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# Improvement of the efficiency in the injection process in a company of the automotive sector through the implementation of the SMED (Single-Minute Exchange of Die) methodology

# Mejora de la eficiencia en el proceso de inyección en una empresa del sector automotriz mediante la implementación de la metodología SMED (Single-Minute Exchange of Die)

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**Abstract**

This work was carried out in order to reduce the excessive time in the changes of injection molds, both for aluminum and wood, each of these in their respective pilot areas that were implemented within strategic points were of great help to detect other areas of opportunity for injection in general. However, the equipment and molds used in the injection process are expensive, therefore, the use for product customization in the automotive industry forces the companies that supply inputs to the assemblers to reduce defects and downtime. The results obtained with the implementation of the present methodology generated positive numbers with respect to the time for mold change, obtaining a record change time of 15 minutes, demonstrating that if we look for the appropriate conditions and the necessary tool, we can have the minimum time in addition to obtaining also a maximum time of 3 hours and obtaining a saving of over 93 % equivalent to 255,549.37 USD.

**SMED, Automotive industry, Efficiency, Process improvement, Loss reduction**

**Resumen**

El presente trabajo se realizó para poder reducir el excesivo tiempo en los cambios de moldes de inyección tanto de aluminio como de madera, cada uno de estos en sus respectivas áreas piloto que se implementaron dentro de puntos estratégicos fueron de gran ayuda para detectar otras áreas de oportunidad para inyección en general. Sin embargo, los equipos y moldes utilizados en el proceso de inyección son costosos, por consiguiente, el uso para la personalización de productos en la industria automotriz obliga a las empresas que proveen de insumos a las ensambladoras exigen la disminución de defectos y tiempos muertos. Los resultados obtenidos con la implementación de la presente metodología generaron números positivos con respecto al tiempo por cambio de molde obteniendo un tiempo récord de cambio de 15 minutos, demostrando que si buscamos las condiciones apropiadas y la herramienta necesaria podremos tener el mínimo de tiempo además de obtener también un tiempo máximo de 3 horas y obteniendo un ahorro por encima del 93 % equivalentes a 255,549.37 USD.

**SMED, Industria automotriz, Eficiencia, Mejora de proceso, Reducción de pérdidas**

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## Introduction

Products that are used on a daily basis are mostly made by injection moulding, the most common materials that go through this process are; plastics and metals. Regardless of the material, this type of production is complex due to the amount of parts that are used in the moulding of the materials (Pacheco & Heidrich, 2023). To achieve the injection moulding process a certain amount of time is required to generate the quality parameters after performing a mould change (Kemal Karasu et al., 2014). An assembly can be defined as the set of activities in which equipment is prepared or configured for product manufacturing (da Silva & Godinho Filho, 2019). The methodology that has so far proven to support the reduction of downtime is Single Minute Exchange of Die (SMED). To achieve greater efficiency in the processes of changing, adjusting or testing tooling, SMED has been developed as a technique that supports the implementation of lean manufacturing (Lozano et al., 2019).

The present research work demonstrates the development of SMED methodology in the injection moulding process for the elimination of excessive time for mould changes to significantly increase productivity and decreasing monetary losses due to downtime due to changeover.

## SMED (Single Minute Exchange of Dies)

Changeover time is generated in processes and is defined as the time between the last product that meets customer specifications and the first good product of the new production order (Ferradás & Salonitis, 2013). Several proposals have been developed to reduce these times, the most common is the methodology proposed by Shingeo Shingo called Single Minute Exchange of Die (SMED), which was designed as a technique for shop floor improvement focused on low-cost proposals based on Kaizen, later evolving to the Toyota production system (Jebaraj Benjamin et al., 2013; McIntosh et al., 2001). The SMED methodology according to its creator has four stages; process mapping, classifying activities as external or internal, transferring external and internal activities, streamlining external and internal activities (Rosa et al., 2017).

The sequence of assembly activities can be classified as internal and external with the aim that most activities are performed when the machine is in operation (external activities) in order to reduce the time the equipment is out of operation (Juarez-Vite et al., 2023; Moxham & Greatbanks, 2001).

SMED has been evaluated in several works where the advantages and improvements obtained with the implementation of the methodology are evaluated, in addition to obtaining information on the advantages and savings expected in the elimination of activities that do not add value to the products or processes (Almomani et al., 2013). SMED was initially limited only to manufacturing processes, nowadays, it is applied in various management services and assembly operations (Trovinger & Bohn, 2005).

## Methodology

This research work was developed by choosing a qualitative approach because the aim is to collect information to be able to test a hypothesis based on a measurement that is subjected to statistical analysis.

The type of research presented is descriptive, because it seeks to describe the characteristics of a process, which serves for decision making and implementation of methodologies or tools that allow for improving the production process (Hernández Sampieri, Roberto / Fernández Collado, Carlos / Baptista Lucio, 2014).

The research design refers to the development of a work plan to collect the information required to answer the research question posed, this work is based on a descriptive design, since the collection and analysis of information is required to present the data collected for decision making in improving the injection process (Hernández Sampieri, Roberto / Fernández Collado, Carlos / Baptista Lucio, 2014). Mould changes in the injection moulding area are very recurrent due to the planned level of production as the week progresses and the requirements per project, changes have become a complex procedure involving staff training, tools, adjustment parameters and safety, which becomes a critical issue at the time of making approximately 20 changes per day in this area,

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Without counting the changes that were not planned and that for some reason tend to be made from one moment to the next, therefore the response capacity of the assemblers, supervisors and managers of the area have to be optimal to make the change as quickly as possible, without affecting productivity at that time, without leaving aside the safety of personnel and physical assets that are included in that period. Structuring the above can be shown in the following diagram the phases to attack this condition and the tools and / or means that we will use, in Figure 1 shows the methodology proposed for the development of this research.


**Figure 1** Methodology applied
*Source: Own Elaboration*

### Development of the study

On the production floor, mainly in the injection moulding area, excessive time was observed when changing moulds on the injection moulding machines, which in the long run translates into large economic losses for the company, if we take into account the number of changes per day due to the time it takes to make a change either by waiting for the mould to reach the right temperature for assembly or by adding the number of SCRAP (defective parts).

The number of changes per week on each machine is shown below, with emphasis on the machine with the highest number of paths, as shown in figure 2.

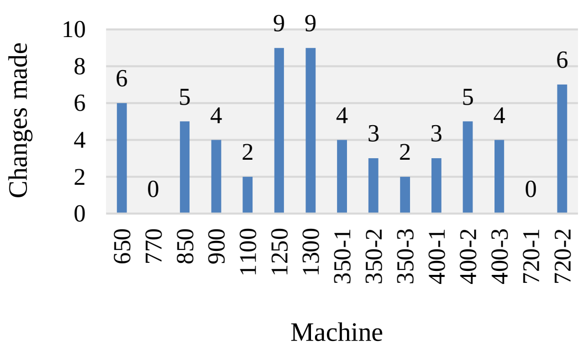


**Figure 2** Change reporting
*Source: Own Elaboration*

Using as an example the 1250 machine for wood and the 720/2 for aluminium, the following figures are obtained, expressed in minutes and subsequently, the cost of having them on standby for an average time. Taking a minimum time of 145 minutes with respect to the activities carried out during the mould change considering the times established in the table 1.

| Activity | Time (minutes) |
|---|---|
| Machinery shutdown | 20 |
| Transfer of moulds | 20 |
| Assembly to installation | 80 |
| Preparation and djustment | 25 |
| Total time | 145 |

**Table 1** Time study
*Source: Own Elaboration*

The above allows us to establish the production costs for products A and B that were subjected to analysis of the lost time generated by tooling changes. Table 2 shows the relevant calculations for two machines that process wood (A) and aluminium (B).

| Weekly stoppages | |
|---|---|
| Product A | Product B |
| Equipment 1250 | Equipment 720-2 |
| 9 (stoppages) x 145 min | 6 (stoppages) x 145 min |
| 1305 min = 21.75 hrs | 870 min = 145.5 hrs |

**Table 2** Calculation of weekly stoppages
*Source: Own Elaboration*

How much does it cost us to make a change with a duration of 145 minutes (2:25 hrs) of between six and nine changes in two variants, (A and B) on two machines during one week, while the price of product A (wood) is € 2.36 and product B (aluminium) is € 2.77 using equation 1.

$$Costos = Piezas\ (hr) * Costo\ unitario \quad (1)$$

In one week for nine changes corresponding to machine 1250, where the runs were established for the parts of product A, we obtained 21.75 hours per mould change, taking into account that the minimum time was 145 minutes per change. From the above data, equation 1 can be developed to estimate the losses caused by tooling changes.

Having potential losses of between 3,213.2 and 4,517.04 euros per week, giving a total between these two parts of 7,730.24 euros in one week. This also generates problems of downtime, leading to bottlenecks and resulting in productivity problems and affecting other areas dependent on the injection moulding area.

The calculation of times was carried out by means of the study of times and movements, as such, we started by taking the cycle time of the machines and began to have an orderly record per machine in terms of its cycle time per machine, this also helped to obtain the production rates that later will help us to calculate the necessary times with respect to the time of preparation of the mould. As such, time study is defined as the procedure used to measure the time required by a skilled worker, working at a normal level of performance, to perform a given task according to a specified method, with due allowance for fatigue, personal delays and unavoidable delays (Maynard, 2006).

The four rules necessary for mould change were then implemented. The four Rules for performing a mould change are a set of requirements to ensure that the basis for a mould change is in place, thus tackling the bad habits that are taken when performing a change or adjustment, and they were established with the relevant process engineer to ensure that the procedure is performed as agreed.

Subsequently, we start with the process of calculating the parts per hour that are produced in an injection moulding machine, this calculation is developed from equation 2. The result of this equation is very important because only by knowing this information we will be able to know the most approximate time of completion of our current run. Knowing the end time of our production will allow us to properly prepare the mould to be assembled. Both assembler, materialist and operator will have a clear schedule and will be very attentive to perform their functions in a mould change.

$$Piezas\ x\ hora = \frac{3600}{TC * CAV} \quad (2)$$

Based on equation 1, calculations are made for products A and B where the injection cycle time of the aforementioned gates is, in the case of product A, 81 seconds and the mould has two injection cavities, which gives us two pieces per cycle.

In the case of product B, with a shorter cycle time of 45 seconds and with two cavities, we also obtain two pieces per cycle. Carrying out the operations, 3600 seconds equivalent to one hour are divided by the cycle time of the machine and multiplied by two in this case, the result will tell us the number of parts produced in one hour.

## Results

In order to be able to compare the impact of the project, a first time measurement was carried out on the M1300, M1250, M1100 and M900 machines, the times for mould changes were obtained on these machines, the diagnosis of the production lines was started, and in figure 2 you can see the times that will be reduced.

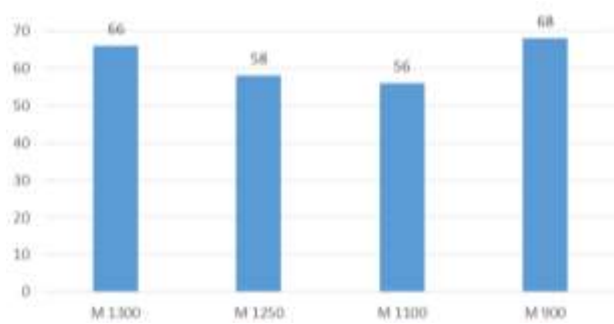


**Figure 2** Initial mould change time
*Source: Own Elaboration*

The times obtained with respect to the minimum initial time condition (145 min) are shown in table 3.

| Observation | Time |
|---|---|
| Initial condition | 145 minutes |
| Test 1 | 53 minutes |
| Test 2 | 25 minutes |
| Final test | 15 minutes |

**Table 3** Test times
*Source: Own Elaboration*

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Based on these results, the annual cost for equipment preparation and non-productive hours, which directly affect the plant's productivity, was calculated. In the cost factor, the annual calculation was made taking as a reference the times obtained during the test and the period in which the first results were obtained. Taking as a reference the minimum value of the previous condition, changeover time for one hundred and forty-five minutes equivalent to two hours and twenty-five minutes compared with the result of the test runs (53, 25 and 15 minutes). In the case of product A, table 4 shows the results obtained in an initial condition prior to the implementation of the SMED methodology.

| Initial condition | |
|---|---|
| Unit cost | € 2.36 |
| Weekly | € 4, 5147.04 |
| Monthly | € 18, 068.08 |
| Annual | € 216,817.92 |

**Table 4** Non-productive time costs
*Source: Own Elaboration*

The weekly, monthly and annual calculation was made based on the production rates, a calculation corresponding to the product of the number of pieces per week that are produced by the unit price of each piece, this initial condition having an annual cost of 216,817.92 euros. When carrying out the test runs to take the time that was reduced, it can be seen in table 5, in relation to the cost of these changes in the year. Obtaining savings of up to 90 % equivalent to 194, 388.48 euros.

| Cost | Initial Condition | Test 1 | Test 2 |
|---|---|---|---|
| Unit cost | € 2.36 | € 2.36 | € 2.36 |
| Weekly | €1651.06 | € 778.80 | € 467.28 |
| Monthly | €6604.22 | €3115.20 | €1869.12 |
| Annual | €79250.6 | €37382.4 | €22429.4 |

**Table 5** Cost reduction
*Source: Own Elaboration*

For the case of product B, the same was the case, here we could observe the variant of changes in the machine 720 / 2 corresponding to aluminium injection, since this one, presented a smaller number of changes per week, in table 6 the relevant calculations are observed where there is an obvious difference between unit cost and the ratio of changes per lapse.

| Condición inicial | |
|---|---|
| Unit cost | € 2.77 |
| Weekly | € 5, 301.78 |
| Monthly | € 21,207.12 |
| Annual | € 254,485.44 |

**Table 6** Costs for non-productive times
*Source: Own Elaboration*

By performing the test runs to take the time that was reduced by applying the same calculations that were used for product A, now with the price of product B, the comparative results are shown in table 6.

| Cost | Initial Condition | Test 1 | Test 2 |
|---|---|---|---|
| Unit cost | € 2.77 | € 2.77 | € 2.77 |
| Weekly | € 1174.48 | € 554.00 | € 467.28 |
| Monthly | € 4697.92 | € 2216.0 | €1869.12 |
| Annual | € 26375.0 | € 26592 | €22429.4 |

**Table 7** Cost reduction product B
*Source: Own Elaboration*

In this case the values were different as there was a variable with respect to the number of changes per week made by the machine where the part is run, this number corresponds to 6 changes per week, 3 less than the machine but without a doubt important figures were obtained at the end of the productive year. Obtaining a saving of over 93%, equivalent to 238,530.24 euros, the figure that we obtained by having carried out these three runs to be able to take the non-productive time and on this basis work on standardising the method.

The application of the SMED methodology is reflected in the medium term and reflects the success in mould change times. The initiatives that were implemented for the improvement of the processes took place gradually, the changeover time at the end of the project reduced the mould changeover times on various machines as shown in figure 3.

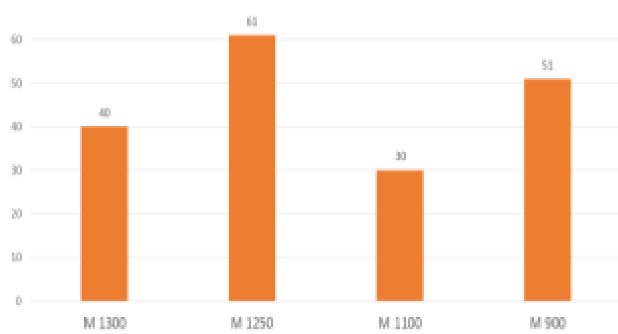


**Figure 3** Final time reduction
*Source: Own Elaboration*

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## Conclusions

In summary, positive numbers were obtained with respect to the time per mould change, obtaining a record change time of 15 minutes, demonstrating that if we look for the appropriate conditions and the necessary tool we can have the minimum time as well as obtaining a maximum time of 3 hours; the causes for which these times were obtained are shown in the history, as well as the control of these changes.

This work was carried out in order to reduce the excessive time in the changes of injection moulds for both aluminium and wood, each of these in their respective pilot areas that were implemented in strategic points were of great help in detecting other areas of opportunity for injection in general.

The work was documented in relation to the design of a S.M.E.D. system in order to optimise times in the injection moulding area, specifically when making mould changes in the machines due to an unforeseen or planned change. This system will help us to achieve minimum times in the changes, with an elaborated and standardised method to also increase the productivity of the area, reducing losses due to tooling changes, dead times, eliminating bottlenecks without affecting the flow of the process and also the quality of the product.

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