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Cost reduction and quality improvements in the printing industry

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Abstract

Competitiveness has been the key factor for the survival of the companies. The economic crisis that marked the beginning of this millennium forced the total readjustment of processes and operations which, in some cases, gave origin to deep changes in the organizations. In addition, concerns and consequent environmental constraints have begun to increase. Printing industry was strongly influenced by these factors. This study aims to reduce the use of toxic products and general costs in offset printing process, as well as promote a productivity increase in the printing industry. Because this kind of industry is largely influenced by weather conditions, historical data was collected, allowing to reach the balance between the printing consumables usage and working methodologies, leading to implementing important improvements. At the end of the study, it was possible to observe very good results, increasing the Overall Equipment Effectiveness (OEE) and the Mean Time Between Failure (MTBF) and reducing the Mean Time To Repair (MTTR) relatively to the equipment. The biggest achievement was the massive reduction of the isopropyl alcohol consumption in the offset printing process, increasing the air quality at the facilities, reducing the costs and most of the problems during the printing process.

Keywords: *Engineering, Industrial Management, Graphic Arts, Offset Printing, Maintenance, Continuous Improvement, Process Optimization, Reliability, Availability, Failures, Cost Savings, Environment.*

1. Introduction

In the last decades, the Printing Industry has experienced times of change caused not only by the continuous replacement of paper by digital media but also by the constant environmental concerns associated with processes

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and deforestation. The regular use of inks and other toxic printing consumables increased the need to reduce their consumption, assuming a priority role regarding forest care (usually associated with paper consumption) that have been demystified [1]. In Portugal, in addition to environmental issues, the economic crisis that has been felt has forced the industry, in general, to adapt to new realities, adjusting processes and methodologies to overcome the difficulties.

This study was performed in Marsil, a familiar printing company located in Porto district, Portugal. Costs reductions have been identified on a general level to make the company more profitable. Taking advantage of the need to reduce the costs and the additional environmental concerns regarding legislation, it was decided to deepen these issues. The plan consists of reducing the consumption of toxic consumables to the minimum possible that permits to print regarding the expected quality standards, improving the equipment performance.

2. Literature review

2.1. Offset printing

Offset printing is a process which consists of repulsion between water and ink, in other words, the areas that need to be printed do not repel the ink, and alternately the remaining area that stays wet repels the ink through an aqueous solution [2]. This aqueous solution is named fountain solution and it is here where the printing success relies on. The offset name suggests that the printing is indirect, which means, the ink passes through an intermediate cylinder before being transferred to the paper. Fig. 1 schematizes the printing process [2].

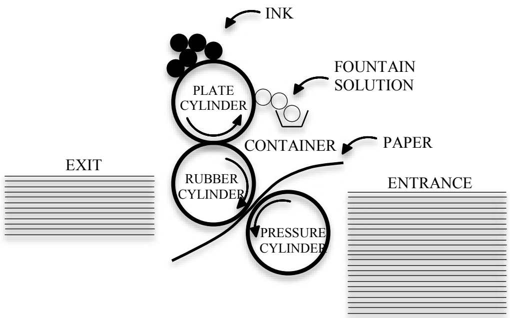

Fig. 1. Offset printing process [2].

The ink spreads into the ink roller battery until a thin layer stays in contact with the plate, which, with the help of the fountain solution, will make the separation of the areas to be printed. Then, the ink that was fixed on the plate is transferred into the intermediate cylinder and subsequently to the paper [3-4].

The fountain solution, together with the plate, constitutes the chemical constituent of the process, which depends on various consumables and has a greater influence on the printing results [3]. A good fountain solution system should be able to operate correctly with as low as possible ink quantities, without compromising the printing standard quality. This depends on the following factors [5]:

- Ink: the amount of ink printed, temperature and viscosity of the ink;
- Machine: velocity, roller battery and tuning/cleaning conditions;
- Plates: nature and hydrophilic characteristics of the aluminium coating;
- Fountain solution: water quality and additives type.

The fountain solution quality is influenced by the hardness and acidity of the water, as well as its conductivity and superficial tension [3]. The hardness, acidity and conductivity are controlled by the water supplier and with the help of additives, while the water superficial tension is controlled by the addition of isopropyl alcohol. Fig. 2 and 3 help understanding the influence of the alcohol addition on the superficial tension [6].

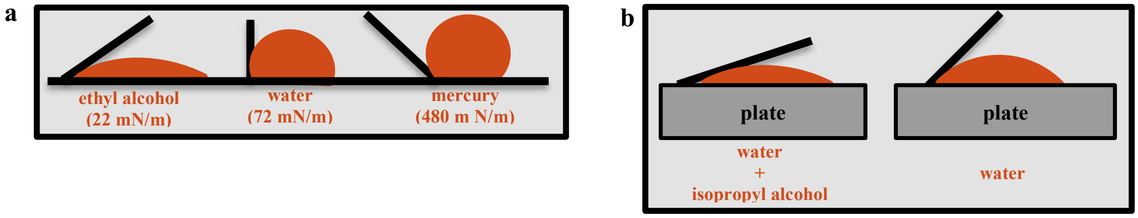

Fig. 2. (a) Superficial tension for different substances. (b) Reduction of superficial tension with the inclusion of isopropyl alcohol in the fountain solution [6].

In summary, in average terms, the recommended physic-chemical characteristics and aspects to consider for the fountain solution are [7 10]:

- Printing room temperature between 20 and 25ºC;
- Relative humidity between 60 and 70%;
- Fountain solution temperature between 8 and 12ºC;
- Use of additives to control fungus and corrosion and maintain controlled pH between 4.5 and 5.5;
- Water conductivity control values between 600 and 1200 micro Siemens/ centimetre;
- Adjusted surface tension to obtain the maximum coverage area with the minimum water possible;
- Good maintenance and regular cleaning of the system.

2.2. Performance, Reliability and maintenance indicators

OEE is a performance indicator that allows measuring the overall efficiency of the equipment [11,12]. With it, it is possible to know what is the productive efficiency of a company, department or machine. OEE can be considered a three-dimensional indicator because it considers three indicators in its calculation [13-16].

- Useful operating time;
- The efficiency of operation, i.e., the ability to produce at a nominal rate;
- Product quality.

OEE is a percentage value obtained by the following equation (1)

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Quality} \quad \textbf{(1)}$$

Where:

$$\text{Availability} = \frac{\text{Available Time to Produce}}{\text{Time Set}} \quad \textbf{(2)}$$

$$\text{Performance} = \frac{\text{Theoretic Time to Produce Real Quantity}}{\text{Available Time to Produce}} \quad \textbf{(3)}$$

$$\text{Quality} = \frac{\text{Produced Quantity} - \text{Damaged Quantity}}{\text{Produced Quantity}} \quad \textbf{(4)}$$

Relatively to MTBF, like the name indicates, it is the average time between a failure to occur, since the last failure. Its calculation can be made with the equation (5) [17-18]:

$$\text{MTBF} = \frac{\sum_{i=1}^{n} \text{Useful time of working (TW)}}{\text{Total nº of failures on that period}} \quad \textbf{(5)}$$

Where (6):

$$\mathrm{TW} = \mathrm{TT}\ (\text{Total Time}) - \mathrm{TF}\ (\text{Time of Failure}) \quad \textbf{(6)}$$

The MTTR is used to evaluate the maintenance activities performance and it is obtained by the equation (7) [13]:

$$MTTR = \frac{\sum_{i=1}^{n} \text{Time of reparing}}{\text{Total nº of interventions on that period}} \quad \textbf{(7)}$$

At last, the Availability can be obtained by the equation (8) [8]:

$$\text{Availabilty} = \frac{\mathrm{MTBF}}{\mathrm{MTTR} + \mathrm{MTBF}} \times 100\% \quad \textbf{(8)}$$

3. Methodology

According to the goals initially set and to achieve the expected results, the following methodology was adopted:

- *The initial calibrating procedure was made:* In the initial stage, a general tuning of the ink tones has been made, because if the machines are not calibrated correctly, the results obtained will not be reliable. The tuning process consists of disassembling the entire roller battery and placing them one by one in the correct order, adjusting the pressure to that set by the manufacturer, by adjusting the corresponding screws. Taking advantage of the fact that the roller battery was removed, all bearings and washers were changed.
- *Reduction of pollutants was implemented*: Considering the ideal fountain system parameters, and according to the average atmospheric conditions in the printing room, new additives have been selected with the aid of the equipment representative in order to reduce the amount of isopropyl alcohol and other toxic products to the desired levels, while also helping to reduce the machine set-up time and the ink drying time. In this sense, solutions were also discussed to reduce the consumption of scroll cleaning products simultaneously with the reduction of the time spent to do this task with the use of new machine software options.
- *New washing program to reduce pollution and cycle time was carried out*: Besides the reduction of the usual global cycle time, a quick wash program was created to achieve significant savings in this field, along with new production planning rules. The savings are reflected in the quantity of cleaning product used, reduction of energy consumption and reduction of chemical residues.
- *New dryer activator to avoid maintenance operations was used*: Regarding the inks used, a special dryer activator started to be used, which only works when the ink contacts with the paper, instead of starting to work in the moment of the ink addition. This avoids problems of ink drying in the scroll and in the printing plate, also becoming easier the performance of the Plate Cleaning System.

In order to evaluate the results obtained with the introduction of this new methodology, data regarding the pollutants used, isopropyl alcohol, non-conformities cost and so on were collected over two years (2015-2017). The values relative to the year of 2017 were estimated based on the first nine months.

4. Results and Discussion

Based on the methodology described, the following results were achieved according to the proposed objectives.

4.1. Reduction of the consumption of pollutant products and improvements in the drying of paints

With the use of historical data from the previous 2 years, Table 1 was compiled to compare the consumption of the main pollutant products used in the printing. The data from 2017 corresponds to the values obtained after the interventions. During the study, the isopropanol supplier was the same, and the average price was also the same 1.26 €/liter. For other pollutants, in 2017, the suppliers/products were changed. In the case of the new cleaning solvent, the cost changed from 1.63 €/liter to 1.93 €/liter with the supplier change. As for the fountain solution, the cost also changed from 3.11 €/liter to 3.97 €/liter with the supplier and product changes. Based on Table 2, the Fig. 3 was created to show the evolution of the consumption over this period.

Table 1. Costs of pollutant products over the period from 2015 to 2017.

	Isopropyl alcohol		Cleaning solvent		Fountain solution		Total (€)
Year	**Qtt (l)**	**Cost (€)**	**Qtt (l)**	**Cost (€)**	**Qtt (l)**	**Cost (€)**	
2015	1600	2 016.00	175	288.75	140	435.40	3 980.40
2016	1650	2 079.00	150	247.50	160	497.60	4 276.10
2017	1000	1 260.00	145	279.85	175	694.75	3 444.60

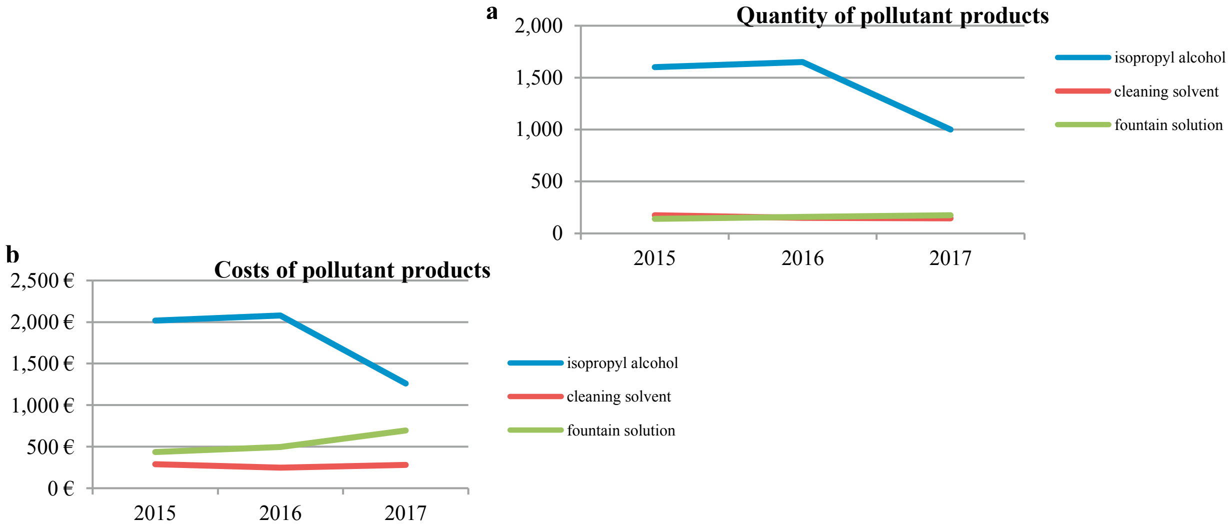

Fig. 3 Quantity (a) and costs (b) of pollutant products, from 2015 to 2017.

Taking into account the data on the consumption of toxic consumables for printing, it can be seen in Fig.4 the estimated costs for the year 2017, through linear regression.

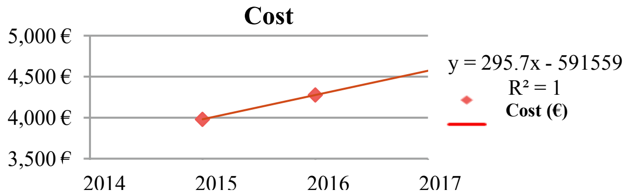

Fig. 4. Linear regression of total costs from auxiliary printing consumables.

The main conclusions obtained from this data are:

- A reduction of about 30% of the isopropyl alcohol consumption is achievable;
- A slight reduction in the cleaning solvent consumption, although associated with an increase in costs, due to the increase of the unit price compared to the previous one can be attainable;
- These changes imply an increase in costs and additive consumption of the fountain solution by 33%;
- In general, a theoretical reduction of about 1 125 € for all consumables can be reachable.

After implementation, the financial and environmental benefits were notorious and these implementations also brought improvements in the inks' drying and other factors in printing. As these parameters are very difficult to measure, historical data of costs with nonconformities (dull ink, wrong colors, excessive ink absorption) and complaints associated with repainting and other printing defects were used. This historical data is represented in Table 2. The theoretical value for 2017 is 5 300€ (obtained by linear regression), which leads to observe that there is a reduction of around 3 560€ in problems associated with drying (represented in Fig. 5).

Tab. 2. NC costs evolution.

Year	NC Cost (€)
2014	11 229.90
2015	9 508.25
2016	7 242.71
2017	**1 742.09**

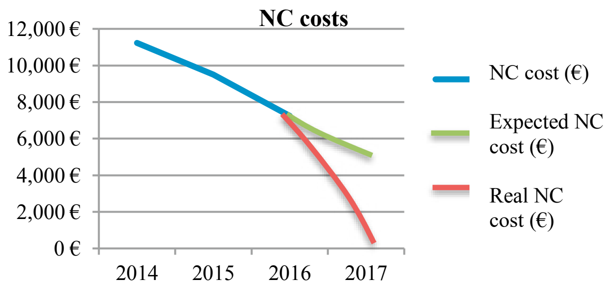

Fig. 5. NC costs evolution.

4.2. Machine set-up times

Based on a sample of work between 2013 and 2017, Table 3 was created representing the average values for set-up time regarding the machines SM52/2, SM52/4 and SM74/5 over this period.

Table 3. Average machine set-up times, for the main equipment under study (Time in minutes).

Year	SM52/2	SM52/4	SM74/5
2013	29.6	29.7	38.1
2014	30.8	30.8	40.7
2015	30.0	26.3	42.7
2016	27.2	26.5	37.1
2017	21.0	20.5	30.9

Tab. 4 intends to summarize and compare the set-up values obtained for each equipment over the period 2015-2016 and the positive evolution expected in 2017 regarding the changes carried out.

Table 4. Average machine set-up times (Time in minutes).

	SM52/2	SM52/4	SM74/5
Average set-up time 2013-2016	29.4	28.3	39.7
Average set-up time 2017 (theoretic)	27.2	26.5	37.1
Average set-up time 2017 (real)	21.0	20.5	30.9

4.3. Performance, liability and maintenance indicators

In this section the printers SM52/2, SM52/4 and SM74/5 were studied regarding the reliability and maintenance indicators, MTBF and MTTR. Historical data were recorded which allowed knowing if the changes were effective. In Table 5 are presented the data collected between 2012 and 2016 and the data collected after the implementation of the new method (part of 2017).

Table 5. Auxiliary values for MTBF calculation.

	2012-2016		2017	
	TF (h)	Nr. failures	TF (h)	Nr. failures
SM52/2	271.5	38	53.4	7
SM52/4	105.8	18	18.6	4
SM74/5	54.4	12	27.0	3

Using equation 5 and 6 to calculate MTBF, and considering 2080 annual working hours, the following values for MTBF were obtained and presented in Table 6:

Table 6. Values of MTBF before (2012-2016) and after implementations (2017).

	MTBF (h)	
	2012-2016	2017
SM52/2	266.54	289.52
SM52/4	571.90	515.34
SM74/5	574.76	684.33

Regarding MTTR, and applying equation 7, the data presented in Table 7 were obtained. Concerning this data, it is possible to calculate the availability of each machine (Table 8).

Table 7. Values of MTTR before and after implementations.

	MTTR (h)	
	2012-2016	2017
SM52/2	7.15	7.63
SM52/4	5.88	4.66
SM74/5	4.53	9.00

Table 8. Values of MTBF before and after implementations.

	Availability (x100%)	
	2012-2016	2017
SM52/2	0.9739	0.9743
SM52/4	0.9898	0.9910
SM74/5	0.9922	0.9870

Relating to performance indicator, OEE, and using equation 1, 2, 3 and 4, the evolution of this indicator is presented in Table 9. To reach these values, the data from financial management were used, which assumes that the damage with raw material is about 15% (constant = 0.85). The values presented in Table 10 are related to performance.

Table 9. OEE values before and after implementations.

	OEE (%)	
	2012-2016	2017
SM52/2	68.16	72.38
SM52/4	70.80	74.59
SM74/5	72.14	74.38

Table 10. Performance values before and after implementations.

	Performance	
	2012-2016	2017
SM52/2	0.82	0.87
SM52/4	0.84	0.89
SM74/5	0.86	0.89

Conclusions

Taking into account the previous results, it can be stated that the results are quite satisfactory, allowing to state that:

- The average set-up time has been decreased by 8 minutes and 20 seconds compared to 4 years ago (average value for the studied equipment);
- The change in printing consumables saved 1127,60 € compared to previous years;
- The nonconformity cost has been decreased by 32,9% compared with the expected value by linear regression for 2017;
- The MTBF has been increased in two of the three studied equipment;
- The MTTR has been decreased in one of the three analyzed equipment;
- The OEE of the studied equipment has been decreased between 2 and 4%;
- The company's performance regarding product quality has been improved.

In addition to the economic advantages, it should be noted that this saving is mainly motivated by the drastic reduction of the consumption of isopropyl alcohol in the fountain solution. As this compound is extremely volatile, this reduction has also improved the atmosphere into the printing room, improving the working conditions of operators, such as the reduction of toxic waste, which benefits the environment and saves the company's cost with their treatment.

Thus, with this work, it was drawn a valid way to be followed by other printing industries, which can reduce the costs selecting appropriated consumables, also improving the quality of the final product, the environment into the company and the global environment, generating less waste.

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