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THE PRACTICAL APPLICATION OF TPM PRINCIPLES IN THE CASE OF AN ELECTROSTATIC PAINTING DEPARTMENT

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Abstract: *The central theme of this paper is to analyze a processes from an industrial company and to find resources to improve them in order to increase their quality as well as to achieve products quality. One of the questions addressed and tried to find solutions in this paper is "How could the principles / methods / means used in Total Productive Maintenance (TPM) be applied in order to improve the electrostatic painting process and implicitly the quality of the results and overall elevators?" For this, a cause effect diagram is used and the solutions found to eliminate the causes are summarized in a series of measures for improvement in the directions of four of the pillars of the TPM.*

Key words: *Total Productive Maintenance (TPM), continuous improvement, cause effect diagram, 5S, maintenance quality.*

1. INTRODUCTION

Increasing customer satisfaction and timely delivery of orders considering the risks and opportunities associated with the economic context and its objectives are desirable of any company regardless of the type of product offered.

Determining ways of improvement that are consistent with achieving the regulations imposed by quality management standards is and will always be an essential problem that we can say that it never ends, the link between quality, management and improvements is emphasised for example in [1-3].

Companies must constantly change, innovate, keep up with competition, market, and customer demands and for example, if at some point a company meets all the requirements of a quality management standard, tomorrow, under new conditions, it maybe that the requirements of the standard may not be fully met, so that a permanent update and continuous improvement efforts are necessary.

The culture for removing the problems appearance - and not solving them immediately when they occur, which involves significant additional costs - is part of a general approach of continuous improvement and elimination of production losses.

In this respect, there are recognized the positive effects that total productive maintenance (acronym TPM) applied within a company, documented by the specialized literature are e.g. the important role of maintenance and good trained employees in production systems - design and the development process of production systems is demonstrated in [4], higher quality of products and processes [5], fewer defects, loss reduction [2,6], improvements in overall equipment effectiveness [6] less unplanned maintenance and equipment downtime [2,6], lower manufacturing costs [7], workplace safety, improved employee satisfaction [8]. TPM implementation in SME's are analysed in literature [7,9,10] and a specific approach is proposed in [9].

The TPM concept is based on the idea that productivity can be improved if operators perform daily inspections, lubrication, part replacement, and troubleshooting, precision checks on their equipment to keep equipment in normal working condition. Therefore, the previous concept "I use you repair" has moved to "I use I maintain", thus, accidental falls,

unplanned stopping of machines and high fault rate, to no longer occur or to be reduced to a large extent so that the reliability of machines and equipment is substantially improved.

The TPM philosophy has as a central element the staff engaged throughout the company, personnel who perform various tasks and who are also the basis of daily maintenance and in this way contributes to obtaining the efficiency of the equipment [11,12]. Employee's management and improvement are also two of the principles of quality management. The employee training greatly contributes to the production activities performance besides other factors such as motivation, technology, managerial behaviour or the work environment. Specialized studies have shown that the organization that has good training plans for employees can achieve their performance, as it motivates them to reach higher levels of performance [8,13].

In this paper are analysed, with the help of a cause-effect diagram as a working tool, the problems that lead to non-compliant products both from a qualitative and quantitative point of view in the electrostatic painting compartment of a company – and then some positive aspects that the application of techniques associated with TPM can bring in solving the reported deficiencies are highlighted. The result consists in visible insights that can be integrated into a general approach of ensuring quality management, increase of customer satisfaction and maintaining a favourable position on the market of the company.

2. STEPS IN THE TECHNOLOGICAL PROCESS

The technological process of guide rail/drive assembly - the products made by the company that are the object of the analysis -involves three existing departments:

a) The department responsible for the guide rail/drive assembly realization - depending on the operating conditions stated by the clients, it performs: measurements to the customer, design of stairs, necessary materials, mechanical processing for the execution of the raceways, control of the executed parts, assembly of the components, finishing and sandblasting of the components, etc.

b) Machinery/machine tool maintenance department - his leader has as main responsibility the inspection and repair of equipment, being assisted by a planner or a maintenance supervisor. In smaller operations, the maintenance director will typically cover all these roles.

c) Painting Department - The technological process of painting includes three stages (Fig. 1):

1. Sandblasting
2. Painting,
3. Polymerization.

Before starting the technological painting process, the verification of the received parts takes place, respectively the exact quantity, and the conformity of the reception, the lack of elements, possible deformations, non-compliant welding points, bends, rust or other imperfections. The control of the elements to be painted and the holes to be protected is carried out according to the technical drawings received from the design department.

The proper conduct of the painting process is carried out by respecting some work instructions by the quality department; periodical verification of the manual gun, adjustment of and supplying the equipment, identify the painting powder area and perform tests on sample plates before painting; direct and continuous follow-up of the process by the operator.

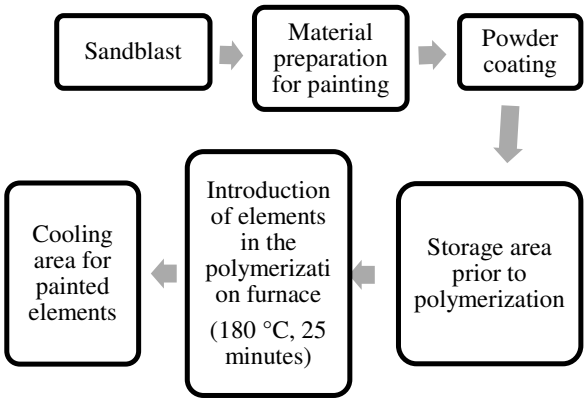

Fig.1. Technological process of painting

The management of each operation whether it is from the execution / painting or maintenance

department and the correlation between them is essential for the proper functioning and highlighting the elements that can generate problems. Regarding the development of the activity in each compartment and following some complaints regarding the compliance with the indications of the quality management system for the painting area, it was proceeded to analyse it's the activities.

3. ANALYSIS OF QUALITY LOSSES / DEFECTS GENERATED BY THE PAINT COMPARTMENT

The company must use all practical means for the prevention, detection and correction of errors that occur in the work process. In order to achieve a real quality control [14], tracking the identification of the causes and then improving the problems that have arisen is essential. In this case, variables relating to the result of human activities, the component of materials and the performance of equipment must be controlled. Quality control must be carried out at the stages prior to painting processes, during painting, on the finished products, at their delivery and at the stages of use of the products by customers.

In order to detect the causes that lead to losses within the painting department, the causal diagram method was used in detecting problems (method and process) in the department. This type of approach to the problem allows for a clear analysis and will identify ways to implement corrective or preventive actions.

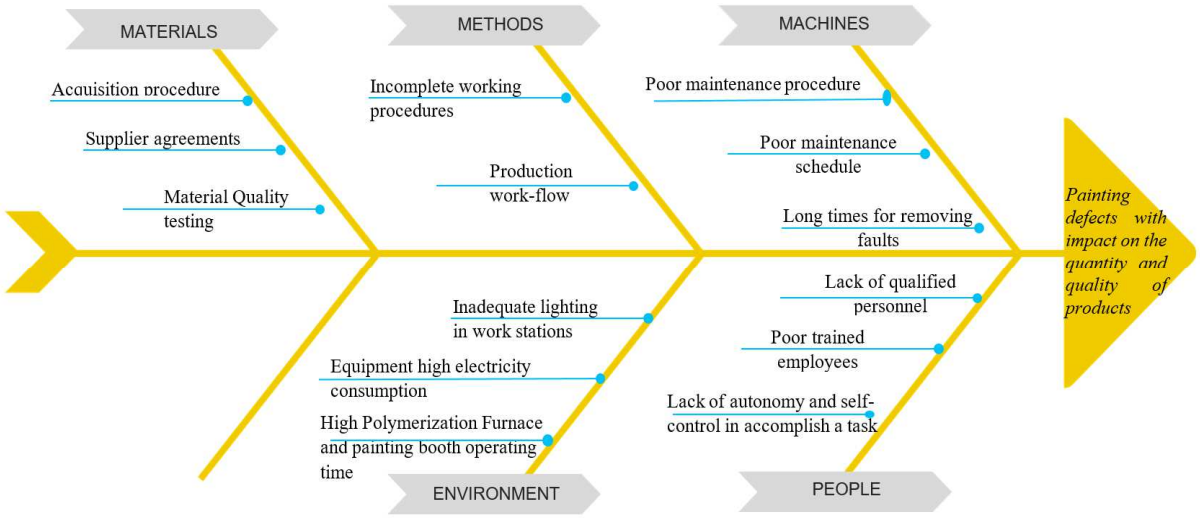

Fig.2. Cause-effect diagram

The defects noticed at the painting with impact in the quantity and quality of the products are the negative effects which, at an analysis from the point of view of man, machine, method, material, and environment, reveal multiple causes rendered in diagram in figure 2.

Following the analysis, the possible causes for the defects in the painting area can be divided as follows:

- ✓ Human resources,
- ✓ Methods
- ✓ Machinery, work equipment.

3.1 Human resources

A first problematic situation may be the one related to the environment necessary to achieve a good activities development. Thus, the insufficient and poorly trained staff, the lack of qualified candidates in the paint department disrupt the work environment and the other employees who take on extra tasks being a main factor that contributes to the stress and fatigue of the employees at work.

3.2 Methods

In terms of methods, the working instructions are either missing in some areas, existing ones prove to be difficult to apply or confusing or the work instructions is sometimes done with difficulty.

In addition, there was also a poor traceability of the control of the changes - keeping some information, documented, record keeping track, highlighting the responsible persons, transcription of any measures taken, who authorizes the respective actions, etc.

3.3 Machine

A more detailed detail of these causes highlights the fact that the company's equipment is outdated, and finding spare parts is hampered by the fact that suppliers no longer sell these types of parts. This directly affects the optimal use of equipment and installations and, accordingly, influences the achievement of quality standards. The security of a proper maintenance of the tools and equipment used is deficient and the paint space is not used at full capacity.

The analysis carried out must have as its purpose the correction, prevention, or reduction of undesirable effects and at the same time the identification of the resources necessary for their realization.

Therefore, from the initial findings, as the first directions of removing the causes of nonconformities in the paint shop, one can distinguish: the need for proper management of the paint space, the use of principles related to workspace cleaning (5S), the elimination of material losses, a staff for servicing better trained, motivated, responsible for working with equipment, simplified and standardized instructions/processes. Thus, it will be possible to add added value in the work process and human errors can be prevented until eradication - desiderata that are intended to be achieved in any company.

4. IMPROVEMENTS IN THE WORK PROCESS USING TPM PRINCIPLES/ACTIONS

Starting from the question "What principles/methods/means can be used to improve the electrostatic field painting process and implicitly the quality of the company's products?" the answer can come from the TPM area, the pillars that are guided by being dedicated to improving the work, reducing the number of defects and applying some preventive maintenance rules, all in support of the efficiency of work processes.

The TPM concept has provided answers to similar practical problems in numerous other cases, each with concrete approaches conditioned by the specifics of the processes to which they were applied.

The specialized literature showed that a series of techniques, methods or tools belonging to TPM can be applied for increasing the quality of products, the equipment operation, the quality control etc. Thus, the authors of the paper chose, to solve the problem, the use of the strategy of improving the quality control of the parts painted in the electrostatic field with the inclusion of the basic elements that constitute the pillars of TPM, resulting in the following milestones to follow during the approach:

- 5S measures
- Autonomus maintenance
- Maintenance quality (CM)
- Employees training

4.1 5S measures

All measures to organize and make the work process more efficient are shown in a form that indicates what needs to be done, indicating some clear and precise elements so that the work area and related equipment (Fig. 3.) is easy to manage. Thus, elements related to:

- Sorting - all objects that are not necessary for production will be removed and properly identified;
- Organization - all equipment, tools and materials necessary for production will be identified and placed in the appropriate locations;
- Cleaning - all equipment used as well as the work area must be periodically cleaned. For this, table 1 was drawn up - which contains some key elements of the areas that require cleaning, as well as the frequency of performance and the persons responsible for this activity;
- Standardization - measures will be taken to ensure that these rules/standards/norms are

respected and updated, being visible and placed in an appropriate location;
- Discipline - as a result of putting into practice the measures presented, the work area must look like in figure (3).
- * it is necessary to carefully consult and learn the points related to cleaning and maintenance from the work procedure for painting.

Table 1

Key elements of the areas that require cleaning, frequency and responsible for this activity.

No.	Zone type	Location	Activity	Person in charge	Tools for cleaning	Time	Frequency
1*	Accessible	Painting booth	Paint cleaning	Operator	Vacuum	10 min	S
2*	Accessible	Painting booth	Paint spray gun and atomizer cleaning	Operator	Compressed air gun	5 min	S
3	Accessible	Floor	Cleaning the dust/impurities/residues	Operator	Specific tools + textile materials and specific cleaning solutions	10 min	Z
4	Accessible	Cabinet	Cleaning the dust/impurities/residues	Operator	Specific tools + textile materials and specific cleaning solutions	10 min	Z
5	Accessible	Table	Cleaning the dust/impurities/residues	Operator	Specific tools + textile materials and specific cleaning solutions	5 min	Z
6	Difficult to access	Inside of Polymerization Furnace	Cleaning the dust/impurities/residues	Operator; Responsible from the maintenance department	Specific tools + vacuum+ compressed air gun	1-2 h	L
7	Difficult to access	Electric panels	Cleaning the dust/impurities/residues	Operator; Responsible from the maintenance department	Specific tools + vacuum+ compressed air gun	1 h	L

- S = shift end, Z = daily, L = monthly
- Improvement proposals are encouraged and brought to the attention of the direct leaders.

Fig. 3. Painting working area

4.2 Polymerization Furnace Maintenance

Before and after painting, the furnace and its electrical resistances are controlled functionally and from the point of view of technical and physical parameters.

Currently, the resistances are checked with a digital measuring device, with the help of which the amperage passing through the wires is measured - figure 4. If these electrical resistances are defective, the heating time of the oven, as well as the polymerization time will be longer. A modification of the warning system and detection of faulty resistors in the polymerization furnace is proposed by introducing light (and/or auditory) warning devices that would cause them to be signalled much easier and much faster by human operators. For this purpose, contact will be made with the manufacturing company of the electric polymerization furnace to implement the changes.

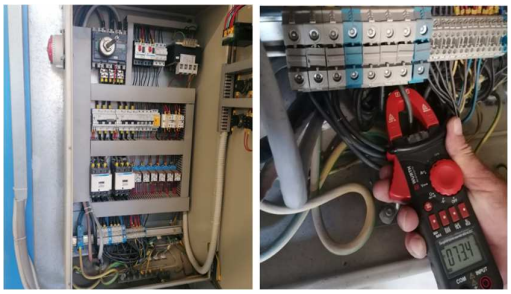

Fig. 4. Polymerization furnance electric panel

4.3 Equipment periodic maintenance

In this direction, it is necessary to implement a periodic maintenance plan for the equipment to ensure their proper functioning, according to the revision schedule shown in figure 5. Thus, the consequences of an action can be followed as well as those who are involved in solving the problems, who, where, when and how they solved an existing problem.

PROCESS: PRODUCTION
SUBPROCESS: MAINTENANCE

	Draw up	Verified	Approved
	Technologist	Activity manager	Subprocess manager
Name			
Date			
Signature			

EDITING DATE:

REVISIONS AND REPAIRS CHART

TECHNOLOGIST:

PLAN NUMBER:

START DATE: END DATE:
START HOUR: END HOUR:

Nr.crt.	Equipment code	Equipment designation	Area	Intervention code	Prioritization	Obs.
1						

Fig. 5. Scheduled revisions and repairs

4.4 Maintenance quality

In addition to verifying the correct execution and on schedule of the maintenance work for the equipment in the paint department, a verification of the result of the painting process is also required. Since there is no special paint adhesion measuring device, the company needs to purchase such equipment to improve the control process. This test apparatus uses cross cutting according to BS 3900 E6 - BS/EN ISO 2409 - ASTM D 3359 - GB/T 9286 and testing with adhesive tape compliant with ISO 2409 (Fig. 6.).

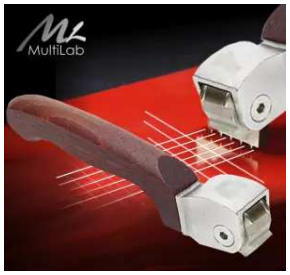

Fig. 6. Instrument for determining the adhesion of the layer to the substrate by the scratching method [15]

A possible improvement considered regarding the polymerization process is the verification of both the adhesion and the thickness of the paint layer by using the MiniTest 650 FN device (Fig. 7) and the results will be centralized in a specially designed form and displayed in figure 8.

Fig.7. MiniTest 650 device

PAINTING CONTROL REPORT

Product:	Project no.:	Internal command:
Sub assembly:		
Assembly position /assembly part: ……		
Specifications for control before painting: ……		
Visual control:…….		Standard gauge:……..
Roughness- prescribed values……		Roughness- realized values:…..
Fulfill req. ☐		Not fulfill req. ☐
Painting specifications: ……..		
		Specifications for material
Meth. Determining the layer thickness:……		No. of testing:…
Meth. Determining the layer adherence:….		No. of testing:…
Imposed/specified number of testing:……		Realized number of testing:…
Visual painting control procedure:……..		
Fulfill req. ☐		Not fulfill req. ☐

	Name surname	Signature	Date
Inspector for quality check			
Supervisor CTC			

Fig.8. Paint control report

4.5 Employees training

The absence of professional skills training in painting technology has led to large gaps among current workers. Over time, the company has used the services of a local private firm that offers professional training in painting technology and provides formal on-the-job training for operators in the paint department. This action, however, must be continued, so that the final satisfaction of the client is largely based

on the performance and skill of the painters, whose duties include the direct and continuous monitoring of the painting process. The measures taken to remedy these issues are as follows:

- The implementation of 5S measures, with an emphasis on: updating the work instructions - in this sense, in the work instructions, the specifications regarding the necessity of cleaning the workplace, the periodic maintenance of the equipment in the painting area, etc., were expanded;
- Organization of an on-site training course specialized in the field of electrostatic field painting - training focus on improving knowledge, skills and work techniques;
- Checking the knowledge, abilities, skills acquired during the training;
- Training to remove or reduce employee fatigue;
- Implementation of a reward system according to everyone's performance.

5. CONCLUSION

Measures that can be applied immediately, with minimal effort and involvement of resources, were taken into account, this does not mean that the analysis stops at this point and other causes are less important.

The considered measures, specific to TPM, are part of the quality management system to which any company must subscribe.

Although the problems are visible and the possible solutions at hand and apparently trivial, the reality is extremely complex, which makes their application difficult. Disturbing factors are given by the almost permanent turnover of personnel, the lack of qualified personnel, the fluctuation of prices for raw materials, the ever-increasing demands of customers. Effects generated by Man, Method, Machine generic causes have been removed by:

- Application of 5S measures and their permanence;
- Purchase of measuring equipment and instruments;
- Training of the staff in the painting department;
- Updating work procedures to be much clearer and comprehensible to operators.

The improvement of the current painting procedure with the newly introduced elements take into account some rules of maintenance and cleaning of machines and certain devices, such as: maintenance and repairs of the manual painting booth, cleaning and maintenance of the injector, cleaning and maintenance of the manual gun, etc.

Comparing to other works in regarding TPM implementation in SMEs, our work, actions and proposals are steps to follow in order to increase the employees and management awareness regarding 5S measures, daily routine and cleaning activities, importance of accurate following of work procedures and instructions, importance of good trained and conscious workers.

Following the presented analysis, the importance of respecting some of the basic elements of TPM is evident and proven by the improvements brought to the activity of the paint department in the sense of increasing the company's ability to deliver high-quality, high-performance products at a competitive price, promoting as a way of working the design of the production process under controlled conditions, namely: availability of information on product characteristics, work instructions for operations and processes, availability of equipment, measuring and monitoring devices, an effective information collection system.

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APLICAREA PRACTICĂ A PRINCIPIILOR TPM ÎN CAZUL UNUI DEPARTAMENT DE VOPSIRE ELECTROSTATICĂ

Tema centrală a acestei lucrări este de a analiza un proces de la o companie industrială şi de a găsi resurse pentru a le îmbunătăţi în vederea creşterii calităţii acestora, precum şi pentru a obţine calitatea produselor. Una dintre intrebarile adresate si la care s-a încercat să găsească soluţii in aceasta lucrare este "Cum ar putea fi aplicate principiile/metodele/mijloacele utilizate in Mentenanţa Productiva Totala in vederea îmbunătăţirii procesului de vopsire electrostatica si implicit a calităţii suprafeţei produselor vopsite într-o companie?" Pentru aceasta, se utilizează o diagramă cauză efect iar soluţiile găsite pentru eliminarea cauzelor sunt rezumate într-o serie de propuneri de măsuri de îmbunătăţire regăsite în patru dintre pilonii filosofiei mentenanţei total productive – TPM.

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