PARTICULARITIES OF THE PAINTING PROCESS IN THE AUTOMOTIVE INDUSTRY

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Rezumat. *De cele mai multe ori vopseaua de pe autoturisme este considerată un lucru ce nu necesită o atenție deosebită fiind asociată doar cu aspectul plăcut al caroseriei. Vopseaua automobilelor este un produs chimic complex, rezultat al unor procese tehnologice complicate, și totodată este cel mai "torturat" element ce-l deține orice automobil, având în vedere fenomenele naturale: soarele (canicula), grindina, ploaia, ninsoarea, praful. De aceea, vopseaua constituie una dintre principalele caracteristici avute în vedere de client atunci când decide să cumpere un autoturism. În această lucrare se prezintă totalitatea activităților desfăşurate în vederea asigurării calității în cadrul procesului de vopsire a automobilelor și importanța vopselei pe caroserie. Sunt identificate defectele ce pot apărea în urma procesului de vopsire, defectele din aval, datorate montajului pieselor pe caroseria vopsită, şi sunt propuse recomandări cu privire la prelungirea duratei de viață a vopselei și eliminarea acestor defecte.*

Abstract. *Most of the times, the paint on the cars is considered something that does not require special attention. It is usually associated only with the pleasant appearance of the care. The paint on an automobile is a chemically complex product, the result of a long and complicated technological process. At the same time, it is the most "tortured" element of a car: it has to perform at the highest standards in sun, hail, rain, snow, dust. Therefore, the paint job is one of the most important features a client takes in consideration when buying a car. This paper presents the totality of steps taken towards achieving a paint job of the highest quality. It also states the importance of paint on a car body. The defects that may appear as a result of the painting process are identified, as well as the downstream defects that occurred due to the assembly of parts on the painted car body. Recommendations regarding the elimination of these defects and the extension of paint life are made.*

Keywords: Automotive, Quality, Painting process, Defects, Retouching.

1. Introduction

In a very competitive industry such as the automotive industry, quality is what makes the difference. When we want to deliver a product on the market, it is very important to think about what the customer wants: a vehicle with an attractive

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appearance, to drive safely, comfortably, at a price to can afford and does not have to pay frequent visits to service [2].

The present study, placed in the center of the approach, the total quality management with all the implications arising from the procedural context of its implementation at the level of all departments of the enterprise [8].

In order to satisfy the clients requirements, the maintenance and improvement of the quality must occur in all the fields of activity of the company, not only in those directly involved in achieving the finished products [1].

The cars have car bodies and car body elements covered with four layers of paint, each of them having a well-defined role. The four layers of paint are [12]: • primer; • starch; • water-soluble base (color paint); • the protection lake (transparent paint).

Painting operations are carried out successively, by immersing the car body in a bath with solution (primer) and then the other components (starch, base, protection lake) are added by using the robots or manual, with the gun, in the areas that are difficult for the robots.

On a car is applied, on average, 12.5 kg of mastic and 7.5 – 8 kg of paint. The complete system of the four layers of primer, starch, water-soluble base (color paint) and protection lake (transparent paint) will have, after drying, a thickness of 100 – 120 μm [6].

The process of painting a car body is the most difficult in any car manufacturing company. From the moment the car body enters the *Painting* department and goes through the entire technological flow, it takes eight hours, after which it leaves this section and enters the *General Assembly* department.

2. Current state

2.1. Stages of the car paint process

In order to protect the car body against corrosion and to give it the final appearance according to the quality requirements stipulated in the references, the painting process involves five stages [12].

2.1.1 Surface treatment

This process involves two operations [6]:

- **degreasing** - represents the operation performed on the assembled car body from the *Car Body* department; it is achieved by washing with demineralized water having the role of removing the remaining impurities after the car body is joined;

- **phosphating** (cataphorisis) - the process after which the first layer of anti-corrosive solution is applied to the car body, the electrostatic paint in the immersion bath.

After the completion of the operation of preparing the car body for the actual painting, the metal surface is treated with zinc phosphate by immersing the car body in a solution bath for 3 to 5 minutes (fig. 1). Simultaneously, the submerged car body is applied a voltage between 250 – 500 V while another electrode is positioned in the bath (fig. 2).

Fig. 1. Solution bath [4]

Fig. 2. Voltage electrode [4]

The electrically charged solution particles stick to the metal and form a layer of approximately 20 μm, to protect the surface against corrosion. The drying is carried out in a drying oven (cabin) operating at a temperature of 60 °C.

2.1.2 Mastic application

It represents the process after which mastic straps are applied in the joining areas of the elements that make up the car body (figs. 3 – 4). The length of the mastic strap applied to a car body is between 115 – 139 m, depending on the model. Its sole purpose is to ensure the tightness of the car and is carried out with the help of extrusion guns.

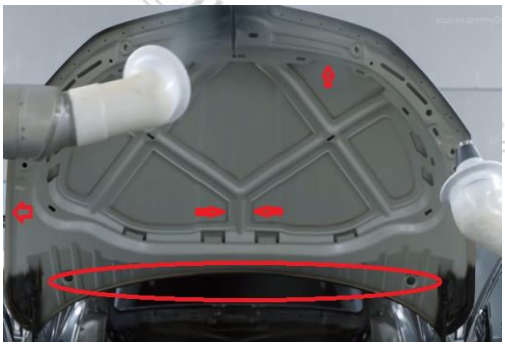

Fig. 3. Front cover mastic straps [5]

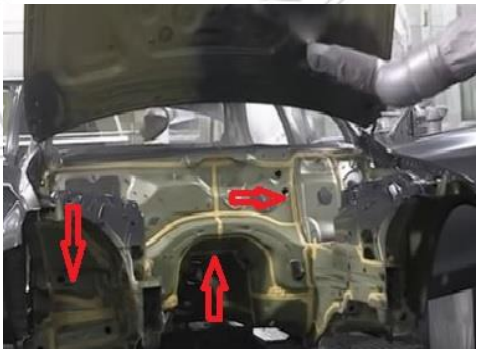

Fig. 4. Engine compartment mastic straps [5]

2.1.3 Starch application

The starch, the support layer of the color paint (water-soluble base), has a thickness between 30 – 40 μm, being the thickest layer. It is composed of fillers such as gypsum, chalk or talc, which can penetrate into the smallest cracks. Its application is done with robots, thus eliminating a wide range of defects (fig. 5).

Fig. 5. Starch application

The starch has two main roles: surface straightening (leveling) and adhesive support for the base paint (color). It has a high elasticity, soft enough to be easily sanded when needed with abrasive materials and can prevent the color of the paint from variation. Its drying is carried out at a temperature of 87 °C.

For example: if the paint of the car is attacked by pebbles or hail, this layer absorbs the impact shock and prevents the paint from splitting, by dispersing the energy.

2.1.4 Application of color paint (base)

The color paint is the layer that any customer can identify (figs. 6 – 7), but it is the least important. It does not provide corrosion protection or fixing for the next stage (the protection lake).

Fig. 6. Basic application (color) [4]

Fig. 7. Basic application (color) [5]

The color paint has a thickness between 15 – 20 μm. It is found in hundreds of different shades, with pigmentation or pearl effects, it contains special ingredients that give it a metallic hue or even chameleon-like color combinations.

2.1.5 Application of protection lake/transparent paint

The protection lake (figs. 8 – 9) is overlaid with color paint, in a layer with a thickness of 35 – 40 μm, its purpose being to give the car the glossy appearance and to protect it from external factors (dust , rain, sun, snow, etc.).

Fig. 8. Application of protection lake [5]

Fig. 9. Application of protection lake [3]

Due to its special composition it successfully performs the role of protection against temperature fluctuations. For example, in winter, when the front hood (engine) can go from a temperature of - 20 °C to a temperature of + 40 °C in a few minutes, this layer of transparent paint is the one that protects the rest of the layers from these differences of the temperature by preventing paint cracking.

The two layers of paint (color and transparent) are dried at a temperature of 100 – 120°C, for 45 minutes.

In conclusion, after analyzing the entire process of painting it can be said that the protection lake is the most important layer of paint in the process of auto painting and most exposed to all traumas, regardless of their nature.

2.2. Defects that may occur as a result of the painting process

Defects may occur during the technological flow in all areas of product manufacture and too at painting of the cars, a series of defects arise, the causes being multiple [9, 10, 12, 14]. Forwards, the most common defects are presented, that have a high degree of penalty according to the current standards. Their generating causes are presented too. These defects can be easily detected by any client, regardless of professional training.

2.2.1 Transparent paint leak

It appears in several forms: like a candle, a wave or a tear (fig. 10).

The generating causes: unregulated gun, failure to observe the application distance of the lake, uncontrolled movement of the operator's hand.

Fig. 10. Paint leak

Fig. 11. Lake sticks

This defect can become a generator of nonconformities of the type: **stinging / lake blades** (fig. 11).

The stings are defects rated with a high degree of non-compliance because they cause two major quality problems, namely, related to the corrosive and unsightly appearance. They appear as a result of paint leakage in a large quantity, which in turn, after the drying process, forms air bubbles that subsequently break down and into water, a factor that leads to corrosion of the respective area (rust).

2.2.2 Granules/paint impurities/particle deposition

These are very common defects on the surface of the car (fig. 12). They appear either due to the involuntary deposition of particles (dirt) in the paint space, or due to the impurities that are found in the paint (non-filtered paint).

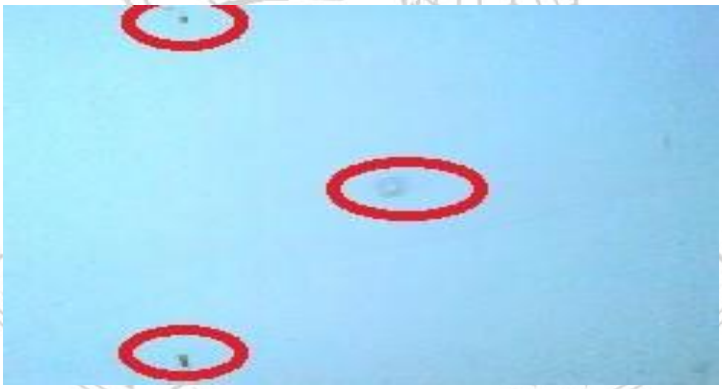

Fig. 12. Paint granules/impurities

2.2.3 Non-compliant paint and peeling paint

Non-compliant paint (fig. 13) and peeling paint (fig.14), the both defects create the feeling of refusal to look at the respective area.

The generating cause: failure to comply with the standards of preparation of the elements to be painted.

Fig. 13. Non-compliant paint retouches

Fig. 14. Rear paint bark peeling

Other defects also appear outside the technological flow, in the company or at the customer, due to the non-observance of the minimum conditions of maintenance of the vehicles.

For example, the sun is the biggest enemy of car paint. Even if the paints made today are much more efficient over time than in the past, the sun is the one that harms them the most. In a hot summer when outside is 38 – 40 °C in the shade, the car body can reach even 90 – 100 °C. In this case, the small particles of dust or gravel penetrate the paint more easily, especially if we travel quickly, and the roads are full of sifting. The paint layers are specially designed to withstand high temperatures, but they become softer and brighter when the temperature is very high.

In conclusion, in order to take care of a car, it must be washed regularly, and every 2 – 3 months a product for polish, with the role of "sealing" the paint, must be applied. It forms a protective barrier that prevents water from coming into contact with the exposed metal in the form of scratches, flaws. This will slow down the corrosion process and there will be no problems with the paint even at high temperatures.

3. Case study

In the standard SR EN ISO 9001: 2015, quality is defined as "the extent to which an intrinsic feature set meets the requirements" [8]. Today, customer demands have increased and they are more exigent, choosey.

The managers of an organization are not only interested in the good functioning of the technological flow, they also analyze and look for solutions to solve all the problems that have arisen, especially those regarding the quality of the finished products [11, 13]. Quality is and always will be an important competition factor.

3.1 General concepts of the *General Assembly* department

The assembly is the last stage of the manufacturing process of a car (figs. 15 – 16).

Fig. 15. Airway band GA [4]

Fig. 16. Ground band GA [7]

The painted car body, with zero paint defects, receives the motor-propulsion group, the interior and exterior components that make the car functional.

In the *General Assembly* department most of the activities are carried out by the operators. Any activity with human participation presents the risk of dysfunctions that can generate various anomalies. Therefore, the managers of the organization carefully supervise all the activities to prevent the occurrence of anomalies, to detect them and to treat them in time [6].

For example, in this department there is the risk of new paint defects, such as peeling or scratching of the paint, caused by operators or machines that do not meet certain standards.

To remedy the defects occurring throughout the technological flow, in the *General Assembly* department a retouch space is allocated (fig. 17).

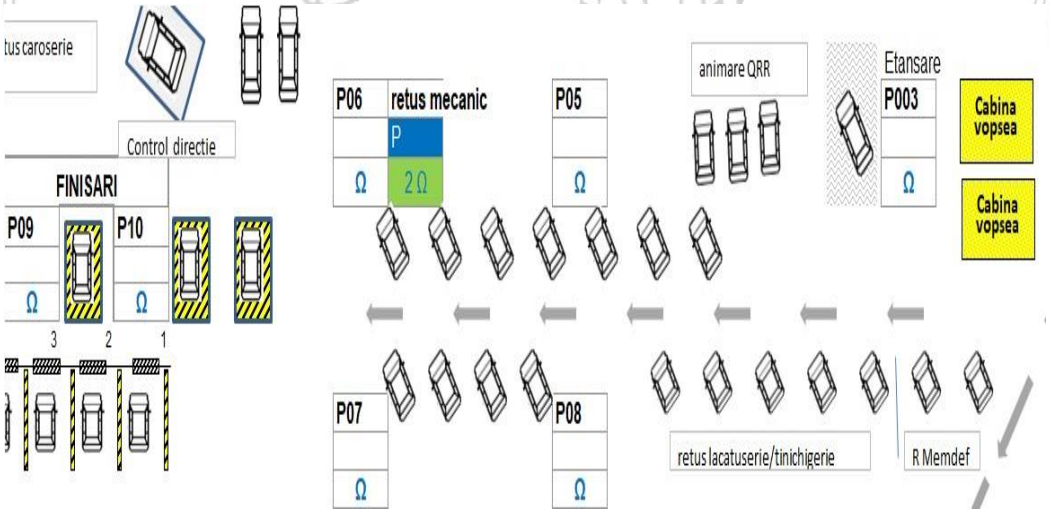

Fig. 17. Area for retouching [6]

In this space arrive all cars with defects of bodywork, paintwork, assembly and from suppliers, identified by the quality operators, according to the current standards. These defects could endanger the image of the manufacturer.

Because the space is relatively small, an area has been set up outside the department (car park) where defective cars wait to be retouched depending on the availability of internal seats. This solution is less favorable to the company because it generates additional costs.

3.2 Implementation of the "Check-Man Entity" procedure

Within the analyzed company, between 13 and 23 January 2020, 2795 vehicles have been manufactured, out of which 1118 vehicles with various defects, from bodywork, painting and assembly and from suppliers (fig. 18). These were identified by the quality operators.

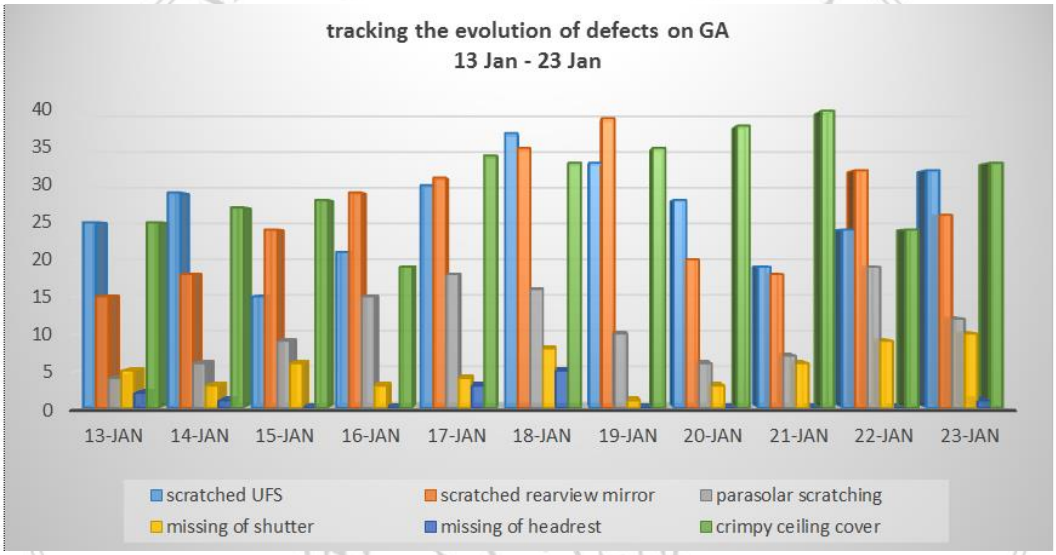

Fig. 18. Defects penalized *GA*

Out of the total of 1118 non-compliant units, 548 cars can be repaired with the help of qualified operators throughout the entire manufacturing flow, and the remaining 570 cars must be transferred to the retouch area because it requires a long time to repair.

Part of the defects, such as parasol scratching (122 units), missing of shutter (75 units), missing of headrest (15 units) and crimpy ceiling cover (336 units) require a short time to remedy if their detection is done in real time.

For this, it is proposed to implement a new working procedure, in accordance with the quality standards, a procedure called "Check-Man Entity". This procedure involves the training, in the field of internal and external quality standards, of the operators of the factory that deal with the verification and control of the different aspects of the vehicle. Thus, these operators will have much more complex knowledge about the quality of the manufactured product. By placing them

throughout the entire technological flow, any problem that arises can be solved in a much shorter time, without incurring additional costs, such as:

- payment of overtime to operators involved in remedying defects;
- costs of materials, electricity needed for the retouching;
- delaying deliveries to customers of vehicles;
- increasing the number of complaints from customers;
- increasing the stock with non-compliant cars.

The efficiency of the implementation of the "Check-Man Entity" procedure can be seen from figs. 19 – 20.

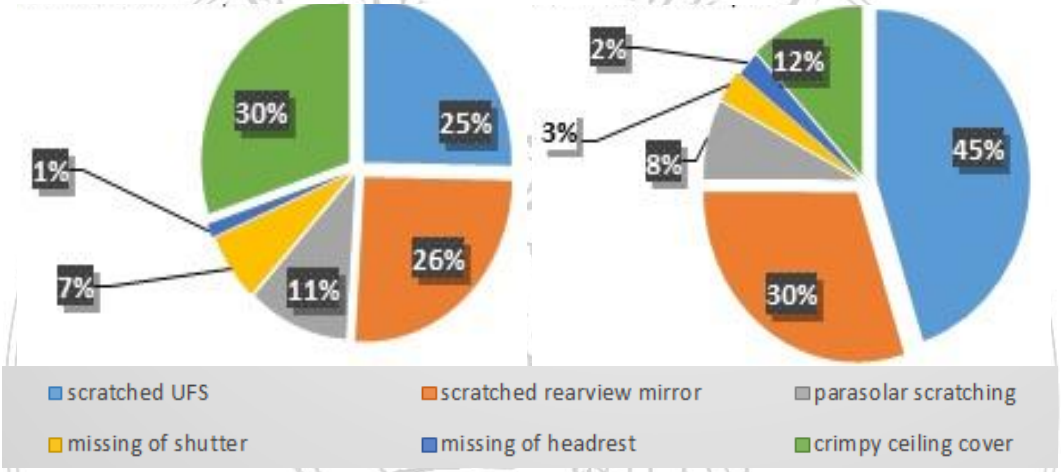

Fig. 19. Space allocated for retouching by types of defects 13 – 23 Jan.

Fig. 20. Space allocated to retouching after implementation procedure 3 – 14 Feb.

Between 3 and 14 February 2020, there is a significant decrease in the stock of vehicles aimed at retouching due to the defect of the crimpy ceiling cover. If between 13 and 23 January there were 336 units corresponding to a percentage of 30 % of the area allocated to retouching, between 3 and 14 February there is a decrease to 40 units (- 296 units), which represents a percentage of 12 % of the surface.

Another significant decrease is due to the sun-scratched defect, from 122 units between 13 and 23 January, with a percentage of 11% of the space, to 25 units (- 97 units) with a percentage of 8 % of the space occupied during 3 and 14 February.

The missing of a shutter defect contributes positively to the decrease of the stock: from 75 units, with a percentage of 7 % of the space on January 13 – 23, to 10 units (- 65 units), with a percentage of 3 % of the space allocated to retouching between February 3 and 14.

From the analysis of the three defects, we can observe an increase in the retouching space. If between 13 and 23 January, the three defects occupied 48% of the space allocated to remediation, between 3 and 14 February it decreased to 23 %, registering a gain of 25 % of space. This space can be used for defective cars that require a longer retouching time and cannot be remedied in the technological flow, without the need to store them in the car park allocated to retouching, such as "scratched left front door" and "scratched rearview mirror".

Between January 13 and 23, the scratched defect left front door (UFS) registered the figure of 283 units, with a percentage of 25 % of the space allocated for retouching, being necessary to store some vehicles in the car park, due to insufficient space. Between February 3 and 14, there was a decrease to 150 units and an increase in retouching space to 45 %.

The scratched rearview defect makes a positive contribution to the retouching area. Between 13 and 23 January, 287 units were registered, with a percentage of 26 % of the space allocated to retouching, and between 3 and 14 February, the number of occurrences decreases to 100 units, with a percentage of 30 % allocated to retouching space.

In conclusion, if between 13 and 23 January the number of vehicles heading to the retouching area was 1118 units, following the implementation of the new working procedure, between 3 and 14 February, there is a significant decrease, with 785 units on the same sample, that is, 40 cars / day in a period of two weeks.

Therefore, it can be stated that this working procedure, specific to internal quality procedures, has a high efficiency, compared to the previous period, when the manufacturing operators did not have the necessary information about the quality standards and the methods of their application.

The advantages offered by the "Check-Man Entity" are:

- reduction of the stock of motor vehicles with non-conformities directed to the car park;
- reduction of retouching costs and payment of operators performing this activity;
- removal of blockages in the retouching area;
- compliance with the delivery time of the finished product to customers;
- decrease in the number of complaints from customers;
- maintaining the image of the organization on the competitive market.

3.3 Resolving non-compliance ’’scratching left front door paint’’

In order to eliminate the defect scratched on the left front door (fig. 21), the causes of its appearance are analyzed. The study starts from the data previously presented in figs. 19 – 20.

Between 13 and 23 January, this defect was registered at 283 units and between 3 and 14 February, there was a decrease of 133 units compared to the previous period. This positive effect is attributed to the implementation of the "Check-Man Entity" procedure. This procedure helps to detect and resolve non-conformities in the technological flow, which leads to a decrease in stocks in the retouching area.

Fig. 21. Defective zone signaling

Fig. 22. Door conveyor (swing) [4]

The objective is to obtain zero vehicles with such non-conformities. For this, it is necessary to detect the cause of the defect. Following the information received from the “Check-Man” operators, it was found that the non-compliance occurred due to the damage of the rubber rollers on the balance that carries the equipped doors in the body mounting station (fig. 22).

In conclusion, the root cause of the defect is technological.

The rollers on the conveyor, which have the role of fixing the doors on the swing, are guaranteed to a number of *x* doors (established by each producer), after which it is necessary to replace them. The time and purchase price of these rolls is high. Therefore, another solution is proposed, with a very short and equally efficient solution time.

Fig. 23. Rubber protection

Fig. 24. Protection fixing area

The solution consists in sorting the rubber slides (the windows that come mounted on the windows) located in the area dedicated to scrap and sizing them to 15 cm

(fig. 23) to obtain rubber protections. They will be fixed in the area where the doors come in contact with the damaged rollers (fig. 24) of the door conveyor and will fulfill the role of protection for the paint on the doors.

In conclusion, the proposed solution to the problem has the following advantages:

- defect elimination;
- extending the duration of use of the rollers on the screed;
- rubber protection is reusable;
- recycling and reuse of waste;
- reducing the amount of materials used to perform retouching (repair);
- eliminating the risk of reaching a customer with a defective car.

Conclusions

The paper presents the stages of the painting process of a car body, the defects that may occur as a result of the painting process and the resolution of non-conformities that occur after assembling the painted parts in order to obtain the finished product that is the vehicle.

The study highlights both the connection and its intensity, between manufacturing and quality. Teamwork allows the implementation of the initiatives of each department and the identification of new opportunities in solving problems.

If the *Painting* department has delivered a car body with zero paint defects, it must also reach the final customer. This objective is constantly influenced by the involvement of all operators competing to achieve the finished product. Hence the idea of proposing and implementing a new working procedure in the quality management system, by training and teaching of manufacturing operators in a new entity under the name of "Check-Man", in strict compliance with quality standards.

The successful involvement of employees in achieving the objectives leads to the progress of the company and, implicitly, to maintaining or even raising the company's position on the competitive market. Aware of the fact that any activity with human participation presents the risk of malfunctions that generate anomalies, the managers of the organization carefully supervise all activities to prevent the occurrence of anomalies, to detect and treat them in time.

The advantages of implementing "Check-Man Entity" did not take long to appear. In a period of two weeks there is a significant decrease in non-compliant products, with 785 units out of the 1118 vehicles detected on the same sample that is 40 cars / day.

Recycling and reusing non-compliant items brings significant benefits to the business.

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