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Application of single minute exchange of die tool in a food industry company to eliminate waste

Hubert Kędziora[1] , and *Justyna* Trojanowska[1,*]

[1] Poznan University of Technology, Faculty of Mechanical Engineering, Piotrowo 3, 60-965 Poznan, Poland

Abstract. Dynamically occurring changes in the economy and social environment require enterprises to monitor and improve the effectiveness of their production processes in order to remain competitive. The paper describes a research project aimed at improving the flow of materials by changing the organization of production and using Lean Manufacturing tool in a manufacturing company from the food industry, which is characterized by specific requirements and legal standards. Among others, a tool for organizing the workplace and a tool allowing to shorten the time of changeovers, taking into account the specific requirements of the food industry, were used in the research project. The effect of the implemented changes is an increase in production efficiency by 11% and obtaining annual financial benefits in excess of EUR 100,000. It should be noted that the implementation of the project did not require any capital expenditure. All tasks were completed within the working hours of the company's employees.

1 Introduction

Following the footsteps of the largest production plants in the world, food production companies strive for continuous development and improvement of production processes. The complexity of production processes and the disruptions that affect them force managers to take a fresh look at the situation. The Lean Manufacturing concept, broadly understood as lean enterprise management, is a solution to their expectations. The main ideas of the concept include high quality of the manufactured products, flexibility and elimination of waste. It is difficult to make new investments today, so companies focus on the best possible use of their resources, at the same time aiming to minimize production costs. That is why the right approach to managing and organizing workstations and material flow becomes so important. Even a few percent reduction in the cost of production, inventories, or improvement of other production indicators may significantly affect the economic situation of the company. History shows that companies that implement the Lean Manufacturing concept find it easier to survive a crisis. This topic is particularly important

* Corresponding author: justyna.trojanowska@put.poznan.pl

because lean management makes it possible to use the full potential of the company. The aim of the paper is to demonstrate the potential benefits of implementing Lean Manufacturing in a selected food manufacturing company. Particular attention will be paid to the analysis of the organization of selected workstations and the reduction of changeover time.

2 Analysis of the literature

Lean Manufacturing is a continuous production improvement concept consisting in the identification and subsequent elimination of waste, and raising the value added of activities [1-4].

The lean approach is founded on delivering value through the elimination of seven types of waste, which were originally defined by Ohno [5] for the automotive manufacturing environment. These types are transportation, inventory, motion, waiting, over-production, over-processing, and defects. Later these set of wastes were extended by Liker [4] with an eighth type, which is unexploited skills. These eight types of waste are widely discussed in the literature [6-14]. To identify this waste and strive to eliminate it, operational perspective must be applied. From an operational perspective, Lean implements a set of shop floor tools and techniques that aim to reduce waste. These tools include work standardization, kaizen, setup time reduction, visual displays, and Kanban [15-18].

Single Minute Exchange of Die (SMED) is a tool used to achieve improvements reduction or elimination [19-21]. SMED was developed in the 1950s by Shigeo Shingo. The purpose of SMED is to bring the complete the changeover process in under 10 minutes, which facilitates reduction of waste by setting a minimal lot size. The starting process of a fabrication line is an important part of production and should not be neglected. This process could be a significant waste of time if it is not performed well. Decreasing the production changeover time or instant adjustments reduces the setting time. Therefore, the setting time of the production changeover can be reduced by adopting two major procedures [19]:

• Internal operations, which could be carried out only if a machine is stopped and does not produce anything.

• External operations, which could be carried out while a machine is producing something.

By strictly following these four steps [22], this technique can be employed:

1. Identification of internal and external operations

The result will be affected if this is not accomplished well. These operations are mixed in traditional settings, which means some internal operations are carried out in an external way, and vice versa. A precise review of the production changeover is carried out should be done at any given moment. Filming of one or more changeovers is a way to accomplish this step. The films can then be analyzed by the workers that took part in the changeover. There are 12 operations in the production changeover that must be identified: preparation, settings, test, fixing, rectification, over-production, displacement, transport, waiting, stocks, operation, and staff use.

2. Separation of internal and external operations

This is an important part of SMED because if operations are separated by types, it will be easier to reduce wasted time. This should be carried out by a varied group of people.

3. Transformation of internal to external operations

Traditionally, most possible tasks have been placed in external settings, even though external settings could be realized during production mode. These external times could be minimized to the extent that everything for the following production changeover could be prepared by the worker.

4. Rationalization of settings tasks

The final step of SMED consists of settings times minimization. A time gain is generated by the conversion of internal settings to external settings. If we rationalize settings, the minimization of the production changeover time could be improved.

However, the time that is defined in the final standard must be maintained, which is why results should be graphed. Staff should find the main cause every time a limit is reached or exceeded, and then establish time goals.

Maintained stability of the production process is achieved with successful implementation of SMED, which also enhances flexibility, and shortens lead time.

Using a systematic literature review, [23] showed that single-minute exchanging of die (SMED) technique should be combined with application of other 9 lean tools such as 5S's (five esses), standardized work, kaizen, overall equipment efficiency, total productive maintenance, poka-yoke, value stream mapping, A3 methodology, and visual management.

According to [24-26], SMED offers many benefits, such as: increased productivity; eliminates stocks fail due to errors in estimating demand; increased work rates and production capacity of machines; fewer or no errors in machines setup; improved product quality; increased security in operations; improved setup times; reduced lot size costs.

Food and beverage industries have faced increasing regulations, which has resulted in increased costs. These increased costs could be minimized with process improvements and innovations. A large number of authors have stressed the lack of Lean Manufacturing tools, and the need of Lean Manufacturing tools in these industries in order to stay competitive [10, 27, 28, 29].

3 Status quo evaluation

The company under study belongs to the group of small and medium-sized enterprises. It is a manufacturer of convenience goods. Production planning is based on orders received from the customer. From the moment of receiving an order from the customer, the company has 24 hours to fulfill the order and ship it to specific distribution centers. Due to the short shelf life, it is not possible to produce stocks. In the production zone, the temperature is low, not exceeding 6°C, and the pressure, humidity and air purity are controlled. Food products are packaged in the cleanroom technology. This means that air is supplied into the production rooms through a dedicated ventilation unit using a specialized air filtration system. The technology significantly contributes to sterile and hygienic working conditions.

Figure 1 shows a diagram of the production process in the analyzed company. The warehouses store raw materials such as bread, meat, cheese, vegetables, sauces, etc. These are released from the warehouse for production on the basis of a document following a production order. The raw material is transferred through an airlock system to the cleanroom. In the cleanroom, raw materials are packaged depending on the agreed production schedule. The ingredients are dosed according to the recipe.

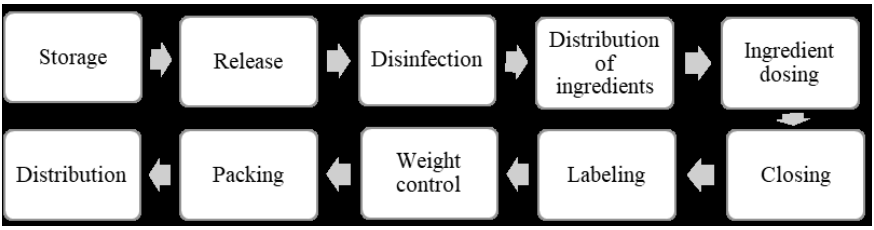

Fig. 1. Diagram of the production process.

Finished products are sent to the packing room, where they undergo checks on a metal detector. The product is then placed in a collective packaging and is transported to a high bay warehouse. The company has a system that monitors each manufactured product.

The production process is carried out on two lines:

• Line 1 - production of triangle sandwiches

• Line 2 - production of baguette sandwiches

The load on the production lines is uneven, as shown in the diagram (Fig. 2). About 58% of all orders are prepared on line 2. Due to the specific features of each line (mainly due to different packaging technologies), it is not possible to transfer production from line 1 to line 2.

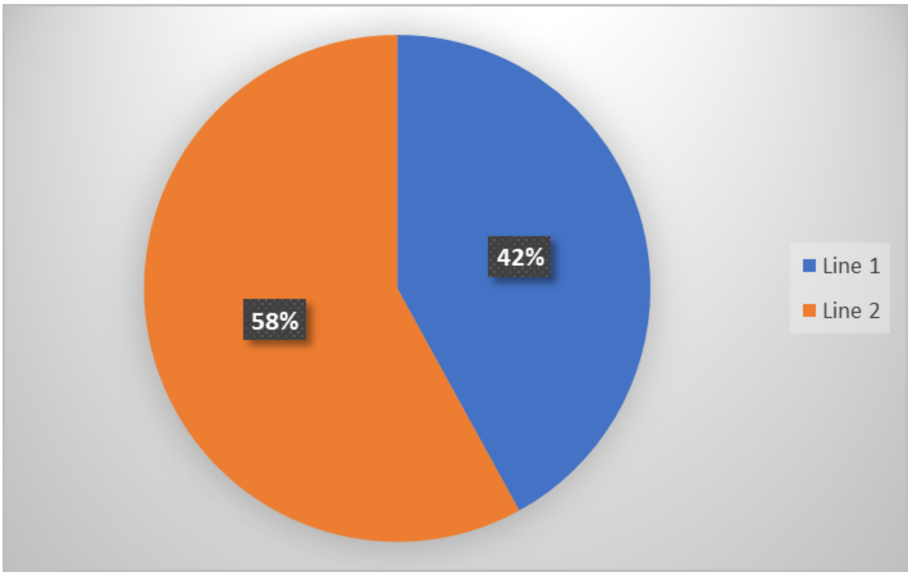

Fig. 2. Percentage share of customer orders produced on lines 1 and 2.

The data recorded in the IT system shows that the average pace of work on the production line 1 is 11.1 pcs / min. (Table 1). In turn, line 2 achieves a capacity of 12.3 pcs / min. (Table 2).

Table 1. Data: production line 1.

Line 1					
Production time [h]	Production time [min]	Approved packagings [pcs]	Nonconforming product [pcs]	Capacity [pcs/min]	Nonconforming product %
2333	140000	1554000	11500	11,10	0,74%

Table 2. Data: production line 2.

Line 2					
Production time [h]	Production time [min]	Approved packagings [pcs]	Nonconforming product [pcs]	Capacity [pcs/min]	Nonconforming product %
2845	170731	2100000	19000	12,30	0,90%

On average, 4 to 8 items are produced on each of the lines. Observations of the production process on line 2 revealed that shortening the changeover time of the line is important in terms of time efficiency. Every time the product range is changed, the line must be changed over.

4 Proposed methodology of conduct

The main purpose of improvements implemented in the company is to reduce the changeover time. Due to customer requirements the company produces a wide range of products. Changing the type of product to be prepared on the given line is time consuming and requires many complex steps. The implementation of SMED in the company was divided into stages, as shown in Table 3.

Table 3. Stages of SMED implementation.

STAGE 0	Analysis of the changeover process
STAGE 1	Separation of changeover activities into external and internal
STAGE 2	Elimination of unnecessary activities and conversion of changeover activities from internal to external
STAGE 3	Introduction of improvements

4.1 Analysis of the changeover process

The work aiming at improving the changeover time will be carried out on the production line 1 (Fig. 3). The analysis focused on activities carried out when the line is changed over from product A to product B. Before the start of stage 0, a training for the staff was organized to help them understand the process. The implementation time of the SMED method was set at 4 weeks.

The changeover between recipe 1 and recipe 2 was analyzed. In addition to the differences in the ingredients of these products, their packaging and labels also differ. Additional tasks performed while preparing for the production of a new item include cleaning the welding machine, disinfecting machines and handheld equipment, and disposal of waste out of the production area. Stage 0 began with analyzing the changeover process and describing the changeover stages in detail.

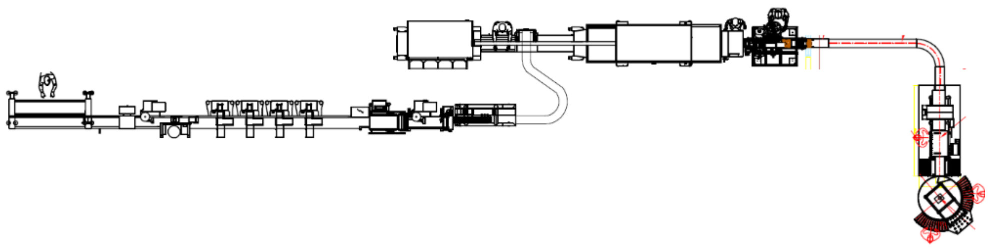

Fig. 3. Plan of production line 1.

The process was registered and each operation and activity was thoroughly analyzed. It was noted that the majority of activities were performed simultaneously. The analysis revealed chaos during the changeover. Some of the tasks were performed by too many people. Line leader, with the most experience, tried to do all the activities on his own.

During the changeover process, the employees used only the information contained in the recipes, i.e. concerning the components, weight and the method and sequence of layering. Workers who performed the changeover did not use the workplace instructions. The entire staff working on the line, i.e. 12 people, participated in the changeover process. The staff consisted of one leader, three operators and eight production workers.

The total changeover time was 19 minutes and 34 seconds. The activities performed during the changeover and their duration are listed in Table 4.

Table 4. Activities registered during the analysis of the changeover process.

No	Activity	Time [min]
1	Exchange of ingredient 1 (bread)	7
2	Exchange of ingredient 2 (sauce)	5
3	Exchange of ingredient 3 (vegetable)	1
4	Exchange of machine dosing ingredient 4	1
5	Exchange of machine dosing ingredient 5	10
6	Exchange of ingredient 6 (dairy)	2
7	Change of weight parameters	1
8	Exchange of ingredient 7 (sauce)	5
9	Exchange of packaging	5
10	Cleaning of the welding machine	10
11	Programming and labelling exchange	5
12	Programming of the control weight	4
13	Preparing of the collective cartons, pallets, labels	4
14	Cleaning of the workstations	16

4.2 Separation of changeover activities

The observed activities were separated into internal and external activities. The first type of activities is performed when the production line is at standstill. Whereas, external changeover activities can be carried out when the line is running. In the analyzed case, all the activities listed in Table 3 were classified as internal activities. The lack of external activities shows the large-scale waste of time and human potential.

4.3 Conversion of changeover activities

The conversion of changeover activities resulted in three activities being converted from internal to external. It was suggested that activities no. 1, 5, and 13 be organized in a way that makes it possible to execute them when the line is still running (when the previous product is being made). Activity no. 1 can be carried out when the previous batch is being produced. The construction of the bread dosing machine makes it possible to load different types of bread into each compartment. As a result, machine setup may take place when the previous order is still in progress. The time-consuming activity no. 5, i.e. the exchange of ingredients, setting the weight and the parameters of the photocells can also be performed much earlier. It is possible thanks to the mobile design of the machine; it can be put aside and installed on the production line at any time.

4.4 Improvements

The transformation of activities from internal to external resulted in the reduction of total changeover time. The complexity of the process required changing many parameters on the machine control panels during the changeover. In this phase, the parameters have been permanently programmed. From that moment, the employee would no longer enter them manually, but only choose the appropriate program for the required product. Fixed parameters were programmed for labelling machines, photocells, dispensers and weight data. Additionally, a changeover manual was implemented. It included information on the sequence of activities performed during the changeover, the number of people required for the changeover of the given machine, and the estimated time needed to perform the job. As a result, the production leader responsible for the changeover was well acquainted with the tasks.

5 Results

The introduction of the SMED method brought tangible benefits to the company. The total changeover time was reduced by approx. 39%. The following indicators were used to verify the effectiveness of the SMED method:
EWR - effectiveness of waste reduction
EAC - effectiveness of activity conversion
ETI - effectiveness of technical improvements
TESMED - total effectiveness of the SMED method implementation

The formulas presented in Table 5 were used to determine them.

Table 5. Indicators verifying the effectiveness of the SMED method.

Indicators verifying the effectiveness of the SMED method
Effectiveness of waste reduction:
(1)
Effectiveness of activity conversion:
(2)
Effectiveness of technical improvements:
(3)
Total effectiveness of the SMED implementation:

(4)

Symbols used:
– duration of internal activities
– duration of external activities
– time savings related to the implementation of improvements
– duration of redundant activities

In order to determine the effectiveness, it was necessary to examine the changeover times after the implemented improvements. Table 6 shows the times for individual activities before and after the implementation of the improvements. After the implementation of SMED, the total changeover time was reduced by over 7 minutes and is now 12 minutes.

Table 6. Analysis of the SMED method.

Activity	Changeover time before SMED implementation [min]	Changeover time after SMED implementation [min]	Time saving [min]	External activities	Internal activities
1	7	6	1	**X**	
2	5	4	1		**X**
3	1	0,5	0,5		**X**
4	1	1	0		**X**
5	10	7	3	**X**	
6	2	1,5	0,5		**X**
7	1	0,5	0,5		**X**
8	5	4	1		**X**
9	5	2	3		**X**
10	10	9	1		**X**
11	5	4	1		**X**
12	4	3	1		**X**
13	4	3	1	**X**	
14	16	12	4		**X**
SUM	**76**	**57,5**	**18,5**		

Having collected the data (Table 6), it was possible to designate EWR, EAC, ETI and TESMED (Table 7).

Table 7. Indicator values for the analyzed production line.

Indicator	**Production line 1**
EWR	1

EAC	0.79
ETI	0.69
TESMED	0.55

All registered activities turned out to be necessary during the changeover process. Some of the activities were simplified, thus shortening the time of their execution. The EAC indicator shows the transformation of activities from internal to external activities. In the analyzed case, it was successfully done for 3 activities. Other activities are performed while the line is at standstill. The ETI indicator means that thanks to the introduced improvements it was possible to shorten the times for many activities. Time savings were achieved for almost every activity. The TESMED value means that the total changeover time was significantly reduced. The complete changeover between recipe no. 1 and recipe no. 2 was shortened by almost 8 minutes.

As a result of the implemented improvements, the changeover time between the products was significantly reduced, making production line 1 more flexible. The time that has so far been used to carry out activities during the changeovers can now be spent on work related directly to production. An increase in efficiency on the tested production line was observed, from 11.1 pcs / min to 12.3 pcs / min, which means an 11% improvement. Apart from measurable factors, work safety has also improved.

6 Summary

The use of the SMED method on the selected production line significantly shortened the total changeover time. A detailed analysis of the process made it possible to quite accurately define and examine all activities performed during the changeover. The obtained indicators confirm the effectiveness of the implemented changes. The versatility of the method enables efficient and effective implementation of improvements. The key to success in the case of SMED is the appropriate preparation and collection of reliable data, which must then be subjected to detailed analysis. In line with the assumption made at the beginning of the paper, it was possible to eliminate waste by saving time. The next step should be to start working on maintaining the implemented changes.

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