Research Article
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Production optimization in the automotive industry using check sheet to reduce unscheduled downtime

Summary

The study was developed in an automotive industry, due to the increase in unscheduled stops in the cylinder head production line and the lack of information and records. Therefore, the verification sheet was applied as a methodology, as it is a quality tool that aims to evaluate the production inefficiency index, in order to guarantee improvements in the indicators. With the help of indicators and in order to increase productivity and reduce costs and waste, the analysis of stops in the production process was divided into four sectors, namely maintenance activities, tooling problems, preparation and the production process itself. After this analysis, it was necessary to quantify the hours lost over the three months. Therefore, after the study, improvement was achieved in filling out the verification sheet, records and complete and correct information, trained employees in addition to a significant reduction in downtime and a significant increase in production.

Keywords: productive inefficiency, quality management, stops, production line, check sheet

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Introduction

The automotive industry is a highly competitive and demanding sector, which demands efficient and quality production processes to guarantee customer satisfaction. The company A xxus Motors, a manufacturer of automotive cylinder heads, faces challenges related to production losses in its production line. This issue directly impacts the company's productivity and operational performance, making it necessary to search for solutions that optimize the production process.

A xxus Motors automotive cylinder head production line and to propose a new recording system that allows clear and precise control of the data obtained. The implementation of this new system will result in significant improvements in the recording of information provided by operators, time savings and the correct assignment of responsibilities in relation to production stops.

With the need to improve the collection and recording of data in the production line, in order to increase the efficiency and productivity of the operation. It is believed that a more accurate and available recording system to support decision-making will enable better identification of unscheduled production stops, as well as the correct attribution of responsibility and the development of indicators for each sector of cylinder head production.

It is expected that this study will result in a new, more efficient production recording system, providing more accurate data and assisting in decision making. These improvements will contribute to optimizing the company's operational performance, increasing productivity and efficiency in the automotive cylinder head production line.

General objective: To study the rate of production inefficiency in a cylinder head production line for motor vehicles.

Specific objective:

a) Survey unscheduled production stoppages.

b) Identify which sector was responsible for the stoppage and time for interventions;

c) Propose improvements in the way of identifying stops carried out;

d) Propose indicators for each sector of cylinder head production;

Reference

Productivity

Productivity is linked to a company's manufacturing power and its ability to produce competitively and efficiently. It is also one of the fundamental economic indicators as it is directly linked to the production of jobs and profitability. With this in mind, one of the strategies adopted is the use of batch production.[1]

Batch production

Batch production is a common strategy in several industries, including metallurgy, which seeks to optimize the production process and reduce production costs. After the second industrial revolution, the mass production model became dominant as a manufacturing method, which resulted in the establishment of a market-centered economy in consumption.[2]

However, batch production can present some challenges, such as the need to manage large volumes of raw materials and finished products. Inadequate inventory planning or inefficient control can result in financial losses. Keeping inventory costs to a minimum can be a huge competitive factor.[3]

It is essential that the company is always looking for improvements in the production process. Aiming for better use, reduced losses and lower costs of manufactured products, one option is to improve the quality management system processes.[4]

Quality

Quality in relation to products and/or services has several definitions. As a product that meets customer requirements, it has value to be added, something that similar products do not have, cost-benefit, etc. Quality is the adequacy and conformity to the standard and requirements established by customers. ISO 9001 describes quality as ''a quality management system designed for companies to improve their performance". The first information about uniform quality control methods dates back to the 1920s. Quality control and quality management are also terms related to quality in industry and services. The terms are used in different fields by quality indicators and standards such as ISO 9001, and others. Quality ranges from improving products, services, systems and processes to ensuring the effectiveness of the entire organization.[5]

Quality tools in maintenance

Quality Management in maintenance aims to ensure the stages of industrial processes, obtaining greater use of the functionality of the machinery, in order to reduce expenses and the impact on productivity.

It can be said that ''to assist in day-to-day maintenance incidents, equipment and machinery failures, in organizational environments there are tools and methodologies that can be adopted, thus facilitating the direction of our decisions".[6]

Statistical or management tools in quality control are:

a) **Check sheet:** it is a tool considered simpler and more useful, as it collects data and demonstrates the occurrences of the process. Furthermore, it also helps save time by eliminating the hassle of collecting data from decentralized sources.

b) **Ishikawa diagram:** The cause and effect diagram helps to find out the root cause of the problem. This tool can point out defects and their reasons.[7]

c) **Pareto chart:** Pareto is represented by a graph, with bar shapes, correlating a problem to its cause, guiding managers towards the cause with the highest incidence.[8]

d) **Flowchart:** is a graphical representation that allows easy visualization of the steps of a process. The flowchart serves to describe the process, but you need to know the process to control it using this tool.[9]

e) **5W2H:** "tool used mainly for mapping and standardizing processes, developing action plans and establishing procedures associated with indicators". It is a method that during an action plan needs to be answered seven questions, that is, translated into Portuguese they would be: what, why, where, who, when, how and how much it will cost.

f) **Stratification:** aims to separate the information collected into different groups, which can be stratified by shift, by type, by date and/or by location, and from this reveal the root cause of the problem.[9]

Maintenance: predictive, corrective and preventive

It can be said that maintenance is the act of maintaining, preserving, sustaining, preserving something or something and especially repairing it. Maintenance consists of a set of actions that contribute to ensuring good and correct operation. Maintenance is a strategy for achieving results in organizations and contributes to increased productivity, and must be linked to problem management support. Maintenance seeks to ensure that the equipment achieves its best possible performance, achieving production goals and employee safety.[10]

Maintenance is currently in its fourth generation and there are three maintenance concepts: corrective, preventive and predictive.

a) **Predictive:** Predictive maintenance is the planned and systematic action of inspecting, controlling and monitoring equipment following a maintenance plan. It is performed regularly for the purpose of reducing or preventing equipment failures. This frequency can be linked to time, productivity and mileage. Predictive maintenance predicts trends, behavioral patterns and links through statistical or machine learning models to predict failures and improve the decision-making process for intervention, mainly to avoid downtime.[11]

b) **Corrective:** Corrective maintenance according to NBR 5462 is maintenance carried out after a component has been damaged or broken so that it can be put back into service. It is considered the most expensive form of maintenance, as it takes more time and causes production losses. By these concepts, it is understood that corrective maintenance is what occurs after a functional failure has occurred, therefore this type of maintenance has the aggravating factors and complements already mentioned in the previous topic. Generating more costs, as in case of emergency it is necessary to purchase components;

c) **Preventative:** Preventive maintenance aims to prevent the equipment situation and find errors early, before they are harmful to the equipment and the production process. Preventive maintenance is maintenance that allows more precise control of the good performance of the relevant asset through a statistical analysis of the condition of the device. The objective of preventive maintenance is to prevent the occurrence of breakdowns by carrying out maintenance according to pre-planned criteria, such as time, hours of operation, productivity or a combination of these factors.[10]

Methodology

Introduction

This article aims to identify the productive inefficiency of the production line of the company AXXUS Motors, located in Contagem-Minas Gerais. Considering the losses in the automotive cylinder head production line, the need for a critical analysis was observed through hourly production records, with the aim of improving logistical assertiveness and minimizing production losses.

Variables

The variables that were evaluated in the production process consist of 4 main groups, these being: Maintenance, Tooling, Preparation and Production. These groups aim to identify the root cause of production losses, facilitating the recording in the production record, with its appropriate justification, assisting in decision-making to remedy the failure; these decisions are made using Pareto chart, 5W2H, PDCA and diagram by Ishikawa.

Sample

For the study carried out, data were collected from the hourly production record for the first quarter of 2023, (January, February and March) from the first shift of the company AXXUS Motors, these data were compiled in table 1. After analyzing Table 1, the persistent failures of the automotive cylinder head production line with the purpose of assisting in decision making using the following methods: 5W2H, PDCA and Ishikawa diagram.

Measuring instruments and techniques

The information collected for the development of procedures is a highly valuable tool in conducting research. It allows the organization and visualization of the steps necessary to prepare the work, assisting in the planning and execution of activities. In this way, Figure 1 becomes an important source of control and monitoring of the process, allowing a clear and objective view of the activities to be carried out.

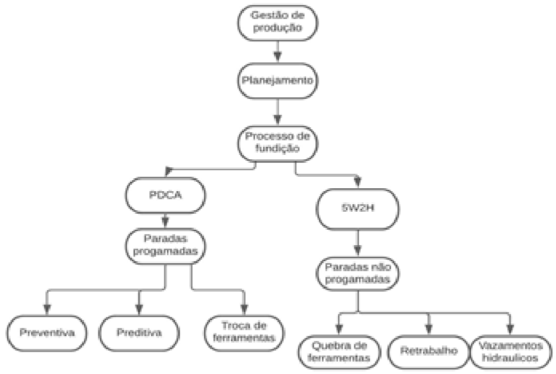


Figure 1 Project analytical structure.

Procedures

The entire procedure can be followed in Figure 1.

Working hypothesis

The proposed working hypothesis is that the implementation of a new production recording system will save time and allow for assigning the correct responsibility for stoppages, as well as clear and precise control of the data obtained, combined with an interface that offers clarity to the operator when opening the service order. This will result in a significant improvement in the reporting of information. It is believed that this improvement in data collection and recording will result in an increase in the efficiency and productivity of the operation, since the information is more accurate and will be available to support decision making.

Results

The results demonstrate that during the months of January, February and March, stoppages were recorded in the production line, divided by sectors: maintenance, tooling, preparation and production. This information is essential for a comprehensive analysis of the line's performance in that specific period. To facilitate this analysis, an updated verification sheet was created, in which the stops were categorized by codes. See ANNEX B.

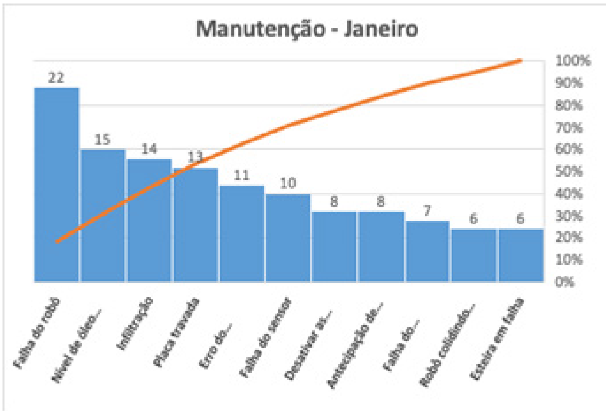
These stops can be attributed to different factors, such as maintenance activities, problems with tooling, preparation and the production process itself. To understand the extent of these interruptions, it is essential to analyze the stoppages that occurred in each sector and quantify the hours lost over this period. This analysis will allow you to identify critical areas that require attention and implement improvements to reduce downtime and increase productivity.

During the period analyzed, stoppages that occurred due to maintenance activities on the line were recorded. These stops may be related to preventive, predictive or corrective maintenance of equipment. The analysis of these stops together with the interruption hours will allow us to identify possible recurring problems and areas that require greater attention in terms of maintenance. Highlighting the following flaws as shown in Table 1.

These failures were the ones with the highest downtime rate in the first quarter (January, February and March), and through them the data presented in Graphs 1, 2 and 3 were collected.

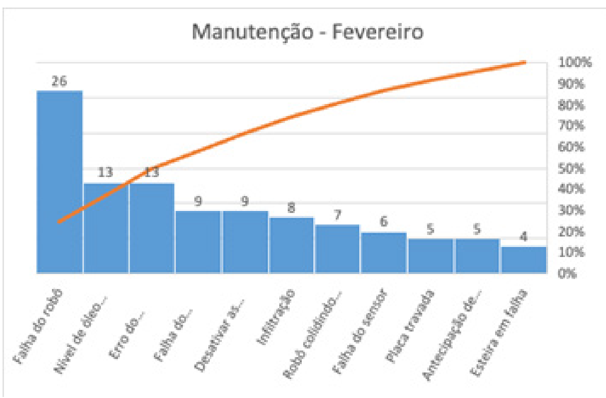
Table 1 Description of stops

	Description
	Robot failure
	Low hydraulic oil level
	Caliper device error
	Hydraulic device failure
	Infiltration
Maintenance	Deactivate the bombs
	Board locked
	Robot colliding with part
	Sensor failure
	Robot Seal Anticipation
	Failed treadmill



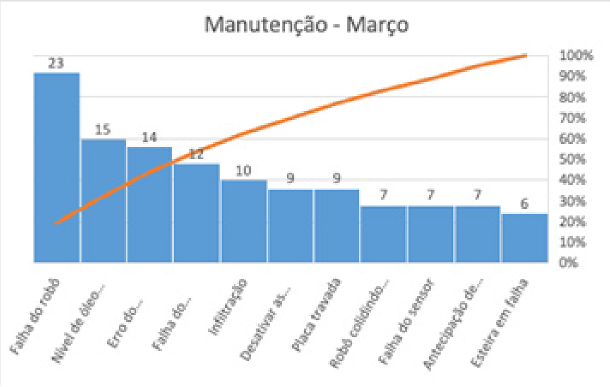
Graph 1 Maintenance stops.

Graph 1 represents the number of hours of maintenance downtime according to the failures presented in the production line in the month of January.



Graph 2 Maintenance stops.

Graph 2 shows the cumulative number of hours stopped due to maintenance in the month of February. Graph 2 shows the cumulative number of hours stopped due to maintenance in the month of February.

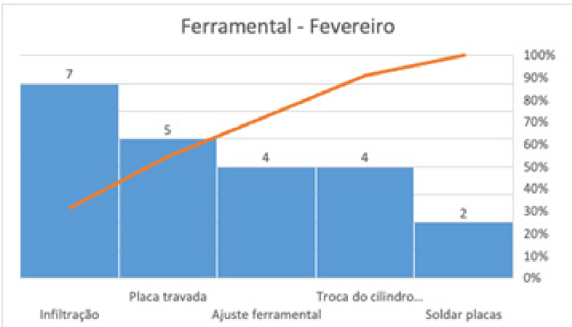


Graph 3 Maintenance stops.

Graph 3 shows the total number of hours stopped in March in decreasing order. During the same period, line stoppages related to the tooling sector used in production processes were recorded. Occurrences such as tool breakage, lack of suitable tools or the need for adjustments may have contributed to these stoppages. By analyzing this data and downtime, it will be possible to identify points for improvement in tooling management and avoid unnecessary interruptions.

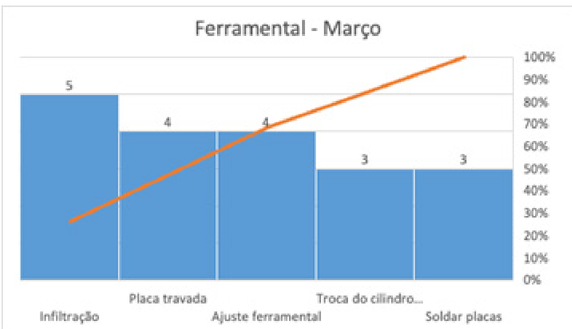
According to Table 2, the main causes of stoppages in the engine head production line are as follows.

Graph 5 shows the stop hours during the month of February.



Graph 5 Tooling stops

Graph 6 shows the hours generated by tooling intervention in the month of March.



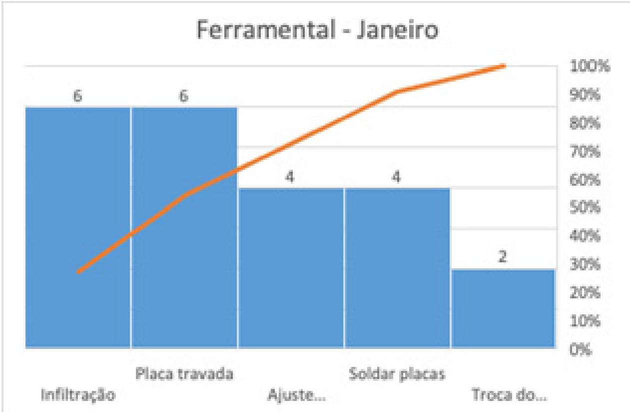
Graph 6 Tooling stops

During January, February and March, stoppages were recorded on the line due to preparation activities, such as tool changes, configuration adjustments and raw material changes. These stoppages can significantly impact productivity, as they consume valuable production time. Analysis of downtime related to preparation will help identify bottlenecks and find solutions to speed up this process. Table 3 describes the fundamental stops carried out by the preparation sector.

Table 2 Tooling stops

	Description
	Infiltration
	Board locked
Tooling	Tool adjustment
	Changing the tool cylinder
	Welding plates

The description of the stops makes it easier to collect data and count the downtime according to the note made by the employee on the production sheet. Graph 4 reports the number of hours stopped in January.

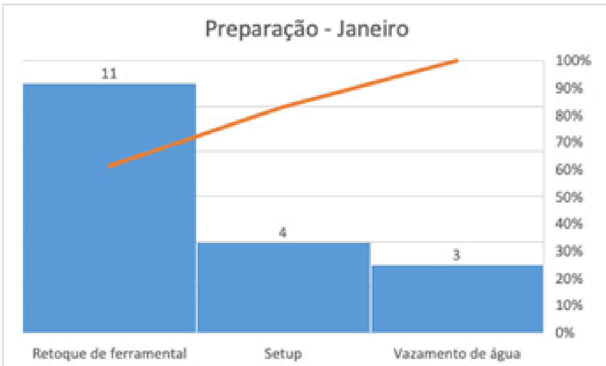


Graph 4 Tooling stops.

Table 3 Description of stops due to preparation

	Description
	Setup
Preparation	Water leak
	Tooling touch-up

Recording stoppages on the production sheet makes it easier to collect data and add them up to close the month, calculating the number of hours stopped by the preparation sector. Graphs 7, 8 and 9 show the number of hours stopped and the causes of the stoppage.



Graph 7 Preparation time analysis.

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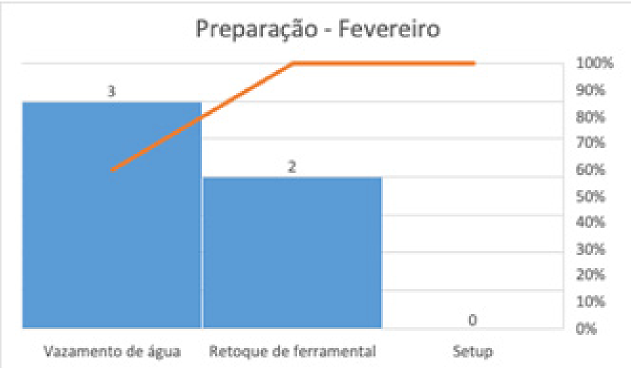
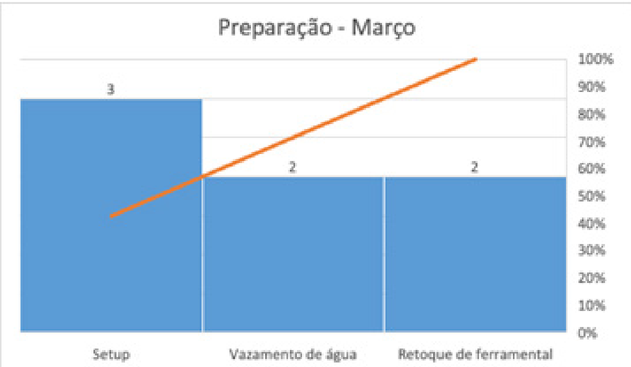
Graph 8 shows the downtime for preparing the production line.



Graph 8 Preparation time analysis.

Graph 9 displays the hours stopped for preparation of the production line.



Graph 9 Preparation time analysis.

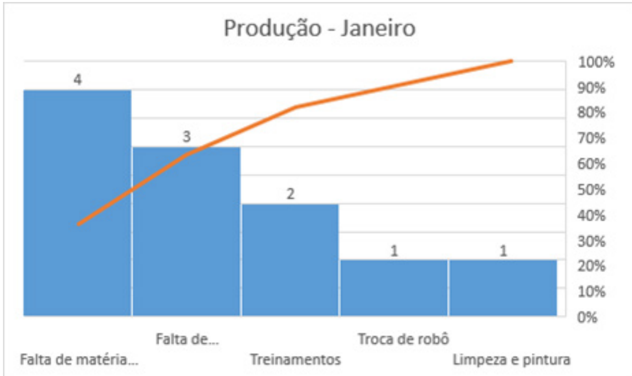
During the period mentioned, there were stoppages on the line directly related to the production process. These stops may be associated with problems such as equipment failures, lack of raw materials or operational errors. By analyzing downtime in this context, it is possible to identify the main causes of these interruptions and develop strategies to minimize them.

According to Table 4, the main factors that caused the production line to stop through production are listed.

Table 4 Description of production stops

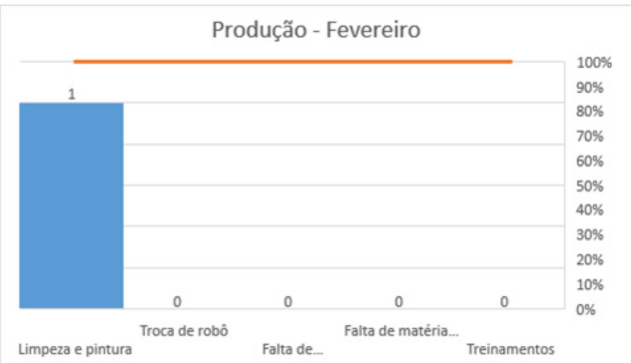
	Description
	Robot Swap
	Lack of supply
Production	Cleaning and painting
	Lack of raw material
	Trainings

In the month of January, Graph 10 identifies the sum of hours stopped by production on the production line to make adjustments and improvements in the process.



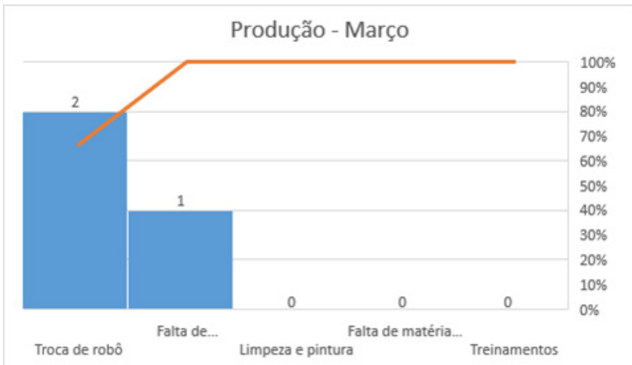
Graph 10 Production analysis.

In the month of February, Graph 11 shows that only one hour was spent changing robots, and no incidents were recorded regarding lack of supplies, cleaning and painting, lack of raw materials or training.



Graph 11 Production analysis.

Graph 12 for the month of March shows that 2 hours were spent changing robots, one hour waiting for supplies, and no incidents related to cleaning and painting, lack of raw materials or training were recorded.

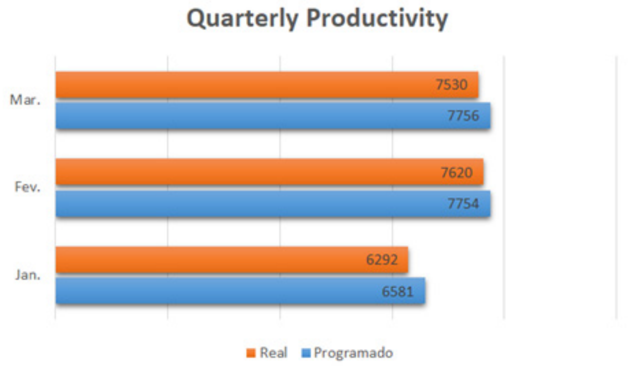


Graph 12 Production analysis.

After a detailed analysis of each sector, it is possible to conclude that there was a significant reduction in downtime when compared to the months of January, February and March of the year 2023. This reduction indicates progress in the efficiency of the production line, resulting in an increased global productivity. However, to ensure the sustainability of these results, it is important to continue monitoring stoppages and implement appropriate preventive and corrective actions to maintain optimized line performance.

Through the data collected in the first quarter check sheet, possible causes of non-compliance with the schedule to be produced are identified. It was possible to identify where the main causes were.

Graph 13 shows quarterly productivity for the months of January, February and March. The old verification sheet, annex A, was still used in the production process. Comparisons show that the line has a production deficit of almost 200 pieces per shift.

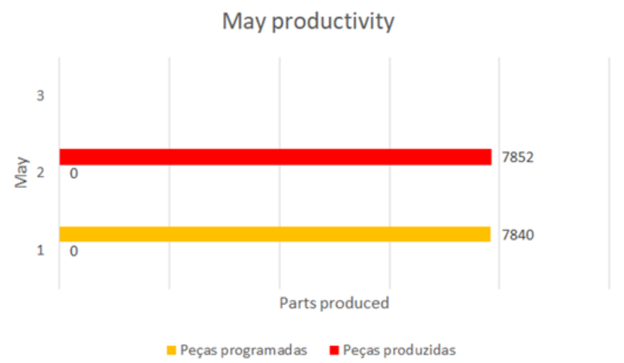


Graph 13 Quarterly productivity.

It was identified that it was necessary to make a modification to the production record sheet, due to it presenting a variety of errors in recording and recording production. Annex A brings the verification sheet used in the production line during the production shift.

Annex B brings the implementation of the new production record sheet and brought a series of benefits to the process. Among the improvements, the significant reduction in downtime, greater organization and precision in the information provided by operators and ease in analyzing the data obtained from the standardization of stops in codes can be highlighted. The check sheet can be associated with production analysis. In addition to the implementation of autonomous maintenance, where the employee himself makes small repairs during the process. Thus, reducing the downtime between the report and the arrival of the person responsible for maintaining the equipment.

The new production record sheet was implemented in May in the second shift, with the compilation of data it is possible to see a significant improvement in the number of productive parts according to Graph 14.



Graph 14 Monthly productivity in May.

Graph 14 shows the monthly productivity for the month of May. In it, the new check sheet is being used in the production process. Comparisons show that the lines have a surplus of 12 pieces beyond the expected schedule for the month.

During the mentioned period, it was evaluated that the downtime of the lines decreased with the implementation of autonomous maintenance and the simplified check sheet, Annex B. Thus contributing to a positive production balance during the implementation in the shift monitored for study.

A analysis did not take into account the quality of the pieces, and they were segregated to confirm their origin while this article was still being prepared. To confirm that the parts are compliant for the next stage of the process, more analysis time will be required.

Conclusions

The objectives of identifying unscheduled production stops in the automotive cylinder head line, identifying the sectors responsible for these stops and the time spent on interventions, improving the way stoppages are identified and developing specific indicators for each sector of cylinder head production were addressed. . The results obtained showed significant improvements in the production process. With the implementation of the new check sheet and the adoption of autonomous maintenance, it was possible to considerably reduce downtime on production lines. Furthermore, there was greater organization and precision in the information provided by operators, facilitating data analysis and standardization of stops in codes.

The comparative analysis demonstrated that the lines presented a surplus of 0.15% in relation to the expected schedule for the study period. This indicates an improvement in the efficiency and productivity of the process, in accordance with the proposed objectives. Since the new production recording system made it possible to save time, correctly assign responsibilities and precisely control the data obtained. The implementation of this system, combined with a clear interface for the operator when opening the work order, contributed to a significant improvement in the recording of information.

Authors such as Figueiredo, Schmidt and Rados (2018)[4] corroborated the development of this study by emphasizing the importance of constantly seeking improvements in the production process, aiming for efficient use, reduced losses and lower costs of manufactured products.

The contributions and relevance of this study are related to obtaining results through adequate training and the correct use of the check sheet. After implementation, new stop codes and methods were created to minimize the completion of the check sheet on non-critical items, allowing the operator to perform up to three maintenance tasks without the need to call the maintenance team.

In short, the application of the new verification sheet provided greater agility to operators, optimizing the filling process and eliminating ambiguities involved in the process. Overall, the implementation of the check sheet was effective and brought positive results to the production process. These improvements are expected to be maintained and improved over time, contributing to the efficiency and productivity of the automotive cylinder head production line.

Acknowledgements

None

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None

Conflicts of interest

The authors declare that they have no competing interests.

Attachments

Annex A Check Sheet

ACOMPANHAMENTO DE PRODUÇÃO	CLIENTE:		TURNO:__________DATA:______/______/______ LÍDER: ________________________			COLABORADOR :	VISTO GESTOR:
HORARIO	PROG	REAL	REFUGO	MOTIVO		INÍCIO	FIM
06:00 A 07:00							
7:00 A 8:00							
8:00 A 9:00							
09:00 A 10:00							
10:00 A 11:00							
11: 00 A 12:00							
12:00 A 13:00							
13:00 A 14:00							
14:00 A 15:00							

Annex B Updated check sheet

ACOMPANHAMENTO HORÁRIO DA PRODUÇÃO

NOME MÁQUINA/LINHA:

PRODUÇÃO PREVISTA:

DATA:	DESCRIÇÃO DO PRODUTO:	CÓDIGO DO PRODUTO:
OPERAÇÃO:		PROCESSO DE FIXAÇÃO:
OPERADOR:	REGISTRO:	ASSINATURA DO LÍDER:

1 TURNO

INTERVALO		PEÇAS BOAS		QUANTIDADE SEGREGADA			CÓDIGO PARADA	TEMPO PARADA	OBSERVAÇÕES
		LINHA	RETRABALHO	REFUGO INTERNO	REFUGO FORNECEDOR	RETRABALHO			
06:00	07:00								
07:00	08:00								
08:00	09:00								
09:00	10:00								
10:00	11:00								
11:00	12:00								
12:00	13:00								
13:00	14:00								
14:00	15:00								

QUANTIDADE SEGREGADA	
RETRABALHO	
REFUGO FORNECEDOR	
REFUGO INTERNO	
TOTAL DE PEÇAS	

OBS:

COD	[illegible]
34	Falha do dispositivo hidráulico
2	Antecipação de selo de robô
28	Reparo de vazamento de óleo
4	Nível de óleo hidráulico baixo
29	falha do robô
30	Erro do dispositivo da pinça
31	Desativar as bombas
5	Falha do sensor
6	Troca de cilindro
7	Esteira em falha
COD	FERRAMENTAL
2	Infiltração
3	Troca do cilindro de ferramental
10	Soldar placas
11	Ajuste ferramental
8	placa travada
COD	PREPARAÇÃO
32	Retoque de ferramental
33	Vazamento de água
15	Setup
16	Aguardando ajuste setup
12	Aguardando preparador
COD	PRODUÇÃO
21	Falta de abastecimento
18	Troca de robô
22	Falta de obra prima
13	Limpeza e pintura
19	Treinamentos
COD	PARADAS PROGRAMADAS
14	Refeição
20	banheiro
25	Limpeza geral
26	Iniciando comandos
COD	OUTROS
35	Falta de energia

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