Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 180 (2021) 79–85

Procedia Computer Science

www.elsevier.com/locate/procedia

International Conference on Industry 4.0 and Smart Manufacturing

Waste reduction in printing process by implementing a video inspection system as a human machine interface

Pérez Juárez Carlos Alberto[a]*, Pérez Juárez Sonia Karina[a], Soler Anguiano Francisca Irene[a], Ramos Álvarez Adrielly Nahomee[a]

[a]*National Autonomous University of México, Av. Universidad 3000, Ciudad Universitaria, Coyoacán, Mexico City, Mexico.*

* Corresponding author. Tel.: +52-5591-9791-37. *E-mail address:* carlos@capingenieria.com

Abstract

Human mistakes are the main cause of most of the production failures and rejections for bad impressions in the printing industry, for this reason the industry has been working on the development and design of complementary equipment with the aim of reducing the rejections caused by these errors using human-centered design that allows focusing on reducing these mistakes, improving interaction and cooperation between the user, the machine and the process. Contextual research showed that there is currently qualitative evidence regarding the improvement of prints by having a machine video inspection system, but there is no quantitative analysis of the true cost-benefit that exists from having a video inspection and justify its implementation.

Therefore this work defines a preliminary study of a video inspection system, used as a complementary equipment to a flexographic rotary printing machine, to improve the printing process focus on machine-human interaction, in a printing company of Mexico City after a notable need for an effective improvement in the printing process in order to reduce waste in production and in rejections for poorly printed jobs.

Five representative jobs will be selected, and the cost per meter of linear printing will be evaluated, to give a value to the waste, later the decrease due to production and rejections of a run will be counted for each of the five selected jobs, with and without the system of video inspection, and finally with a comparative analysis of costs, the profitability of the equipment will be determined, obtaining as a result the viability of the equipment, which is directly related to the value of the decrease, since there is an equilibrium point between this value and the value of the equipment, where from there the implementation of the video inspection system is justified; due to the current situation of COVID 19, it was not possible to carry out the necessary measurements to validate the system. Therefore, only the proposed methodology will be described.

Keywords: printing process, video inspection, human-machine interface.

10.1016/j.procs.2021.01.131

1. Introduction

Currently, with all the technological advances in advertising and marketing, there is a trend of improvement in the quality of prints in terms of designs and finishes, due to the fact that consumers are increasingly demanding quality products, which has caused an increase in waste, associated with production errors during the printing process or customer rejections. therefore, the graphics industry has seen the need to update its equipment and improve its processes, with the aim of being more efficient and able to meet new demands, both in terms of variety of products and their finishes. Because the graphics industry is very broad, it is divided into four main markets [1] (Drupa, 2020):

- Commercial: direct advertising, commercial printing, security, large format, commercial printing finishing, transactional printing, and photographic products.
- Editorial: newspapers, magazines, catalogs, books, digital printing of short runs, and books on demand, finishing of publications.
- Packaging: cardboard labels, packaging and flexible packaging, corrugated cardboard / secondary packaging, rigid boxes, POS material, banners.
- Functional (industrial / decoration / textile): printed electronics, 3D, ceramics, textiles, wall covering and other decorative printing applications.

This research will focus on the packaging market, for two principal reasons, the first one is because in terms of volume is the largest one of all and the second one, as shown in graph it´s the most used in market terms, in addition of this also is where the prices had a greater increase, although the functional market is the one with the greatest expansion, but the profit margins and prices were quite reduced on this market [2].

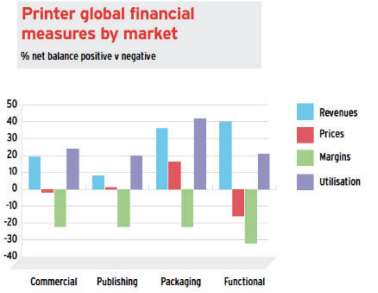

Figure 1. Printer global financial measures by market.
(6th_drupa_Global_Trends_Executive_Summary_2019)

One of the main causes of the waste is related to operators that find difficult to verify the correct printing of their jobs, this can be mainly attributed to the fact that they do not count with real-time verification equipment, and due to operating speeds, it is impossible to verify the labels while the machine is working. Therefore, it has become essential to have auxiliary equipment, such as an online video inspection system to guarantee product quality and avoid waste due to unidentified production errors on time and / or rejections, which represent economic losses, and additional production times.

Finally, it is important to highlight that the importance of this research lies in establishing the methodology to identify from which point the value of waste decrease justifies the implementation of the video inspection system, since the brands of this systems only refer to characteristics of the same and their benefits, but none is clear regarding real savings.

1.1. Automation approach

Industry 4.0 is closely related to the automation of processes and digitization of information, although this trend is not alien to the graphics industry, especially if we consider the fact that the demand for the quality and variety of products has been increasing, which has led to the industry updating, either by optimizing its equipment or acquiring new ones, like digital printing machines.

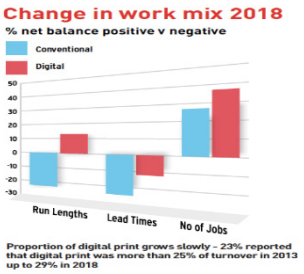

Figure 2. Change in work mix 2018
(6th_drupa_Global_Trends_Executive_Summary_2019)

The following graph shows the trend that exists in the graphic industry regarding digital printing Web to print in 2018, Installation rate stalled. - 25% in 2014 and 25% in 2018. % Of turnover via W2P grows - 17% reported more than 25% of turnover by W2P in 2014 up to 23% in 2018 [3].

1.2. Cost approach

Due to the high competitiveness in the current market, most companies have focused their efforts on developing and investing in equipment that helps them reduce their production and operating costs, with the aim of improving their profit margins, since the prices are regulated by the market. And for the specific case of the graphics industry, reduce waste, which is the main cause of economic losses and reduction of operating margins in this industry, to achieve this companies tendencies (figure 1) is to invest in digital printing, although in the case of packaging, which is where the video inspection system was evaluated, we see that flexo and offset (the two most used printing techniques), are still the main areas of investment [4]. So, investment in automation of this equipment is a priority for this market.

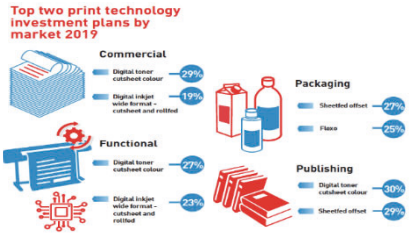

Figure 3. Top two print technology investment plans by market 2019.
(6th_drupa_Global_Trends_Executive_Summary_2019)

Figure 4. Suppliers confidence in market sectors.
(6th_drupa_Global_Trends_Executive_Summary_2019)

As we can see on figure 4, the suppliers of equipment has a lot of confidence in their respective market sector, that means that they can follow invest in new technologies, being the packaging market the one with the highest volume and the most trusted.

1.3. User-machine relation

Although different design methodologies consider stakeholders within their procedures, they focus more on contradictions or technical and physical specifications. On one hand, these methodologies focus on updating the characteristics of the central objective, but on the other hand, they leave the human factor unattended.

Human activities are probably the most important factor in any system. These activities are mainly oriented towards decision-making and include fault detection, monitoring diagnosis, recovery, and validation of operations, among others. Since the operation of the system depends on decision-making, the activities mentioned above must be carried out correctly to achieve the established objectives. Failures, malfunctions, and errors appear primarily in decision-making activities. These technical problems are associated with the complexity of the system and, of course, with the errors made by human operators.

Errors can become fatal in industry therefore, the human factor is not only an important issue, but also a crucial element to work and ensure a safer production, flow and operation of systems. Therefore, the development of these systems must be designed in such a way that their use is easy for the operator.

2. Video inspection system

No matter how well you maintain and control the printing or production process, there will always be the possibility of errors and defects appearing on the printed roll or on the surface of the material, making the installation of a video inspection system that allows, a 100% inspection of the product for the detection of defects that are imperceptible to the human eye due to printing speeds, and this have better quality control, as a good solution to the waste problem. There are several brands of video inspection systems with different characteristics and associated benefits, table 1 shows a comparison where it can be observed that although they all describe the advantages of having this type of system, none specifies how much the savings in numbers or percentage.

Brand	Resolution	Cover area	Options	Price
Canada	High	Motorized travel riel	Automatic scan, save works, remote control, multiple monitors and customizable features	$
Germany	High	Motorized travel riel	Optical zoom, lighting options, split screen, bar code verification and detect errors with low contrast	$$
USA	HD	100%	Automatic detection, UV and vanish viewing, all types of materials, alerting on defects	$$$
Japan	UHD	100%	Detect printing defects and tracing it on a map, inspect all type of materials, inspect the printing and defects on the material and is applicable in wide and narrow band	$$$

* $ Under de average of the market. $$ Average of the market. $$$ Up the average of the market.

Table 1. Comparison of the features of video inspection systems

3. Methodology

The objective of this work is to validate the installation of a video inspection system, in a flexographic rotary machine, installed in a factory located in Mexico City, making a comparison of the value of the equipment vs. the value of the waste that would be saved by the system implementation.

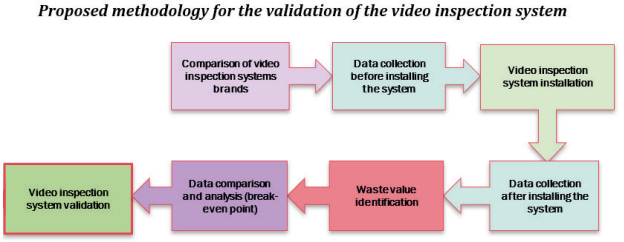

Figure 5. Proposed methodology for the validation of the video inspection system

To achieve this objective, the steps shown in the diagram in figure 2 will be followed:

1. Video inspection systems price and selection, brands comparison: Perform a price comparison of the existing video inspection systems to obtain its average investment cost, since this value will be our point of comparison to validate the system.
2. Data collection before installing the system: Selection of most representative works, by volume, repetition and importance, from which the sample will be taken so that the waste, in linear meters, of each one can be measured before installing the system.
3. Video inspection system installation: Once these data have been taken, the video inspection system is installed to carry out the testing proves.
4. Data collection after installing the system: The waste measurement is carried out in the same works as in point two and these data are collected already with the system installed (to avoid a bias in taking this data, the measurements will be carried out until the operator is familiar with the system and can operate it properly).
5. Waste value identification and calculation: Once all this information has been collected, the estimation of the average value of monthly waste for both cases is made by analyzing:
   1) The factor that increases or decrease the value of each job, number of printed colors, material and finishes (laminate, Hot stamping, varnish, Embossing, Cold stamping, among others).
   2) The number of linear meters of waste, during the production process of each printed job.
   3) The number of linear meters of waste, due to the rejection of customers.
6. Data comparison and analysis (break-even point): Once all the information has been collected and analyzed, the comparison of the company monthly savings obtained from the difference of the waste values calculated in step five against the value of the system itself.
7. Video inspection system validation: to validate the system, the equilibrium point is found in terms of the number of months it would take the company to recover its investment, and the monthly cost savings it would have after recovering it, in order to make a decision.

3.1 Stage 1 Video inspection system selection

For point 1 of the methodology, the comparison of the prices of different brands and selection of the video inspection system, we can see in the following math model, how will be the evaluation for validate the investment:

$$t = \frac{P}{\Delta_w}$$

t= time in months for recovery the investment P= price of the video inspection system $\Delta_w = w_b - W_a$

W_b *= Average cost of the waste before install the system (per month)* $W_{a=}$ *Average cost of the waste with the system (per month*

Otherwise for the selection of the system is important to recognize that even that the price will be important, there are other operations factors that the printer needs to review before take a decision, like the type of the machine where the system will install because the type of sensor depends on it, for example a mechanical gear transmission machine needs an inductive sensor that's installed on the gear that change with the "*printing format"* (defines the number of printing repetitions in the printing length), or in a no gear machine that work with servomotors use a encoder installed on a printing roll or on optical sensor following the register mark, this is important because the sensor will indicated the camera the printing speed for take the pictures that will be display on monitor. Other important consideration is the type of material because some inspection systems can detect defects on transparent materials, like films. And finally the operation speed of the machine, because for example a inspection system that used a motorized travel riel, the camera needs some time for put in the right position so if the speed is to high the operator can lose some images and make the inspection process slower.

3.2 Stage 2 waste value

For points 2,3,4 and 5 of the methodology, as we can see in stage 1 the validation of the investment depends directly of the value of the waste, so for the data collection both before and after installing the video inspection system, as well as identifying the value of the waste, will be carried out as follows:

For the evaluation of the waste value five of the most representative jobs of the company will be considered first, the one with the most volume per print run, the most monthly volume, the greatest printing complexity, the largest client and the largest number of colors and finishes. Once these works are defined, table 2 is filled to calculate the linear meters of monthly waste per job, this table is made before and after having the video inspection system, and table 3, to evaluate the cost of the waste per linear meter for each job.

Work	Printed meters	Production waste [m]	Repetitions per month	Rejection waste [m]	Total waste [m]
1					
2					
3					

Table 2. Total waste per month of the flexo-printing machine 1

To obtain the average monthly waste of the machine, the number of meters printed by the times that job is repeated per month is multiplied, this value will be compared with the total meters printed on the machine at the end of the month, which is estimated by multiplying the hours of production by the average speed of operation, to estimate the percentage of the taken sample.

At the same time, the production waste of each job is measured and multiplied by each time the job is repeated to obtain the total production waste, afterwards the total number of meters for rejects is added, which is obtained from the total of rejected works by quality area or the final client, multiplied by the number of meters of the printed work. Once the total waste has been evaluated, a monthly total for the machine is estimated. This is obtained by comparing the proportion of the total number of meters printed with the measurement of the waste obtained.

Work	Material cost	Ink cost	Finishing cost	Fixed cost	Total cost per meter
1					
2					
3					

Table 3. Cost of the waste of the flexo-printing machine 1

For the cost per linear meter of waste, the average cost per linear meter of the five selected jobs will be considered, this cost is calculated by adding the cost of the meter of material to be printed, plus the cost of ink, which varies depending on the number of colors and coverage that is required, plus the cost of the finishes that the machine has, laminate, die-cut and stamping, if applicable, it is important to highlight that not all jobs require all finishes and lastly fixed costs, which include all the consumables necessary for the printing process such as polymers, lateral cutting system and die, among others.

3.3 Stage 3 Break-even point

For points 6 and 7 of the methodology, the data comparison is performed as follows in order to make a decision as to whether the investment in the system is justified (validation). To be able to validate if installing the video inspection system is profitable or not for the company, a comparison of the data analysis is made, by multiplying the difference in total waste before and after installing the inspection system of video by the average value of the waste obtained resulting in the real monthly savings of the company when installing the video inspection system on the flexo machine 1. By comparing this value with the average price of the analyzed brands of video inspection systems the equilibrium point is determined which shows the investment recovery time of the company and the beginning of its production costs reductions.

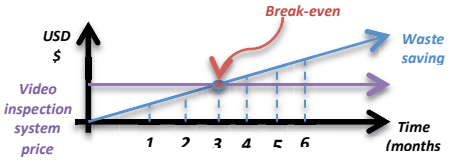

Figure 6. Example of how to calculate the brake even point, the time needed for recovering the investment depends on the waste value that we can see in the math model of the stage 1.

4. Conclusions

In conclusion, although brands currently do not have a quantitative analysis of the real benefit of having a video inspection system, it is important to highlight that for the market to which this type of equipment is directed (the packaging market), which impressions have higher added value and are directly related to the value of waste per linear meter, implying that in most cases the return on investment will be relatively fast.

On the other hand, it is also important to note that this type of equipment helps human-machine interaction, since it facilitates work, which makes it less susceptible to errors, in addition to optimizing the operation process because it removes a concern to the operator which allows him to be more efficient in the operation and tuning of the machine, which translates into higher quality work in less time. From this human-machine interaction it was possible to conclude that user satisfaction is evident both quantitatively and qualitatively when complementary systems are used, taking advantage of new technologies that favor this interrelation.

Regarding the economic savings reached by reducing waste, time saving is also associated due to the automation of part of the process, which reflects in fewer quality rejections, by adding all these saved times, a more efficient process, less waste and fewer repeated jobs due to the decrease in rejects, an extra benefits as free machine time to produce other jobs can be observed.

References

[1] Drupa Global. “7th Drupa Global Trends Report: the international graphic industry facing. April 2020.
[2] Drupa Global, April 2019. “6th Drupa Global Trends Report 2019 Executive Summary”
[3] MIIP Vision (2020). Reviewed June 20, 2020. https://miipvision.com/miipcam
[4] BST-Eltromat (2020). Reviewed June 20, 2020. https://www.bst-eltromat.com/es/productos/ipq-center/?M=236
[5]AVT-Inc (2020). Reviewed June 20, 2020. https://www.avt-inc.com/jupiter-2/
[6] Futec (2020). Reviewed June 20, 2020. https://www.futeceurope.com/es/
[7] Kotler, Philip & Gary Armstrong. Fundamentos de marketing. USA. Pearson. (2003).