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Reducing scrap and improving an air conditioning pipe production line

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Abstract

The automotive industry is considered one of the most demanding and competitive sectors in the global market. This increasingly implies having a stable and optimized production process, always with a view to continuous improvement. Therefore, it is very important to be aware of all the waste that is generated in all production and logistics operations and take action to reduce them. In this regard and considering the process of producing air conditioning pipes for the automotive industry, a high scrap value was detected mainly due to soldering process. Therefore, the entire production process is analyzed in order to identify the main causes behind the high scrap value. Several Lean and quality tools are used to reduce not only the amount of scrap but also to increase the line productivity. In order to face this challenge, after elaborating the action plan and corresponding implementation, the scrap value is reduced by 12% in general, and productivity increased by 29%, 55% and 22.5% in three different references produced by the same machine. Although this solution is a bit expensive, the corresponding payback is reduced, so it can easily be applied transversally to other similar machines allowing extremely interesting gains in the short term.

Keywords: Automotive industry; Waste; Air conditioning pipes; Welds; Scrap; Quality tools; Lean; Continuous improvement; Production line.

1. Introduction

In a market that is increasingly competitive and flexible, it is imperative to find ways to reduce production costs and increase productivity. In this way continuous process improvement is essential as it should make the enterprises more effective and efficient through the implementation of methodologies that meet the desired objectives, making them grow at various levels, especially in size and scale, in a global context [1–3]. Adopting the Lean Manufacturing philosophy and adopting a methodology that can combine work analysis with Lean tools and principles simultaneously allows customers to provide a high-quality product at a reduced cost by eliminating activities that do not add value added to the product or other types of waste [4]. In order to remain competitive in the face of competition, companies were forced to design production systems that not only produced high-quality, low-priced products but also respond quickly to market changes and the needs of their customers [5]. The Industry 4.0 concept encompasses a wide range of applications from product design to logistics [6]. Known as the fourth industrial revolution, it is a reality that integrates people and machines interconnected in a digital way with the internet and information technologies. They play a very important role in the implementation of Total Productive Maintenance (TPM) [7]. For instance, industry-related industry approach 4.0 relates to the connection of sensors, which observe the functions of the equipment in real time and to act whenever maintenance is required. In this way, both employees and maintenance operators are aware of the current state of their equipment, providing an increase in availability [8,9].

The automotive industry is one of the most competitive and innovative areas, considered one of the most demanding sectors in the global market, resulting in a continuous increase in

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productivity [10]. For this to be possible, products and/or production processes need to be optimized in order to be competitive [11]. For this, it is necessary to keep in mind some Lean-Thinking principles that are based on the elimination of wastes in the definition of the concept of value, as determined by the client [12].

The study described in this article is developed in an automotive company that manufactures components for air conditioning and power steering. The theme addressed in this work follows the company's continuous need to optimize its indicators and production processes, increasing efficiency and capacity, reducing rework and scrap. In this way, its main objective was the optimization of an area of preparation for a new production line.

This article is divided into five sections: section 1 consists of the introduction; Section 2 presents the literature review of similar works, as well as publications addressing Lean Manufacturing techniques and tools. Section 3 deals with the methodology that was adopted to carry out the work; section 4 presents a comprehensive description of the practical work developed, the problems detected, the proposals for improvement, the results obtained and their discussion. Finally, section 5 presents the conclusions.

2. State of the Art

Many researchers have researched the improvement that TPM tools can bring to the table when applied in different areas of the industry [13]. As such, this set of continuous improvement and management tools is not specific to the automotive industry and can be used in any type of industry. According to [12], in order to achieve the expected results, it is necessary for all operators to be involved, and not only in the identification of problems but also in the implementation of activities and exchanges of information. As an example, Rocha [14] used Lean Manufacturing tools to improve the production management and control process. The adoption of these tools allowed the company a greater productive organization, standardization of some procedures, reduction of Lead Time, financial gains, low inventory, among others [15,16]. The most notable tools are Value Stream Mapping (VSM), Cycle Plan-Do-Check-Act (PDCA), Kaizen, Kanban, Single Minute Exchange of die (SMED), Visual Management, among others [17–20].

Several positive results can be achieved by employing these tools. In [21] was achieved a 10% improvement in the monthly machine availability rate and 8% in Overall Equipment Effectiveness (OEE), based on this Lean philosophy. In [10] SMED is used in an automotive supplier in a case in which an electron beam machine (EBM) is utilized as the target of intervention and this tool helped to reduce the setup time in more than 50%. In a different study, the number of plastic bag rolls made per day, in a plastic bag manufacturing unit, increased from 28 to 50 and in which the application of lean manufacturing tools, such as VSM, increased the value-added time by 74.5% [22]. A methodology that combines multidimensional process mining (MDPM) techniques with VSM was applied and evaluated in a case study at a German automotive manufacturer, in which 7500 parts and 15 reference processes were analyzed [23]. A waste analysis that included an analysis strategy by utilizing the obtained MPDM results in this study allowed a systematic approach for experts to identify the potential for continuous improvement.

With the introduction of Industry 4.0, it was possible to employ the use of sensors to evaluate the sustainability of manufacturing processes, through the measurement of parameters and the establishment of KPI (Key Performance Indicators) [24]. It was possible to also quantify the productivity through the collect data. An advantage of using this type of technology is being able to obtain information of the state of the machines and the useful life of their elements, thus detecting the need for preventive maintenance [25]. It is also something that is not restricted to new machines, since older machines, which have not been prepared for this type of coupling connections, can be easily altered [24]. Barbosa et al. [26] developed a cell capable of being connected to one or two machining centers for automatic feeding of machines using robots. It is a cell that can be customized depending on the needs of the customers relative to the shelf sizes and type of sensors used.

3. Methods

The products covered in this article are air conditioner pipes for the automotive industry. They are divided into two major groups: low pressure and high pressure. They are also divided into several references where almost all go through the same production process. This process is represented in the scheme of Figure 1.

The major challenge in this manufacturing unit is the high level of scrap produced in the preparation areas. As a result, there is a low production capacity of succeeding assembly lines.

Before applying any correction to the productive system, it was necessary, firstly, to make an analysis of the current situation. To do this, and in terms of contextualization, the cost of rejected parts of the three assembly lines receiving the components of that area was analyzed in order to determine the most impaired line in terms of scrap.

The period of analysis used was from February 1 to April 31, 2018, and the summary of the data obtained can be analyzed in Table 1. From Table 1, it can be concluded that the line that have a higher cost of scrap is the line AA12 that, in approximately 3 months, generated 25 701,39 € in non-conforming components corresponding to 52% of the costs of parts that were rejected.

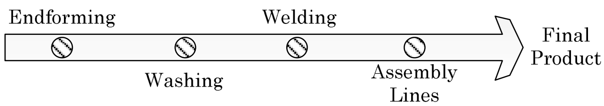

Fig. 1. Production Process Operations Scheme.

Table 1. Cost of rejection in each production line during the studied period.

Line	Total rejected parts (units)	Total cost of rejected parts (€)	%
AA10	5829	15 548,35	32
AA12	6445	25 701,96	52
AA14	3409	7646,52	16

4. Results and discussion

In order to solve the issue at hand, the following steps were taken. First, a Pareto analysis for the defects was made, then a Pareto analysis by references for the chosen defect was made. Afterwards, the Ishikawa Diagram was employed and then an action plan was crafted. Finally, the actions outlined in action plan were implemented and further analyzed.

The next step was to verify which defects contributed the most to this high scrap value. This analysis was accomplished through a Pareto analysis and is represented in the chart of Figure 2 that show the most critical defect in the production line, and which in turn affects the production.

From Figure 2 it can be concluded that the most critical defect is leakage (FU) followed by incorrect bending (CI) and non-OK pressing heights (AP). It was then decided to analyze the leakage defect because it is the most critical problem. The next step was, for the chosen defect, it was decided to analyze if there were more critical references than others. For this purpose, another analysis of Pareto was performed, focused on the references rejected as leakage. This chart is represented in Figure 3.

There are three references which are most affected by this defect being R70429-G5, R70430-G5 and R70620-G5, originating the final products designated by T.70429, T.70430 and T.70620, respectively. This leakage defect is the one that has a higher scrap cost, since the control that detects this type of defect is made only at the end of the process, when the product is already assembled with all the remaining elements. These leaks, in most cases, are due to poor welding from the preparation area that precedes the production line.

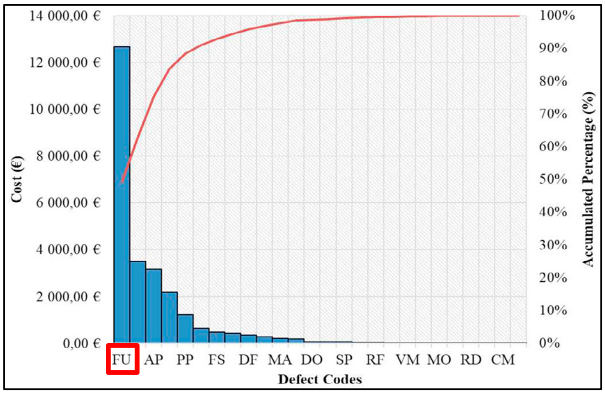

Fig. 2. Pareto's analysis of the defects for AA12 line.

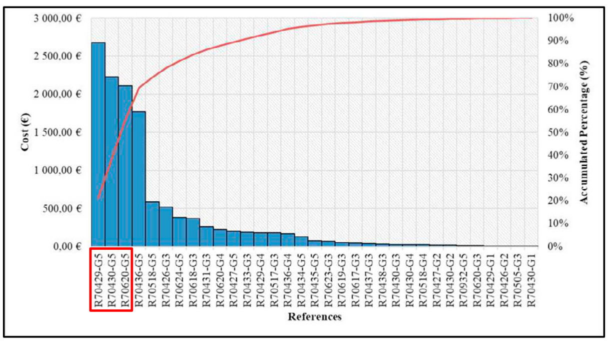

Fig. 3. Pareto's analysis by references for the chosen defect (Leaks).

Therefore, the preparation line that is capable of producing these components was then a target of analysis. For this purpose, the preparation line was divided into two different areas: area PRG6 and area PRG7.

In that areas the general problems are the followings:

- Area PRG6 – where a high percentage of scrap is generated;
- Area PRG7 – where a low productivity occurs due to a high amount of scrap that is generated.

It is these two main problems that pushed engineers to try to study and find the root causes. Then, after they were able to find these causes, the next step was to elaborate an action plan in order to minimize the prevailing problems. In order to perform this study, Ishikawa diagrams are employed in order to determine the potential causes of the problem. The diagrams are represented in Figs. 4 and 5.

For the problems encountered and after their causes were determined, an action plan was prepared in order to act in each area. These actions are described in Table 2.

After implementations were carried out in the preparation area, Table 3 shows the reduction of the obtained times, as well as the gain of parts per hour. In the Fig. 6 it can be observed the setting before and after doing the rectification of the brazing welding machine by adding an extra blower.

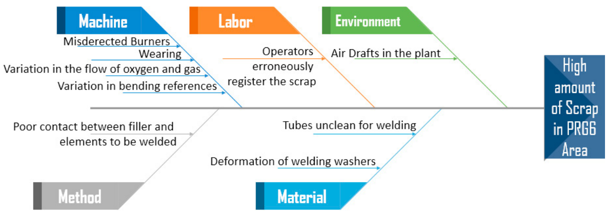

Fig. 4. Ishikawa's analysis for PRG6 area.

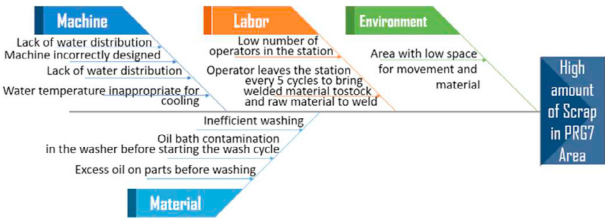

Fig. 5. Ishikawa's analysis for PRG7 area.

Table 2. Identification of problems/solutions for the analyzed processes.

Area	Action
	Implementation of an AIP for the correction of the technical files; Training operators on how to reject scrap; Creation of a visual aid for the job; Negotiation with the supplier with a set of washers with greater thickness; Implementation of a scale to assist the regulation of oxygen in the flame welding machine; Balancing the PRG6 area; Tuning and cleaning of welding cars by brazing.
PRG7	Switching of welding machine connections by brazing; Coupling a new blower to the machine; Tuning and cleaning of welding cars by brazing.

After the intervention on the brazing welding machine, a significant reduction in machine time was observed in all references. For instance, by analyzing Table 3, it possible to observe that the machine of reference T.70430 could only produce 41 parts per hour and after the intervention it is able to produce 53 parts per hour (an increase of approximately 29%). For reference T.70429 the reduction in machine cycle time is around 41% on side A and 25% on side B. For reference T.70620, there was a reduction 22% (25 seconds) and 23% (27 seconds), respectively from side A and side B.

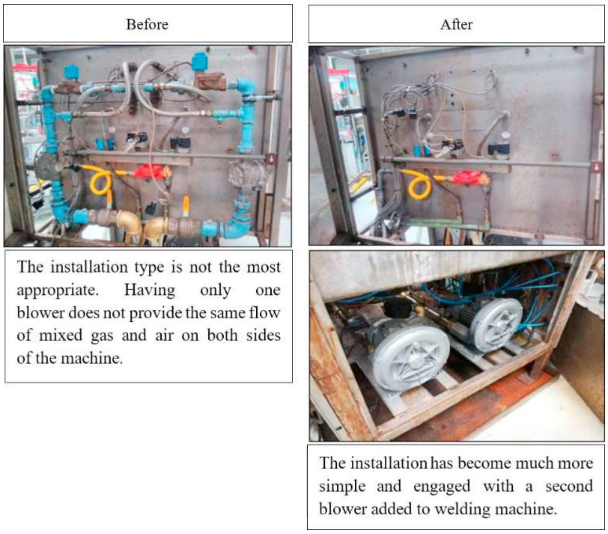

Fig. 6. Brazing machine before and after an extra blower has been added.

After cleaning and rectifying the welding cars, as well as exchanging the wear components during vacations of the plant, the scrap trend from this area was also reduced, as can be seen from the graph of Figure 7.

Table 3. Reduction of brazing welding machine cycle time.

Average cycle time	References					
	T.70430		T.70429		T.70620	
	Side A	Side B	Side A	Side B	Side A	Side B
Before (s)	182	169	162	115	115	117
After (s)	131	139	84	92	90	90
Variation (%)	**-28**	**-7**	**-41**	**-25**	**-22**	**-23**
Parts/hour (Before)	20	21	22	31	31	31
Parts/hour (After)	27	26	43	39	40	40
Variation	**+7**	**+5**	**+21**	**+8**	**+9**	**+9**
Total Gain/Hour (Parts)	**+12**		**+29**		**+18**	

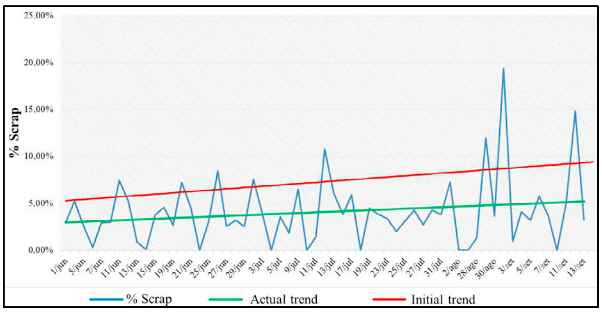

Fig. 7. Evolution of the scrap in the PRG7 area, in percentage.

In the case of the area PRG6 in Figure 8 shows the evolution of the percentage of scrap barely registered in the area, after training the operators and putting the visual aid on the workstation.

Having the datasheets changed in May, which had 15% of scrap erroneously registered, the following month there was a reduction of 5%. At this stage, even though operators were sensitized to the problem, there were still incorrect records. With the arrival of new operators during the month of July, the percentage increased 2% compared to the last value. It was during this period that training was given to the operators and a visual aid was added to the workstation. As a result, in the months of August and September, the percentage of scrap that was incorrectly registered was reduced to 0%.

The chart in Figure 9 initially shows a continuous increase in the percentage of scrap, mainly due to incorrect registration. After the improvements were implemented, the trend started to decrease. As such, Table 4 shows the evolution of scrap cost in the area for the chosen analysis period. After the new production balancing performed for the PRG6 an overall improvement was achieved in the production of the references as can be seen from Table 5.

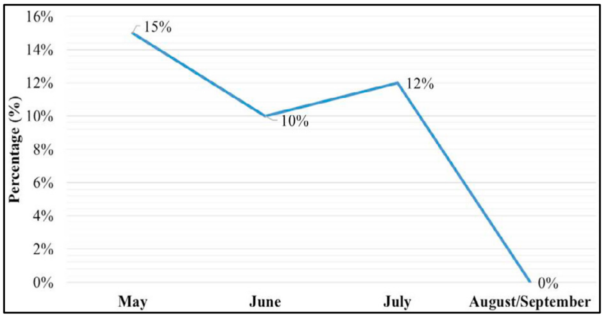

Fig. 8. Evolution of the erroneous registration scrap in area PRG6.

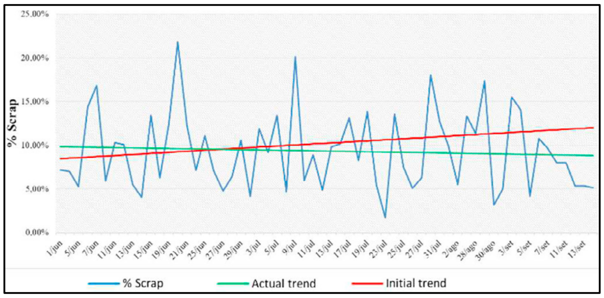

Fig. 9. Evolution of scrap in area PRG6.

Table 4. Improvement obtained in the value of scrap in area PRG6.

Analysis period	Average scrap cost	Achieved Improvement (%)
February to April	6802,26	**-12**
June to September	6013,41	

Table 5. Increase in production targets due to rebalancing in PRG6.

Product family	Production/hour (parts/hour)					
	Before		After			
	1 Oper.	2 Oper.	1 Oper.	Gain (%)	2 Oper.	Gain (%)
T	24	45	27	+12,5	50	+11,1
NT	27	47	32	+18,5	58	+23,4

Initially, the line could produce 45 and 47 pieces/hour for the references of the "T" and "NT" families, respectively, for the standard number of operators in the station (two operators).

In an initial analysis, the operations of each station for the "T" family are as follows:

- Station 1: drilling, induction welding and brazing;
- Station 2: bending, blowing, manual bending and obstruction test.

With the updating of the operating and cycle times, it was concluded that the distribution of the operations by the two stations is the most adequate, having only been necessary to update the times, as the faster and more experienced operators, were better matched.

After this balancing was achieved, the cycle time was reduced by approximately 6%. This result provided an increase in the production from 45 to 50 parts/hour, which is equivalent to a 11,1% increase.

For the reference "NT" the operations of each station are as follows:

• Station 1: drilling, induction welding and brazing;

• Station 2: bending, blowing, manual bending, obstruction test.

In this case, it was noted that there was a mismatch between the cycle times of each station. It was then decided to pass the drilling operation to the next station, thus obtaining a better balance. Along with the update times, there was a reduction of 22% in the cycle time. This provided an increase in the number of parts per hour from 47 to 58 (an increase of 23,4%).

5. Conclusions

This work had as main objective the improvement of an area of preparation for a production line of an industrial unit from automotive industry. After analyzing the most critical problems in the production lines to identify the preparation area for study, identify root causes of the problem, draw up a plan of actions and implement them, it was possible to improve the preparation area, bringing benefits to the production line that was most affected by the identified problems. The improvements that were obtained were as follows:

• A reduction of scrap in the preparation area by 12%;

• Increase in yield of the area by 29% for reference T.70430, 55% for reference T.70429 and 22.5% for reference T.70620;

• Increase of the production in PRG6 area by doing a production balancing in the area in study.

In addition, two other works were implemented to further optimize the area. These were:

• Creation of a production follow-up framework. This framework allowed the operators to see which reference to produce in sequence, as well as the quantity and the machine where they will be made. This allowed to improve the visual management of the production, allowing to know the sequence of these references and which one of them had the highest priority;

• The introduction of visual stop management boards. These boards are present in all existing machines in the lines and contains 3 cards (green, yellow and red). If the green card is inserted in the machine, it means that the machine is in production. On the other hand, if the card is red it means that the machine is under maintenance. Finally, if the machine has the yellow card, it means that it is in preparation and validation is required by the monitor of the area, the person in charge or production manager.

These improvements were very important for the industrial unit and showed how the implementation of Lean Manufacturing tools can improve the performance of the production line. This allowed the lines to work continuously, avoiding to stop due to a lack of material in the preparation area, as was happening before in a recurring fashion, which exemplifies how many problems were outright eliminated by employing these tools.

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