APPLICATION OF QUALITY AND MAINTENANCE MANAGEMENT TOOLS IN THE SCR SYSTEM REPAIR TECHNIQUE IN DIESEL TRUCKS IN A WORKSHOP: CASE STUDY

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Abstract: In the search for the continuous improvement of the services provided by the companies, the proposed work aims to analyze the application of quality and maintenance management tools to improve a process of repairs of the selective catalytic reduction (SCR) system, which is responsible for the reduction of nitrogen oxide emissions generated by diesel engines, in a company in the field. The method used was the case study, starting with data collection and applying the failure modes and effects, from which an action plan was prepared. As a result, there were improvements in the quality of the diagnostic process and troubleshooting of the SCR system and obtaining a history of failure data to optimize services.

Keywords: Quality tools; SCR system; Continuous improvement; FMEA; Maintenance management.

APLICAÇÃO DE FERRAMENTAS DE GESTÃO DA QUALIDADE E MANUTENÇÃO NA TÉCNICA DE REPAROS DO SISTEMA SCR EM CAMINHÕES DIESEL EM UMA OFICINA: ESTUDO DE CASO

Resumo: Na busca do aprimoramento contínuo dos serviços prestados pelas empresas, o proposto trabalho tem como objetivo analisar a aplicação de ferramentas de gestão da qualidade e manutenção para melhoria de um processo de reparos do sistema de redução catalítica seletiva (SCR), que é o responsável pela redução das emissões do óxido de nitrogênio gerado por motores à diesel, em uma empresa do ramo. O método utilizado foi o estudo de caso, iniciando através da coleta de dados e aplicando os modos e efeitos de falha, a partir disso foi elaborado um plano de ação. Como resultado, verificou-se melhorias na qualidade do processo de diagnóstico e a resolução de problemas do sistema SCR e a obtenção de um histórico de dados de falhas para otimizar os serviços.

Palavras-chave: Ferramentas da qualidade; Sistema SCR; Melhoria contínua; FMEA; Gestão da manutenção.

1. INTRODUCTION

In the search for better positioning in the market and the increase in demand for the provision of services, companies are increasingly concerned with the internal organization of processes and the quality of the work offered, that is, the continuous improvement process [1].

With this, it is necessary to implement a quality management system, which has several options for organization and productivity tools. As with any other company, a mechanical workshop needs organization so that productivity is present in the environment, thus causing a better performance in the delivery of maintenance services results and greater satisfaction of both the customer and the employees. Otherwise, there will be internal and external problems [1].

The tools that make it possible to analyze the facts and make decisions are necessary to implement the quality management system, which leads to a high level of efficiency in the processes, and by standardizing the solutions put in place, it causes a great deal of framework for continuous improvement [2].

Because of the above, this case study aims to use and implement quality management and maintenance tools for the correction of recurring failures in the provision of the repair service of the SCR system of trucks in a mechanical workshop, located in Feira de Santana, in the state of Bahia.

The selective catalytic reduction (SCR) system is one of the main systems applied in diesel-powered vehicles, it aims to reduce the emission of nitrogen oxides (NOx) in the environment, spraying a solution composed of water and urea called a selective liquid reducing agent (ARLA) in vehicle exhaust [3].

In this way, this study will outline an action plan aimed at reducing the occurrence of these failures to obtain improvements in the quality of the diagnosis process and troubleshooting of the SCR system, record a standardized failure data history to optimize future maintenance on other trucks. and have more transparency with the customer, providing an understanding of the reasons for each intervention in the maintenance of your vehicle's SCR system.

Furthermore, the importance of identifying problems in the process of the SCR system repair technique is notorious. To assist this activity, it is necessary to apply quality and maintenance tools. After that, a description of the implementation of the improvements in the workshop is performed, together with the evaluation of the results obtained from their use, and in this way, the result of the standardization of the improvement processes is reached.

The SCR system (Selective Catalytic Reduction) is the system that provides a reduction in the emission of nitrogen oxides (NOx), one of the main pollutants generated by diesel engines. SCR is well known for being the best way to treat diesel engine exhaust gases, without compromising their performance. And vehicles manufactured from 2012 onwards, especially those powered by diesel, must have this system installed to comply with the emission limits recommended by Brazilian legislation [4-6]

The Automotive Liquid Reducing Agent, sold in Brazil under the name of ARLA 32, is one of the main components of the SCR system. This substance is composed of water and urea, with 32.5% urea. The substances present in ARLA 32 react with the gases resulting from the burning of diesel oil, and thus reduce the levels of NOx emitted by diesel engines [7].

The Air Pollution Control Program by Motor Vehicles (Proconve, in Portuguese) was created in 1986 by the National Environment Council (Conama, in Portuguese) and its main objective is to reduce the emission of pollutants from light and heavy motor vehicles. The implementation of the Proconve program (P7) in Brazilian legislation from 2012 onwards is intended to reduce the emission of pollutants from diesel combustion in motor vehicles, which are largely responsible for the release of nitrogen oxides and particulate materials into the atmosphere, considered the main pollutants harmful to the environment and human health. In this way, for a more organized service provision, a vehicle maintenance company is equipped with the SCR system [5,8].

All company employees must have knowledge and access to the quality tools that are part of the corporate culture. There are many quality tools, and the most basic of them allow data collection of a company's operational processes, with this purpose being the best management of the organization's resources. Among these tools, we can highlight the PDCA cycle, the Ishikawa diagram, and the action plan, also known as 5W2H, the FMEA, among others [1].

The management of maintenance processes is important to ensure the performance of operations. It can be performed through three managerial actions: control, planning, and improvement. Generating control, planning and quality improvement [9].

The process begins with the P phase of the PDCA, which consists of identifying the problem and analyzing the process and action plan. Phase D is acting following the action plan to block root causes. In step C, the confirmation of the real existence of the action plan is carried out to analyze whether the blockage was confirmed. In phase A, the definitive elimination of the causes is carried out so that the problem does not appear and the review of activities and planning for further work is carried out [10].

The process analysis has relation to cause and effect factors. The control method is to discover the causative factors that contain the fully functioning processes. In this way, quality, cost and productivity control are the results of the control carried out in the process [11].

The cause-effect diagram, also known as the Ishikawa diagram, or fishbone diagram, is a simple quality tool, but widely used. It is a device that makes it possible to identify and analyze the causes of process variation, as how these causes interact with each other. In addition, it is used to analyze organizational problems [12].

Another quality tool is the 5W2H, which works as a kind of checklist of important actions that will be carried out with certain prior planning. The acronym 5W2H comes from English, where the 5 Ws are: What (what will be done?), Why (why will it be done?), Who (Who will be responsible for the action?), Where (where will it be done?), When (when will it be done?), and the 2H: How (how will it be done?), How Much (how much will it cost?). So, this is the applied methodology based on the answers to the seven questions of the action plan [13].

The FMEA tool has the function of analyzing the incidence of failures in processes, activities or projects. The acronym derives from English, being: FMEA - Failure Mode and Effect Analysis - Analysis of Failure Modes and Effects. The method aims to identify and analyze products or processes, whether administrative and/or industrial, in which the objective is to measure the quantity, incidence and cause of possible failures, through a series of practical analyses, also to determine the impact on systems in general [14].

2. METHODOLOGY

Aiming in this research to analyze the application of quality management and maintenance tools to improve a process in a diesel truck workshop, an exploratory qualitative-quantitative approach will be adopted, using the case study as a technical procedure.

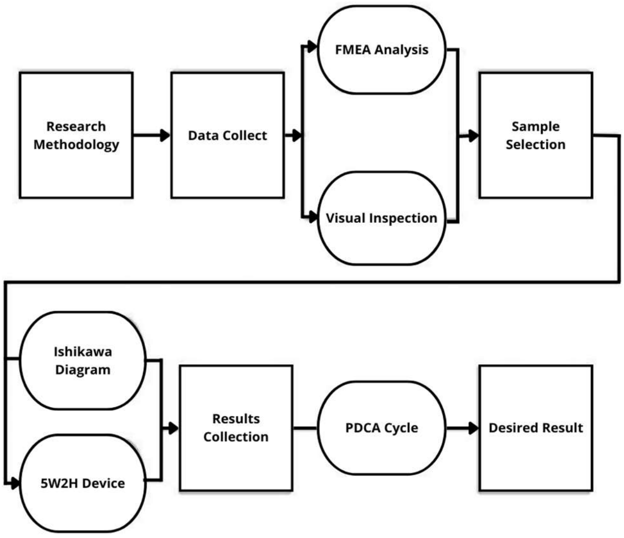
At the level of data collection for the case study, documents were created and filled out that can be analyzed during the truck workshop processes, thus resulting in the application of quality and maintenance tools. In the following topics, step-by-step data collection, sample selection, and results collection will be described. Data collections were made, first, through a visual inspection of the vehicle, certifying that no component (catalyst, air pump, air tank) is out of place or unused. In addition, the diagnostic device will be used to detect SCR system failures, through their analysis the service will be performed.

The failures were parameterized in a spreadsheet and the FMEA analysis of the case was built based on their incidence, severity and ease of detection. This way facilitates future solutions to similar problems in the SCR system.

As for the execution of the maintenance action, the 5W2H tools and the Ishikawa diagram were used. Based on the previous FMEA failure analysis, the creation of the maintenance plan was supported through the responses of the 5W2H device, and the thorough analysis through the Ishikawa diagram. As a result, visualization was easier, as it simplified the understanding of the actions to be taken.

Based on the collection of the results obtained in the previous phase, it is of paramount importance for the completion of the service, to use the PDCA cycle, to make an overview of the services performed, standardize them, in addition to correcting possible errors, so that they do not reappear in the future, harming the SCR system and, consequently, the other systems of the vehicle. Figure 1 presents a flowchart that summarizes the methodology that will be developed in the work.

Figure 1. Diagram of Methodology



3. RESULTS AND DISCUSSION

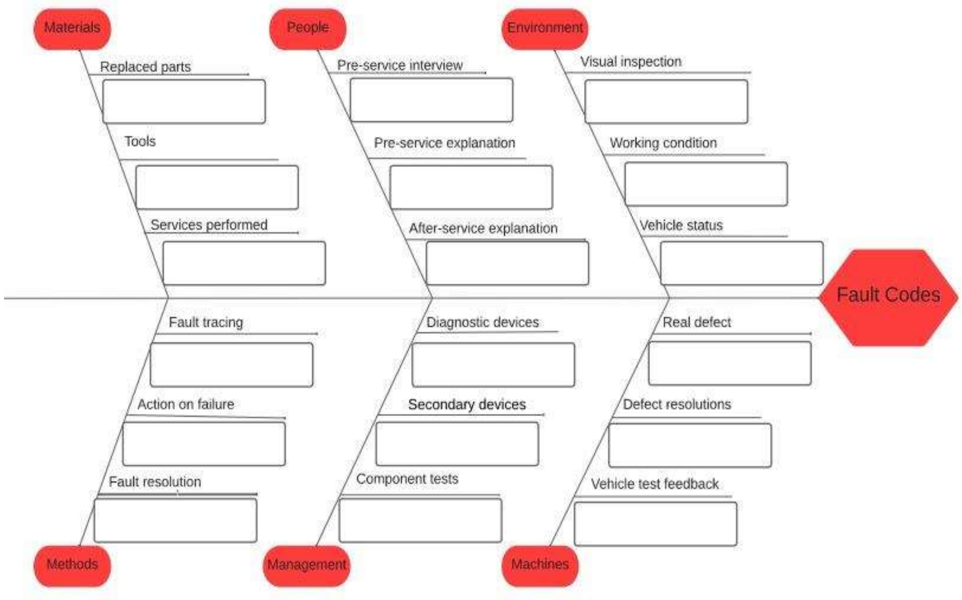
Data collection and sample selection were carried out through visual inspections, monitoring, and the use of diagnostic equipment in the maintenance of trucks in the workshop. From the data obtained, an FMEA was prepared (Chart 1), based on the main failures observed during the process, so that the tool can help the next services with their analysis of failures, detailing the severity, incidence, and ease detection.

Chart 1. FMEA SCR System

Component	**Function**	**Failure**	**Effect**	**Failure occurrence (O)**	**Failure severity (S)**	**Failure detection (D)**	**O x S x D**	**Corrective Action**
SCR Pump	Generate necessary pressure for the hydraulic system	Dirt hydraulic system	Pressure loss in hydraulic system	9	6	2	108	General system cleaning
		Electric Motor Defect	Fully depressurized system	5	10	3	150	Electric motor replacement
SCR Module	Control the electronic and hydraulic system	Module without power supply	Totally inoperative system	7	10	5	350	Checking and repairing module electrical wiring
		Hardware defective module		5	10	6	300	SCR Module Replacement
SCR Injector	Inject ARLA into the exhaust system	Injector without power supply	ARLA injection loss	6	7	5	210	Checking and repairing module electrical wiring
		Clogged or burnt injector		5	7	4	140	Injector Replacement
Electrical Wiring	Interconnect the components	Broken or semi-broken wire	Loss of communication	7	4	6	168	Checking and repairing electrical wiring
			Power loss	8	4	5	160	
Filters	Keep the system clean	Dirt hydraulic system	Pressure loss in the system hydraulic	9	5	2	90	Replacement of Filters
ARLA tank	Store the fluid			9	5	2	90	General tank cleaning
NOX Sensor	Inform the module essential parameters	Internal electric short	System does not work due to lack of essential information	6	6	6	216	NOX Sensor Replacement
Temperature sensor				7	7	6	294	Temperature Sensor Replacement
Fluid Level Sensor				5	4	6	120	Fluid Level Sensor Replacement
Fluid Pressure Sensor				3	3	5	45	General system cleaning
Ceramic Catalyst	Reduction of polluting substances	Catalytic Inefficiency	Exhaust system clogging	5	10	4	200	Catalyst Replacement
Catalyst Steel Structure		Hole in the external structure	Exhaust system smoke leak	4	10	3	120	

In view of this, it was realized the need to implement an identification and diagnosis document, which uses the Ishikawa Diagram tool (Fig. 2) which in its structure at the center has the fault code of the SCR system and in its subdivisions are composed of: "materials" where it is demonstrated which tools will be used, which parts will be replaced and which services will be performed, "people" records about the problem reported by the customer, also about the explanation of the procedure to be performed and finally about how the resolution service was performed, "environment" discusses the visual inspection of the vehicle, its working condition and its current situation, "method" records the action of how the failure was discovered, in addition to which methods were carried out to remedy the fault, and what is the actual resolution of it, “management” explains which diagnostic devices will be used, which secondary equipment and the tests that are performed on the components of the vehicle's SCR system, finally “machine” demonstrates the real vehicle defect, its real resolution and the feedback from the final test.

Figure 2. SCR Ishikawa diagram



The 5W2H Action Plan determines what type of service will be performed, what are the main reasons for performing the service, who will perform it, where in the company the vehicle will be located, the forecast of the duration of maintenance, how the maintenance will be carried out and finally the total budget, thus generating better transparency in the process for the customer, thus generating a better organization in the provision of the company's services.

Finally, after collecting the results obtained in the previous phases, finalizing and assisting the employee in the provision of services, it was observed the need to create a PDCA cycle (Chart 2). In this way, the tool will help the user to verify how the service was planned, as well as how it was carried out, in addition to the final check of the service and, finally, the overview of the cycle for the release of the vehicle and completion of the services.

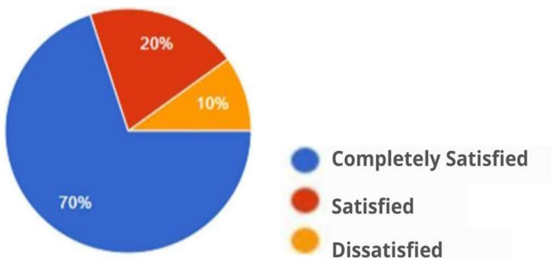
Chart 2. SCR PDCA Cycle

PLAN	Planning of actions to be taken, (Pre-service)
DO	Service in the act of execution
CHECK	Final check of the service performed
ACT	Overview of the cycle

After the application of quality tools in the company, the detection rate of real vehicle problems in the SCR system decreased by half, and the previous average of two days of service was reduced to one day, this demonstrates that with the use of the reports from previous services, the resolution of present defects has become simpler, because many failures have a high occurrence in certain vehicles, in addition, the quality tools for using tables and figures make the visualization simpler and more intuitive, this way that makes problem-solving much easier.

Through a customer satisfaction survey, results have been obtained that show that the implementation of quality tools was positive. As shown in Graph 1, around 70% of respondents were completely satisfied with the maintenance process, from service to after-service. However, 20% were satisfied and 10% showed dissatisfaction, this percentage was due to divergences in the matter of total service time, where even though they were faster than usual, customers wanted even greater agility, which did not happen so that they did not compromise the quality of services.

Graph 1. Customer survey



4. CONCLUSION

Due to the aforementioned facts, the quality tools chosen to assist in the process of organizing the truck mechanic shop standardized the actions in the face of problems, providing precision in the execution of activities by the employees.
Taking these aspects into account, it became possible to briefly solve the problems presented by the company related to the SCR system. Through reports of services already performed, it became possible to optimize time for a new analysis of the problems. Since it is common for similar trucks to arrive with the same faults, only the brand and model vary.

In this way, after the implementation of quality tools in the work routine, the satisfaction of employees in the execution of activities, and the satisfaction of customers in having their problems solved briefly and satisfactorily became notorious. To obtain customer feedback about this, a satisfaction survey was created where the customer was required to inform the make/model/year of the vehicle and answer some simple questions and leave suggestions for the next service

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