Creators of this methodology were Sakichi Toyoda, Ki'ichirō Toyoda and Taiichi Ohno. The main types of waste identified in manufacturing companies are usually divided into seven categories (overproduction, inventory, unnecessary movements, unnecessary over-processing, defects, unnecessary transport, and waiting) [1] and one of the tools greatly used to reach improvements reduction or elimination regarding these categories is the method of Single Minute Exchange of Die (SMED) [2, 3]. The creator of the SMED methodology is Shingeo Shingo, who introduced the concept of rapid changeovers in 1950.

II. LITERATURE REVIEW

The increasing speed of technological change and globalization of emerging markets has enlarged competition worldwide, leading manufacturers face unprecedented pressure levels. The tensions created by the appearance of foreign products, new product introductions by competitors, more innovative methods, items with shorter life and advances in production and information technology forced companies to respond to these demanding and growing challenges, as stated by Karim Smith, Halgamuge, and Islam, in 2008 [5]. As a result, organizations that understood the importance of belonging to a global market sought to become more competitive through the use of operational methods based on innovative production systems, distinct from traditional manufacture models, as referred in 2005, by Rawabdeh [6] unable to meet the requirements and paradigms of the current situation. Thus, Companies have been forced to look beyond costs, looking for a greater emphasis on products that are needed by customers, while providing answers more quickly than its competitors and exceeding the quality requirements [6].

According to Womack and Jones, in 2003, in order to achieve these objectives outlined by the organizations it is useful to apply Lean Production (LP) methodology [7]. This concept was introduced by John Krafcik, referred by Womack, Jones and Roos, in 1990, as a way of referring to Toyota Production System (TPS) [8]. LP is defined by Shah and Ward, in 2003, as a multi-dimensional approach that encompasses a wide variety of tools in an integrated system [9], which main underlying ideas consist on the continuous elimination of waste, as being all the activities that add no value to the process or product, and requiring a fundamental organizations' culture change, as stated by Liker, in 2004 [10], and Pavnaskar, Gershenson, and Jambekar, in 2003 [11]. As stated by Melton in 2005 [12], the lean philosophy leads to many benefits, such as reduced lead times, reduced need for rework, reduced costs, increased robustness of processes, reduced inventory and elimination of "Muda".

In The well-known book "Toyota Production System: Beyond Large-Scale Production" by Ohno, in 1988 [13], the author identified the overproduction, defects, excess inventory, drives to overproduce, transport and waits as the seven wastes to be eliminated through the implementation of this methodology. Later, Liker, in 2004 [10] pointed to the wastage of the creativity of workers as the eighth waste, believing that the fact that organizations that do not involve or listen to their employees are responsible for loss of time, ideas, and opportunities for improvement and learning.

The Lean methodology is based on five fundamental principles put forward by Womack and Jones, in 2003) [7] - Value, Value Chain, Flow, Pull and Perfection - which, according to Hines, Found, Griffiths and Harrison, in 2011 [14], enable to demonstrate how this approach can be extended to any organization or company, regardless of the kind of industry on which they operate or the country where they are placed. The value specifies what does add actually value to some process or product, according to the customers' perspective, and is the first critical step on this philosophy. Creating Value Chain ensures that each step provides value, summing up the set of activities necessary to obtain a product or service that satisfies the customer. The flow rearranges the processes for products to move smoothly through the steps of creating value. The Pull strategy allows the client to "pull" the product, rather than being pushed to him. Finally there is the Perfection, which is based on a constant effort in order to meet customer needs, in order to improve processes and achieving "zero defects", as stated by several authors, namely by Womack and Jones, in 2003, and by Staats, Brunner, and Upton, in 2011 [7, 15, 16, 17]. When implemented together, these principles form the Lean thinking for simplifying how the company produces value for its customers while eliminating all kind of waste, forming a solution process that, through incremental and gradual changes, can completely change work processes and mostly people [18].

The Lean production model provides a set of tools that assist in the identification and steady elimination of "Muda" in a company or organization, as referred by Kumar and Abuthakeer, in 2012 [19], such as Kaizen (Continuous Improvement), Value Stream Mapping (VSM), 5S, Total Productive Maintenance (TPM), Single Minute Exchange of Die (SMED) and Just-in-Time (JIT). The Kaizen philosophy is the starting point for all Lean initiatives and is based on continuous improvement throughout the organization, as referred by Ortiz, in 2006 [20]. The VSM, as an analysis and diagnostic tool, displays and identifies waste and its sources, as stated by Rother and Shook, in 2003 [21]. Courtois, Martin-Bonnefois, and Pillet, in 1997 state that the 5Ss aim at the systematization of the Companies' activities, and the organization and cleaning of workspaces [22]. Moreover, Swanson, in 2001refere that the TPM seeks to improve the performance of the equipment while constantly preventing the occurrence of faults [23].

The SMED allows a decrease on the equipment setup times, providing many benefits to Companies, such as reductions in stock levels, the WIP, the size of the lots, the times of production and delays, as well as improvements in quality, flexibility of production, safety and capacity, as stated by Shingo, in 1985 [24]. Moreover, according to Courtois et al., in 1997 [22], the JIT philosophy aims to produce only what will be sold at the time needed, attempting to eliminate as much waste in organizations in order to achieve zero inventory, as is also referred by Ha and Kim, in 1997 [25]. However, Liker, in 2004 [10] recalls that the use of Lean tools in a Company is not in itself a guarantee of success, since the possibility of making the adoption of this philosophy, in a competitive and sustainable advantage, is dependent on the follow-up of all the principles that make it up. When this is not accurately accomplished, Companies are only able to generate short-term results and will turn unsustainable.

III. Single Minute Exchange of Die

The SMED method means a fast changing tool aiming at reducing the time of a production changeover. This method does also facilitate the reduction of waste by setting the minimal lot size.

During the production changeover, there is an important aspect of production that should not be neglected: the starting process of a fabrication line. This part could represent a significant time waste if it does not perform well. The objective is to reduce the setting time, for decreasing the production changeover time or instant adjustments. Hence, in order to reduce the setting time of the production changeover two major procedures may be adopted [2]:

- Internal operations: It corresponds to operations that could be done only if the machine is stopped and produces nothing.
- External operations: Those operations could be performed even if the machine is in production mode.

In order to apply this technique, we should follow strictly four steps [4]:

1. Identification of internal and external operations

This first step will affect the result if it is not done well. In classic settings, internal and external operations are mixed. It means that some internal operations are done in external way, and vice versa. A precise analysis on how its production changeover is done, at a given moment, should be undertaken. One way to accomplish this step is to film one or more production changeover. Those films will be analyzed by a group of workers or technicians. It is necessary to identify each operation in the production changeover. There are 12 distinct operations – preparation, settings, test, fixing, rectification, over-production, displacement, transport, waiting, stocks, operation, and staff use.

2. Internal and external operation separation

This is probably the most important step in the SMED process. In fact the more operations are separated from one type to the other, the easier it will be deleting waste time. This is why this point should be done by a group of various persons.

3. Internal to external transformation

Mostly, everyone wants to put as much as possible tasks in external settings. In fact, external settings could be realized even if the machine is in production mode. Those external times could be minimized in so far as the worker could prepare everything for the next production changeover.

4. Settings tasks rationalization

The last steps of the SMED method consist on minimizing settings time. The conversion of internal settings to external settings generates a time gain. However, when we rationalize settings, we could improve the minimization of the production changeover time.

Of course it is necessary to maintain the time that has been defined in the final standard. That is why results should be recorded on a graph. Each time, the time limit is reached or exceeded, staff has to check what the main cause was. Then, time goals could be established.

Successful implementation of SMED will maintain the stability of the production process, thus enhancing the flexibility and makes it possible to shorten the lead time.

IV. INDUSTRIAL STUDY

Tests were carried out in a Company of wood manufacturing where one of the main products are porous fiberboards. The research was conducted at the department of coated surface. The analyzed section performs the following operations: bonding, grinding, cutting of panels on the format and milling edges of the plates. The type of cutter used in the milling operation is dependent on the product that is currently being produced.

The diagram of the process is shown in Figure1.

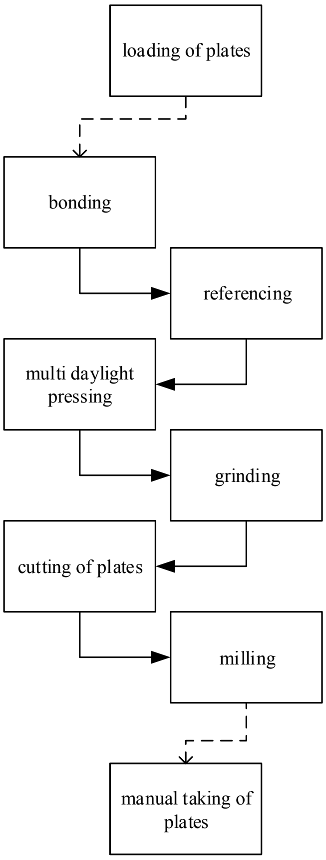


Figure 1. Diagram of production process.

In the analyzed Company, employees work following a four-brigade system. On the line where the research was conducted there is one operator for milling machine, one operator for gluing line and two operators for helping on the process. In addition, in the department are also a master and a foreman who participate in the process of changeover. The tasks of operators are:

- loading semi-products on the line,
- control of adhesive dispensing,
- collection of plates,
- quality control,
- changeover of machine,
- maintenance of lines at a standstill.

A. Analysis of the changeover process

Before the measurements all changeover activities are divided into two categories:

- C1 - change the machine settings involving the change in the dimensions of the plate and adjustment of the position of the elements involved in the changeover;
- C2 - change machine settings and cutter involving the adjustment of the position of the elements involved in the changeover and replacing the cutter.

During the month this research took place there were a total of 39 changeovers, with a total time of 3699 min. More detailed information regarding the changeovers is summarized in Table 1.

TABLE I. CHANGEOVERS INFORMATION

Type of changeover	C1	C2
Number of changeovers	19	20
The average time of one changeover	61 min	127 min

Changeover made by operators was recorded on the video camera, and then all the films were analyzed for changeover process improvement opportunities. Analysis of the current situation revealed a number of factors negatively affecting the changeovers times, which can be grouped into the main classes: method, material, machine, man and environment, including factors such as: lack of work standards, lack of tools, lack of maintenance, failure to follow processing instructions, lack of automation and obsolete machinery, along with lack of motivation and adequate competence of operators. These kind of main sources of irregularities are presented in the form of Ishikawa diagram in Figure 2.

A thorough analysis of the Ishikawa diagram indicated that the most important factors affecting the long changeover times are mainly due to:

- Operators performing changeovers have not been trained, and therefore performing various actions takes a long time, what means that operators do not have the awareness of the costs they generate by long changeovers.
- Among the operators can be seen lack of motivation and lack of communication between them.
- Information about products that will be produced in a next order is delivered late to operators.

- Storage of tools is too far from the machine, and is disordered. The lack of standards for storage of individual mills, as well as the lack of a set of necessary tools is also visible, so operators use other tools, which extends the changeover process.
- After more particular analysis, factors affecting the duration of changeover time were identified, which are mainly related to the lack of work standards, obsolete machinery and lack of operators training. The critical factors were indicated using Pareto's analysis shown in Figure 3 and summarized in Table II.

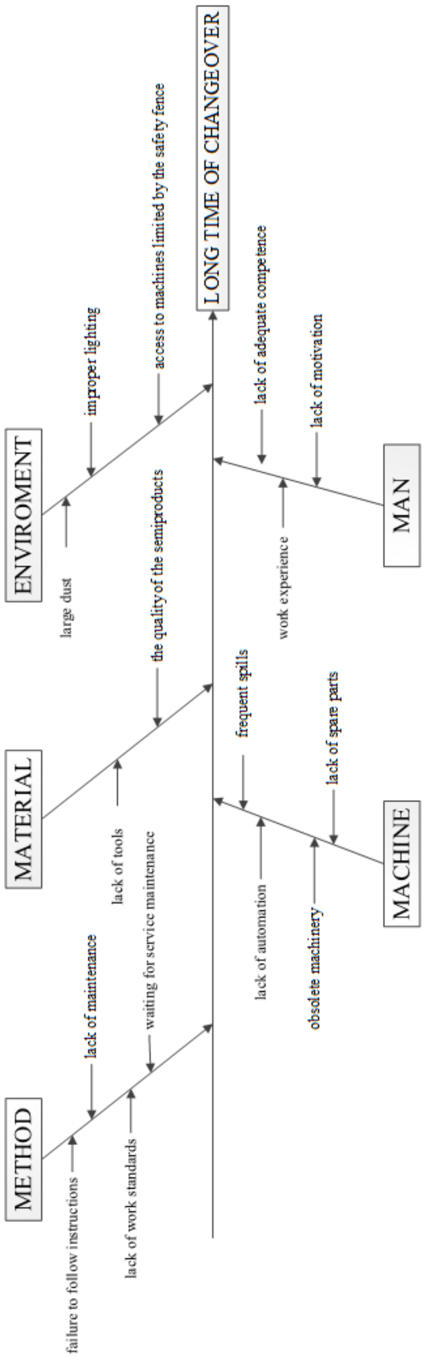


Figure 2. Ishikawa diagram.

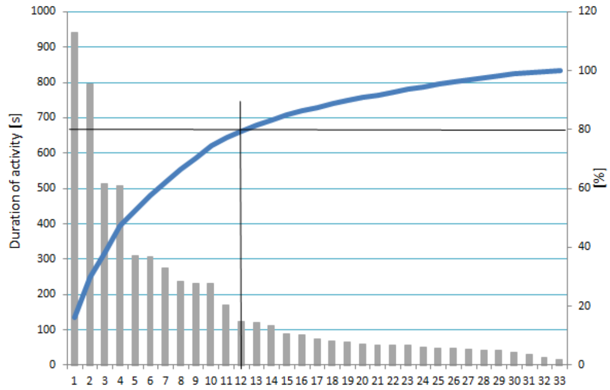


Figure 3. Pareto analysis.

For each critical factor the causes were identified. The results are summarized in Table 2.

TABLE II. CRITICAL FACTORS

No	Critical factors	Causes of occurrence
1	Correction of toaster settings	Seal of toaster construction
2	Change insert of cutters	Lack of cutters standardization
3	Correction of milling settings	Wrong settings for the first time
4	Removing cutters	Wedged cutters
5	Control measurements of fiberboard	Incorrect production line setting for the first time
6	Assembly of cutter	Complicated assembly - lack of training
7	Idle motion of milling	Slow work of machine
8	Transfer of cutters behind milling longitudinal	Lack of preparation tools before starting of changeover
9	Set up cutters guard	Lack of an adequate number of tools
10	Idle motion of crawler track	Lack of proper tools
11	Take off of air hoses	Lack of proper tools
12	Correction settings on the fiberboard tray loading	Mistakes made by operator

A timetable for the implementation of new solutions was formulated and employees were informed about plans concerning to introduce changes in the changeover process.

B. Shortening changeover time

In an effort to increase production flexibility was introduced in workplaces shadow boards and toolboxes, and cleaned up tools. Introduced visual storage standards for cutters and a number of changes in the spatial development (Figure 4).

Figure 4. Cutter's store.

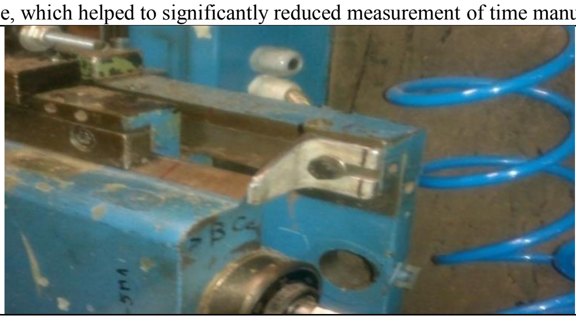
Minor design changes were introduced to improve changing instrumentation on lines, examples of changes made in the analyzed area is shown in Table 3, which presents a resume about the main changes that were introduced in the factory and the underlying manufacturing processes, and which led to a general improvement on the whole production environment and processes. These improvements were mainly related with the introduction of alternative changeover scenarios, along with training sessions for operators, and also a set of activities for enabling an improved preparation of materials and cutters before production.

TABLE III. DESIGN CHANGES ON LINES

Crank with a long shoulder, through which operators are doing it faster and with less strength

The compressed air hoses to facilitate purification of slots

Scale, which helped to significantly reduced measurement of time manually



Stopper to prevent movement of the cutter

Modified safety fence, so as to ensure safety do not inhibit access to milling machines

Folding covers are mounted, thereby avoiding the problem of dirt and clog the movements of milling working

So, summarizing, the main improvements introduced were related to the introduction of scenarios for changeovers and for machine maintenance. Moreover, all operators were trained, and outdoor activities like preparation of cutters and delivering them to the workstation were performed before stopping the line.

V. CONCLUSIONS

Implemented solutions helped to reduce changeover times by 50%. Moreover, production flexibility was increased and significantly shortened the turnaround time for the customer. Through training and involvement of operators workflow is also further improved. Furthermore, standardization of changeovers and reduction of the cost of staging the line contributed to increase the Company's competitiveness in the market, by enabling a quicker and better answer to the clients requests.

ACKNOWLEDGMENT

This work is supported by Portuguese National Funds through FCT “Fundação para a Ciência e a Tecnologia” under the projects: “Projeto Estratégico–UI 252–2011–2012”, reference PEst-OE/EME/UI0252/2014, and FCOMP-01-0124-FEDER-PEst-OE/EEI/UI0760/2014.

REFERENCES

[1] M. Wiśniewska and E. Malinowska, "Management of food quality", Difin Publishing, Warsaw, 2011.

[2] S. Shingo, "A revolution in manufacturing: the SMED system", Productivity Press, Portland – Oregon, 1985

[3] J.P. Womack, D.T. Jones, "Lean companies. Elimination of waste - the key to success", Warsaw, 2001.

[4] S.A. Kumar and N. Suresh, "Production and Operation Managements", New Delhi, 2008.

[5] Karim, M. A., Smith, A. J. R., Halgamuge, S. K., & Islam, M. M. (2008). A comparative study of manufacturing practices and performance variables. International Journal of Production Economics, 112(2), 841-859. doi: 10.1016/j.ijpe.2007.07.005.

[6] Rawabdeh, I. A. (2005). A model for the assessment of waste in job shop environments. International Journal of Operations & Production Management, 25(7-8), 800-822. doi: 10.1108/01443570510608619.

[7] Womack, J. P., & Jones, D. T. (2003). Lean Thinking: Banish Waste and Create Wealth in Your Corporation (2nd ed.). New York: Free Press.

[8] Womack, J. P., Jones, D. T., & Roos, D. (1990). The Machine That Changed The World: The Story of Lean Production. New York: Rawson Associates.

[9] Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. Journal of Operations Management, 21(2), 129-149. doi: 10.1016/s0272-6963(02)00108-0.

[10] Liker, J. K. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. New York: McGraw-Hill Professional.

[11] Pavnaskar, S. J., Gershenson, J. K., & Jambekar, A. B. (2003). Classification scheme for lean manufacturing tools. International Journal of Production Research, 41(13), 3075-3090. doi: 10.1080/0020754021000049817.

[12] Melton, T. (2005). The benefits of lean manufacturing - What lean thinking has to offer the process industries. Chemical Engineering Research & Design, 83(A6), 662-673. doi: 10.1205/cherd.04351.

[13] Ohno, T. (1988). Toyota Production System: Beyond Large-Scale Production. New York: Productivity Press.

[14] Hines, P., Found, P., Griffiths, G., & Harrison, R. (2011). Staying Lean: Thriving, Not Just Surviving (2nd ed.). New York: Productivity Press.

[15] Staats, B. R., Brunner, D. J., & Upton, D. M. (2011). Lean principles, learning, and knowledge work: Evidence from a software services provider. Journal of Operations Management, 29(5), 376-390. doi: 10.1016/j.jom.2010.11.005.

[16] Pedro Salgado, Leonilde R. Varela, “Cellular Manufacturing with Kanbans Optimization in Bosch Production System” (2010), The Romanian Review Precision Mechanics, Optics & Mechatronics, (20)37, pp. 147-158.

[17] Salgado, P., Varela, M. L. R. (2010), “Kanban Sharing and Optimization in Bosch Production System”. Proceedings of the International Conference on Knowledge Management and Information Sharing 2010 (KMIS 2010), Valencia, Spain, 25-28 October 2010, pp. 81-91.

[18] Pinto, J. P. (2008). Lean Thinking: Introdução ao pensamento magro: Comunidade Lean Thinking.

[19] Kumar, B. S., & Abuthakeer, S. S. (2012). Implementation of Lean Tools and Techniques in an Automotive Industry. Journal of Applied Sciences, 12(10), 1032-1037. doi: 10.3923/jas.2012.1032.1037.

[20] Ortiz, C. (2006). All-out kaizen. Industrial Engineer, 38(4), 30-34.

[21] Rother, M., & Shook, J. (2003). Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA. Brookline, MA: Lean Enterprise Institute.

[22] Courtois, A., Martin-Bonnefois, C., & Pillet, M. (1997). Gestão da Produção (4ª ed.). Lisboa: LIDEL - Edições Técnicas, Lda.

[23] Swanson, L. (2001). Linking maintenance strategies to performance. International Journal of Production Economics, 70(3), 237-244. doi: 10.1016/S0925-5273(00)00067-0.

[24] Shingo, S. (1985). A Revolution in Manufacturing: The SMED System. Cambridge: Productivity Press.

[25] Ha, D. S., & Kim, S. L. (1997). Implementation of JIT purchasing: An integrated approach. Production Planning & Control, 8(2), 152-157. doi: 10.1080/095372897235415.