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OPTIMIZATION OF THE INDUSTRIAL PROCESS OF PAINTING PLASTIC BARS USING KAIZEN METHODOLOGY

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Abstract: *In recent years, Kaizen methodology has been widely used to improve the activities in the manufacturing systems. The improvements achieved by applying Kaizen are small, but at some point, evaluated over long periods are beneficial to organizations. In this regard this article provides optimization strategies by using Kaizen methodology in order to improve the painting process of the plastic parts (bars) and to ensure a growing in cadence from 67 vehicles/hour to 75 vehicles/hour. A real case study from a vehicle company is analyzed, new ideas to improve the quality of the painting product are provided and the financial impact of the improvement proposals is presented.*

Key words: *painting process, Kaizen, optimization, financial impact*.

1. INTRODUCTION

In the last years, due to increasing global competition, the companies have radically changed their manufacturing practices to improve their competitiveness. Many authors have written about the importance of *Kaizen* methodology. This paper reports the study of the Kaizen concept applied in a vehicle company. The concept *Kaizen costing* helps the factories to decrease production costs for existing products.

1.1. Related works

This section reviews the existing debates regarding *Kaizen* methodology. Pinto et al. [1] offered the main characteristics of kaizen and the requirements for continuous improvement success. Ascensão et al. [2] presented *Kaizen-Lean* actions in order to obtain an effective reduction of the existing impurities defect rate in the spray painting lines of MDF (medium density fiberboard) parts. Nhlabathi [3] studied and analyzed the cylinder preparation process and he reduced the identified waste using manufacturing kaizen tool. Rossini et al. [4] presented a new framework for guiding kaizen, applied in a case study and clearly defines project phases, roles and activities for each phase of the improvement process. Singh et al. [5] evaluated the performance of different elements of *Kaizen* in the manufacturing industry and presented real breakthroughs in saving cost. Chanda [6] investigated the relationship between Kaizen practices and improvement in operations performance and determined the influence of Kaizen practices on human resources outcomes and the challenges faced by companies in implementing Kaizen. Ackah et al. [7] showed that Kaizen had a significant impact on key performance indicators of the enterprises which adopted the techniques. They also observed significant differences in behavioral/process indicators between the treated firms and their counterparts that were not trained and had not adopted Kaizen. Modarress et al. [8] showed that adopting new target costing methods and financial practices using Kaizen costing and value-added analysis has helped to further lean manufacturing implementation.

Garg et al. [9] applied the Kaizen tool for reducing the cycle time of the assembly process with 14.16%, so that it follows the Takt Time of the process, and productivity was enhanced by 16.67%. Using Kaizen methodology, not only productivity enhancement and lead time reduction, other gains were also achieved such as throughput time reduction, increase in line capacity and on time delivery of the products.

1.2. The main goal and the structure of this paper

The purpose of this study is to describe the *Kaizen* costs method and to provide relevant improvements and decisions that would be useful to practitioners in the process of painting plastic bars. Our contribution consists in the quality improvement of the bars painting process, by using five Kaizen solutions, solutions which gave a growing in cadence from 67 vehicles/hour to 75 vehicles/hour.

The structure of this paper is as follows. The paper starts with a brief introduction by relating the motivation of the work, the related works and the main goal. Then, Section 2 presents the methodological approach for continuous improvement, called Kaizen methodology. In Section 3 are presented solutions for improving the painting process of the plastic bars. There are analyzed 5 cases of continuous improvements and the financial

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impact of the improvement proposals for the painting process is described. Finally, the conclusions and a general review of the research are provided.

2. CONTINUOUS IMPROVEMENTS – KAIZEN METHODOLOGY

Kaizen is the best method to improve manufacturing systems and is the ideal management system for low-resource organizations. Restructuring or reinventing a company can be destructive, costly and often dysfunctional. By applying kaizen in GEMBA, significant improvements are made, with low costs, in the essential business processes – production and services – and can be achieved as never before, major steps in customer satisfaction, quality, productivity and profitability. Kaizen Strategies aim to involve workers for multiple function area and level of organization in working together to address a problem or improve a particular process [9, 10].

The advantages of implementing the Kaizen concept:

- Implementation costs are low, because the Kaizen method makes better usage of existing resources and it does not require large investments in technology improvement.
- Staff development costs are lower than in other methods.
- Organizations in which the *Kaizen* method was implemented, remarkable results in the field of labor productivity, cost reduction and increased competitiveness have obtained.

The idea behind the Kaizen methodology is to maximize customer value while minimizing losses or in other words to create more customer value with fewer resources. The losses are any activity that adds time or cost to the production/delivery process without adding value. Kaizen organizations understand what value is for customers and focus their processes /activities to continually increase that value. At the same time, it identifies activities that do not bring value (losses) and minimizes/eliminates them [11, 12].

The most effective improvements where an immediate benefit is observed and the losses are eliminated:

- reducing manufacturing time – increasing product volumes;
- reducing costs – increasing the economic efficiency of the company
- improving the cleanliness of workstation, working conditions for workers – increasing the satisfaction of operators.

3. PROPOSED SOLUTIONS FOR IMPROVING THE PAINTING PROCESS OF THE PLASTIC BARS – CASE STUDY

In this paper, a real case study is analyzed, the painting process of the plastic bars of the Duster car body. The stages of the painting process of parts made of plastic materials are presented in Fig. 1.

This paper brings multiples continuous improvements realized in Dacia factory for a certain period. Through longitudinal observations, this paper provides five *Kaizen* case studies consisting of a series of innovations.

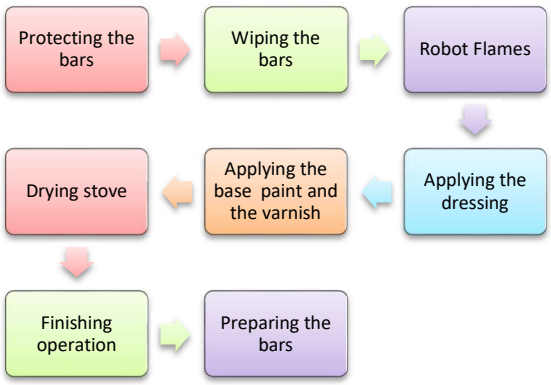

Fig. 1. Mapping the process of painting plastic parts – bars.

3.1. Case 1. The changing of the protection mode of the bars

Description of the problem. The protection of the bars to avoid gassing/spraying with paint during the painting process is done manually with waxed paper glued on the plastic area with adhesive tape. In order to ensure a painting cycle time for the robot cabins of 0.98 cm, a carousel with the manual operation is used. There are 7 operators/teamwork and the activity is divided into 3 teams, namely: 4 operators for the front bar and 3 operators for the rear bar (Fig. 2).

Proposed improvement. A proposed solution for this problem could be the replacement of the waxed paper currently used with an adhesive wrap resistant to high temperatures and without risk of ignition in the flame due to the fact that it sticks to the plastic (Fig.3).

The advantages of using adhesive wrap are:

- reducing fire risks;
- reducing the execution times by 25–40%;
- reducing the number of operators for the execution of operations.

Fig. 2. Front bar and rear bar.

Fig. 3. Improvement -front bar and rear bar.

Fig. 4. Working mode for the separation line.

3.2. Case 2 – Optimization of the working mode for the separation line

Description of the problem. The operation of applying 12 mm adhesive tape to delimit the separation line between the painted part and the unpainted part of the bar is done manually.

This process has advantages, but also disadvantages:

- it is a good process, but quite slow, the operation is done entirely manually;
- requires constant control, if the tape is positioned correctly at the edge; the operator must perform the operation at a constant speed between the part glued to the paper bar and the part unfolded from the roll;
- it is a critical operation on closed curves;
- the quality of the operation depends on the dexterity of the operator. If it does not have enough dexterity it can generate quality defects or there is a risk of not falling within the estimated execution time of the operation (Fig. 4).

Proposed improvement. For process optimization, it is recommended to use an applicator that reduces almost all the disadvantages of manual application. This applicator can be adapted to use a narrower self-adhesive tape, only 9 mm (compared to 12 mm) (Fig. 5).

The advantages obtained in the workflow are:

- facilitates the operation performed by the operator;

Fig. 5. Tape applicator.

Fig. 6. Improvement - Working mode for the separation line.

- reduces execution time;
- the removal of the tape reduces the risk of paint clumps;
- the elimination of the tape removal operation, before entering the bars in the oven, the chemical properties allow the passage through the oven without affecting the gluing on the bar (Fig. 6).

3.3. Case 3 – Automate bar cleaning before painting

Description of the problem. The operation of the chemical cleaning of the bars is performed manually in two stages:

- two operators blow manually and wipe the bars with cloths impregnated with isopropyl alcohol (surface rough wiping);
- an operator at the entrance to the painting booths wipes the bars with polyester pad impregnated with synthetic resins and mineral oil (preparation for painting).

The two coarse wiping operators have a cycle time of 0.96 cm, half of the activity is manual blowing using an air gun (48 cm) and the other half of the time is the wiping activity with the cloth to remove impurities (Fig. 7).

Proposed improvement. The proposed improvement consists in the creation of an automatic ionized air blowing booth for blowing bars before painting. The air blowing cabin is equipped with air introduction, automatic blowing by blowing ramps placed on its walls and extraction of polluting air through PLUUM filters (Fig. 8).

The advantage consists in elimination of a workstation (Fig. 9).

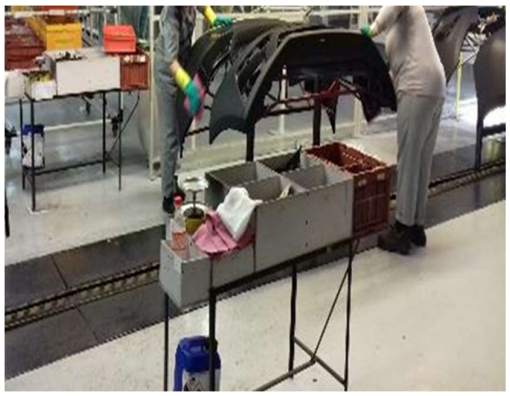

Fig. 7. Automatic bar cleaning.

Fig. 8. Air blowing cabin.

Fig. 9. Improvement –Automatic cleaning.

3.4. Case 4 – Bar conveyor optimization

Description of the problem. The problems are the feathers on the bar conveyor after the cleaning operations of the masts by hitting with the hammer to remove the paint layers resulting from the passages through the painting booths. No guardrail is installed to prevent distant paint blocks from falling into the area of the conveyor chains under the side metal guards (Fig. 10).

Proposed improvement. The proposed improvement is cutting the masts and replacing them during the week, during technological breaks, not only on Saturdays and Sundays.

Advantages:

- the masts are replaced directly on the conveyor without additional resources from the cleaning service.
- cleaning the poles loaded with paint is done by burning in the pyrolytic furnace and not by hitting with a hammer which leads to a complete sanitization (Fig. 11).

Fig. 10. Bar conveyor.

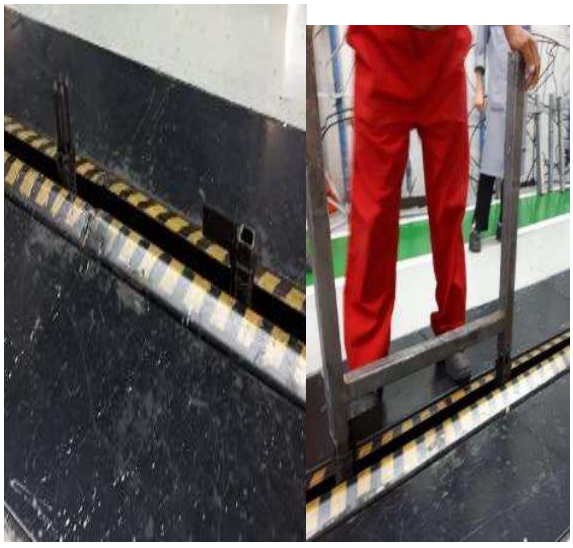

Fig. 11. Improvement – Bar conveyor.

3.5. Case 5 – Realization of the supervision plan for keeping the air system under control

Description of the problem. There is no standard for installation supervision regarding the air system in the painting booths. All recordings are made manually in the shift book.

Proposed improvement. The proposed improvement is carrying out visual management regarding the verification of the air current conformity at the painting booths and wire mounting at each entrance to the cabin with registration in the airspeed detection sheet.

The advantage of the improvement is the reduction of the number of repainted bars from 324 in January to 123 bars in May.

4. FINANCIAL IMPACT OF THE IMPROVEMENT PROPOSALS FOR THE PAINTING PROCESS OF THE PLASTIC PARTS

In the process of the protection bars, the following financial benefits are presented:

- reducing the number of operators. The annual cost pe operator c_o is 16 000 €. The number of operators per shift (o_s) is 2 and there are 3 shifts per day (n_s). After replacing the current process of bar protection, the gain (R_{no})is about of 96 000 €;

$$R_{no} = c_o \cdot s \cdot n_s = 16000 \cdot 2 \cdot 3 = 96000 \text{ €}, \quad (1)$$

- removal of 15 mm adhesive tape (R_{at}) from the process will achive about 30360 €/year. It is used 1 box (b) per shift, i.e. 3 boxes per day (d_b). The cost of a box with adhesive tape is c_b = 46 €, i.e. Average working days (w_d) per year is about 220 days.

$$R_{at} = b \cdot n_s \cdot c_b \cdot w_d =$$

$$= 1 \cdot 3 \cdot 46 \cdot 220 = 96\,000 \text{ €}, \quad (2)$$

For the separation line the gains are:

- improvement of the operation time, the operator must guide the applicator.
- quality improvement regarding the final result of the separation line delimitation operation.
- 13 cars with quality defect were found at the separation line. A retouch made for this type of defect with bar replacement and labor costs is on average 340 €, i.e. until May, 4 080 € were spent with the non-quality of the defect (Fig. 12).
- by replacing the adhesive tape (12 mm) with a durable tape (9 mm, which withstands the temperature of 80 °C), a workstation is reduced. This action brings the company a profit of 48 000 €/year.

If an automatic air cabin is introduced in the process, only one operator will remain for the rough removal of the bars and the amortization of the investment is made in a single year of manufacture as follows:

- cabin cost is 42 000 €;
- costs incurred for an operator are 16,000 €/year;
- they work in three shifts/week. The cost is 48000 €/year;
- the gain in the first year after investment amortization is 6 000 €.

The number of retouched bars per month for the "orange peel" defect due to improper operation of the bar conveyor decreased from 248 repainting in January to 122 repainted bars (Fig. 13).

The cost of repainting a bar is about 8.94 €. For 136 bars earned in May, multiplied by 8.94 €, for a repainted bar the gain is of 1215.84 € per month and for 12 months the gain is of 14 590 €.

Following the daily check of the ventilation at the painting booths and the connecting tunnels, the number of bars with quality defects due to the ventilation also decreased. Thus, from 324 bars repainted in May, the defects decreased to 123 in May.

These bars are also repainted to remove defects, i.e. 8.94 € price difference for the repainted bar. The economy between January and May is 1099.62 €/month

In one year the economy that can be reached is 13195.44 €/year.

All the actions carried out and the benefits produced are presented in Table 1.

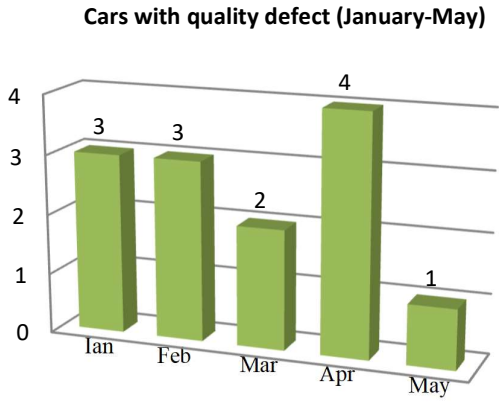

Fig. 12. Number of cars with defects.

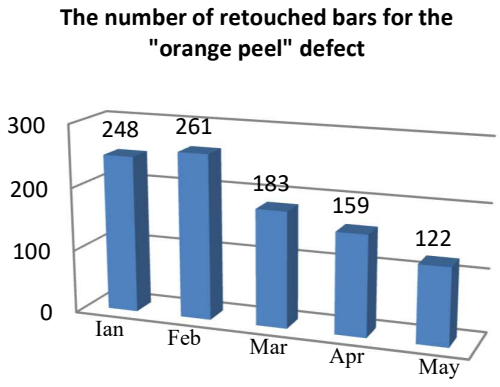

Fig. 13. Number of retouched bars (January-May).

Fb

Table 1

Actions and economy

No.	Actions	Gain/year
1.	The changing of the protection mode of the bars	126 360 €
2.	Optimization of the working mode for the separation line	52 080 €
3.	Automate bar cleaning before painting	48 000 €
4.	Bar conveyor optimization	14 590 €
5.	Realization of the supervision plan for keeping the air system under control	13 195 €
6.	Total	254 225 €

5. CONCLUSIONS

Continuously improving the overall performance of companies should be a permanent goal of organizations. Applying the principle of continuous improvement can lead to engaging a consistent approach across the organization for continuous performance improvement.

This paper is an improvement of the painting process in order to adapt to the following challenges: increasing market competence of car manufacturers, more and more complex manufacturing process, higher and higher quality requirements, cost reduction requirements are permanent. Five cases of continuous improvements were presented, bringing a total gain of 254 225 €/year to the factory. The improvements achieved by applying *Kaizen* are small, but in our case study ensure a growing in cadence from 67 vehicles/hour to 75 vehicles/hour.

For future work, various key will be considered, such as Lean tools and techniques, such as 5S, Total Productive Maintenance (TPM), Just-In-Time (JIT) Production System/ KANBAN, Cellular Manufacturing/ One Piece Flow System, Production Smoothening, Work Standardization, Six Sigma, Single Minute Exchange of Dies, Value Stream Mapping, in order to reduce wastes and to increase profit and productivity of industrial companies.

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REFERENCES

[1] J.L.Q.Pinto, J. C.O.Matias, C. Pimentel, S.G. Azevedo, and K. Govindan, *Lean Manufacturing and Kaizen in Just in Time Factory*, Springer, Cham, pp. 5–24, 2018.

[2] T. Ascensão, M.T. Pereira, and F.J.G. Silva, *Dust in lacquer, evidence of deviation of process in production lines for spray painting*, Procedia Manufacturing, Vol.11, 2017, pp. 671–678.

[3] G.S.Nhlabathi,*Analysis and reduction of waste in the work process using manufacturing kaizen tool: a case study*, Doctoral dissertation, University of Johannesburg, 2014.

[4] M. Rossini, F. Audino, F. Costa, F.D. Cifone, K. Kundu, andA. Portioli-Staudacher, *Extending lean frontiers: a Kaizen case study in an Italian MTO manufacturing company*, The International Journal of Advanced Manufacturing Technology, Vol.104, No. 5–8,2019, pp. 1869–1888.

[5] J. Singh and H. Singh, *Enigma of Kaizen approach in manufacturing industry of Northern India–a case study*, International Journal of Quality & Reliability Management, 2018.

[6] M.D. Chanda, *The study of the relationship between Kaizen practices and operations' performance improvement in Zambian manufacturing companies*, 2017.

[7] C.G.Ackah, R.Atta-Ankomah, and J.A. Kubi, *Management Practices and Performance Improvement in Manufacturing Enterprises: The Case of Kaizen Adoption in Ghana*,Workers, Managers, Productivity, pp. 269–292, Palgrave Macmillan, Singapore, 2020.

[8] B. Modarress, A Ansari, andD.L. Lockwood, *Kaizen costing for lean manufacturing: a case study,* International Journal of Production Research, Vol. 43,No. 9,2005, pp. 1751–1760.

[9] D. Garg, *Implementing Lean Manufacturing in an Auto Industry using Work Study and Kaizen*, 2018.

[10] M. Palgrave, M. Imai, G. Kaizen, *O abordare practică cu costuri reduse, a managementului*, [A practical approach of management with low-cost] Finmedia Ed., 2007.

[11] D.Marincas, D.Abaitancei, *Fabricarea și repararea autovehiculelor rutiere* [Manufacture and repair of road vehicles], Didactică și Pedagogica Ed., Bucharest, 1982.

[12] I. Soare, F. Tanase, E. Baciu, and N. Bejan, *Tehnologia reparării autovehiculelor* [Vehicle repair technology], Didactica și Pedagogică Ed., Bucharest, 1983.