Application of Black Oxidation in Carbon Steel Parts in a Tool Company

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***Abstract*— *The project of implantation and application of the process of black oxidation, in a tooling company, has the objective to improve an improvement in the assembly processes and the machined parts, to reduce the adjustment and finishing time of some of the services performed in the tool shops, resources were applied through an implanted sector to carry out such operations. The elaboration of this project was based on the identification of the problem, which caused delays and excessive expenses due to the logistics of the process that was done outside the industrial center of Manaus, through the methodology of the PDCA, the implemented process, was applied in practice, executing the mounting on the two-pole pole devices, with the machined parts, having the logistics time for 7 days on average, and from now on with the deployment, is done in a few hours, reducing time and costs, and better serving customers that request the services in shorter term, cost and benefit.*
***Keywords*— Black Oxidation, PDCA, Process and Assembly.**

I. INTRODUCTION

With the great competitiveness in the labor market, and the growth of machined parts of various types and sizes, the organizations are adapting themselves, and specializing to keep their customers, in the face of the possibilities companies, seek to apply the black oxidation method, for different reasons. Assigning upgrades, and optimizing final assembly time, one of the problems encountered is the ready-made parts waiting to form a batch, to be able to perform its external service, from the moment the parts are finished and are not sent for black oxidation , they are subjected to corrosion and rust due to the waiting time for shipping, and many times the material needs to be transferred in a machine. Black oxidation is used to maintain the appearance of the parts, improve product aesthetics, and extend durability due to the protective layer that is made in the process. The most common finishes are: Chrome plating, nitriding, zinc plating, anodizing and black oxidation.

The surface coating of the machined parts consists of a set of methods that aim to improve the shape and characteristics of the object without significantly modifying the geometric configurations of the object, which must be precise so that there is no damage to the functionality of the product. It provides a much better presentation to the parts as well as certain weather resistance to which they can be exposed.

Black oxidation is a surface coating that consists of a film applied to the metal surfaces and minimizes contact of the substrate with corrosive agents, in order to minimize the wear of the product by the action of the medium.

The type of coating applied will define the protection time it will exert in the material, the ability of adhesion, its thickness or even permeability and the passage of undesired agents through the coating film.

It is possible to increase the corrosion resistance of black oxidized material through the use of a coating such as oil, varnish or wax, and the wax may alter the color of the material, but it guarantees the best protection.

II. THEORETICAL FOUNDATION

Corrosion is a phenomenon that occurs with all materials regardless of their nature [1]. Even the wood undergoes corrosion when it enters a state of decomposition, that is, biological degradation. In the polymers (pvc, teflon, plastics and etc.), corrosion develops through the action of weather (weathering) and chemicals.

The corrosion processes in steel according to [2] are: galvanic, occluded cell corrosion, corrosion under stress, corrosion-erosion, corrosion fatigue, atmospheric corrosion, microbiological corrosion and in other special cases corrosion by hydrogen.

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Oxidation, the most common chemical process in corrosion, compromises the mechanical structure of steel, which can bring financial and even irreparable damage as loss of life. Corrosion in the metal must be eliminated or reduced to the maximum its action given the possible damages caused by it. Among the most common methods of protecting the metal surface are: Cathodic Protection, anodic protection, change of corrosive medium (substance that inhibits the chemical action of corrosion), metal change (corrosion resistant special construction materials) and protective coatings (non-metallic, non-metallic, inorganic, metallic or protective oxides as a consequence of the oxidation of the metal itself) to ensure the corrosion resistance and the mechanical properties of the steel (the type and process of the coating depends on the application of the steel). As can be concluded, the mechanisms of corrosion are different for each material and may be chemical, biochemical or physical.

2.1 Ferrous Metal

In ferrous metal, corrosion is much more known and studied because its action is easily perceived, as we can see in figure 1, and it is present in daily life among people, as in other materials it occurs by chemical, biochemical and physical [4]. The combination of these factors can further accelerate or slow down the process. When we talk about corrosion, we are referring to the deterioration of a specific material or product, particularly metallic, by chemical or electrochemical action, being of the medium in which it is inserted, related in its mechanical stresses [5]. The deterioration caused by the physical-chemical interaction ends up causing damage and wear to the material, and between its operational environment, attributing the wear on the parts, which implies in the use that becomes inadequate.

2.2 Corrosion

Corrosion assigns direct failure of metals when in service render them susceptible to rupture by some other mechanism [6].

Metal corrosion is the transformation of a metallic material or alloy by its chemical or electrochemical interaction in a given exposure medium, a process that results in the formation of corrosion products and the release of energy. An example of corrosion can be seen in Figure 1.

Fig. 1: Corrosion in polymer caused by the action of chemicals [3].

With the great use of mainly ferrous metal alloys which have low manufacturing value and high mechanical strength properties, compared to other metals, the problem of corrosion has arisen because iron is easily oxidized. Due to the predominant chemical element in the composition of the steels, the iron is perceived in the ores, obtaining forms of oxides, and in the metallurgical is extracted.

This transformation leaves the material thermodynamically unstable. Corrosion, therefore, is nothing more than the return of the metal to its more stable state, that of natural oxide [7].

2.3 Black Oxidation

Black oxidation is a type of coating through a chemical treatment, it can be called blackening or blackening, which guarantees a good resistance to corrosion. The black oxidation, gives the treated parts resistance to corrosive wear during storage, as well as a low risk of contamination, figure 2.

The black oxidation process is used, among other applications in: firearm parts, cutting tools, components and blocks of hydraulic machines, chains, gears, screws, hand tools, valve bodies and automotive components [7].

Black oxidation can be achieved by thermal or chemical processes. In thermal processes, the coating is obtained by heating the workpiece at about 480 ° C, causing the surface of the workpiece to react with atmospheric air to the formation of black oxide (magnetite). The part is cooled to ambient and oiled air. The heating of the parts is usually carried out in ovens [8].

This process has a degree of imprecision associated with the difficulty of distributing the heat load in the furnace and has a high cost with energy. In chemical processes the parts are dipped into various chemical solutions that produce an oxide film in the product.

Black oxidation through a chemical process can be carried out either hot or cold. The so-called cold black oxidation is performed at room temperature, obtained through baths in liquid alkali solutions diluted in water,

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where chemical reactions produce a uniform black film in the pieces dipped in the baths. This process is used for cast iron and steel parts with chromium content less than 12% [7].

The hot process uses caustic solutions, and under the action of temperatures between 135 ° C and 140 ° C form a black layer of ferrous oxide on the surface of the parts. Also recommended for steel parts with a chromium content of less than 12% this process is more advantageous in relation to the cold process by the reaction speed and lower cost with chemicals.

It is suitable for surface steel, stainless steel, copper, brass and tin. Its characteristics and properties become ideal for certain applications, making it a benefit as it protects the metal from further corrosion.

Fig. 2: Parts after layer conversion (black oxidation)[9].

The brightness of the oxidation film, depends on the state of the surface of the part, when the part is polished, the surface would produce shiny black films in the parts. The product formed on the metal surface treated by black oxidation, is an iron oxide, among the several that can form, known as magnetite.

III. TOOLS AND METHODS

The exploratory research allowed to establish opportunities for improvement in the market in the face of the adverse reality of the process then employed, for which the PDCA was used, which means: Plan, Do, Control and Act.

The PDCA cycle according to [10] is considered as an innovative management system, with fundamental principles in the applications, besides corrective actions, the method stimulates the improvement of processes and products.

It is a tool based on repetitions and successively in processes [11], seeking continuous improvement. To plan is to establish the necessary objectives and processes; developing is implementing the plan and executing the process; to check is to measure the data collected; act is to take corrective action and determine where to apply for change.

3.1 Characterization of the Oxidation Problem

For the identification of the problem and conclusive solution was used the comparative logic that advocates the before and after analyzes. Analyzes of pre and post project data were performed both quantitatively and qualitatively, focusing on increasing productivity in the manufacturing of parts and reducing cost while maintaining product quality.

The need for such coatings is justified by the fact that the making of a device takes a certain amount of time, because assemblies and adjustments of the mechanisms thereof are carried out according to the tolerances of the designs, and since most of the parts of the devices are made of steel the carbon was subject to very rapid oxidation. For most cases the protection of the metal surface of manufactured devices could be provided by painting or chromatization.

3.2 Problem Analysis Tools

The research criteria were those recommended by the bibliographical and experimental research, where the coating processes of the materials used in a tooling industry were investigated for the needs to be supplied, pointing to the application of black oxidation. For the background of work and research, the history of the process used before any change was raised. Data were collected before, during and after performance improvement.

Based on the PDCA cycle methods, difficulties were identified in relation to the logistics of the previously executed process, with the implementation performed the following steps were taken;

- Define the problem;
- Identify the possible causes;
- Check the actual causes;
- Propose a solution to the problem;
- Deploy the solution;
- Analyze the results.

3.3 Solution Method

The surface coating process known as hot black oxidation, which is used by several PIM companies, aims to improve product aesthetics and prevent corrosion without affecting the functionality of the devices and tools. This type of coating has gauge thickness; very small compared to the dimensional of the pieces. Therefore it is said that black oxidation does not alter the dimensional of the tools.

The parts sold in a company of the tooling branch, are obtained through the processes of machining, lathe, milling, grinding and CNC. The steel is machined according to a predefined design (mechanical drawing). In the mechanical drawing are defined the geometries and profiles according to each function of the item to be constructed.

The technological problem arises when parts and devices need some form of coating; Causes for such a coating are, among others, aesthetics and protection. Many are the possibilities of building this coating, but due to the search for better performance and reduction of resources employed the problem is to find the best coating (from a quality point of view) that generates less costs. The costs of the process are included: logistics, waste disposal, hiring of labor, effluent treatment, thermal energy and production time.

The most crucial factor in choosing a coating for the devices and tools manufactured by the organization is that it can not change in a significant way the dimensional required in the mechanical design of the product. If this occurs, the item may partially or completely lose its functionality and lead to customer dissatisfaction. By way of example only, suppose a paint layer with a thickness tolerance of ± 10 μm was applied to a layer of paint by means of high pressure paint guns. The paint has a reasonable cost (neither so expensive nor so cheap) compared to other coatings, it has excellent aesthetic finish and gives one of the best possible protection to the metal surface. The only problem with the use of paints is that the minimum aggregate thickness of the paint, using the high-pressure paint method, is 12 μm, which is already greater than the tolerance. Using paint to protect this tool could severely impair the functionality of the tool.

Therefore, there is always a binomial to consider, productivity and cost, linked to the implicit and inherent constraint of the process, the low dimensional change.

IV. IMPLEMENTATION

The implementation of the black oxidation process demands the verification of several factors: quantity of parts, volume of parts, Individual Protection Equipment (EPI's) of the employees who handled the chemical solutions, the geographic location of the sector in front of the industrial plant, the tanks for preservation of the solutions, the need for conveyors, use of thermometers, stainless steel containers for immersion in the heated solution, adoption of gas or electric resistance heaters, use of caustic soldering, use of paint stripper and selection of the appropriate degreaser.

The guarantee of a good finish in the black oxidation process is due to some parameters that must be rigorously maintained. Among the many factors that ensure a good quality of the formation of the conversion layer are: the initial state of the parts, the degreasing, the pickling, the immersion solutions and the temporary coating process of the parts with oil.

Special care should be taken with the handling of the pieces during the black oxidation process, as the uric acid present in the sweat reacts at the moment of cooling of the parts in which the layer was applied.

It has great relevance to the process the chemical composition of the materials on which it is desired that there is deposition of the black oxidation, since the conditioning or differences between materials (finishing machining, tempering, welding, among others) can interfere in the form, in the time , in the tonality or even in the black oxidation itself, not obtaining the same results of the processes due to the variation of some of these factors relative to the initial state of the part to receive the protection conferred by the process.

Contact with materials such as aluminum in the material that causes oxidation must still be considered and observed, as the contact of the aluminum with the black oxidation solution can cause small explosions in the black oxidation tank increasing the risk of accidents.

These explosions are caused by the release of energy (in the form of heat) in the reaction between caustic soda and aluminum.

Certain materials cause damage to the black oxidation process. One of the process steps is pickling. Cuprous materials in the paint stripper react with the solution by transferring the reddish hue that is characteristic to the other materials that are immersed in the pickling solution.

The solution does not change visually. Thus, a large quantity of parts can be contaminated by copper ions.

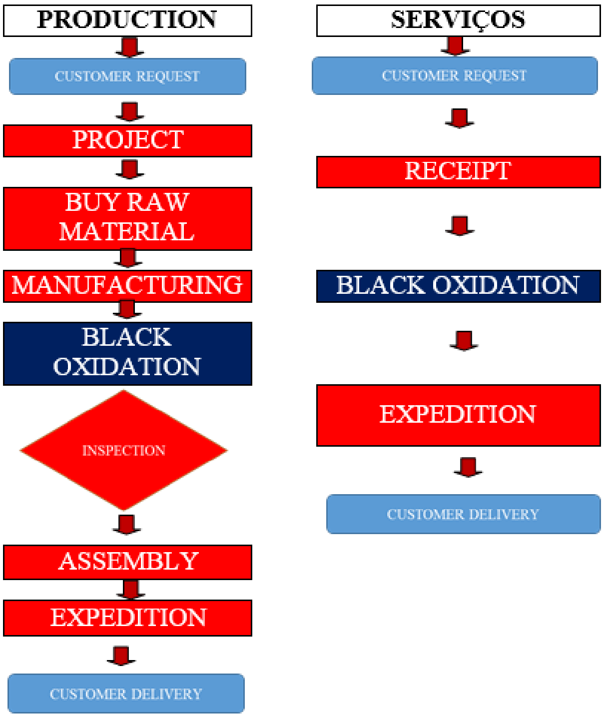

Fig. 3: Current flow of processes and services

4.1 Stages of Processes

Process 1- Selection of raw material

The raw material is separated and selected for thinning at the request of the final customer.

Fig. 4: Raw materials used in the manufacturing process

Process 2- Mechanical cleaning

This stage of the process aims to remove all dirt from the surface of the part, in the companies use: polishing, grinding, tumbling and blasting.

Process 3 - Detach

It aims to remove organic materials such as oils and greases through the solvent and organic baths or alkaline solutions, figure 5.

Fig. 5: Test piece being emerged in the container containing degreaser

Process 4- Rinse

Removes excess degreaser and debris from mechanical cleaning, figure 6.

Fig. 6: Test piece receiving rinse after the degreaser

Process 5- Stripping

A step in which rust and unwanted layers of oxidation are removed, leaving the surfaces of the parts clean and free from impurities and oxides. Acid pickling is the most common and economical, and was used in the experiment and implanted in the tool shop. The FERRUX-CL stripper was used.

4.2 FERRUX – CL

It is a hydrochloric acid compound that acts as a pickling agent for iron and high efficiency steel and contains corrosion inhibitors in a balanced way, allowing an inhibition of the attack of the acid solution on the steel. The tank containing FERRUX can be assembled as a solution containing 20% of the product or more, and may even contain the pure product. FERRUX reacts at room temperature and requires a reaction time between 10 and 20 minutes

Process 6- Rinse

Removes acidic particles and waste from the pickling stage.

Process 7 - Drying

Oxidation preliminary stage, carried out in an oven, made so that the oxide layer is homogeneous throughout the surface of the pieces.

Process 8 - Black Oxidation

The foregoing steps are a surface preparation of the parts for layer conversion known as black oxidation. In

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this step the pieces are immersed in solutions appropriate to the determined temperature where they occur hot or cold reactions, for the formation of the iron oxide black. The product used in the experiment was RQ - OXID FE, which is a strongly alkaline product based on caustic soda, whose specific purpose is to oxidize iron, mainly in the metallurgical industry, tooling and the maintenance of weapons. The product consists of a solid maintained in aqueous solution at a concentration of 650g / l. To promote the process time between 10 and 20 minutes it is necessary to maintain the temperature between 135 ° C and 140 ° C, figure 7.

Fig. 7: Black oxidation test by RQ - OXID FE

Process 9 - Rinse 3 and Dry 2;

It aims to remove alkalis from the previous step, and prepare the surfaces of the parts for temporary additional protection.

Fig. 8: Enxague final após a oxidação negra

These are the steps presented in the process, then the results will be presented.

V. DATA ANALYSIS

Prior to the implementation of a black oxidation sector in the tooling company, outsourced service costs in the black oxidation process were R $ 737.80 / month.

From the implantation of the sector in the company, positive cost / benefit results were obtained, table 1, and figure 9, where the monthly profit refers to the average of the first two months of operation.

Table 1 - Payback of the first month of operation of the black oxidation sector

	OUTPUTS	APPETIZER
INITIAL INVESTMENTS	R$ 1.280,00	
FIXED COSTS	R$ 890,00	
PROFIT OF THE FIRST MONTH		R$ 12.662,00
SUPERAVIT (FIRST MONTH)	R$ 10.492,00	

The organization began to generate profits in place of the previous dividends (expenses with outsourced services), because with the internment of the process of protection by layer conversion, in addition to meeting the internal needs, the black oxidation service became one of the differential services since this type of surface coating was not available in Manaus.

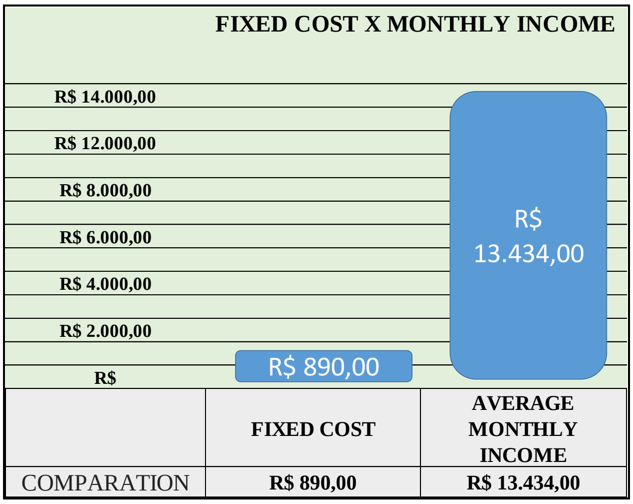

Fig. 9: Comparative Fixed Cost x Monthly Profit

The profits generated in the first month of operation of the sector paid all the investment made in the researches and adaptations of the area to assemble the whole structure for processing the pieces. In this way the production flow of parts that need black oxidation coating.

The relevant planning-based data that was run in the Black Oxidation deployment.

The post-finishing coating, which improves the level of corrosion protection after black oxidation. The protection is conferred by means of oil, wax or varnish; it acts against environmental contamination during transportation.

In the experiments that led to the implementation of the black oxidation sector, low carbon test specimens were used, which are the most used by the organization in its tool construction processes. Note in figure 10 the photo before and after the black oxidation coating. The steels used were: H13, 1020, 4340 and VND.

Fig. 10: Before and after black oxidation - test pieces

The figure shows the comparison before and after the application of the black oxidation made in a test piece.

Fig. 11: Before and after black oxidation - Production

Figure 11 shows the process equation where the black oxidation is made in a test piece.

VI. FINAL CONSIDERATIONS

The application of the study was elaborated with the purpose of presenting the evolution of the process of experimentation and implantation of a black oxidation sector by immersion in the company, analyzing the options available in the market. Through the theoretical basis of some surface coating processes and their applications in the industry in general, the choice of the most adequate form of protection was made, tried and implemented with expressive positive results in the target organization of this project.

The resources available made possible the creation of higher quality products in a shorter period of time, as well as the provision of services previously provided by companies from other states. Another beneficial factor, besides the profit, of difficult measurement is that the process of black oxidation led the company to have a faster delivery of the customer's orders in relation to the others

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