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# Analysis and improvement in the Electrical Discharge Machining process used on the manufacturing of moulds for plastics injection moulding

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**Abstract:** Due to increasing competitiveness in the industry, companies will invariably adopt strategies to ensure that their employees continuously eliminate waste and create more value. This concept was applied at a company that designs, develops, and manufactures steel moulds for the injection of thermoplastics, with the purpose of implementing Lean thinking in the production sector, thus achieving the following objectives: organization of production; preparation of documents to support production, and standardization of graphite stock. Regarding the application of the 5S tool, an improvement in worker safety, and in cleaning was observed, which also led to a reduction in the time wasted when locating tools. Through the implementation of 5S auditing, enabling to verify an overall improvement, from a rating of 35% in the first audit to 85% in the subsequent audit. The tools implemented allowed for improvements in communication between sectors, leading to increased productivity and productive autonomy. Finally, graphite stock was standardized by means of *Kanban*.

**Keywords:** Lean, 5S, *Kanban*, Continuous improvement.

## 1. Introduction

Companies in the mould industry face severe competition, market instability, technological development and customer specificities. Innovation therefore constitutes a priority when ensuring quality at a low cost [1,2]. Lean thinking can identify non-value-added activities and underused resources, allowing companies to improve their operation [3]. This study intends to improve the production processes of a mould maker company using Lean tools. It is expected to minimize the manufacturing time of the processes, ensuring quality at the least possible cost [4]. This article comprises seven sections: section 1 presents the introduction; section 2 consists of a review of literature; section 3 deals with the methodology used to carry out this study; in the course of section 4, the Production Process Mapping of a company in the mould sector is presented. From section 5 onwards, all the practical work developed is described, starting with the identification of problems. Section 6 provides proposals of improvement for the process analysed, and finally, section 7 consists of the conclusions and proposals for future research.

## 2. Literature review

Lean philosophy aims to enhance the value of products by a correct use of various tools [5]. The



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objective is to manufacture products at a lower price following the demand pace [6]. This implies the identification and elimination of those tasks that add no value to the product [7-9]. Thus, a brief literature about Lean tools is presented hereafter. Atieh et al. [10] implemented Lean tools at a glass factory. Value Stream Mapping (VSM) was drawn to identify production bottlenecks. A 6% decrease in productive lead time, and a 32% increase in the performance of the main bottleneck were achieved. Baynal et al. [11] proposed solutions for the problems occurred on the assembly lines in automotive industry. A Failure Mode and Effect Analysis (FMEA) was proposed, resulting in the identification of failures on lines. Regarding the first, there was an improvement of 96%; on the second and third lines, the problem was completely solved. Correia et al. [12] performed a study regarding an electronic device assembly line, using the VSM method to map the different tasks and operations, allowing the identification and improvement of the main bottleneck. Accordingly, it was considered that the implementation of lean manufacturing tools leads to improvements in line efficiency, as well as in the production rate [13]. Das et al. [14] introduced Lean methodology aiming at improving the productivity of an air conditioning coil company, resulting in a 77% increase of coils production per shift. Lean tools (VSM, SMED - Single Minute Exchange of Die and Kaizen) were implemented to decrease setup time on the coil expansion machine by 67%. Added value improved from 5 to 12%. At an automotive component production industry, Mojib et al. [15] applied the VSM tool to identify and eliminate waste and non-value-added activities. Through the implementation of the improvement actions, there was a decrease in lead time from 23.5 to 4.5 days. Dias et al. [16] undertook a study using four distinct approaches and implementing different Lean tools. The main objective of the study was to identify the activities that generated value in the "fulfilment process". They were able to propose a tool which would allow for the identification of the micro inefficiencies detected, as well as their impact on the production subprocess. Rosa et al. [17] applied the SMED methodology, as well as other Lean tools at a company in the automotive industry. The implementation contributed to a reduction of 58.3% (210 minutes per week) in the time spent on setups. Finally, Pombal et al. [18] used 5S methodology to manage consumable materials in maintenance workshops. They reduced the time required to find the desired material by means of visual management (an improvement of 70%). It was also possible to enhance stock control through *Kanban* (approximately 30%). There was a 50% improvement in the reduction of the time required to replenish stock in the consumable material cabinet by using the *mizusumashi* concept.

### 3. Methodology

In this work, an Action-Research methodology was applied. Action-Research combines both scientific and organizational knowledge to solve problems, fully conscious of the fact that all decisions are subjected to constant evolution. Thus, cyclical activity begins whenever the requested result is not achieved [19,20]. It is distinguished by its practical component, and is characterized as research in action, rather than research about the action [21]. Whenever the intended alterations cannot be achieved, the process will be repeated in successive cycles until this occurs. Initially, in the "Diagnosis" phase, the problem should be identified and defined. In the "Action planning" phase, the strategy must be defined. In the "Implementation of actions" phase, the interventions should be applied. In the "Evaluation" phase the results of the implemented actions are studied. In the "Monitoring" phase, the main achievements are highlighted, and the transferrable knowledge is dissected [22-24].

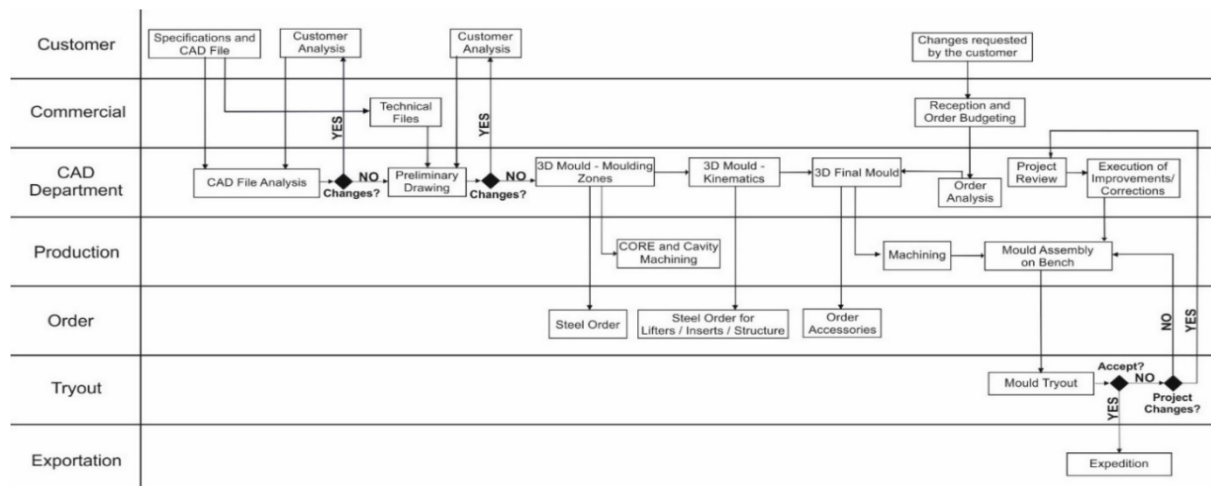
### 4. Mapping of the production process at a company in the mould sector

This process ranges from the entry of a part for moulding in the commercial department to its shipment to the customer. Figure 1 constitutes a representation of the company's entire productive activity.

### 5. Identification of problems

An evaluation of the production process was performed, detecting some improvement opportunities. The analysed sectors were as follows: the workbench, where the adjustment and shaping of the mould is executed, and the electrical discharge machining (EDM) section. Organization of spaces, cleaning, standardization, and other problems have been identified as target for improvement. In addition, the use

of several continuous improvement tools was required to eliminate production errors and production downtime, which were chiefly due to a lack of information and communication between the company's various departments. Finally, the problem of the incorrect ordering of graphite stock has been addressed.



**Figure 1.** Business process of the production activity.

### 5.1. Disorganization of spaces

Intending to increase competitiveness and consumer expectations, the organization of spaces, cleaning, standardization, and so forth, must be improved. One of the problematic areas was the workbench, where the moulds are assembled. In this area, unnecessary objects and general untidiness are found, which led to confusion before use. Moreover, some equipment clearly needs to be renovated, which showed a great deal of wear and tear. This area also needs standardization; it is confusing to both customers and auditors, motivating the company wishes to follow a Lean culture to address these problems.

### 5.2. Lack of documentation to support production

All employees must know what they should accomplish and what constitutes the highest priority. To this end, a set of tools must be created, which are simple to understand and easily accessible, thus eliminating the abovementioned factors. These tools will also seek to minimize production errors and downtime, ensuing from the lack of information and communication across sectors.

### 5.3. Incorrect quantity of graphite to be ordered

Stock management is a key aspect of efficient business management. Knowing when and how many products to order, as well as having a sense of the exact quantity of existing products, helps to simplify tasks and prevent problems such as excessive or inexistent quantities of stock. It is for this reason that a simple but effective tool must be developed to solve the problem of the incorrect orders of graphite quantities. In this way, there will be an exact and standardized system for inventory orders.

## 6. Proposals for improvement

In the first phase, the implementation of 5S methodologies was undertaken. A weekly meeting was also suggested to carry out a 5S audit, with a checklist developed for this purpose, thus ensuring that all standards were being implemented. A framework for continuous improvement was developed including all the necessary information, as well as a Gantt diagram, news, and relevant information regarding the company. It also shows the rates of non-conformities, accidents, and complaints. Concurrently, a job chart was created, allowing the other employees in the department have a sense of the work outline, and are thus able to plan activities ahead of time, depending on priorities. The existing stock of graphite is not standardized, thus, a graphite supermarket in the electrical discharge machining department was created (which is in the production sector), and whose stock is regulated by means of *Kanban*.

### 6.1. Implementation of the 5S Tool

The implementation of 5S methodologies was carried out in the workbench sector. In this section, there is sometimes unnecessary clutter; an example is the amount of unused injected parts. In order to clear the countertops, these parts were forwarded to an appropriate container for later recycling. In this initial phase of the screening process, it was established which materials and tools were required for daily and frequent use. An inventory of all the material that was damaged and required maintenance/overhauling was done. The entire area was tidied up. To enhance organization, it was essential to set up more shelving for the storage of components when the moulds are being dismantled, for example in the case of lifters.

Trying to reduce the movement of operators and make easier the use of work equipment, an inventory of the tools used on each bench was created; a cabinet and drawer were then dedicated for every set of instruments. Each bench manager was made responsible for the logical organization of each set of tools, minimizing occasional disagreements as to the location and importance of tools in existing benches. Thirdly, a general clean-up of the area was performed. The corridor crossing the workbench area should also be cleaned more regularly as oils were often detected on the floor surface. Cleaning of the area around the press was also performed, due to the large accumulation of oils and dust (figure 2) because difficult access makes frequent cleaning a cumbersome task. A cleaning map was created.



**Figure 2.** Before and after cleaning around the press.

Two improvements to facilitate cleaning were advised: i) there should be an adjacent area to plane grinder, where the parts could be "blown"; ii) there should be an appropriate area to clean the mould. This would be beneficial to the operator, as it will protect the worker from contact with chemical products. Once all the components had been cleaned and organized, those which were damaged or required repair were renovated, namely: i) the trestles, since they support several tons; ii) workbenches, where planks required replacement and painting and iii) the metal supports (figure 3). The purpose of the last two Ss in this methodology – Seiketsu and Shitsuke – is to define visual and disciplinary standards to ensure the maintenance of the previous three Ss. All the employees are required to comply with the standards, so that they are aware of the importance of their roles. To this end, a weekly meeting was suggested with the heads of all the benches, as well as one member from each bench group. At this meeting, an audit is carried out for each bench to ensure that all the standards are being implemented; if necessary, action plans are determined for process improvements (see checklist in table 1).



**Figure 3.** Renovation of metal supports.

A first 5S audit was carried out on bench 1, acting as a point of reference, which resulted in a score of 35% (OK:1, 2, 10, 11, 12, 13, 15; NOT OK:3, 4, 5, 6, 7, 8, 9, 14, 16, 17, 18, 19, 20); this means that 65% of the checklist parameters were below the desired performance. After the first audit, strategies

were delineated to mitigate the identified anomalies. A second audit was carried out, where a result of 85% (OK: 1, 2, 3, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20; NOT OK: 4, 7, 9) was obtained, thus pointing to an improvement when compared to the first.

**Table 1. 5S Audit**

Bench n° _____						
Audit N° _____						
Audited by _____						
Date _____						
5S AUDIT – Benches						
5S	N.º	Item to be verified	Evaluation Criteria	OK	NOT OK	Comments
Screening	1	Equipment, tools and other support	Are all the equipment and tools being used and needed?			
	2	Materials	Is there any unnecessary stock of material, or unused material to be returned to the warehouse?			
	3	Benches	Do the workbenches only have updated material and documents?			
	4	Material, intermediate stock	Has there been a separation and identification of material requiring repair, or awaiting material and consumables?			
Organization	5	Access	Is access to equipment and workbenches unobstructed?			
	6	Cabinets and drawers	Are they clean and organised?			
	7	Stock of materials	Are all the materials stored in a designated area, and are they identified?			
	8	General	Is tidying included in daily tasks?			
Cleaning	9	Floor and surrounding areas	Are they clean, and in a good state of repair?			
	10	Machines and equipment	Are they clean, and in a good state of repair?			
	11	Machines and equipment	Are temporary work utensils clean?			
	12	Cleaning utensils	Are there cleaning utensils, are they in good order and stored away?			
Standardization	13	Machines and equipment	Have cleaning schedules been defined for all machines and equipment? Are they updated and followed through?			
	14	Layout	Are the cleaning plans available and accessible?			
	15	PPE	Is protection equipment used, and are the safety measures complied with?			
	16	General	Are the work schedules accessible and updated?			
Discipline	17	Training	Do all the employees have 5S training? Do they know the basic concepts and objectives?			
	18	Kaizen Board	Are the 5S audit reports and action lists accessible and updated?			
	19	5S Audit	Are the defined actions being complied with? Is there a clear improvement in 5S results?			
	20	5S Audit	Are there corrections since the last audit?			
Bench result						[ ] %



**Table 2.** Template file.

Mould N°	Item N°	Task	Operator	Estimated T.	Real T.

### 6.2. Drafting of the support documents

Initially, a meeting is held with all employees of the section, including those responsible, where they are made aware of the different stages of the production process of a given mould, trying to address any doubts that might have emerged during the mould execution. Moreover, a Gantt diagram was implemented, determining the starting date, and forecast for the completion of each project. Customer visits and respective trials were also added to the diagram. Moreover, green, yellow, or red cards were placed in front of each mould on time or facing delays. This diagram was placed in a strategic location. In order to support the Gantt diagram, a board of continuous improvement to deal with the implementation of *kaizen* was set up. There is a space on this board where any employee can attach a post-it note, indicating a need or a problem detected on the bench. Later, this problem will be read by the corresponding responsible, as well as the head of production, who will overcome it. The board will also include the employees' rates of non-conformities, accidents, and complaints. This will contribute to the overall information about what is happening in the productive sector. This will ultimately assist the employees, as a team, in eliminating any problems that may arise. At the same time, it was proceeded with the drafting of a job chart which describes the tasks that must be carried out (table 2). This form is to be filled out by the person in charge of each bench, so that the other bench members are aware of the work set out.

The form presented above is of great assistance in planning as it is extremely simple. It indicates the mould number, item number, task, operator performing this task, estimated time and real time. Table 3 shows an excerpt from an example of a completed form.

At this point, the measurement of real time is carried out by means of a digital tool, known as WorkPlan. Accordingly, the tasks on the sheet must be inserted into the program to allow for the real measurement of the tasks. The Real Time field will help to compare it to the estimated time. This analysis is important since it enables to gain an insight as to whether the estimated time is correct or not. Through this comparison, over time, the initial Gantt diagram can also be implemented, bringing the estimated time for the completion of a mould closer to the real context.

**Table 3.** Example of form completion.

Mould N°	Item N°	Task	Operator	Estimated T.	Real T.
191005-05	SI6200	Adjust lifter	José and Rui	20 min	

### 6.3. Regulation of the graphite stock through Kanban

In order to contextualize this issue, electrical discharge machining (EDM) is used to manufacture parts which present a complex geometry and extreme mechanical strength. During the process, there is a conversion of electrical energy, through electrical discharges between the electrode and the workpiece, subjecting this to thermal energy. The electrical discharge occurs within a dielectric fluid, where the electrode and the piece requiring machining are immersed. Two materials are usually employed for the electrodes: copper and graphite. However, graphite is most used in the company: it has a higher melting point, lower hardness, as well as greater mechanical strength and stiffness, when compared to copper. As it was previously mentioned, the existing stock is rather unregulated. To address this problem, a graphite supermarket in the EDM sector was created, and its stock was standardized by means of *Kanban*. Graphite is ordered in batches and in different sizes, so an inventory was carried out of the quantity in each lot, as well as of the sizes. To this end, several types of cards were created. Table 4 shows an example of a card containing a batch of 10 graphite blocks, measuring 50×50×100 mm in size.

**Table 4.** *Kanban* card.

Location	EDM
Material	Graphite
Size [mm]	50 x 50 x 100
Quantity	10

Thus, it was designed a board which shows three colours: green, yellow and red. For this size, the maximum stock is considered to be 100 units (green), with a backup stock of 40 units (yellow) and a minimum stock of 20 units (red). Later, a *Kanban* board was created for all the sizes used. In this specific case, each card means that there are 10 units. This implementation allowed to reduce the stock in 60%, leading to financial gains of 32% with the reduction of the stock relatively to the previous ownership cost. It should be noted that all the workers in this section are trained in the procedure of *Kanban* methodology. The head of production is responsible for taking the card removed from the board to the purchasing department. Subsequently, the card is replaced with a new set. As soon as the graphite blocks arrive at the company, the card is placed on the board once again.

## 7. Conclusions and future studies

Methodologies and tools were developed with the purpose of implementation in this industry, allowing for improvements which culminated in a tidier workplace, better communication between sectors and the standardization of graphite stock. Regarding the application of the 5S tool, an improvement in worker safety and in cleaning was observed, which also led to a reduction in the wasted time when locating tools. Through the implementation of the 5S audit in bench 1, enabling to verify an overall improvement, from a rating of 35% in the first audit to 85% in the subsequent audit. The implementation of the tools resulted in improved communication between sectors, leading to higher levels of productivity and productive autonomy. Finally, the graphite stock was standardized by means of *Kanban*, allowing important economical savings. Due to the gains achieved, in addition to all the above-mentioned results, a spirit of continuous improvement was implemented, which also motivated all the employees to continue using Lean methodology. The main novelty shown through this work is that implementing simple tools such as 5S and *Kanban*, becomes possible to improve significantly the economical results of SMEs, allowing as well greater work atmosphere, which can improve again the workflow, generating higher profits. Furthermore, the use of records and the enhancement of all the processes involved are of extreme importance; these, in turn, require better communication between the various internal and external sectors in the companies, thus ensuring constant and synchronous improvements in all the action plans. Within the framework of industry 4.0, one of the measures that the company should adopt is the creation of a digital platform and, where possible, include: i) Employee access to their personal page to consult their attendance, declarations, payroll receipts, etc.; ii) Customers following their mould in real time. Other measures would be to create a control of measurements across all of the machining centres in the company.

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