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Project of Automation and Cost Reduction at Spark Plugs Pressing System

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Abstract. This study deals with the gain in quality and cost reduction in the pressing of the spark plug wires from the need to ensure a standard, eliminate quality defects such as poor contact of the cables generating low power failures and unexpected problems. The objective was to study the best practices in the automotive industry, showing potential gains from the analysis of split costs by reducing the time of labor and applying the results on the production line. To understand this work some key points were studied such as: the system World Class Manufacturing (WCM), quality tools like PDCA cycle and Kaizen. These were applied in the pressing process of the spark plug wires, highlighting their advantages and disadvantages. The results show the implementation of automation press the spark plug wires in a positive manner towards the operation performed by the operator. Automation has been accepted and is planning to run the company in 2014. Referring to the layout of the production area there was a reduction in the cycle time of the post. In addition to that, it was observed the shortening of the cycle operator, with consequent reduction of costs and improvement in operator ergonomic point was observed.

Keywords. MTM, Quality, Continous Improvement

Introduction

The interest in having greater caution regarding quality emerged after World War II - the time when countries participated in the war were in urgent need of goods and the Japaneses were the first to be concerned with the quality of their production as they tried so hard to get back to market [1].

After a period of adaptation to the quality management systems and internalization of the concept, modern companies have given increasing emphasis to the role of quality in its products and services. This is because of globalization increasingly influence the daily lives of companies as well as customers, causing them to become increasingly demanding [2].

Always seeking to reduce costs, quality and time, the Alpha Company (fictittious name) and several other companies in the manufacturing and assembly industry, have adopted the World Class Manufacturing (WCM) as the main purpose and an everyday life concept. The World Class Manufacturing is a production system to enhance production standards and eliminate losses. Its principles are applied to all aspects of a plant, the quality maintenance system in a continuous improvement perspective [3].

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The problem did not occur at a specific time, but throughout the work shift with any operator and spark plug wires, and could possibly be linked to operator fatigue in the post by the high physical exertion.

Based on these principles, spark plug wires were identified at Alpha Company that there was no standard for fixing them in the engine, varying with the strength that each employee performed the impact with the hammer.

Current spark cables at the engine production line has been studied in order to solve a rework point of bad compressing the spark plug wires, requiring therefore more efficient and safe system to ensure the final quality of the product. It has been found no logical correlation with the spark plug wire, since the operation is done hundred percent manually making it difficult (nearly impossible) for the operator to follow the same level of force application and the contact point between the hammer and spark plug wire.

In order to correct the differences and to achieve continuous improvement as well as in product quality improvement at the press the job of the Alpha Company, this operation required a more efficient and reliable system that could guarantee the quality of the final product.

In this work is possible to find only the problems encountered due to poor pressing of spark plug wires in the engine related to labor and not the problems related to other parts of supply chain components, considering just two starting points: the quality problem of dealings and the other reducing the station cycle time for implementation of new activities in the workplace.

This paper considers the lean manufacturing concepts to assist in carrying out the activity and implementation of the equipment to be used. The used equipments in manufacture devices processes were produced by people trained at the company. This means that all device costs as well as quality level are Alpha's responsibility.

1. Literature review

The literature related to the Competitiveness & Production Control and Quality Level & Continous Improvement are reviewed and discussed at this space.

1.1. Competitiveness & Control

The current situation of competition between companies in various industry sectors makes them seek increasingly competitive advantages such as cost reduction and employee training. These advantages are achieved by using strategies, lean manufacturing tools, being all of them focusing on the product, quality, cost and efficiency [4]. The competitiveness is regarded increasingly as the key to success or failure of an organization at the market environment. It is the struggle for a wider area of operation which requires companies to adopt certain standardization of attitudes [5]. Quality is more than one factor that determines the survival of the organization [6]. Quality today is an investment. To shape up each organization is a must to management standards focusing at customer satisfaction. It is a top condition for the company to keep itself alive in the market. Therefore it is important to know and measure the performance of services to the customer or the delivered product [7]. It is possible to go further and state that manage the quality not only inserts the companies in the market competitively, but also provides a greater option of choice in terms of strategy. When

high quality standards are achieved, it creates a capability that is not only differentiated. It also raises a strategy to lead while maintaining low cost. Contrary to what many entrepreneurs and laypeople think it is stated [8] that quality and low cost can be attributes to the same product without the need to opt for one of these objectives and leave the other in the background. Based on a case study [9] conducted in a large assembly plant, to improve the quality indices of a company is possible when there are changes in the culture of the company and its employees. Everyone must accept the idea that each employee plays a key role in improving certain process. For the authors, trained and skilled individuals are key to leverage innovations and, in addition, the changes made focusing on innovation standardize the quality, making possible the implementation of a global production system. This makes the company more competitive and enter further into the competition for greater market share. Some of the aspects where you can see the influence of Total Quality Control in production are [5] more and more products free of defects, deliveries performed safely and quickly, and the company's focus setting on continuous improvement and in customer satisfaction.

Total quality is a concept that somehow affect the satisfaction and needs of consumers [10]. Encompasses several areas, among which we can mention: quality, cost, delivery, moral values and security. So when one wants to have total quality within an organization, one needs to first assess the prerequisites, and then be able to have a clear vision of the goal can be achieved or not. A proposed quality management model [11], must contain a step to form work teams with active participation of employees to meet the expectations placed by the customer.

It is emphasized that the overall quality is not a program but a process [12]. A program assumes a beginning and an end, while a process is continuous, not delimited by spaces of time.

1.2. Quality Level & Continous Improvement

Some companies, especially in the automotive sector adopt some tools such as automation, quality tools, lean manufacturing, World Class Manufacturing, Toyota Production System, and others to achieve higher quality, greater efficiency, lower costs and continuous improvement to their factories. Therefore it is relevant to focus the main fundamentals and tools that can be used for a better production result.

It is necessary to compare the concept of quality to humanity itself [13], in the sense that both arose simultaneously. Since the beginning of the first pieces, good or bad, and the word "quality" has become part of the vocabulary of the people. Quality is a subjective term, without a universally accepted definition. The quality occurs when [10] a product or service meets to perfection and reliable, safe and accessible, customer needs. Another important factor in this concept is delivery of the product to the customer.

Based on the reliability of the product/process the quality shall meet the needs of consumers, with the quality or perceived quality, when a preference for a particular product is evident [10]. This preference most often are attracted by the low cost or due to the fact the expectation of consumption have been supplied on a large scale.

With very similar vision it is inserted the need to monitor the sectors that are part of the industry, and making up the product and services related to marketing, engineering, production and maintenance [14]. It can be said that the appropriate quality is also the concept that Taguchi measured because he focus experiments

projects in order to increase profit and product quality, but noted not only the comfort that quality provides, but also the costs it can bring to society as a whole.

Taguchi also concerned himself with the realization of the specifications, for without them there are risks both losses as dissatisfaction [15].

Working groups [16] are the most essential element in the process of continuous improvement. Training, team building and improvements in the workplace are important elements to build an environment in which employees can grow, gain training and contribute to increased quality in the company.

1.3. Tools

KAIZEN: The history of Kaizen [17] starts the Toyota Production System, and states that is considered a key element in the Japanese management system as a principle of lean manufacturing. The thought began on the factory floor of Toyota Motor Corporation, due to scarcity of resources and market competition. Work was carried out to eliminate waste, developing tools such as just in time, kanban and poka-yokes. The concept was restricted to Toyota, until they realize that the problem was global, and Toyota was a big step forward to the other in a matter of management issues, and everyone should follow the way improvements were made. Kaizen is a set of activities in the factory, with the intention of improving the environment and operations. It is always solid, always looking for improvements to quality and efficiency. Its usage is so implicit that workers often act following the philosophy without realizing it. Kaizen is the continuous improvement process applied to reduce costs during manufacturing in the life cycle of a product.

PDCA:

The PDCA method (Plan, Do, Check, Act) [13], also known as "Deming Cycle" is one of the management qualities that allows the control of processes in order to make companies realize that there are no starting point nor an end in an activity, but rather a cycle to occur a continuous improvement process. PDCA cycle [18] is the troubleshooting that EW Deming developed to prepare the "Wheel Deming" with a cycle consisting of four steps: Plan (P), Do (D) Check (C) and Act Correctively (A). Also the PDCA cycle [19] is a tool that aims to maintain and improve the process and each phase of its application are used various tools of literature, with many different purposes and different nomenclatures.

At stage PLAN the company's goal is set and the action plans are defined in order to meet the goals. Please observe the problem to be solved, analyze the phenomenon and discover the causes of the problem. At the stage DO people receive proper training and following the action plans are implemented and the collected data to provide information on obtaining the goal. The CHECK stage is carried out an evaluation of the data collected in the previous phase. The last step ACTION depends on the results obtained in the examination, that is, the more information (facts, data and knowledge) are available, the greater the chances of achieving the desired goals. If the goal has been achieved, it is necessary to establish some means of communication of the obtained results. If not, it starts a new PDCA cycle in order to find other ways to get the expected results.

As an example, please take a look at Figure 1 of PDCA cycle.

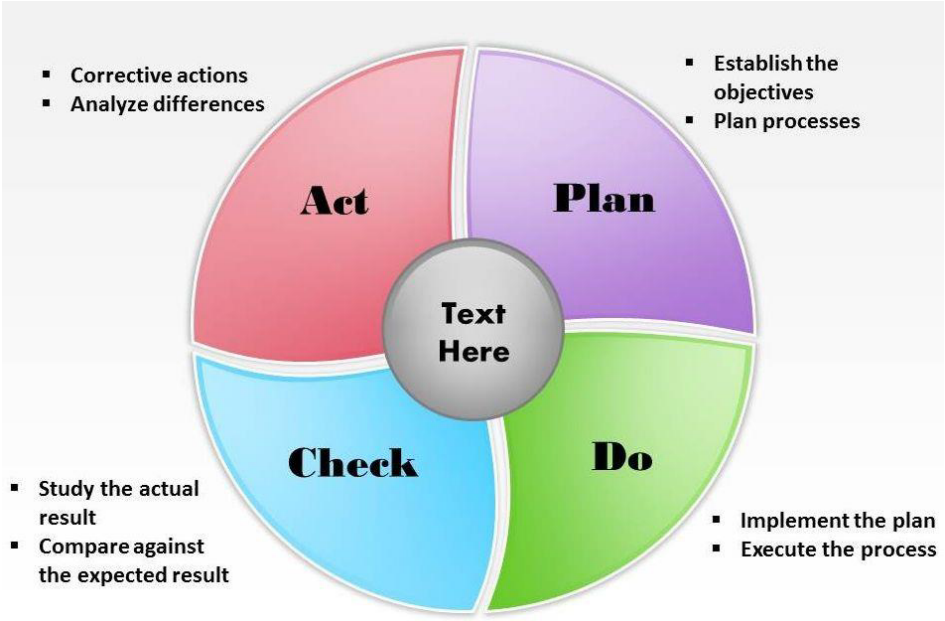

Figure 1. PDCA cycle.

WCM - World Class Manufacturing:

World Class Manufacturing is a set of techniques, concepts and principles for managing operational processes of a company [20]. The WCM model is the result of several activities used in the Japanese manufacturing industry after World War II. After an adaptation to Western context was first introduced in 1982 for several American companies [21]. This model is based on the TPS (Toyota Production System), Toyota production model, which originated through a different philosophy based on Henry Ford and Taylor assembly sequence, where its basic idea is to "do more with less" by eliminating losses and waste [20]. WCM is, in short, the pursuit of excellence by applying the methodologies and tools based on lean manufacturing, which is based on TPS [21]. This new paradigm is based on the analysis of practices implemented by Japanese, American and German companies, which had an outstanding performance at their industries [22] [21] [23].

With the evolution of this model, it allows the application of Just in time methods, Quality Control and Total Productive Maintenance which respectively are: every component that reaches the assembly line at the precise moment it is needed and only the quantity needed for assembly; methods and controls used to achieve the highest quality aimed at Zero Defect and maintenance as center of attention of the productive processes to aim at breaking Zero machines and avoiding unplanned production stops [20]. The main objective of the WCM is to always seek the continuous and rapid improvement in cost, quality, time of production and customer service, always running with all indicators seeking continuous improvement [3].

ISHIKAWA Diagram:

Founded in Tokyo in 1943 by Kaoru Ishikawa, diagram or fishbone chart as it is also known, it is a common technique used in the analysis of production processes with the main objective to identify the most influential factors causing an effect [12]. The

initiation of the process [24] is the best time to use the diagram, so that effects of any kind are identified.

An example of the chart may be found at Figure 2.

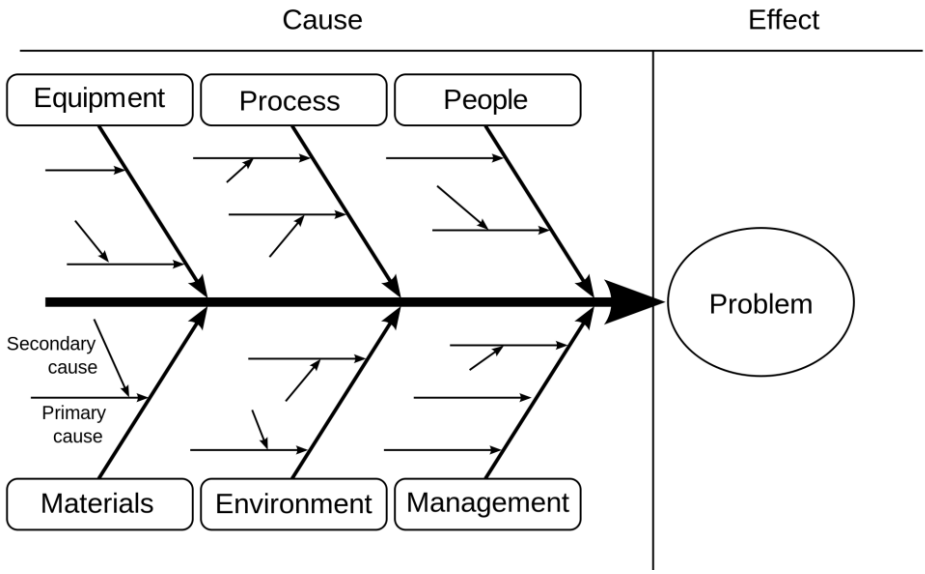

Figure 2. Cause-effect diagram.

2. Methodology

The technics and methods used for this work are mentioned as follows. The study was developed by observing some employees at working station and analyzing the results.

2.1. The Alpha Company Briefing

After two years of investments in technological interventions, Alpha Company launched in 2010 its production unit of medium engines in Latin America. Designed with the concept of lean production, it is a different plant, covering aspects such as ecology, quality, high-level professional staff, management, products and processes - with high automation index and high technology incorporated. The factory has four machining lines: block, crankshaft, connecting rod and head, and a total of 54 machines. One of its main advantages is the automation in the supply of machined the assembly line via gantries (supply by air). The technology allows, for example, the unit to operate without forklifts for supplying materials in the production process. The plant, located in the Metropolitan Region of Curitiba (Paraná – BR), is responsible for the manufacture of propellants family 1.6l 16v and 1.8l 16v, flex and gasoline. This production began in February 2010 with an initial capacity of 330,000 engines per year. The opening took place on the outcome of the acquisition of the former supplier of engines for vehicles such as the Gamma and Beta - the company under study in March 2008. Since then, the multinational made investments nearly to $ 95 million to make the plant even more modern and achieve a level of excellence in products and processes.

With the new plant, the company has increased its installed capacity in Mercosur at around 20%, reaching a production potential of 2.5 million propulsion systems per year. "Before the acquisition, the production of this plant was dedicated exclusively to export, which attests to the global character. Today, the company is ready to meet in addition to the Brazilian and South American market, the five continents within and outside the Group, which is a big step in the company's strategy "- said the Superintendent.

The assembly lines also have ultimate control equipment, to measurement and rating of 100% of machined parts, and model machines in Autonomous and Professional Maintenance, prepared with the most modern concepts of maintenance, aimed at breaking zero index. The excellence of machined parts is also ensured by a sequence of controls capable of ensuring compliance with the quality checks. The three assembly lines, comprising the pre assembling head, the main line and the finishing of the engine equipped with robots sub assembly bushings and 77 devices - 17 stations tests, 12 automatic stations 17 semiautomatic stations and 31 manual stations. These machines are capable of making cold tests with timing simulations, load and vibration, and sealing tests on 100% of the engines.

2.2. The Scenario

The case study for the application of the concepts mentioned [25], was the analysis of a job that allowed the fitting of parts outside the standard and the opportunity to improve its automation system, and the pressing of the spark plug wires. There was a possibility of non-standard parts assembly, inspection found the final assembly. The pressing force was applied according to the employee's strength, with variation depending on the physical fatigue, inattention, bad adjusted point of contact, among others. With this kind problem of risk was added a checkpoint operation generating a cost of approximately $ 3,400 year for the inspection of the quality of the final product, thus ensuring the quality of the final product.

In this case a physical force is required since the employee who operated had to hammer the spark plug wire by applying a force, and carried out this activity for an hour a day, for a total of 320 cycles per hour. The working station was already saturated by activities and the new engine entry, new components needed to be installed, requiring the desaturated station to receive the new product. The only activity that could be moved to another working station was spark plug pressing that allowed full automation of activity, reaching the zero defect in quality, zero ergonomics problems and the ability to get more parts for assembly on the job.

2.3. The Problem

The problem occurred during any shift and not at a specific time, being found in the final inspection. The inspection was done in one hundred percent of the parts through control but without any prior verification of control as error-proofing. The occurrence independently stemmed from the operator or at random shift, which can be linked to operator fatigue in the station as it requires a high physical exertion.

In Figure 3 you can see the problem with your defect and the reason for the same is generated, coming to the conclusion that the concept of the tool does not guarantee the strength, being totally dependent on the operator.

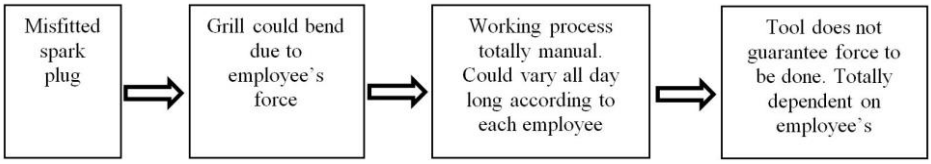

Figure 3. Problem analysis.

The operation is one hundred percent manual, making it difficult for the operator to follow the same level of application force and point of contact between the hammer and the spark plug wire.

By analyzing the problem in order to examine the failure mode and its possible causes, it was concluded that there was no standard for fixing the spark plug wires at the engine, as it varied with the strength each employee when performing the impact with the hammer.

Figure 4 shows the fitted and not fitted spark plugs after operation.

Figure 4. Spark plug fitted (left) and not fitted (right) according to method.

Source: Authors based on ALPHA Company.

It was added a checkpoint operation generating a cost of nearly $ 3,400 per year, for quality inspection.

By analyzing the problem in order to examine the failure mode and possible causes of it, concluding that there was no standard for fixing the spark plug wires at the engine, as it varied with the strength each employee when performing the impact with the hammer.

As there was no check point like error-proofing and the problem did not occur at a specific time, but throughout the work shift with all operators and spark plug wires , it was detected that it was linked to operator fatigue the high physical exertion , since the operation is done a hundred percent manual and difficult for the operator to follow the same level of force application and point of contact between the hammer and the spark plug wire.

Figure 5 shows the ergonomic effort during operation.

Figure 5. Ergonomic effort required by task.

Source: Authors based on ALPHA Company.

During 6 months of follow up there was found a series of misfitting spark plug wires results: 8; 3; 5; 5; 6 and 17 each corresponding month.

3. Implementation

The main purpose of this section is to inform how system was changed and improved from analysis to result.

3.1. Trouble Shooting

In order to solve this problem, it was applied the methodology of PDCA cycle and Kaizen getting results step by step until the full completion of the system itself, by using the specific form of the company in which the work was applied.

After analysis, it was carried out the design for process automation. For this, it was used a load dynamometer to determine the strength of pressing each spark plug wire, coming to the following results (average numbers):

Wire 1: 28.4 kgf/pressing Wire 2: 27.8 kgf/pressing

Wire 3: 26.8 kgf/pressing Wire 4: 29.3 kgf/pressing

To ensure that non-conforming parts could be produced by pressure drop in the compressed air network, was placed a pressure switch, as shown in Figure 6 to control the minimum and maximum pressure. If it is outside the specified limit, it will be presented a failure and the operation redone.

Figure 6. Pressure switch system.

Source: Authors based on ALPHA Company.

After this analysis, it was applied the methodologies of PDCA and Kaizen cycle up to step by step until its full completion, using the specific form of the company in which the work was applied and as a result, the project was carried out for process automation (Figure 7) and used a load dynamometer to determine the strength of pressing each spark plug wire.

Figure 7. Spark plug pressing device (left: off; right: on).

Source: Authors based on ALPHA Company.

4. Results and observations

The device is designed to have a quick construction, easy installation and low cost, with a view to autonomous maintenance. The device design has been thoroughly analyzed, reaching the improvement in pressing the cables, as was done manually by operators. With these assumptions, the company increased the quality of their product. According to the main idea, the spark plug wire pressing device was implemented without any restriction.

With the design of the automated spark plug wire pressing device it was possible to reduce the work station cycle time of 3.88 seconds total time ranging from 35.08 seconds to 31.2 after system modification (based on MTM - Methods Time Measurement). With the reduction in the post cycle time and the redistribution of activities, it was also obtained a better performance of employees.

With the implementation of spark plug wire pressing device there was a rearrengement in the layout of the line. With this change of layout it was possible to realize a gain of space in the line and a reduction of the activity that was previously performed to verify that the cables were pressed, i.e., the device now ensures hundred percent of pressing the cable, obtaining potential gain $ 3,400 per year.

It also had a gain in developing ergonomics, as from now on there is no longer required manual work where the operator hammered the spark plug wires.

Due to fatigue and change in employee strength, satisfactory quality could not be achieved, however, with this work, the operation guaranteed accuracy and constant force in all cables simultaneously presenting no risk any cables leave without being pressed correctly.

During the following months after implementation of the new device the system presented 2 defects in the first month, 2 in the second and ZERO during the whole period of eight months.

5. Considerations

By means of using the PDCA tool and KAIZEN methodology, it was possible to reach the expected result set at the beginning of the work, based on assumptions as quality and improvement of the working station. At the beginning of this work was possible to observe a fully manual station without standard for activity, with non-pattern pressing forces and point of contact, variables for each employee and by this study development, a desaturation of the job to get a new product from a new project.

With the modification of the process and the new method of pressing the spark plug wires, it was possible to eliminate defects and rework quality, obtaining a benefit of nearly $ 6,500 (six thousand five hundred dollars).

Finally it is possible to say that the main objectives have been achieved - to ensure the pressing of the spark plug wires to reach zero defects, reduced rework costs and engine maintenance of a fixing pattern for one hundred percent of the motors with increased quality and productivity of the production line and the desaturation of the working station for new operations.

References

[1] A. Barbosa, *Pesquisa qualitativa em estudos organizacionais*, Saraiva, São Paulo, 2006.
[2] J. M. Juran, F.M. Gryna, *Controle de Qualidade*, MAKRON BOOKS, São Paulo, 1991.
[3] S. Hino, *O pensamento Toyota: princípios de gestão para um crescimento duradouro*, Bookman, Porto Alegre, 2009.
[4] L.F.C. Basso, W.T. Nakamura, U.K. Shimizu, Produção enxuta e desempenho de mercado: uma análise para o setor de máquinas e implementos agrícolas no Brasil, *Simpósio de Administração da produção, logística e operações internacionais*, IX, 2006. São Paulo. Anais. FGV-EAESP, 2006.
[5] A. Coltro, *Gestão da qualidade total e suas influências na competitividade empresarial*, Pioneira, São Paulo, 1996.
[6] J.C. Paixão, C. Cardoso, M.A. Lourenço, Algumas reflexões sobre a qualidade em serviços de documentação, informação e arquivo, *Revista do Tribunal de Contas*, n. 44 Agosto, 2005, pp. 631- 707.
[7] J.A. Belohav, *Quality, Strategy and Competitiveness*, Management Review, California, 1993.
[8] W. Skinner, *The productivity paradox*, Harvard Business Review, 1986.
[9] E.K. Koga, W.B. Oliveira, Evolução do trabalho em grupo como fermenta de inovação nos processos produtivos, *Simpósio de administração da produção, logística e operações internacionais, IX*, 2006. Anais. FGV-EAESP, 2006.
[10] V. F. Campos, *Qualidade total: padronização de empresas*, Fundação Christiano Ottoni, Belo Horizonte, 1992.
[11] J.S. Oakland, *Gerenciamento da Qualidade Total – TQM*, Nobel, São Paulo, 1994.
[12] A. L. Las Casas, *Qualidade total em serviços*, 2ª ed, Atlas, São Paulo, 1997.
[13] W. Shewhart, *Economic Control of Quality of Manufactured Product*, ASQ, 1988.
[14] A.V. Feigenbaum, *Total Quality Control*, 3rd ed, McGraw-Hill, New York, 1983.
[15] N.J. Aquilano, R.B. Chase, M.M. Davis, *Fundamentos da administração da produção*, 3ª ed. Artmed, Porto Alegre, 1999.
[16] B. Broca, *Qualidade total em serviços*, McGraw-Hill, São Paulo, 1994.
[17] A.L. Paniago, *Kaizen – Implementação na indústria de autopeças: resultados na redução das perdas na área produtiva*, São Paulo, 2008.
[18] P.G. Martins, F.P. Laugeni, *Administração da Produção*, Saraiva, São Paulo, 1998.
[19] I. Marshall Junior, *Gestão da Qualidade*, Rio de Janeiro, 2008.
[20] C. D. Barros, *Análise do modelo WCM em uma montadora de automóveis: percepção dos gestores de implantação*, FEAD, Belo Horizonte, 2012.
[21] R.J. Schonberger, *World class Manufacturing; the lessons on simplicity applied*, The Free Press, New York, 1986.
[22] R.H. Hayes, S.C. Wheelwright, *Restoring Our Competitive Edge: Competing Through Manufacturing*, John Wiley, New York, 1984.
[23] R.H. Hayes, *Manufacturing strategy: ta the intersection of two paradigma shifts. Production and operations management*, HBS Press, Boston, MA. V.5, No.1, pp. 25-41, 1996.
[24] N. Kock, C. A. Tomelin, G. Asper, *Qualidade total na prática. PMQP – Programa de melhoria da qualidade e produtividade*, Infobook, Rio de Janeiro, 1999.
[25] S.M. Torminato, *Análise da utilização da ferramenta Cep: um estudo de caso na manufatura de autopeças*, Dissertação (Mestrado em Engenharia Mecânica) - UNIVERSIDADE ESTADUAL DE CAMPINAS, Campinas, 2004.