Chapter

The Use of Lean Manufacturing Tools to Improve the Production of Automobile Parts

Jonathan-David Morales-Méndez and Ramón Silva-Rodríguez

Abstract

The competitiveness of the national and international market for automobile parts requires that delivery times, quantities and agreed upon quality standards for the ordered product are rigorously adhered to. This means that a company must use and keep up with strategies that allow for improvement while maintaining a high performance-level in its production processes. The company accepts their clients' challenge to increase the production capacity and improve levels of quality and productivity for their M300 wheel hub[1] production line. The first step was to carry out a general analysis of the manufacturing process, identifying each of the activities and operations used to make the product. The critical path along with critical activities was identified and deficiencies were found in the execution of the activities along these critical paths. Next, the causes for low productivity and flaws in the production process were identified. This information was used to implement improvement proposals using "lean manufacturing" techniques with the respective results that were achieved. Conclusions and recommendations for continuous improvements in the manufacturing process are presented.

Keywords: wheel hub, productivity, production capacity, standard workflow, 5MQS, Kaizen, lean manufacturing

1. Introduction

The improvement initiative arose when it became clear that production capacity for the front and rear M300 wheel hub needed to increase in order to meet increased demand in Ecuador and Colombia. It is a business that holds potential to deal with SOFASA and General Motors, which required high production volumes compared with the current ones.

At the same time, General Motors demands that "lean manufacturing" be applied [1, 2] as a way of both increasing productivity and ensuring high quality. The goal is to make continuous improvement processes more robust.

These strategies must be applied to the manufacture of the front and rear M300 wheel hub supplied to General Motors.

The plant is divided into two main areas: forging and machining.

[1] Wheel Hub. The wheel hub supports the brake drum. The wheel studs and bearing bracket are affixed to it. This arrangement transmits the torque from the drive shaft to the vehicle's wheels thus enabling movement. The part is made from steel and weights ~2.9 kg.

Operation	Machine	Standard time (seconds)	Goal (pieces per hour)
Forging			
Cutting raw material of wheel hubs	Saw	49.5	73
Heating and forging of wheel hubs	Furnace and press	50.79	71
Heat treatment: standardization	Furnace	15.45	233
Cleaning	Blasting machine	18.33	196
Inspection for cracks	Magnaflux equipment	20.94	172
Machining			
Pre-mechanized exterior of the flange	Lathe-1	146.05	39
Roughing of interior diameter	Lathe-2 for roughing	121	40
Broaching	Broaching machine	61	59
Final lathing of exterior	**Lathe-3 for finishing**	**212**	**17**
Boring and countersinking long holes for stay bolts	Drill 1	79	46
Threading holes	Tap drill	65	56

Table 1.
Main data related to plan operation.

Forge area: The smelting process is carried out under heat. In this area, the forging process is a closed one where the material is formed by applying compression forces. The steel is shaped by pressing it between two blocks (closed matrix) while raising the temperature in industrial furnaces. The furnaces work in the same cell as the corresponding presses. A normalization process and checking for cracks also takes place in this area.

Machining area: here chip removal operations are preformed that result in semi-finished products through roughing (which require subsequent processes), or finished products with their final diameter (finishing processes).

Table 1 shows the machines and the manufacturing process for each area of the plant.

There are currently 14 operators working at the plant:

- **Production capacity** [3, 4]**:** The average real maximum production of M300 wheel hubs was 3000 units during the last half of 2017. Taking stock of performance flaws revealed that there was no record of machine stoppages or other short-comings in the process, and no standardized time tests to identify the maximum installed capacity of the plant along with bottle necks. This implies that no corrective planning and production programming is done leading to cost over-runs, delays and all kinds of waste [5].

- **Time studies:** In order to define the initial productivity level, a time study was done to find the standard time and number of pieces produced per hour in each operation. This can also be seen in **Table 1**.

1.1 Calculating initial installed capacity and OEE (overall equipment effectiveness)

The initial installed capacity refers to the highest possible value given the initial standard times that are calculated. From **Table 1** it can be concluded that the bottle neck [6] is at the final lathing of the exterior with a maximum of 17 pieces an hour (bold value in **Table 1**).

As such, the maximum installed capacity is calculated as follows:

$$17\frac{\text{pieces}}{\text{hour}} * 7.5\frac{\text{hours}}{\text{turns}} * \frac{3\text{ turns}}{\text{day}} * \frac{25\text{ days}}{\text{month}} = 9562.5\frac{\text{pieces}}{\text{month}}$$

In order to calculate the OEE, we compare the actual capacity to the maximum possible capacity [7]. According to the dispatch records for the second 2017 semester, the average monthly production for the plant was 3000 units. Calculating the OEE based on an average evaluation period of 30 days per month we get:

$$\text{OEE} = \frac{\text{actual units}}{\text{possible units}} = \frac{3000}{9562} = 0.3137$$

Since the OEE for the wheel hub is 31.37%, it is clear that the reasons for low productivity need to be found.

1.2 Identification of causes that lead to low productivity in the manufacturing process of the M300 wheel hub

In order to identify the leakages and causes of low productivity, the **5MQS** (methodology to identify waste related to machines, method, materials, man, management, safety and quality) [8] method was used. This was complimented with the use of an Ishikawa diagram to analyze root causes. The general findings were:

- **Machines:** A flow diagrams and switch travel diagrams were used as analysis tools leading to the conclusion that there is a very poor distribution within the plant. On top of that, there are constant stoppages for machine maintenance. No preventive maintenance programs are in place.

- **Method:** In accordance with the time studies, the critical activity (bottle neck) is the final lathing of the exterior, meaning that productivity needs to be increased at this work station [9].

- Making human-machine and machine-machine diagrams showed a **workload imbalance** for the different machines and operators.

- Constant time wasting was observed while tools and devices are sought since they are not kept in a specific place and are far away from the work station. A high level of loss is incurred due to movement of materials and people due to poor distribution of the machines in the plant.

- A space for raw materials is not demarcated and as such it often gets in the way of people and the flow of material in the production process.

- **Checking the degree of compliance with the 5S.** Check-lists were designed for the 5S that were then used to measure compliance. The results are presented in **Table 2** and the diagram of **Figure 1**.

The 55% compliance level for the 5S at the production plant indicate the necessity of implementing the 5S methodology.

- **Material:** There is a large accumulation of inventory at the bottle neck of the process, there is an imbalance in the line and lack of order for placing material.

5S	Maximum score	Machining area	
		Result	%
Sort	25	9	36
Set in order	35	16	46
Shine	20	8	40
Standardize	45	35	78
Sustain	35	20	57
Total	160	88	55

Table 2.
Results of the 5S check-list applied at the plant.

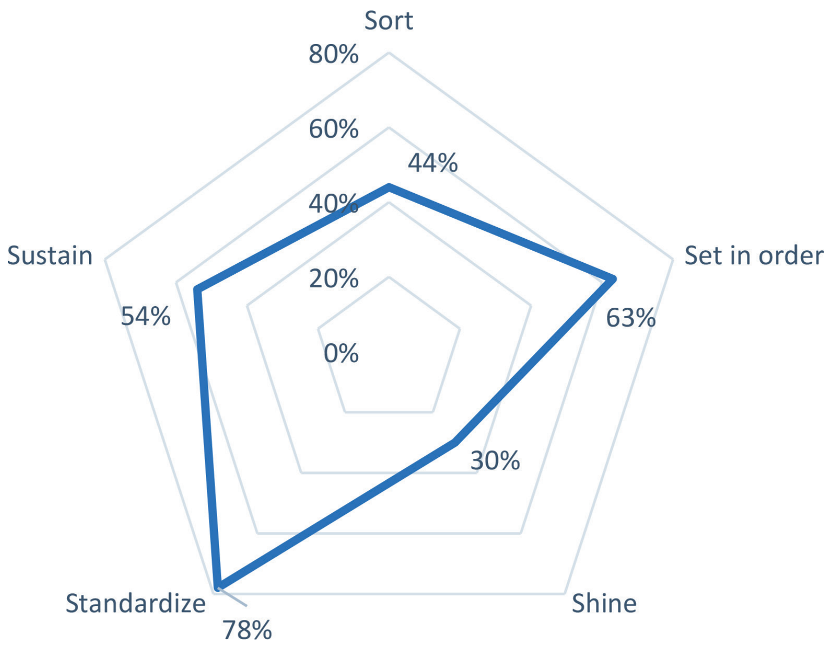

Figure 1.
Diagram of the 5S network at the production plant.

- **Man:** What is seen as weaknesses in the **method** leads to the conclusion that there are no operation standards at the plant resulting in a lack of structured training and formation for operators at the plant.

- **Management:** Quality inspections were carried out on 100% of the finished products leading to a huge loss of time for the operator. In addition, there is low illumination in the inspection area where high visibility is needed to be able to read the instruments.

- **Safety:** There is no established place to keep safety gear which is one of main the reasons why it is hardly used. The lack of order and standard procedures also contribute to unsafe conditions.

- **Quality:** The level of defects found for the period under study (second semester of 2017) is 49,937 PPM (parts per million). Both the company and clients defined the goal as <15,000 PPM.

2. Materials and methods

After examining the different continuous improvement methods available, it was decided to use those associated with "lean manufacturing" to improve the production process of the M300 wheel hub. The Kaizen framework was chosen to guide all the improvements. The project was done in seven steps as follows:

- **Phase 1:** Creation of Kaizen teams [10–13]: Awareness and training on how Kaizen teams work. Training on "lean manufacturing" techniques, especially: 5S's, time loss analysis, standardized work, visual management. Training was also done on OEE (overall equipment effectiveness).

- **Phase 2:** Initial situation assessment of work stations, using photographic evidence, data and analysis.

- **Phase 3:** Definition and approval of workplan: each Kaizen team presented their assessment from phase 2 along with a proposed workplan and schedule, goals (indicators), who was responsible and necessary resources to the company management who approved the plans.

- **Phase 4:** Development and implementation of standards: This phase consisted in documenting the operations in the manufacturing process that each Kaizen considered to be a best practice.

- **Phase 5:** Standardized training and implementing improvements [14]: The learning by doing method was used and adjustments were made to optimize.

- **Phase 6:** Managing and operationalization of the system. This is the last phase in developing the implementation and is comprised of standardizing the operationality of the new system and the administration to include continuous improvement.

- **Phase 7:** Closure of Kaizen first stage projects and commitment on the part of the Kaizen teams to develop new continuous improvement projects leading to the beginning of stage 2.

3. Implementing improvements through the strategic use of lean manufacturing tools

Continuing with the use of the **5MQS**, the improvements that were achieved are described below.

- **Machines:** Starting with balancing the load, a new distribution was set up in the plant. This was complimented by establishing Standardized Work roundtables in each work cell. This guarantees that: the documentation of standardized work, visual aids, measurement instruments, necessary tools, identification of non-conforming material, a container for personal safety gear, and good lighting to aid readings.

A basic preventive maintenance plan was started with the goal of reducing unforeseen machine stoppages.

- **Method:** The problem at the center of the critical activity was solved by using a human-machine diagram [15] to create a balanced lathe cell. This strategy was also applied to second level critical activity sectors at the plant.

A standardized form was designed and used to register daily production at the work stations and planned and unplanned machine stoppages. The goal was to have data to use in the on-going calculation of the OEE.

The OEE for each machine and production line became the standardized performance indicator. Pareto and Ishikawa diagrams were also used to analyze root causes and support the continuous improvement process.

A visual management strategy was used for the continuous display of the OEE and other vital production performance indicators.

Standardized work at work stations became the norm through the use of documentation designed by each of the Kaizen teams. These standards include:

  - **Assessing the 5Ss:** The 5S check-list was put in place for each machine. This document must be filled out by each operator at the start of their shift, evaluating the order and cleanliness found at the work station. The check-list is on one side of the sheet and on the other side the operator registers their findings (non-compliance) as a way to identify root causes. A person responsible for taking action is listed along with the date for compliance.

  - **5S standard card:** There is one for each work station of manufacturing cell, indicating the elements needed for each operation: materials, measurements, tools, information and personal safety.

  - **SMS sheet** [16] (standard manufacturing sheet) for cyclical operations. And **SMI** sheet (standard manufacturing instructions) for every one of the processes.

  - The above standards include the optimization of process variable which resulted in another time study that showed increased capacity at the bottle neck.

- **Material:** Manipulation of material notably improved by the new arrangement of the plant plus the application of the 5S along with standards for material control and trained personnel.

- **Man: Standardized training** was carried out using the standards developed by the Kaizen teams. This kind of material should be constantly updated and is useful for planned re-training as well as orienting new personnel to their posts. Five levels of verified training were established in the following order: operator with basic training (20%), operator approved to carry out operations (40%), operator approved to carry out fine tuning (60%), operator approved to train or rework (80%), operator that can apply lean manufacturing (100%).

It was determined that by the end of the first semester (February to July) of working on improvements, the operative staff must have reached a minimum level of 40%.

Multifunctionality matrix. [17, 18] The operation that each operator is trained in along with the percentage is entered, thus allowing everyone to see at any momento which people are qualified to do certain activities.

- **Management:** Statistical control of the process at the bottle neck was introduced, along with training and increased lighting.

- **Safety:** Protective gear at the work station is guaranteed, as well as safety standards.
- **Quality:** The Kaizen teams carried out root cause analysis by way of the Ishikawa diagram and corrections were applied.

4. Results

Results of applying the 5S: After the 5S trainings at each of the work stations, their condition was assessed again using the check-list **Table 3**. The following results were attained:

See **Figure 2** for the network diagram showing the results of the 5S standards after the trainings. An increased level of compliance can be observed. However, more improvement is needed in the S with the lowest compliance level: shine.

Result for production capacity: Figure 3 shows the number of units produced from July 2017 through September 2018.

From the graph, it can be seen that production increased by 121.9% between the second semester of 2017 and April-September of 2018.

The installed capacity at the bottle neck increased to 19 pieces per hour which generated a monthly installed capacity of 10,687 units. Thus, using the new

5S	Maximum score	Machining area before 5S	
		Result	%
Sort	25	18	72
Set in order	35	28	80
Shine	20	12	60
Standardize	45	37	82
Sustain	35	28	80
TOTAL	160	123	77

Table 3.
Results of the 5S check-list after the trainings.

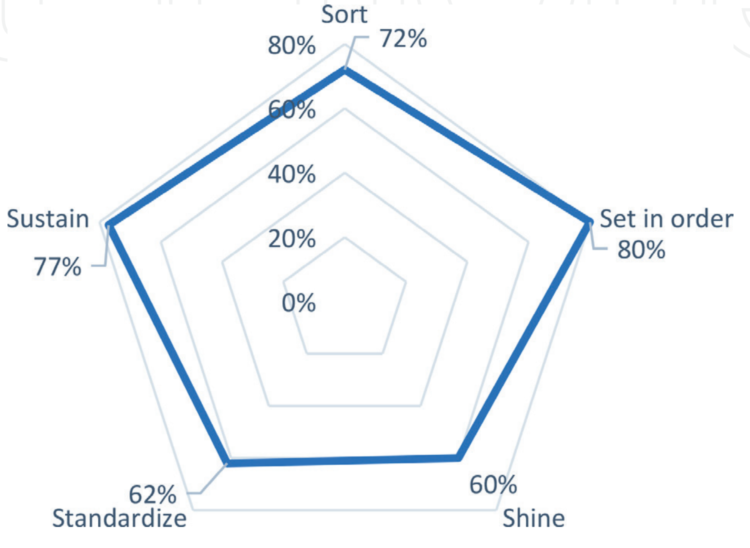

Figure 2.
Network diagram of the 5S after trainings.

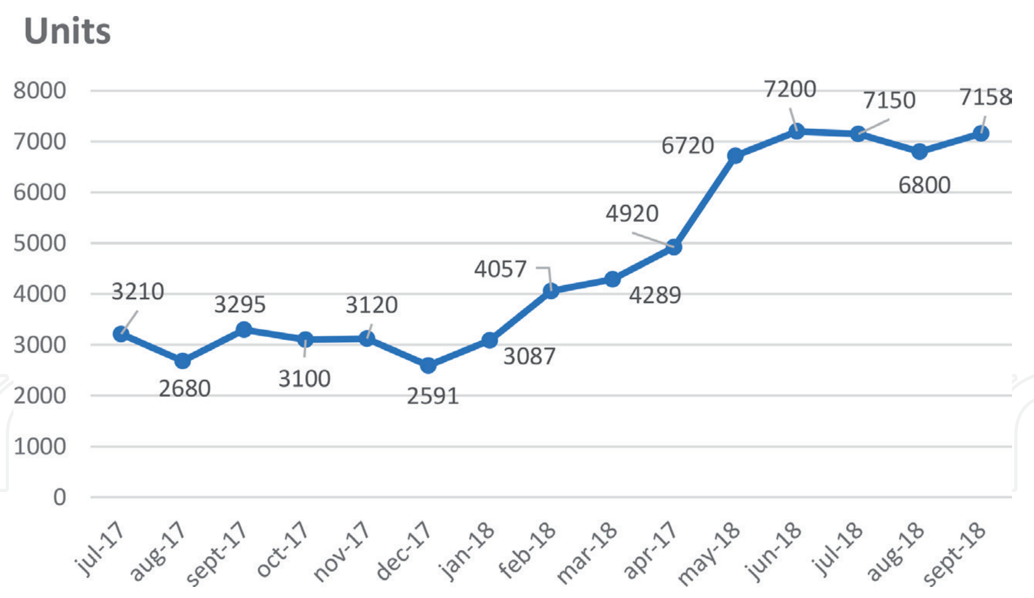

Figure 3.
Increase in production.

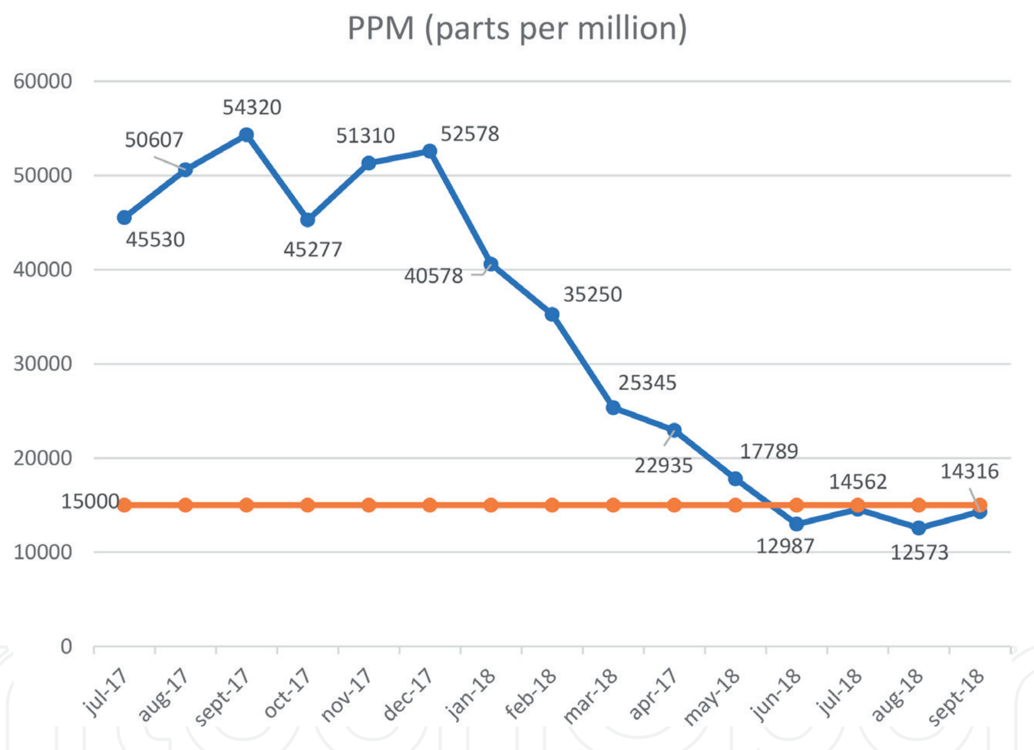

Figure 4.
Flawed PPM.

maximum capacity and the actual monthly average for the previous 4 months (7077 units), the new value for the OEE is 66.21%.

Results for the quality level: The quantity of non-conforming product since July 2017 until September 2018 can be seen in **Figure 4**. A decrease in number can be seen, and during the last 4 months the internal goal of no more than 15,000 PPM was surpassed.

Results for labor productivity [19] (relationship between the value of sales and the cost of labor required to produce the volume mentioned). By rearranging the plant and balancing workloads it was possible to reduce the number of operators from 14 to 11, representing a reduction of 21.42%. This contributed towards improvements in labor productivity from February through September 2018 as demonstrated in **Figure 5**.

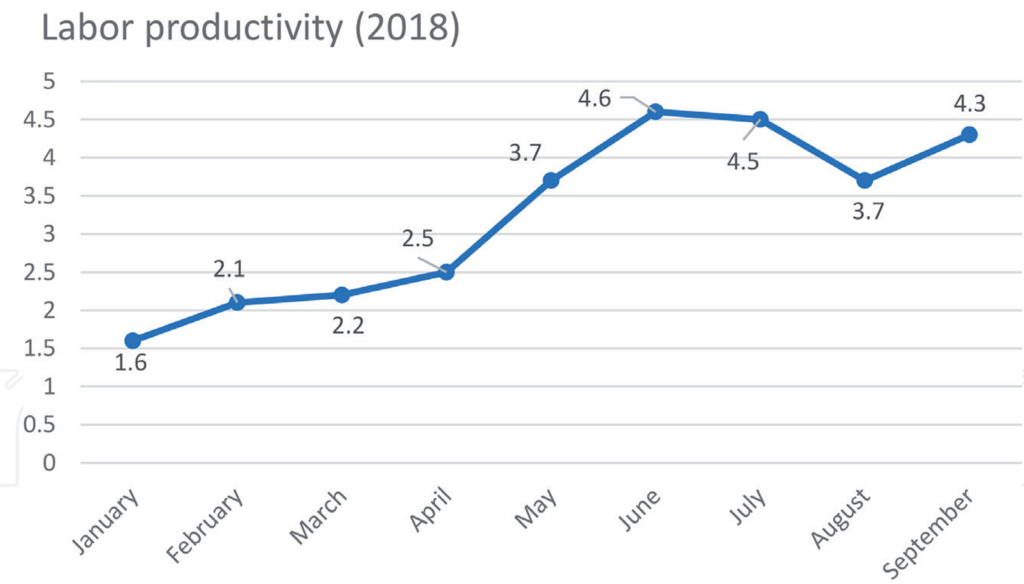

Figure 5.
Labor productivity.

Standardized documents: The OEE became the standardized indicator for measuring the performance of the productive process. The discipline of collecting the necessary date for calculating the OEE was established: machine availability, efficiency and quality.

As the improvements were implemented, but especially as the standards were being met during phase 6, a plant administration was established that embraced the lean manufacturing philosophy.

Lastly, phase 7 was officially closed with the Kaizen teams presenting the goals that were met by using the data illustrated above, and the new projects designed by each constituted team.

5. Conclusions

- The **5MQS** methodology was successfully used to identify waste as a reason for low productivity at the production plant.

- Through time studies and use of switch travel diagrams and diagraming operations it was possible to identify processes that add value and analyze the installed capacity of the critical activity or bottle neck. This facilitated focusing efforts on increasing production at this work station. The result was increased labor productivity and OEE.

- Balancing the work load at the roughing lathes and final machining, together with standardizing the operations, allowed for increased capacity at the bottle neck and improved the continuous flow in the process.

- The human-machine and machine-machine diagrams helped to balance the production line, especially at the bottle neck. This led to reducing distances covered and the inventory of product in process, while also taking better advantage of labor.

- By standardizing the use of the daily and monthly OEE indicator and the Ishikawa diagram, the root causes of stoppages can be identified and problems controlled, leading to efficient solutions.

- Better safety at work and higher quality and productivity levels were seen in the results obtained as a result of implementing the standardized work strategy via the respective documents.

- Safe, clean and organized work stations resulted from applying the 5S methodology to the different operations in the production process. The round tables for standardized work attained a higher level of organization of work stations thus avoiding unnecessary movements to search for things.

- Standardized training was essential in preparing and instructing the operators. They were inducted tin the lean culture and that of standardization.

- Lastly, the results obtained also led to increased labor productivity due to reducing the number of operators and the progressive increase in pieces produced. At the same time, it was possible to be under the goal of a maximum of 15,000 PPM of flawed products during the last 4 months under study.

6. Recommendations

- It is recommended that company management continue to implement standardized work and standardized training with the other production processes at the plant.

- Continue to consolidate lean management at the production plant, placing priority on those products that have a higher propensity to be internationally competitive.

- It is also recommendable to introduce the lean manufacturing strategy into management processes as a way to support all the production processes, thus guaranteeing continuity and improvement in the system.

- The maintenance and general managers should strengthen the preventive maintenance plan even more in order to ensure higher levels of machine availability and trustworthiness. As much as possible, autonomous maintenance should be started sooner rather than later.

Author details

Jonathan-David Morales-Méndez[1]* and Ramón Silva-Rodríguez[2]

1 University Manuela Beltrán, Colombia

2 Servicio Nacional de Aprendizaje—SENA, Centro Industrial de Mantenimiento Integral, Colombia

*Address all correspondence to: jonathan.morales@docentes.umb.edu.co

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