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Feasibility study of chromium electroplating process in stamping tooling

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Due to the great need for reducing production costs, productivity increasing quality improvement of products, the study had its start drafting surface treatment of dies process development, where the first step was a market study looking for the treatment types and their applications. These treatments are intended to stabilize the production process so that there are no variations on the production and increasing the useful life of dies and their appropriate tools. It was determined through analysis, that the parts had problems in dies drawing which influenced on productivity, quality and cost. It had been realized that those parts had similar problems and the treatments could generally minimize such problems. The following step was to apply the treatment of dies and tools, and then realized that the results achieved certain goals, managing to stabilize the stamping process of those parts.

Key words: Automotive stamping, covered tools, electroplating of chromium.

INTRODUCTION

General Motors Corporation (GM) is the largest vehicle manufacturer in the world and it is the global industry sales leader since 1931. It designs, builds and sells cars and trucks around the world. Established in 1908, GM today employs about 325,000 people around the world. Operates in 32 countries and its vehicles are sold in 200 countries. In 2004, it sold nearly 9 million cars and trucks. GM's global headquarters is located in Detroit-USA.

The General Motors of Brazil (GMB) is the largest facility of this company in South America and the second largest operation outside the United States. On 26th January, 2014 had completed 90 years of activities in the country. In 1925, GM came to Brazil and settled in warehouses at Ipiranga, Sao Paulo city. In 1930, it was transferred to Sao Caetano do Sul at Sao Paulo state. Over the years, it achieved several milestones and became a reference not only in this country, as worldwide, through high standards and innovative procedures.

This work was done in the automotive industrial

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complex at Sao Jose dos Campos, in stamping area, which now holds approximately 7,000 employees working in three shifts, and two of them assembly cars. It has a daily average of 780 cars. The GMB's production of Sao Jose dos Campos is intended to supply the domestic market and to export to all over the world. Several problems were found and observed, and then tools to receive hard chromium coatings were selected to this study. Chromium electroplated coatings are widely used in industry for protecting mechanical components against corrosion and wear, to the worn components and dimensional recovery in applications where its repellence is required, as in stamping tools and rubber and plastic extruders.

In industry, it is used mainly with electroplated chromium coating thickness greater than 10 µm, which is called hard chromium to differentiate it from the chromium used as decorative coating, which has typically layer thickness between 0.2 and 10 µm. Hard chromium coatings are used on more than 70 years in the industry, and it is proven their excellent cost/benefit ratio. The application of chromium as coating has the need to increase the service life of the tools because of the high cost of replacement components. Chromium is used as coating when it wants to associate with corrosion resistance and to decrease the wear rates. Electrodeposited chromium presents high surface hardness, which can facilitate crack surface, and it can provoke the superficial degradation.

For this reason, it is proposed in this paper the use of an electrochemical technique to determine and to evaluate the behaviour of this coating. The electroplating is one of the most used methods for obtaining metallic coatings, as it allows the control of important parameters of deposits such as: chemical composition, phase composition, microstructure and layer thickness. Few works are found in literature on electroplating of chromium and stamping process, specially related to automotive sector.

Deqing et al. (2005) reported their work on the study of the temperature effects, current density and time on thickness of nickel, copper and hard chromium coatings produced by a multiple electroplating process. Svenson (2006) listed properties of chromium and its application on plating.

In Abdel Gawad et al. (2006), carbon fibre of PAN (plasma assisted nitriding) type was electrolytically coated with chromium layer, which was transformed to chromium carbide using *in-situ* process. The influence of plating parameters such as current density and plating time on the coating thickness of chromium deposited layer was investigated. Alternating pulsed electrolysis was investigated for the surface modification of carbon steel substrates with carbon contents of 0.2, 0.6 and 0.8 mass% (Yagi et al., 2008).

Bin Sobhi (2008) investigated and analysed the scrap reduction in automotive manufacturing parts, specially the car door production and process, where the stamping process is the main process used. Kumar et al. (2010) had developed structural models for effluent treatment system for electroplating, indentifying benefits to the electroplaters and to end users. Mandich and Snyder (2010) described properties, features and applications of electroplated chromium, such as it deposits rank among the most important plated metals and that is used almost exclusively as the final deposit on parts. Lin and Hsieh (2011) had studied strength of relationships with the partners in supply networks in the automotive industry and their influence in row materials quality. Khodadad and Lei (2014) reported their work, where the trivalent chromium coatings were deposited on the pure aluminium substrate using a thin zincates interlayer.

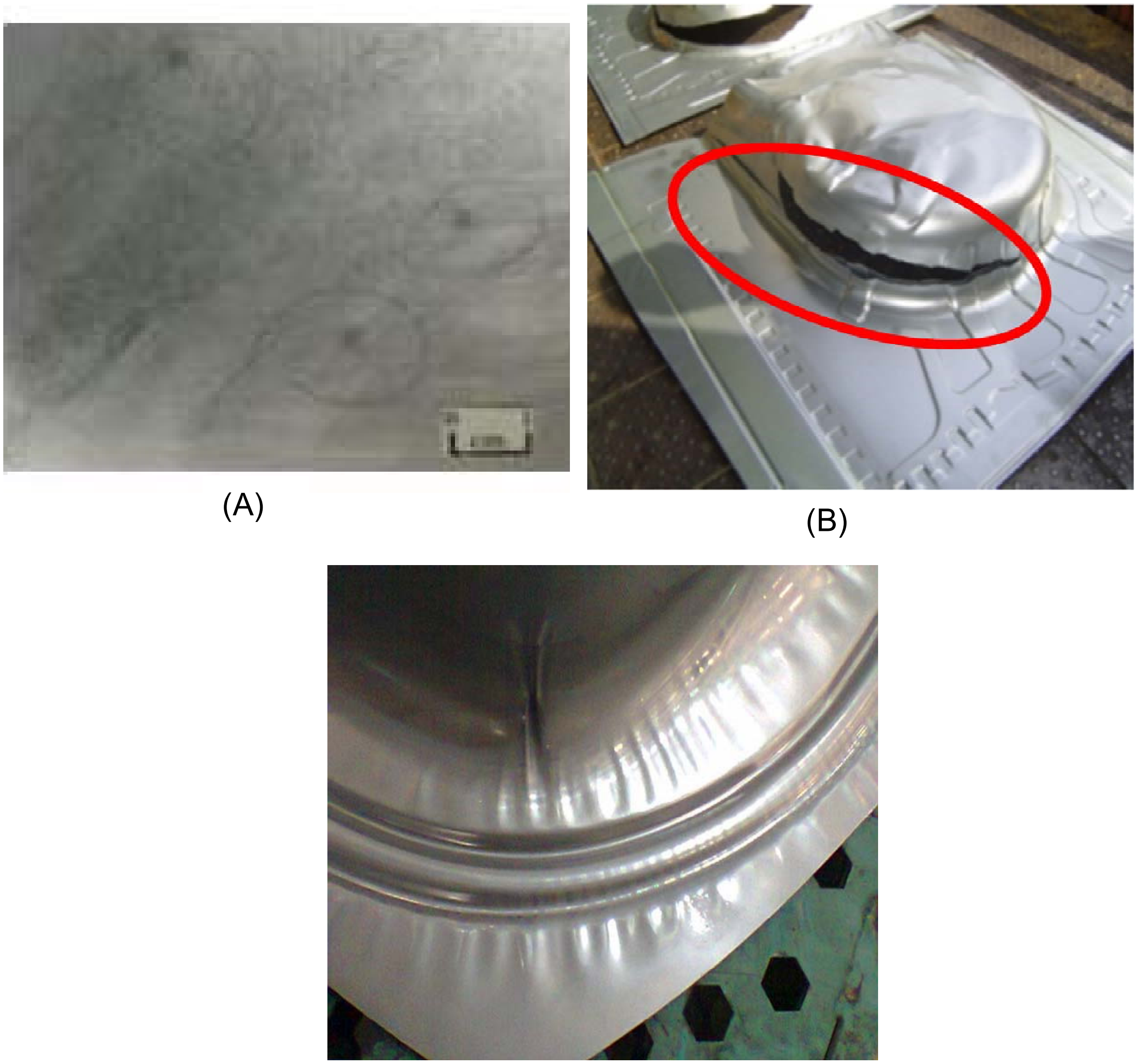
Problem statement

The use of stamped parts in the automotive sector is extremely important, so General Motors of Brazil has been invested in its stamping units at Sao Caetano do Sul, Sao Jose dos Campos and Gravatai facilities, to eliminate waste, and loss of productivity and for continuous improvement in the quality of its products. In stamping unit of the GMB at Sao Jose dos Campos exists losses during the productive process due to problems caused by stamping tools used in the manufacturing of parts. Stamping tools present: Wear, griffin, dirt, weld marks and broken. These deficiencies are generating low availability of stamping tools, high rate of waste parts, rework and overuse of stamping oil. Figure 1 show some of these deficiencies.

Chroming process

According to Newby (2000), the chromium plating is produced by chromic acid solution, which contains one or more catalytic anions. The anions have great influence on chromium deposition, mainly the sulphate found in commercial chromic acid, which may not exceed a certain amount (0.1 mg/m^3 of air) in the relationship of chromic acid for sulphate ion. Therefore, it is essential to use free chromic acid to meet and to take into account the content of these anions, which should be low in chromic acid. Usually admits a maximum content of anions in chromic acid of 0.2% sulphate ion (Weiner, 1973).

According to Silman (1955), the concentrations of chromic acid and sulphuric acid in the bath have secondary importance related to the main factor, which is the relationship of chromic acid and sulphuric acid, which needs to be maintained around 100:1. The concentration for the hard chroming varies from 250 to 350 g (chromic acid)/L, in special cases using extremely high concentrations up to 500 g/L. The properties of a chromium layer, however, do not only depend on the



(C)

Figure 1. Faults occurring in the process: (A) excess lumps; (B) excessive breaks (cracks); (C) wrinkles (courtesy: General Motors).

concentration of chromic acid in electrolyte. Depend of, above all, catalyst and working conditions of electrolysis, for example, current density, temperature, and time deposit (Panossian, 1997).

First working electrodes were built with coating, that is, substrate coated with chromium and uncoated electrodes (only the substrate). The material used in the manufacture of electrodes without coating was carbon steel 1020 (ABNT, 2000). After that, the following steps were determined:

(i) Passivation solution of substrate;
(ii) Ideal concentration of passivation solution;
(iii) Scanning ideal speed of passivation;
(iv) Selection of potential where the chromium does not have chemical reaction and the substrate suffer passivation;
(v) Determination of loads density of substrate passivation of coated and uncoated electrodes for the calculation of porosity;
(vi) Determination of coating thickness;
(vii) Manual polishing (sandpapers with granulation of 600 and 400) for the electrodes without coatings.

MATERIALS AND METHODS

Here, the research classification and the preparation steps of this

Figure 2. Opening doors structure (courtesy: General Motors).

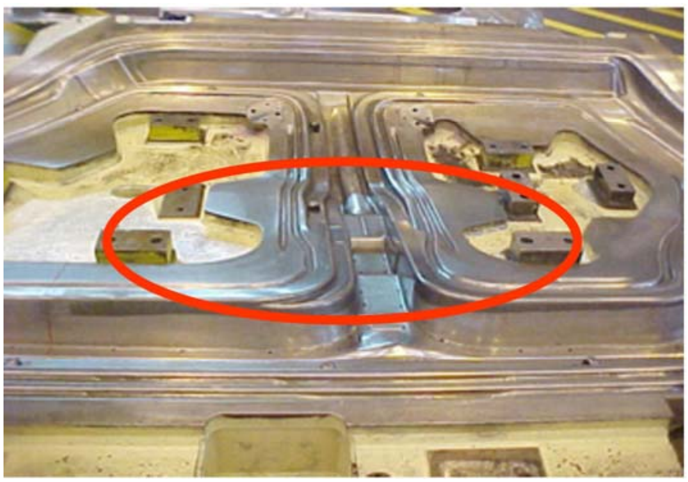


Figure 3. Array of drawn of metallic radius (courtesy: General Motors).

work are explained. The exploratory-descriptive was chosen as research methodology, where the field research and data collection might be previously performed through company data file and also through demonstration of improvements in performance results of metallurgical equipment (tool), specially the process of applying chromium plating. To start the implementation of chromium plating process of the tools, it did a survey of some operational data of the company, and they were:

(i) Index of losses with waste and scraps from total produced;
(ii) Number of returns during the year by the client;
(iii) Amount of material released to experiment;
(iv) More defective and critics products.

Some stamping companies were surveyed, in order to obtain documented procedures and data collection with the suppliers Torata Chromium Plating and Cascadura Coatings, which were evaluated throughout the development of the work.

Development of experiments performed at GMB

Analysing the current process of the company where the problem appeared that the requirements of internal customers had been met partially, since faults such as cracks, wrinkles and tool marks on parts during the manufacturing process steps were found. Based on the practices already adopted by companies in the automotive sector there were developed proposals for modification of the manufacturing process by changing some of its parameters and evaluating variables with reset of this process parameters. All responses generated by the process after the changes suggested were analysed. Recommendations and suggestions for changes on process had been given to reach the expected results by the company and by internal clients.

Once the approximate borders of the situation-problem are identified, also the techniques to be adopted for the full study and decisions which require consideration of the findings obtained in the preliminary exploration of the application of the chromium plating in tooling are defined. It was possible to define the main phases of the project, briefly described hereafter. To maximise the benefits and to minimise the disadvantages of the collection instrument selected, Torata Chromium Plating and Cascadura Coatings recommend the procedures that they had adopted:

(i) Focus group – formed by production processes engineers, materials engineers, and the leaders of the departments of metalwork and CKD export, which have interest in the issues of study, as well as direct clients of services provided;
(ii) Pre-test – the pre-test was conducted following the standards and guidelines established by the companies Torata Chromium Plating and Cascadura Coatings to establish clarity, acceptability and comprehensiveness of product used (hard chromium);
(iii) Note *in locu* – this observation had provided the capture of views, information, and product quality characteristics.

Treatment application

Monitoring and analysis was carried out during the production process to develop the treatments to be applied on the surface of stamping. It has been found through experiments that require surface treatments applications which result in better efficiency possible. Therefore, in order to a more effective study, the treatment of hard chromium in the input radius of drawn matrix part of opening doors structure (Figure 2) in order to analyse the treatment.

After that, it had been taken off the hard chromium layer from tool and the treatment of plating had been applied within the matrix radius, according to Figure 3. There was also another study, applying in the drawn stamping of inner panel part of the trunk cover (Figure 4).

Survey with suppliers

A survey was conducted via the internet and contacts with other plants of the GMB to know which companies of surface treatments are prepared to receive large tools. Due to the average stamping weight 10 tonnes, it is difficult for many companies to perform this work, so it was possible to register two companies:

(i) Torata: Company located in the city of Porto Feliz, in the Brazilian state of Sao Paulo which holds hard chromium surface treatment dies with maximum weight of 16 tonnes;
(ii) Cascadura: Company located in the city of Sorocaba, in the Brazilian state of Sao Paulo that performs processing of hard chromium plating and tools metallization with a maximum weight of 10 tonnes.

Figure 4. Array of back cover of the trunk (courtesy: General Motors).

Figure 5. ES4 model Schuler presses (courtesy: General Motors).

These two suppliers make the budget of surface treatment to be performed and the time for execution.

The stamping setting

Tools adjustment is the most important set to this process, because after the surface treatment is not possible to modify the stamp without damaging treatment. The following procedure was determined for adjustment before treatment:

(i) Punch and matrix: Setting across the surface to eliminate deformations caused by wear, cracks due to heat treatment, welding, and polishing brands in general;
(ii) Press-plate: Ring setting, copying the shape of the array, setting controlled flow of material and determination of equalizers of the press-plate.

Experiments at GMB

The stamping tools to be treated superficially were defined through quality and productivity graphs issued monthly indicating which critical parts with highest rate of problems. The tools were developed in nodular cast iron GM 238, G3500 standard method GMDDS section 85 with graphite Types I and II, pearlitic/ferritic matrix structure, obtained by heat treatment. It has high mechanical properties, good harden ability and good surface finish. The material has behaviour of tensile strength and yield strength similar to SAE 1040 (AISI, 2013) steel hot-rolled, in condition melting gross. It consists of graphite in the form of nodules (spheres), forms I and II, sizes 6 to 8, according to ASTM A247-10 (ASTM, 2014). The matrix is a pearlitic/ferritic structure, with approximately 50% of perlite and a maximum of 5% of carbides dispersed. The carbon content ranges are specified for each group of gauge, in order to control the type and size of the graphite. The variation within a song is about 0.20%. Magnesium is added with the goal of favouring the formation of spheroidal graphite. The pieces were stamped on semi-automatic mechanical presses, ES4 model Schüler of five operations (Figure 5) which have the following specifications:

(i) Head area: 4,572 × 2,500 mm;
(ii) Strokes per minute: 7 a 14;
(iii) Press capacity : 2,000 tonnes;
(iv) Standard height for tools: 1,220 mm;
(v) Mobile table: 4,500 × 3,000 mm

Product validation and decision-making

After stamping of parts, a visual assessment was performed following the internal procedures used at GM, they are used for evaluation of a normal part of production. In this evaluation took into account the surface aspects (deformations, brands, tearing of material etc), structural aspects (cracks, remounting, sprains) and aspects of dimensional and form (number of holes, wrinkles, lack of material). 100% quality control of all parts manufactured by performing a visual assessment of the same is accomplished during the production process of parts, with the aim of observing any faults in the production process, for example, pits, cracks, wrinkles, overlap etc. The results obtained from this quality control showed a significant contrast between the materials. The use of phosphatised material generated a great reduction in the number of total defects, especially in the pits, with a reduction from 3.2 to 0.8% of lumps in the total production of parts in a same period of time. It was observed that the lumps are due to the tearing of the galvanized coating layer during the stamping process. The images obtained through the MEV shows clearly the low grip between galvanized and metal coating base.

The use of phosphatised materials, as the BH 180, 210, 260 and 280 used in precision metal stampings, showed greater efficiency, especially when it concerns the lumps, improving the adhesion of the coating to the metal base compared to materials using only the electro-galvanized layer. It is observed from this study and tests that, the use of materials with layered phosphatised becomes feasible in parts that will be used in external panels of vehicles, where its quality control is more accurate when compared to internal parts. The use of chromium plating done in tools has a number of advantages for both the stamped parts and the tools employed in these experiments. The chromed surfaces showed a layer of superficial hardness of approximately 900 HV (Vickers), giving a high wear resistance and durability of the tool.

RESULTS

Then it can observe the results obtained after the chroming processes of 14 tools of three vehicles selected for the study, for those two study cases will be presented. The external side panel part LD for car model Montana

Figure 6. External side panel LD (courtesy: General Motors).

Figure 7. External side panel LD (courtesy: General Motors).

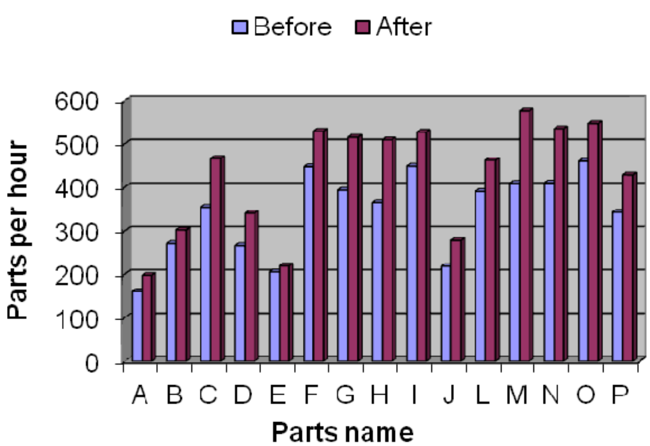


Figure 8. Productivity of the pieces studied.

had low productivity due to interference caused in the production process by the tool to eliminate rework from gripping (Figure 6). After it had been held the plating treatment of incoming rays of productivity matrix had a gain of 112 parts per hour due to non-interference of the productive process by the tooling department. Table 1 shows the other gains for the surface treatment of plating. The external panel on the right side of the car model Corsa featured a high number of wastes, totalling 37 parts per month (Figure 7). After presented the superficial treatment of chroming on the press-plate and at the matrix of the stamping of fountain there was drawn a decrease of 35 parts per month in the number of waste. Table 2 shows the gains for the surface treatment of chroming. Then, it is shown that the increase in productivity of the parts studied, compared to productivity before the achievement of surface treatments and after the completion of the work (Figure 8).

It can be checked in the Table 2 that the productivity of the parts studied in three vehicles had an increase of 87 parts per hour being indicated by the letter P in Table 3, which corresponds to a 26.4% gain in productivity. Table 3 presents the legend adopted in this work to indicate the parts studied.

With the work performed, the number of scraps of the parts studied decreased from 354 parts to 14 parts per month, with a 96% reduction. Figure 8 shows a reduction in the number of scraps. Table 4 shows the legend adopted in this work to indicate the parts studied used in Figure 9. It has been gotten through the surface treatments carried out in the studied parts reduce the rework of 712 parts to 29 parts per month, which is equivalent to a gain of 96%. Figure 10 corresponds to gains in all parts studied. Figure 11 shows that the economy hit with elimination of lubricating oil known as Green Rust which it was used around 800 L/month and it was generated a monthly cost of R$ 7,848.00 (US$ 3,246.06 in February 4th, 2014) in the processes of the parts, which have a unit value of 9.81 R$/L (4.06 US$/L in February 4th, 2014).

DISCUSSION

It was possible to observe that chromium has low coefficient of friction, allowing the reduction or even elimination of lubricants, and therefore the operating cost in a chromed surface, due to its high repellence characteristic, there is no particle adhesion, eliminating the risk of fouling, and avoiding even the rework of tools. When adorn galvanized sheet metal, chromium coating does not allow for accession of zinc particles on the surface of the tool, avoiding the need for polishes, and improving the quality of the surface of the stamped parts. The chromium job enabled greater efficiency in printing, from the use of cheaper cast irons. The use of cast irons also results in advantages in the machining of parts, given the lower hardness of material which facilitates its processing, promotes increase in service life of cutting tools and more efficient use of the machine. Other benefits were observed:

(i) Reducing and eliminating the need of lubrication in the stamping process, also reducing environmental problems

Table 1. Monitoring of the parts gain: external side panel LD.

Variables	Before	After	Gain	Gain (%)
Productivity (parts/hour)	354	466	112	31.6
Scrap (parts/month)	0	0	0	0
Rework (parts/month)	37	0	37	100
Hours of downtime (hours/month)	3.68	0	3.68	100
Maintenance hours (hours/month)	41	2	39	95

Table 2. Monitoring of external panel LD gains.

Variables	Before	After	Gain	Gain (%)
Productivity (parts/hour)	447	529	82	18.3
Scrap (parts/month)	37	2	35	94.6
Rework (parts/month)	8	1	7	87.5
Hours of downtime (hours/month)	1.7	0	1.7	100
Maintenance hours (hours/month)	18	0	18	100

Table 3. Caption of Figure 8 letters.

A	Column "B" inside	H	Inner panel of front door LE
B	Rear floor Panel extension	I	Inner panel of front door LD
C	External side panel LD Corsa	J	Rear floor panel
D	Inner Wheel box LD/LE	L	Inner panel of the trunk lid
E	Door structure of S10	M	External side panel LD of Montana
F	Rear door inner panel LE	N	External front door panel LE
G	Rear door inner panel LD	O	External front door panel LD
P	Average		

Table 4. Parts studied subtitles.

A	Column "B" inside	H	Inner panel of front door LE
B	Rear floor Panel extension	I	Inner panel of front door LD
C	External side panel LD Corsa	J	Rear floor panel
D	Inner Wheel box LD/LE	L	Inner panel of the trunk lid
E	Door structure of S10	M	External panel LD of Montana
F	Rear door inner panel LE	N	External front door panel LE
G	Rear door inner panel LD	O	External front door panel LD
P	Total		

involved;
(ii) Reduction of downtime spent in stamping process, after reducing the need of polishing during the process, due to low adherence of material, reduction of faults or problems occurred during the stamping parts resulting in quality and productivity gains;
(iii) Increase in tool life and greater ease in the recovery of the same, being need only the replacement of the chromium layer.

Conclusions

The application of hard chromium surface treatment used in this work represents an advantage in critical parts stamping process, achieving stability in the production. With the study conducted in selected parts, it was defined as procedure that helps in treatment analysis to apply. This procedure enables to apply the surface treatment in order to achieve the best efficiency, increasing the life of

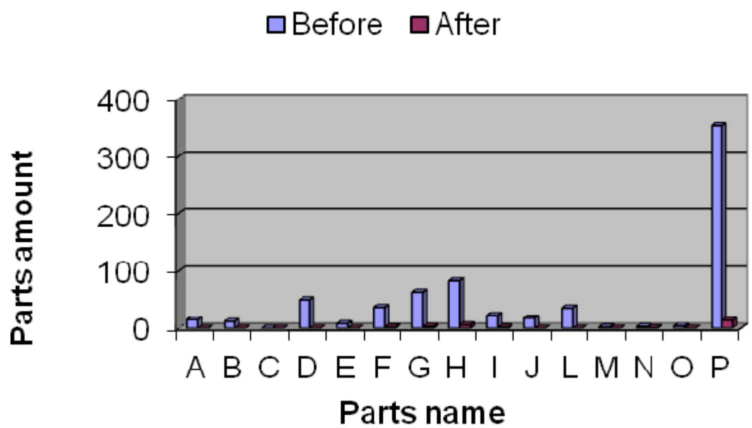


Figure 9. Studied parts waste.

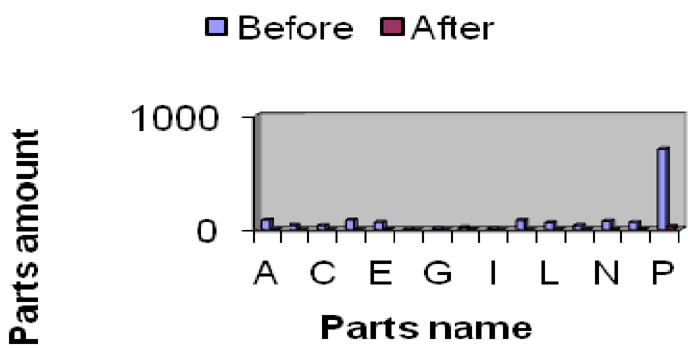


Figure 10. Rework of the parts studied.

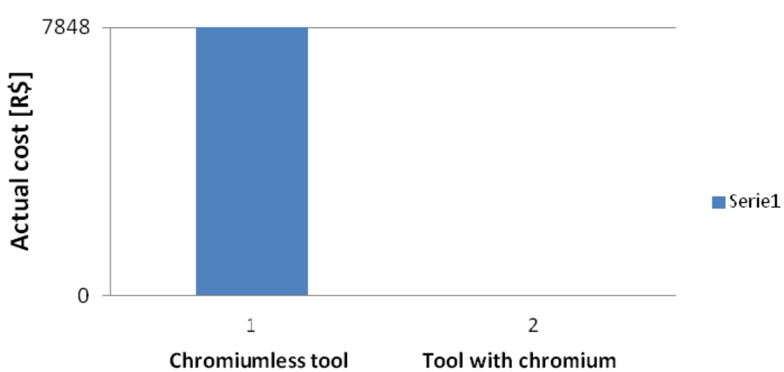


Figure 11. Cost of representation with oil consumption.

stamping and achieving greater stability of the process. It has to follow the procedure for the application of two types of treatments used in this project:

(i) Plating: used when the part shows constant and located gripping caused by rays of matrices and puncture;

(ii) Chroming: used when the part shows gripping in the press-plate, scratches on the surface of the punch and matrix, cracks and wear on tooling.

It was concluded that all these results and previously cited gains are coming from the properties that the chromium plating gave to the tools used in this work, analysed and previously described and carried out at General Motors presented high performance during the process. A large etching efficiency factor of this project lies in the use of high strength steel plates, which provide the high mechanical properties, to the vehicle and smaller thicknesses used for manufacture of structural elements and automotive panels, resulting in more resistant vehicles and at the same time lighter and economical.

In order to shape these plates, due to its characteristics and properties, it was necessary the development of new techniques, which were designed to ensure an efficient production of automotive elements, otherwise it would not be possible using conventional techniques. Watching the production losses of parts by quality problems, it has been seen that this indicator has increasingly strategic importance in the production chain of automotive group from which General Motors is part.

The strategic importance due to the fact that the guarantee of quality of the final product must be sustained once, if not only supplies products directly to the internal client such as metalwork, as well as for external customers of other productive areas of the group as its dealers, parts for export and other plants of the corporation in Brazil and South America.

In the years 2011 and 2012, the goal of production loss was established taking into account the history of the equipment and the process, being respectively 25 and 20%. The lost production is a percentage; in this case, it was adopted a tolerance range since this is a measure of reliability of the processes production equipment (tools). The actual values of production losses and losses of processes affected in the years cited were respectively 30.15 and 22.20%, which demonstrates a performance improvement in product quality and in the process between the years 2010 and 2011, but the range of the goal is still the challenge.

Conflict of Interests

The authors have not declared any conflict of interests.

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