IMPLEMENTING THE ”KAIZEN IN 2 DAYS” METHOD IN AN AUTOMOTIVE DYEING PRODUCTION LINE

Gheorghe-Marius VOICULESCU [1], Emilia BĂLAN [2]

Rezumat. *Kaizen este o activitate zilnică desfășurată în scopul îmbunătățirii productivității într-o linie de producție. La proiectele Kaizen pot participa angajații de la toate nivelurile unei companii. Metodologia Kaizen include executarea de schimbări și monitorizarea rezultatelor, apoi ajustarea activităților în linia de producție. Linia analizată este de vopsitorie auto, formată din zonele cataforeză, aplicare mastic și aplicare apret, bază și lac. În lucrare sunt prezentate procedurile implementate în linia de vopsitorie auto pentru mai multe variante de proiecte Kaizen derulate timp de două zile în scopul reducerii numărului de operatori și a creșterii gradului de utilizare a roboților în linia de vopsitorie. Totodată s-a constatat creșterea calității produsului și micșorarea consumului de materie primă. Implementarea proiectelor Kaizen a contribuit la creșterea competențelor operatorilor și la modificarea fluxului de producție.*

Abstract. *Kaizen is a daily activity carried out to improve productivity in a production line. Employees from all levels of a company can participate in Kaizen projects. The Kaizen methodology involves executing changes and monitoring the results, then adjusting activities in the production line. The analysed line is an automotive dyeing production line, consisting of the areas of cataphoresis, mastic application and primer application, base and varnish. The paper presents the procedures implemented in the auto dyeing production line for several variants of Kaizen projects carried out over two days in order to reduce the number of operators and increase the degree of use of robots in the dyeing production line. At the same time, an increase in product quality and a decrease in raw material consumption were observed. The implementation of Kaizen projects helped increase the skills of operators and change the production flow.*

Keywords: Kaizen in 2 days, dyeing production line, examples of procedures, robots percentage

1. Introduction

Kaizen (改善, a Japanese word meaning “continuous improvement”) is a Japanese philosophy that focuses on continuous improvement in all aspects of life. It has also begun to be applied in the business environment, and Kaizen activities continuously improve all business functions, from production to management and from the CEO to workers on the production line [1].

The Kaizen format can be carried out individually, by each operator, in the form of a suggestion system or in small or large groups of operators [2].

[1]Master student, Faculty of Industrial Engineering and Robotics, Robots and Production Systems Department, POLITEHNICA Bucharest, Romania (e-mail: marius.voiculescu@dacia.com).
[2]Assoc. Prof., PhD Eng., Faculty of Industrial Engineering and Robotics, Robots and Production Systems Department, POLITEHNICA Bucharest, Romania (e-mail: emilia.balan@upb.ro).

The Kaizen methodology involves the execution of activities that produce changes in the workplace, monitoring the results obtained and then adopting and standardizing the new work skills. Large-scale planning and extensive projects schedules are replaced by smaller experiments that can be quickly adapted to new requirements [3, 4].

“Kaizen in 2 days” is a method of improving the workplace that requires a sustained activity of a work group and which needs 2 days to put the improvement solutions into practice.

Within the enterprises, for the continuous improvement of its performance and for the increase of the quality of the produced products, different solutions characterized by a series of activities were proposed. The grouping of activities in order to achieve certain goals has transformed over time into distinct methods, with characteristic particularities, specific to each industry.

In the automotive industry, among the most frequently used methods are: the 5S method, the Value of Merit, Just in Time, Total Productive Maintenance, Kanban method, method 5 “why”, the 4 principles of motion economy [3, 5, 6].

The Kaizen activity report is the form that is completed at the time of completion of the Kaizen site, in which all the details and actions that were taken to achieve the improvement will be specified, the initial situation and the final situation will be presented. This report will be signed by all the people, the managers of the sector where the Kaizen site was built, but also by the people responsible for the security of the perimeter, the quality of the products manufactured in this process and the other functions involved in its development or its possible consequences. This report will also be accompanied by the MPPC (Continuous Product Process Change) sheet, which will also be signed and assumed by the support functions responsible for this change. These sheets will be archived to be able to justify and present the validation of these processes in case of possible audits [7].

2. Description of the automotive dyeing department

The automotive dyeing department is one of the most complex and sensitive departments out of the four: Pressing, Bodywork, Dyeing and General Assembly, through which a car passes from stamping the metal sheet in the Pressing department, to mounting and assembling them by spot welding or with CO_2 cords in the Bodywork department and the assembly of parts in the General Assembly department.

The automotive dyeing department includes a diversity of processes and parameters that must be strictly maintained throughout the production flow, any small deviation of these parameters or processes being immediately seen in the quality and durability of the paint layers.

At a glance from the outside, the dyeing department is the area where the sheet is dyed in a certain color. In reality, inside this department, a lot of processes and procedures are carried out that make the layers of paint, and not only, ensure both the aesthetic role, noticed at first sight by the customer, as well as the roles of tightness of the bodywork and durability against corrosion.

Next, both the flow and manufacturing processes within this department, as well as the problems that led to the start of some Kaizen sites, will be presented in detail. Since in this department the operations are carried out both manually and robotically, the goal of the implementation of the "Kaizen in 2 days" sites was to reduce the number of operators and increase the degree of robotization of the production line.

Due to the specificity of this department, it is the largest consumer both of electricity used in the cooling and air conditioning systems of the dyeing lines, but also in terms of natural gas consumption used in the burners of all ovens for drying the layers applied to the bodywork. It is considered that the dyeing department consumes approximately 80% of the amount of electricity and natural gas used on the entire platform of the car factory.

2.1. **Areas/workshops of the Dyeing Department**

Usually, all the automotive dyeing departments are divided into three large distinct areas called workshops, within which the activity is completely different. In the first part of these departments, we will find the treatment area of the metal sheet surface and its priming (cataphoresis in specific technical terms). This process is the most important because it ensures the anti-corrosion protection of the car body.

The second area is the application area of mastic and hot-melt (thermofusible) shutters to achieve both the tightness of the car bodies and the coatings against hitting damage on the car bodies on their lower side. The last area, the one with the greatest visual impact for the customer, is the primer, paint and varnish application area, the area that gives the shine and color requested by the customer.

Fig. 1 shows the scheme of an automotive dyeing flow, from the entrance of the Bodywork department to the exit to the General Assembly department, specific to the company where the case study was carried out. The first area is colored in yellow; the second one is colored in green and the third in blue.

In each of these areas, the operations performed, their sequence and importance were analyzed. Also, the problems that appear in the production flow were identified and for which "Kaizen in 2 days" sites were started.

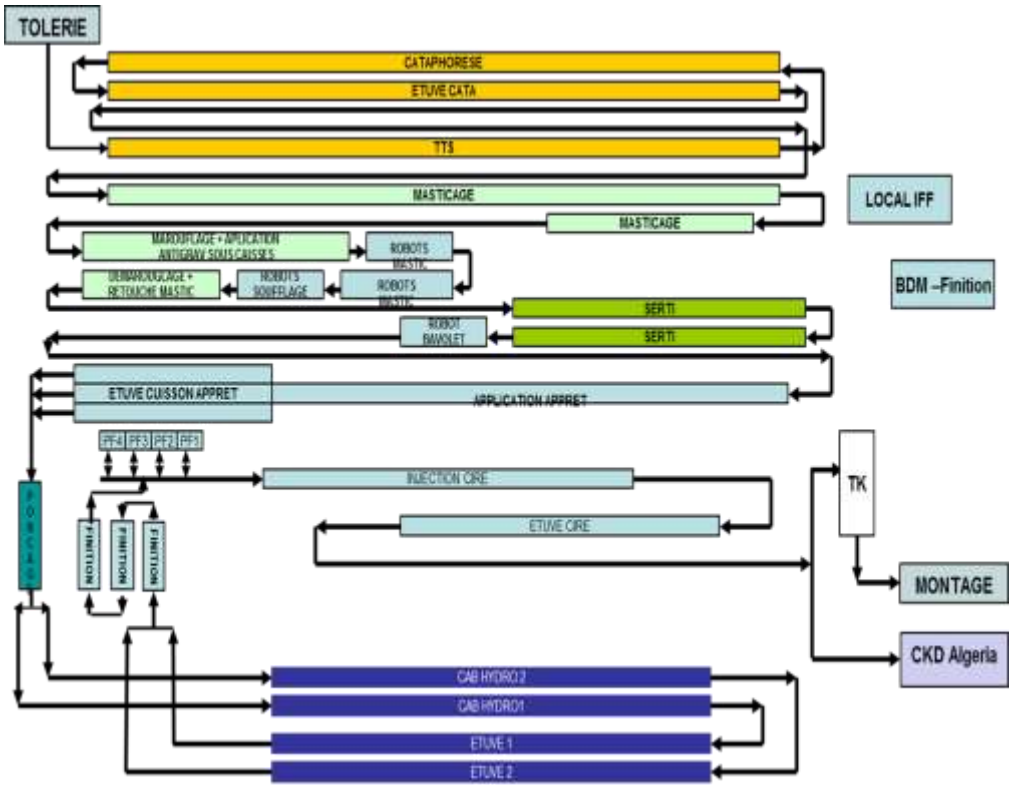

Fig. 1. The scheme of an automotive dyeing flow.

3. “Kaizen in 2 days” site in UEL Sealing

For the beginning, the analysis of compliance with the 4 motion principles was carried out for the entire mastic application area on the inside of the car body. 16 workstations out of the 24 existing in UEL were monitored. It was identified that each operator is forced to open and close at least one car door to apply the mastic cords inside the bodywork. This leads to waste of time. A loss of 6 seconds was estimated for each workstation separately, for each car body.

This first gap which would lead to a loss of 96 seconds, i.e. approximately 1.5 workstations, cannot be eliminated or improved due to the production flow and the constraints of the production systems and the bodywork, the doors cannot be left open on the production flow.

Another problem that competes with exceeding the cycle time is due to the way in which the mastic cords are applied. On a half of the bodywork, the mastic is applied from a distance that facilitates this activity, but it is done through several successive passes. Therefore, several cords of mastic are applied, wasting both time and a quantity of mastic.

Due to the multiple applications of mastic cords, quality risks were also identified regarding the impossibility of mounting parts or making it difficult to carry out operations in the General Assembly department.

At the same time, the analysis carried out in the area shows that the operator performs, due to the difficulty of the activity, a much smaller number of operations compared to the DST (Direct Standard Time) transmitted by the engineering department, a fact that leads to a non-performance of the mastic line.

Analyzing the identified problems and balancing the large number of mastic application workstations inside the car body and the small amount of operations that can be performed by the operator due to the constraints of the production flow, the decision was taken to send the file, with all mastic application FOPs (Process Operations File) made, to the purchasing department in order to obtain a price offer for the implementation of mastic application operations in a robotic process. Also, the price of the amount of additional applied mastic and the quality problems that may arise were also taken into account.

This decision to send the file, with the request for the implementation of some robotic cells for the application of mastic inside the car body and in the engine and trunk compartments, to the purchasing department came about as a result of the impossibility of taking actions to improve the cycle time and the quality of the operations in that area. Also, the changes made to the other dyeing departments by using the robotic system in these areas were considered.

Following the analysis of the mastic cord application requirements specified in the FOPs submitted in the task notebooks, 2 of the approved suppliers submitted the price offers and the changes that will appear regarding the fulfillment of the specified requirements.

Based on the difference in price and quality, a supplier was chosen who can carry out the work of implementing 3 robotic cells, with 2 robots each, with 7 axes in each of the robotic cells, equipped with a system for checking the car body position and recalibrating the trajectories in case of deviations, at a price of 1000 KEuro.

In order to be able to start the case for the purchase of these robots, a decision must be made regarding the possibility of amortizing this investment within the maximum term of 12 months. For the amortization calculation, the company that implements these robotic cells was asked to accurately specify the amount of mastic applicable with them, in order to then analyze in the field the number of mastic application workstation in the robotic system that can be won.

Following the result of the specifications, the supplier assured the company that it can take over a percentage of mastic cords in the robotic system with a DST of 12

workstations, so in the first phase the direct savings would be 12 workstations. In addition to this savings, the supplier has committed to reducing the amount of mastic by 10%, 300 g/car, due to the precision with which these robots apply the mastic cords.

Performing the economic calculation of investment amortization, we can say that the value of the savings guaranteed by the supplier would be the following:

- 12 workstations × 65 Keuro (annual price related to the salaries of one workstation) = 780 Keuro annually.
- 10% of the mastic percentage related to the 12 workstations = 0.3 kg × 350000 cars annually × 4 euro/kg = 420 Keuro annually.

So, the result of the annual savings guaranteed by the supplier and engineering department is:

- 780 Keuro + 420 Keuro = 1200 Keuro, compared to 1000 Keuro investment cost.

Considering this economic calculation, the project for the implementation of the three robotic cells for the application of mastic cords inside the bodywork and engine compartment, fulfilled the amortization requirement in a maximum of 12 months, and the administration gave its approval for the realization of this investment.

In Fig. 2, some pictures of the mastic application area are presented, in which it is clearly seen that the doors cannot stay open due to the mastic supply hoses, the positioning of the mastic cords and the non-ergonomic position of the operators when applying the mastic in a manual process.

Fig. 2. Mastic application area in manual process.
a. Positioning of mastic supply hoses **b.** The non-ergonomic position of the operators **c.** Positioning of mastic cords

In Fig. 3 can be seen the thickness of the mastic cords applied in a manual process, the consumption of which the supplier considers will be improved by 10%.

Fig. 3. Mastic cords applied in a manual process.

a. Bodywork; **b.** Trunk compartment.

After a period of 12 weeks, during which the supplier implemented the 6 mastic cord application robots in the manufacturing line, the supplier began the operators training period by commissioning and handing over to the manufacturing and maintenance departments. Apart from the advantage of reducing the amount of mastic, the implemented robots have also improved the quality level of the cords and their position. This is due to the innovative vizio camera system (Security & Surveillance Video Equipment), type ISRA (technologies for industrial image processing - machine vision), a system that photographs the reference points of the body's coordinates and is able to make small adjustments to the robots' trajectories or stop the production line if the deviations are too large.

In Fig. 4,a it can be seen the positioning of the vizio and ISRA cameras in the entrance area of the robotic cell, the second picture shows the interface of the program for checking and comparing the referential holes of the car body, and in the third picture it is the view from the manufacturing line of the robots in the "home" position or waiting position.

Fig. 4. The robotic cell.

a. Vizio cameras; **b.** Program interface **c.** Robots on "home" and waiting position.

Fig. 5 shows the robots at the time of applying the mastic cords in the engine compartment area.

Fig. 5. Robots applying mastic cords in the engine compartment area.
a. Robot at work; **b.** Robot at rest.

It should be mentioned that these robots need to have the doors of the car open at the time of application, because the size and the working space do not allow them to penetrate through the area of the side windows and the windshield.

3.1. The profit obtained with the help of the Kaizen site with investment in UEL Sealing

Fig. 6 presented the initial version in which we had 24 workstations in which the mastic application process was a manual one.

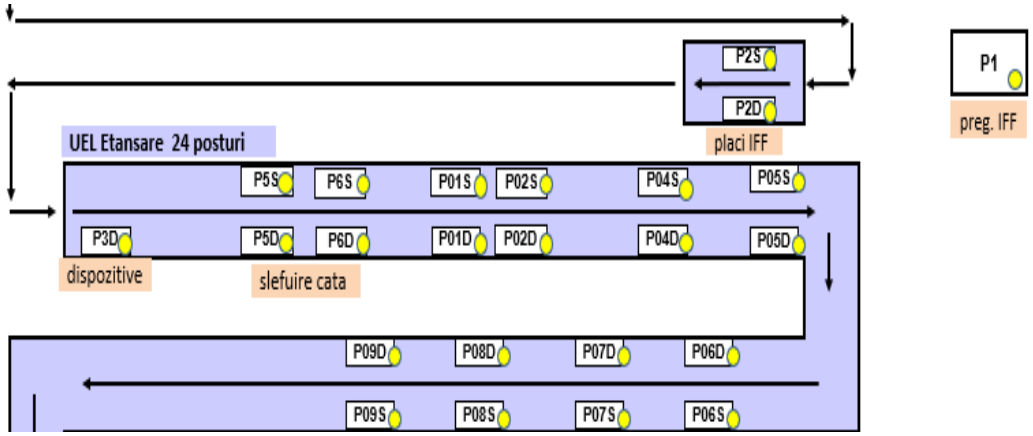

Fig. 6. The UEL Sealing with manual mastic application process.

Fig. 7 presents the final situation after the realization of the Kaizen site with investments of 1000 Keuro and an annual profit of 1200 Keuro, implicitly the reduction of several 12 mastic application workstations.

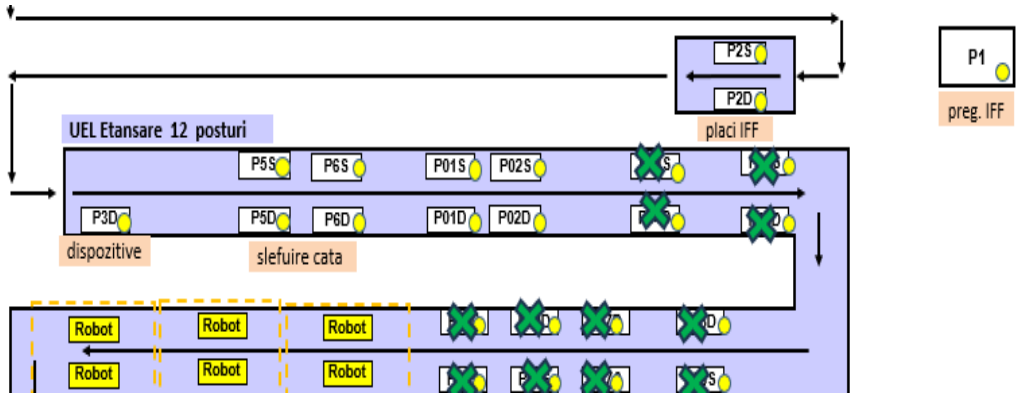

Fig. 7. The UEL Sealing with robotic cell process for mastic application.

As a conclusion of this Kaizen site: it is one made with funds, financial resources, so it falls into the area of Kaizen sites with investment; it is put into practice due to its amortization in less than 12 months by obtaining substantial savings both in terms of the suppression of several 12 workstations as well as the reduction of the amount of mastic used by 10%.

This type of Kaizen site requires a much longer time for implementation, because when any work with investment is carried out, it must be analyzed, and subjected to the decision of compliance or an amortization deadline set by the company. And last, but not least, especially in the case of the development or implementation of robotic cells, the execution time is high due to the complexity of the acquisition, assembly and production of these production systems.

At the same time, as an advantage for the entire dyeing department is the increase in the robotized percentage from 40% to 48% by taking over the activity in automatic mode.

4. "Kaizen in 2 days" site in UEL Soundproofing

The procedure was the same as at the previously presented Kaizen site, but with small differences, because in this UEL there are also robotic processes that were checked by the operators of the Kaizen site. For robotic or automated processes, the degree of their loading or the level of inactivity is checked.

On the layout of this UEL, inactivity was identified both in the 4 underbody mastic application workstations and in the extruded, sprayed and coatings against hitting damage mastic application robots in the area under the bodywork.

Taking into account that the total level of inactivity of the 4 workstations dedicated to the application of mastic under the bodywork did not reach the value of 1 minute necessary to suppress one of them, and in that area there is no longer the possibility of bringing other operations to load these workstations, it was

proposed to carry out the analysis of the transfer of mastic cords in a robotic process, because these cells had capacity as well as cycle time.

Following the analysis of the workstation of the manually applied mastic cords and the possibility of application with the existing robots, it was concluded that they have accessibility to apply these mastic cords. These were not introduced in the robotic process from the project phase when the old project was started with another provider company, due to the complexity of realizing the trajectories of these mastic cords.

In Fig. 8 it can be seen a detail with two of the robots that apply mastic under the bodywork, but also with an installation manager who programs the trajectory of a robot.

Fig. 15. Applying mastic under the bodywork.

a. with two robots; **b.** programming of robot trajectories.

Taking into account the fact that the plant managers serving these robots had been trained at the time of the implementation of the robotic cells, to intervene and modify the trajectories of the mastic applying robots, but had not been allowed to do this, the decision was made to try in the first week-end to change the trajectory of a robot in order to try the eventual introduction of a mastic cord from the manual process to the robotic one.

Having favorable results from the first change, the decision was made to encourage the installation managers to make changes to the robot trajectories in each weekend with the aim of making robot loading and unloading manual workstations more reliable.

In a period of 6 weeks, the installation managers, being morally supported and continuously encouraged to try to modify the trajectories, developed their modification skills and managed to take over the entire activity of 2 mastic application workstations under the bodywork by realizing the robots' trajectories.

In addition, compared to this gain of the 2 workstations, the biggest benefit was that of the professional development of the installation managers with the aim of immediate intervention on the robot trajectories in case of errors and the realization, internally, of all the robot trajectories that apply mastic under the bodywork.

4.1. The profit obtained with the help of the Kaizen site without investments, but with professional development, in UEL Soundproofing

Fig. 9 presents the initial version of the UEL Soundproofing in which both the robotic cells had no load and the operators from P06S/D workstation.

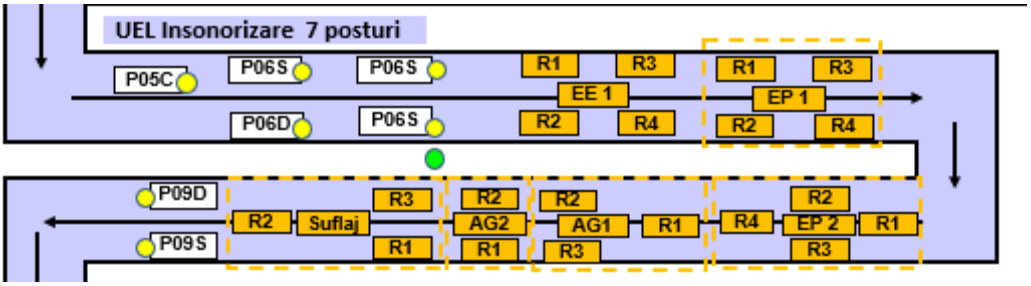

Fig. 9. The UEL Soundproofing initial version.

After taking over the operations from the PO6S/D workstation in a robotic process, the profit of the two workstations was realized, but also an increase in the degree of robotization from 48% to 50% related to the introduction of new operations from the manual process to the robotic process. Fig. 10 presents the final version of the UEL Soundproofing.

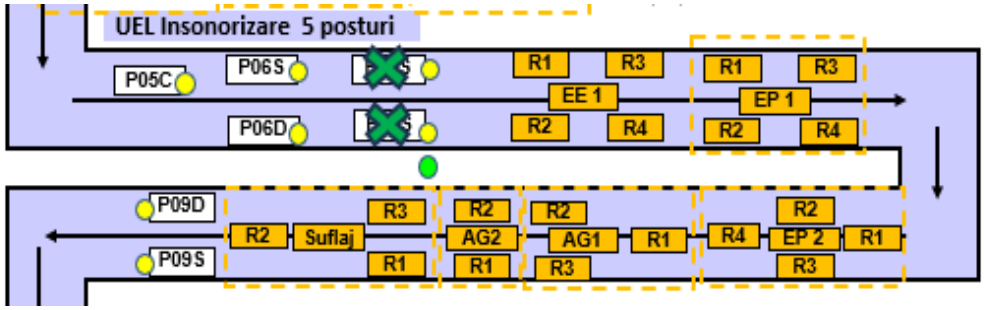

Fig. 10. The UEL Soundproofing final version.

In addition to the gains obtained related to 2 workstations and the 2% degree of robotization, through the implementation of the Kaizen site without investments, but with professional development, it was concluded that the two UELs Sealing and Soundproofing can be unified resulting into the benefit of 1 workstation of SUEL (Headman of Elementary Unit of Labor). Because there are only 5 workstations left in the UEL Soundproofing and an installation manager who is

already autonomous, and there are 12 workstations left in the UEL Sealing, a new UEL Sealing has been formed, which will have a number of 17 workstations in its composition and an installation manager.

This type of action to unify UELs to obtain 1 workstation of SUEL as profit, can fit into the Kaizen site through reorganization without investment. Fig. 11 presents the new UEL Sealing with the active and suppressed workstations.

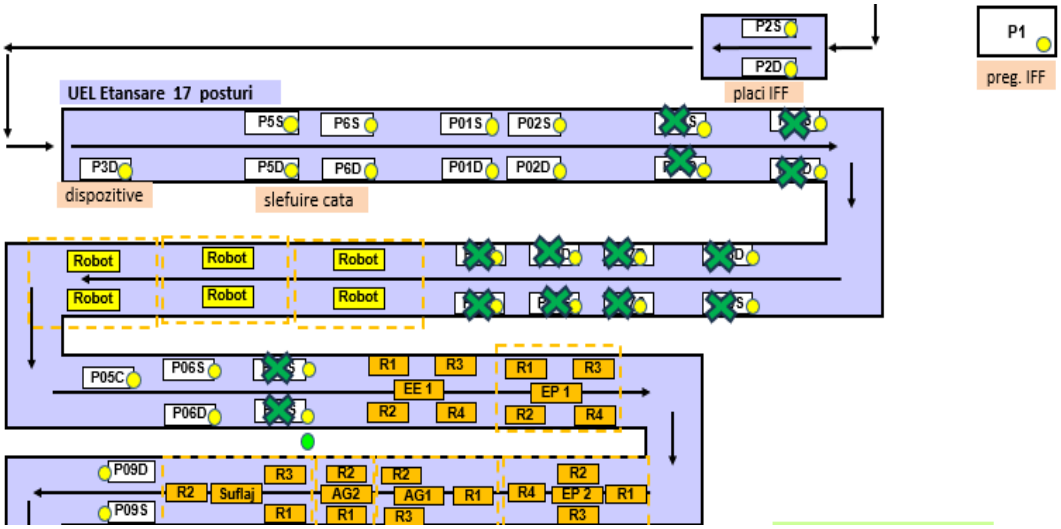

Fig. 11. The new UEL Sealing.

5. “Kaizen in 2 days” site in UEL Stripping / Shutters

Considering that the entire production line of strippers and shutters is a manual one, the analysis of this production line by the Kaizen team focused on the identification of unnecessary time and non-compliance with the 4 principles of motion economy.

From the start, an important problem was identified in the last 8 workstations of UEL P11/P12/P13/P14, both left and right; the workstations are conditioned by the table provided with “stop and go”, because here pneumatic grippers are used to lift the front hood and rear hood.

Due to the use of pneumatic grippers and the time lost in these workstations for the “stop and go” conveyor belt, it was concluded that each of these 8 workstations waits for 12 seconds both at the car entrance and at the car exit, and, in addition, the 4 workstations which are in the area of the front hood and the rear hood, waits for approximately 18 seconds to raise and lower the hood.

So, with a quick calculation we have 12 seconds × 8 workstations = 96 seconds, and 18 seconds × 4 workstations = 72 seconds. If the conveyor belt were scrolling,

96 + 72 = 168 seconds would be saved, which translates into a profit of 3 seats in the case of not using "stop and go" tables.

For the table with "stop and go" there was no solution at the moment because it was constrained by the hood gripper; if the gripper had been transferred to another workstation or stopped, all the lost time would have been won. In Fig. 12 it can be seen the rear hood gripper.

Fig. 12. The rear hood gripper.

Analyzing in detail, it was noticed that upstream both the front hood and the rear hood are kept open by using a hook to keep the elements open, the only problem with it is that the ergonomic position was not like the gripper. In Fig. 13 it can be seen a hood holding hook in the wax line.

Fig. 13. A hood holding hook in the wax line.

Through minimal intervention, the geometry of the hook was modified to hold the rear hood to simulate the height of the "stop and go" workstation line. After completing the hook modification operations, only 4 of the 8 workstations were

transferred to the striping line, the other 4 workstations no longer being loaded. In Fig. 14 it can be seen the modified hook.

Fig. 14. The modified hook.

5.1. The profit obtained with the help of the Kaizen site, of machine modification without investment and reorganizing of workstations in UEL Soundproofing

Fig. 15 presents the UEL scheme before the start of the Kaizen site, where this workshop was served by 24 manufacturing workstations and 1 logistics workstation.

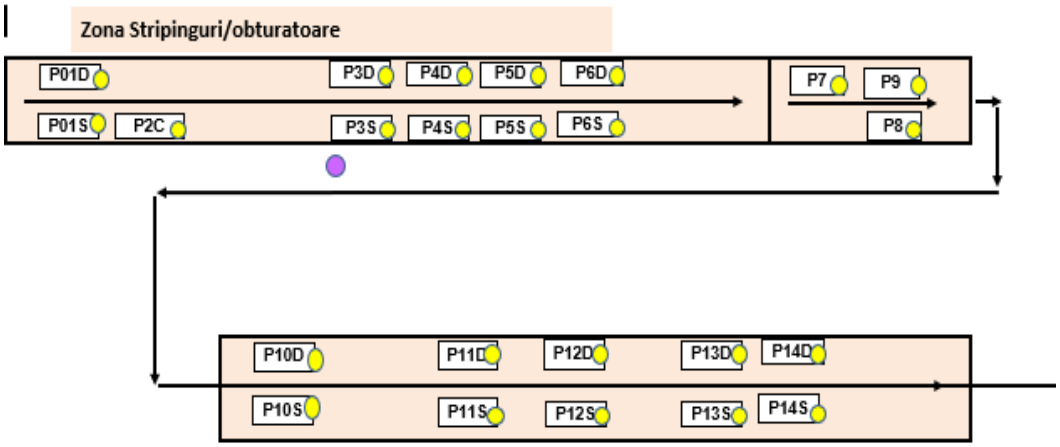

Fig. 15. The UEL Soundproofing scheme before the start of the Kaizen site.

Fig. 16 presents the scheme of the UEL after the implementation of the Kaizen site in which the rear hood support equipment was modified, without investment; then the operations were reorganized by moving them to the rhythm area of the scrolling conveyor belt, helping us with hook and thus eliminating dead times.

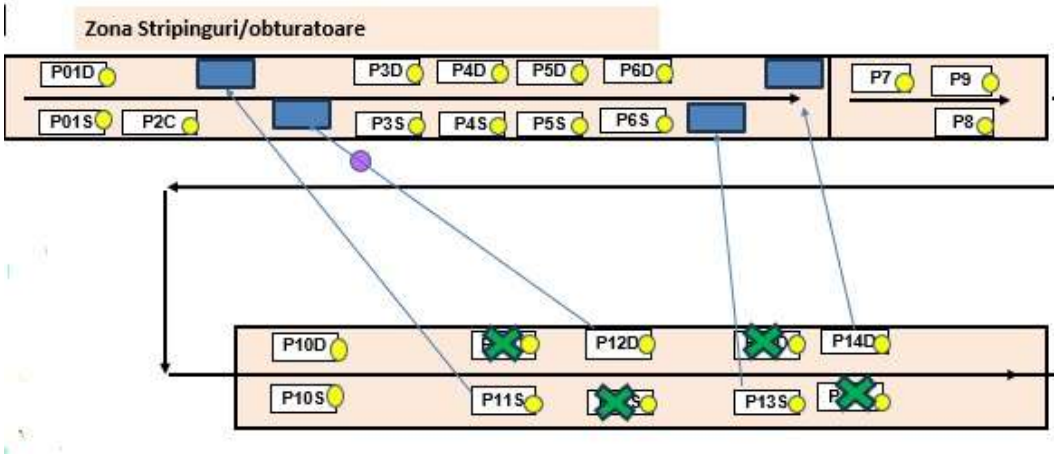

Fig. 16. The UEL Soundproofing scheme after the implementation of the Kaizen site.

Through the realization of this Kaizen site, 4 workstations were won, and the other workstations remaining in the "stop and go" area were transferred to the line and loaded accordingly.

This type of Kaizen site, considering that the systems production has been modified, but, in its own regime, falls under Kaizen without investments with process modification.

Conclusions

"Kaizen in 2 days" is a method of improving the workplace that requires a sustained activity of a work group, and which needs 2 days to put the improvement solutions into practice. The purpose of the implementation of the "Kaizen in 2 days" sites was to reduce the number of operators and increase the degree of robotization of the dyeing production line.

The Kaizen site in UEL Sealing is one made with funds, financial resources, so it falls into the area of Kaizen sites with investments; it is put into practice due to its amortization in less than 12 months by obtaining substantial savings both in terms of the suppression of a number of 12 workstations as well as the reduction of the amount of mastic used by 10%. At the same time, as an advantage for the entire dyeing department is the increase in the robotized percentage from 40% to 48% by taking over the activity in automatic mode.

The Kaizen site in UEL Soundproofing is one made without investments, but with professional development. After taking over the operations from the PO6S/D workstation in a robotic process, the profit of two workstations was realized, but also an increase in the degree of robotization from 48% to 50% related to the introduction of new operations from the manual process to the robotic process.

The Kaizen site in UEL Stripping/Shutters is one made without investments, but with process modification in its own regime: 4 workstations were won, and the other workstations remaining in the “stop and go” area were transferred to the line and loaded accordingly.

The implementation of Kaizen projects helped increase the skills of operators and change the production flow. At the same time, an increase in product quality and a decrease in raw material consumption were observed.

Abbreviations

UEL - Elementary Unit of Labor;
DST - Direct Standard Time
FOP - Process Operations File;
ISRA - Technologies for industrial image processing (machine vision);
SUEL - Headman of Elementary Unit of Labor.

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