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Dust in lacquer, evidence of deviation of process in production lines for spray painting

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Abstract

This paper concerns work carried with a view to reduce defect occurrence rate in the spray painting lines of MDF (medium density fibre cluster-medium density fibreboard) parts of a multinational mobile manufacturing. The determination of the causes for the excessive rejection values is elusive for the multiplicity of factors and parameters involved and the dispersion of application times, not always sufficiently or properly documented. A process analysis methodology was applied to diagnose possible causes of defect occurrences. Considering that the highest defect rate concerned impurities, data collected over a six months' period was analysed using SPSS to find the correlation between parameters, to find optimal limits of some parameters and evidence of their influence. Kaizen-Lean actions were discussed and implemented conducing to an effective reduction of the existing impurities defect rate, which decreased ninefold related with initial work values.

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Keywords: defects, dust in lacquer, quality, spray line, paint, production.

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1. Introduction

This project was carried out in spray paint lines. In the painting of MDF (Medium Density Fibre Density - Medium Density Fibreboard) parts the rejection values lead to a significant loss of productivity, with impact on internal performance and consequent financial reflection on cost to the final customer.

The lines with the highest occurrence of defects are spray painting lines for the complexity process makes the pieces susceptible to the appearance of imperfections. The determination of the causes for the excessive rejection values is elusive for the multiplicity of factors and parameters involved and the dispersion of application times, not always sufficiently or properly documented.

This project had as main goal the defects rate reduction, particularly in spray painting lines, hence, the main tools of Lean Production have been considered. Thus it will be necessary to determine and deepen the knowledge of the causes of the occurrence of defects in the parts, regarding the spray paint and provide the introduction of corrective actions in the productive process, leading to improved quality and productivity. For this project, emphasis will be given to the study of the most critical spray paint defect by a previous Pareto's analysis, the impurities defect, and all process variables at the root of this defect, showing this as a possible anomaly in the productive process. The remain of this paper is organized as follows: section 2 presents the literature review, section 3 presents the used methodology, section 4 presents the case studied and the methodology applied to do the data collection and its analysis, section 5 presents the case study results. Section 6 presents the main conclusions, limitations and future work.

2. Literature review

Lean Production became widely used in the last two decades of the last century, fostered by globalisation and the increase of competition, that require organizations to seek new production strategies to reduce their costs and increase competitiveness. Production processes innovation will add more value to products/services from the customer's point of view. Considering these factors in the same production system and adding an immediate reduction of detected wastage (defects, transport, among others), a better organizational model capable of responding to the company problems emerges [1]. Lean Thinking seeks to do more with less, i.e. looking to produce, at the right time, the right quantities of the right products, using less equipment, less time, less space, less human and material resources [2]. In short, Lean production can be defined as "doing more with less" [3]. In addition, 5S are a methodology which aims the storage activities systematization, organization and cleanliness of workplaces in order to keep a work environment conducive to the development of industrial activities. Mondan [4] also states that it is a methodology that seeks to change the way of thinking and acting of people involved in the organization. Kaizen is a Japanese word which means continuous improvement – "Kai" means change, and "Zen" means better [5], and it is usually implemented jointly with Lean. Total Productive Maintenance (TPM) emerged at the same time when it became necessary to obtain greater equipment efficiency when just corrective maintenance was done, i.e. maintenance tasks were performed only in case of equipment failure [6]. According to Ohno [7] the machine value is not determined by years of service but by the income power that remains. It is a set of strategies to train and develop all staff members of the organization to take care of the equipment as if it were their personal property. The great goal is to decrease and even eliminate corrective maintenance and encourage the use of the equipment to perform autonomous maintenance operations, ensuring that the production system works efficiently with minimal possible stops [8]. The OEE (Overall Equipment Efficiency) index has been increasingly used in the industry and is a key component in both TPM and Lean Maintenance. Its use allows companies to monitor and improve the efficiency of various production processes. This index is a much more comprehensive performance measurement of production aspects, focusing not only on the equipment availability and performance, but also losses in efficiency that result from rework and non-compliant products. According to [9] the OEE methodology lists three factors of utmost importance: quality, availability and performance. Another important concept is the SMED (Single Minute Exchange of Die), that seeks to reduce the tools exchange times when carrying out a change of production activity to less than ten minutes, i.e. the time between the last part produced in the previous batch and the first part produced in the next lot. This time interval is also called setup time [10].

3. Methodology

For this project a literature review was conducted, with the objective of acquiring knowledge, researching case studies in the same context and analysing the methodologies used, as well as obtaining more detailed and in-depth information of Lean Production:

• **First step:** Kaizen, for observation and data collection and carry out a situation analysis, 3 R's (Resources, Resourcefulness, Respect) and later scientific validation, Diagnostics and root cause mapping;

• **Second step:** applying Lean tools to reduce/eliminate the amount of impurities in the spray painting process in the final product:

- ✓ machine: preventive maintenance (1st level) and TPM (Total Productive Maintenance);
- ✓ processes/human resources: standard work; painting parameters; 5S training and awareness.

Research conducted based on bibliographical sources - primary sources, e.g. company records and other documents, secondary information, such as books, dissertations and scientific articles; and other documents and other related contents.

The research relied on the active participation not only the researchers but also the workers involved in the project. This involved a set of 5 phases: diagnostic (mapping and registration of the controlled parameters from each process phase (The Pink elephant), planning of actions; implementation of actions, evaluation of results and learning specification. The first step was a situation analysis to understand the state of the company in respect to the impurities defects, in order to collect information needed to identify cause and effect for the problem under study.

In the planning phase we sought to identify various action plans, and power train the staff to address the problems found.

The next stage was the implementation of actions where they were laid out and solutions were simulated, intending to reduce impurities, and thus decrease *Outsorting* KPI (Key Performance Indicator) used to measure levels of quality in the company.

In the assessment phase and discussion of results, performance measures were compared to evaluate the consequences of actions taken and discuss results. With the results obtained in the previous step, current values of *outsorting* were compared, specifically with regard to the category "impurities", so as to realize how much was won, how much was lost and what the strategies can be used to improve the results.

The last phase, completion and learning, sought to identify the main results and the main solutions, and their quantification, leading to greater reduction of impurities in various processes along the spray paint production lines.

4. Case Study

In 2015, for a total amount of 13 582 695 parts produced, there was a percentage of total general outsorting of 12.86% in the factory, of which 4.81% originating in the paint area. Of these 12.86%, 3.47% outsorting was due to impurities defects; the aim of this project. This project was developed in one of the painting lines in the painting section, since this was the area that presented a greater quantity of defective products, and where the impurities defects registered the highest incidence.

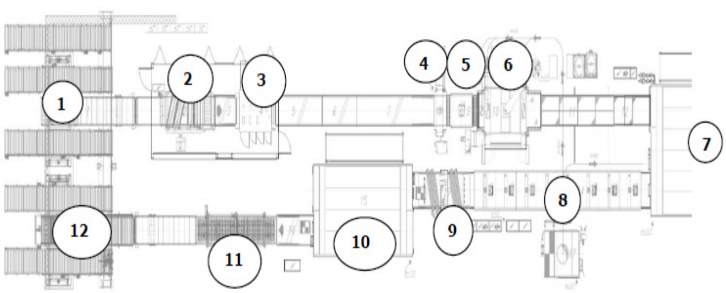

Figure 1 - Process Phases in line production

This production line has 12 different process phases according with process transformation (usually following the name of the machine or process used) (see Figure 1):1 - Infeed; 2 - Brushing machine - parts brushing; 3 - Sanding Machine – parts sanding; 4 - Ionization bar - remove the static electricity of the parts; 5 - Oven IR (INFRA-RED) - heating and preparation for painting; 6 - Box Spray - spray painting parts location; 7 - Oven - cure of parts; 8 - Infrared tunnel - the parts go to another oven, light bulbs go up to 100 ºC to complete the reaction; 9 - Ultraviolet tunnel - and if you're applying ink top, the parts undergo a last oven drying (UV oven) to meet both chemical and physical resistance specifications of the paint film; 10 - Cold oven - After the UV oven, parts at 100º C go to a cooler to prevent warping of parts due to thermal shock; 11 - Flipper - the parts are turned when necessary; 12 - Outfeed.

5. Results discussion and improvements

Analysis of occurrences and discussion of the results

Data presented, as already mentioned in the methodology, in the previous section, was collected from November 2015 to July 2016.

Given the quantitative data nature, and the goal of the project – the collection and processing of data to understand the scope of the problem, the correlation analysis of the variables related to impurities and a greater understanding their relationship [11].- *outsorting* rate decreased, due to the actions implemented which in turn, resulted in a lower number of parts rejected for impurities defects. As for statistical analysis, hypothesis testing to 1 and K samples, Association measures analysis of variance were performed. Normality of the data was checked to define whether to use parametric or nonparametric tests. The parametric tests are more robust that the nonparametric, if the assumptions of normality of the data is established [11, 12,13].

Data treatment is carried out using SPSS (Statistical Package for Social Sciences).

In response to the rejection for impurities issue, the following hypothesis has been formulated:

H0 = there is no relationship between the appearance of impurities in parts, with regard to environmental factors, machine, method (process), labour, and raw material (ink and MDF);

H1 = there is at least one link between the appearance of impurities in parts, with regard to environmental factors, machine, method (process), labour, and raw material (ink and MDF).

In response to H0, a set of assumptions for each of the factors was designed, in accordance with Figure 2.

Analysis of the normality of the data

The normality of the data is a necessary condition for the use of parametric tests, such as hypothesis testing, variance analysis, correlation, etc. When this condition is not verified, the literature [11,13,14] advises the use of nonparametric tests. For a variable to have a normal distribution, its variability must be influenced by a large number of causes, independent of each other, that Act so addictive, each effect causes small, compared with the total of all effects [12] (see table 1).

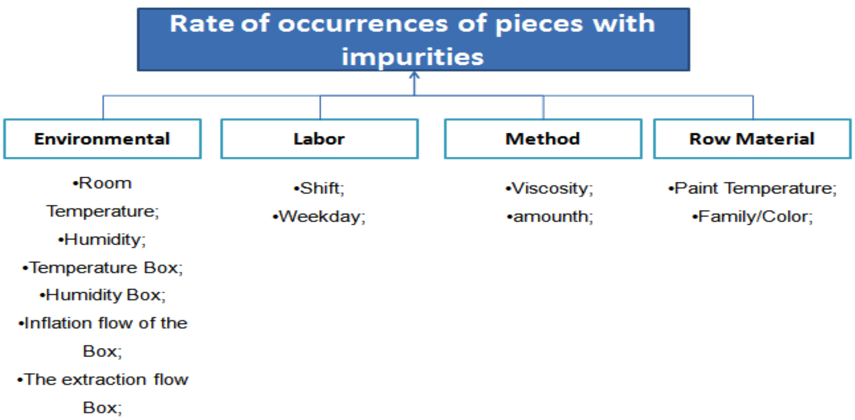

Fig 2. Scheme of testing hypotheses with the different factors that influence the rate of occurrences of

Table 1- Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
amounth	,246	94	,000	,903	94	,000
viscosity	,233	94	,000	,902	94	,000
caudalin	,223	94	,000	,895	94	,000
caudalout	,188	94	,000	,865	94	,000
HumidityBox	,210	94	,000	,920	94	,000
TemperatureBox	,133	94	,000	,958	94	,004
HumidityEnv	,207	94	,000	,930	94	,000
TemperatureEnviro	,143	94	,000	,919	94	,000
Painttemperature	,175	94	,000	,784	94	,000

a Lilliefors Significance Correction

As the significance level (sig) is less than 0.05, we can conclude that none of the continuous variables assume a normal distribution. In this way, correlation and statistical tests in this study will be performed using nonparametric tests, such as Spearman's rank correlation [12].

Influence of environmental, machine, labour and raw material in occurrences of parts with impurities.

The impurities are actually evidence of abuse of process in production lines for spray painting. This statement was proven by statistical analysis performed to variables defined in the methodology, with at least one link between the appearance of impurities in parts, with regard to environmental factors, machine, method (process), labour, and raw material (ink and MDF) (see Tables 2,3,4).

Table 1. influence of location, family/colour, weight

One-Sample Kolmogorov-Smirnov Test		Basetop	Local	Familycol	amounth
N		94	94	94	94
Normal Parameters(a,b)	Mean	2,00	2,67	3,90	157,3617
	Std. Deviation	,000(c)	,724	1,360	8,76927
Most Extreme Differences	Absolute		,495	,376	,246
	Positive		,324	,376	,150
	Negative		-,495	-,211	-,246
Kolmogorov-Smirnov Z			4,797	3,647	2,384
Asymp. Sig. (2-tailed)			,000	,000	,000

a Test distribution is Normal.
b Calculated from data.
c The distribution has no variance for this variable. One-Sample Kolmogorov-Smirnov Test cannot be performed.

Table 2. influence of viscosity, insufflation and extraction air, humidity box

One-Sample Kolmogorov-Smirnov Test		viscosity	caudalin	caudalout	HumidityBox
N		94	94	94	94
Normal Parameters(a,b)	Mean	21,5000	7239,8617	10122,0319	49,5927
	Std. Deviation	1,69598	2656,96701	3088,44186	9,06924
Most Extreme Differences	Absolute	,233	,223	,188	,210
	Positive	,233	,133	,112	,098
	Negative	-,124	-,223	-,188	-,210
Kolmogorov-Smirnov Z		2,259	2,159	1,823	2,032
Asymp. Sig. (2-tailed)		,000	,000	,003	,001

a Test distribution is Normal.
b Calculated from data.

Table 3. influence of box temperature, environmental humidity, environmental temperature and paint temperature

One-Sample Kolmogorov-Smirnov Test		TemperatureBox	HumidityEnv	TemperatureEnviro	Painttemperature
N		94	94	94	94
Normal Parameters(a,b)	Mean	26,5216	38,6904	26,2479	26,8085
	Std. Deviation	1,53030	5,13146	2,71447	2,56824
Most Extreme Differences	Absolute	,133	,207	,143	,175
	Positive	,133	,136	,143	,175
	Negative	-,127	-,207	-,094	-,166
Kolmogorov-Smirnov Z		1,286	2,008	1,384	1,696
Asymp. Sig. (2-tailed)		,073	,001	,043	,006

a Test distribution is Normal.
b Calculated from data.

The statistical treatment demonstrated that there are correlations between the variables and the environmental factors, which require future technical/scientific deepening by analysing the existing line monitoring to validate these relationships.

Improvements applied to the process for reduction of impurities

Analysing Figure 3, we can see that the rejection of parts with impurities in the beginning of the study was of approximately 8000 parts per week and after the implementation of the improvements and awareness of operators, these parts were down to approximately 1000 per week. On examining figure 3, the graph, shows, in chronological order, the implementation of the improvements described above. Some of these were also implemented on other spray painting lines, and some painting lines are currently in test phase:

1. implementation of cleaning routines at 1st level maintenance, relying on the operators' competence gained through training and awareness raising actions;
2. installation of blowers and ionize bar as well as anti-static bars;
3. optimization of flow rates and inflation air extraction from inside the box;
4. placement of Wandres dust cleaning parts and conveyor belts;
5. use of self-cleaning nozzles for the pistols of the boxes;

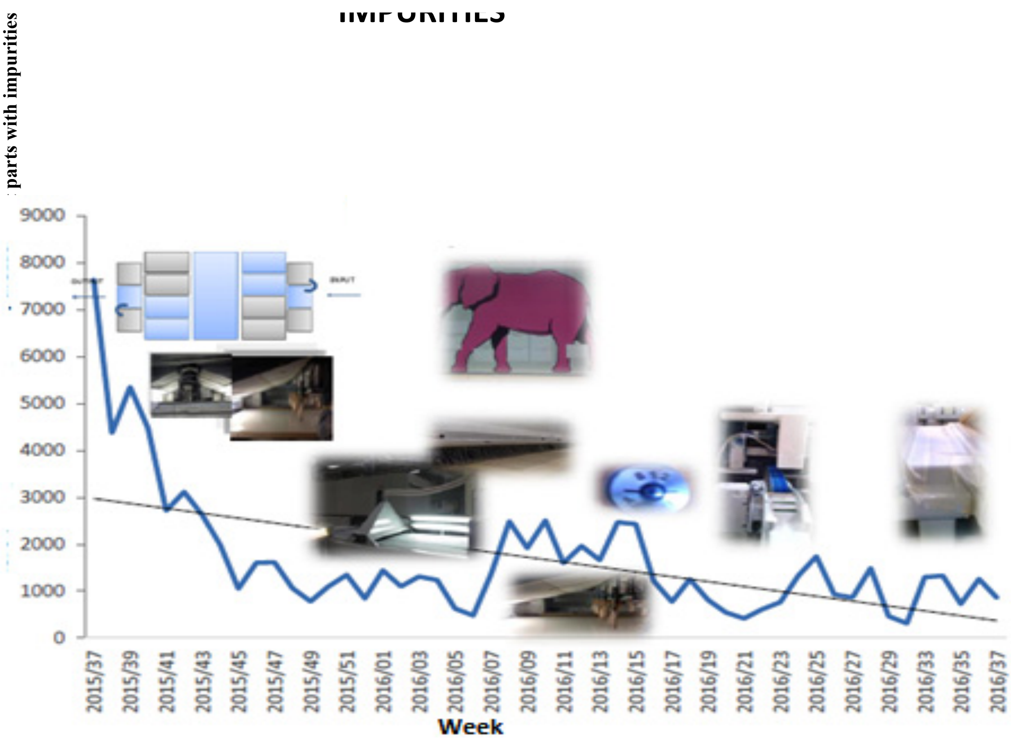

Figure 3. Evolution the impurities during one year

6. Conclusion

Having identified the problem to solve, defects by impurities, and having set the goal of this study about impurities, identifying anomalies of processes in production lines for spray painting, we conclude our goal has been completely fulfilled. The methodology was implemented to spray painting production line, during the period of 10 months. Data collection was performed from November 2015 to July 2016.

Further to this project, the following conclusions can be highlighted:

- The cause-effect diagram, shows that when problems are of industrial origin, their main causes are related to machinery, materials, methods, labour and environment [15]. Therefore, the main causes that can influence the amount of parts impurities have been defined and the main environmental causes contributing to the appearance of impurities are the ambient temperature and the box, the humidity and the box and the inflation and the extraction flow rates of the box. Shifts and days of the week proved evident in the labour cause. As for the method/process, causes that may influence the rate of occurrences of parts with impurities were weight and viscosity of the ink. As for raw materials, the temperature of the paint and the family/colour were the possible causes for the appearance of pieces with impurities.
- Following the definition and record of target variables, which enabled a deeper understanding of the main causes of the appearance of impurities in parts, it was necessary to perform a statistical analysis in order to understand the influence of each variable on the occurrences rate. Thus the null hypothesis was formulated and with the statistical analysis carried out it was found, with a significance level of 95%, that there is a relationship between the appearance of impurities in parts and environmental factors (room temperature, humidity and box, and inflation and extraction flow in box), machine, method/process (weight and viscosity), labour (shift and day of the week) and raw materials (ink and family/colour temperature). With this assumption, effectively, the impurities are evidence of abuse in the process regarding spray painting production lines.
- For each of these causes, and through the use of Lean tools discussed in section 1, the improvements implemented have led to a decrease from 32.8% to 12.9% in rejection of parts with impurities, in a year.
- By standard work, routines for 1st box level maintenance spray were created, which contributed in the reduction of impurities. The training and awareness actions to all the company's employees was important for the implementation of these routines. To regulate and stabilize of the box flow spray, a suction fan with greater

power was installed, in order to make up for inflation values of approximately 8000-10000m3 and suction values of approximately 14000-15000m3, thus avoiding overspray of paint. The placement of the bars, anti-static blowers and Angela, were a solution adopted as these enable total removal of the dust before these parts go inside the box. Another improvement made was the use of sticky-net among the various conveyor belts, so as to prevent the deposition of impurities on the surface of the parts before and after they are painted. The use of self-cleaning agents in the box's gun sprays was another measures adopted to decrease the rate of rejection of parts with impurities.

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