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Analysis of the Energetic and Productive Effects Derived by the Installation of a Conveyor Belt in the Metal-mechanic Industry

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ABSTRACT

Energy efficiency is a topic of interest due to the financial decisions that involve; high costs must be avoided and regulated by means of strategic decision with low-cost invest. The research presents an operational improvement in the production chain of metal parts in a metal-mechanic micro-enterprise by means of the installation of a conveyor belt, a comparison is made between the energy consumption of the previous system and the system with the conveyor belt, and the results present improvements in execution times, production and energy consumption per number of manufactured parts.

Keywords: Energy Efficiency, Metal-mechanic Industry, Conveyer Belt
JEL Classifications: L61, Q41

1. INTRODUCTION

Micro, small and medium enterprises (MSMEs) play a key role in a country economy (Velásquez and Rodríguez, 2014); all of them will help the development, providing employment and supplying products and services to the larger companies that they require for their process chain (Velásquez and Rodríguez, 2014), which would activate economic and allow the economy to grow faster.

According to the Colombian Association of MSMEs (ACOPI), in the third quarter of 2017 Colombian SMEs are a guild of approximately 2.5 million, with a participation of more than 90% in the Colombian industry market (ACOPI, 2017). In the case of the manufacturing industry, the MSMEs are made up of 99.3% by micro, 0.5% by small and 0.1% by medium (Confecamáras, 2017). The report (Confecamáras, 2017) indicates which factors such as innovation are key to the success of the company's growth in Colombia, which represents a great competition among them and a commitment to respond to customer requirements.

This dynamism requires that competitiveness levels and productivity are developed; among the strategies to achieve this are found the reduction in fixed production costs and in prices of final products (Alvarez and Durán, 2009; Kosov et al., 2018). According to Kondakov, productivity is defined as the amount of input that becomes output, as well as companies must manage their processes and resources use to achieve greater efficiency in their operational costs (Kondakov, 2016).

In Colombia, high production costs are the biggest concern of MSMEs entrepreneurs, approximately 11% (Quintero et al., 2016), including energy cost. According to the report on consumption in the regulated market (UPME, 2016); from 2012 to 2015, MSMEs in the manufacturing sector had an average consumption of 21.3% the total electrical energy used by the market. The metal-mechanic industry is one of the largest consumers of electrical energy and it must improve its productivity and efficiency rates (Paez et al., 2017; Gómez et al., 2018).

Productivity improvements commonly come from savings in materials and energy consumption; (Buchelli and Marín, 2011); raw materials account for approximately 40 per cent of total production costs, including energy, and this figure increases considerably (Prokopenko, 1989; Di Foggia, 2016), as better use of energy consumption will have a positive impact on their profitability (Herrera, 2012; Jafari, 2018). The indicator that allows us to measure the improvement in energy efficiency is energy intensity (Groover, 2014), which can be understood as how to obtain the same level of production with lower costs and less pollution (Reinhardt et al., 2011; Duran et al., 2015).

The process of a plant can be understood as a network of equipment, which are basic components and perform the task of processing materials, the automation of the equipment must follow a rhythm until it is completed in the whole plant (Sun et al., 2017). Operating costs can be reduced with improvements to the conveyor system such as conveyor belts (Hager and Hintz, 1993; Marx and Calmeyer, 2004). The research evaluated the performance of a conveyor belt against the production of metal parts in terms of productivity and energy efficiency.

1.1. Production Process

The microenterprise in study produces perforated metal parts, according to the orders given by the client, can vary the shape, the thickness of the part and number of perforations. Since its inception the microenterprise has operated manually and due to its success has decided to implement automation in its transport system to increase the speed of manufacture.

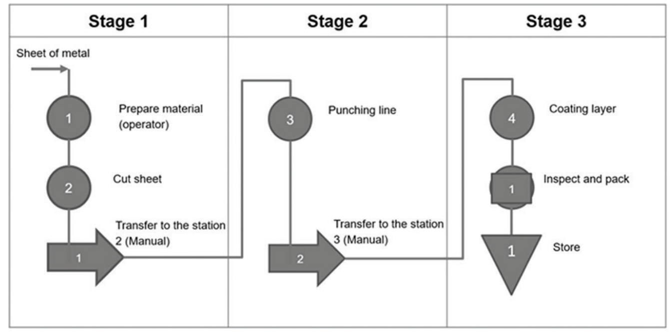
The process has equipment such as manual shears, drills and painting equipment; this equipment are distributed in three defined stages, within the production process of the parts, as shown in Figure 1.

A supply and transport system is established, which will allow to increase the production due to reduction in loading and distribution times of inputs (Figure 1). The equipment installed does not represent a major investment, but it can increase the electricity consumption cost; conveyor belts have a high efficiency due to the ability to transport at different distances and different materials, simple design and low maintenance (Zhao and Lin, 2011).

1.2. Efficiency in Processes

A process can be automatic, semi-automatic or manual; this nature will have a strong impact on production variables (Katz, 1986; Quintanilla, 2005). Variables related to human resources, machines and equipment play a decisive role in productivity (López, 2016) improvements commonly come from savings in materials and; one of the difficulties is the transfer of products in the processes that workers have to carry out from one station to another one, which represents not only a waste of time, but also risk factors for their health.

Figure 1: Operational diagram without conveyor belt



ACTIVITY	NUMBER OF ACTIVITIES
Operation	4
Transfer	2
Operation/Inspection	1
Store	1

Process optimizations can be made, depending on economic and technical factors; these can be classified into four types of improvements (Turner and Doty, 2006; Capehart et al., 2008), these are:

Figure 2 shows the types of improvements and the percentage of improvement or contribution that can be achieved; it is understood as modifying behavior when there are changes in the operating instructions, schedules, and operator training. Equipment efficiency using maintenance or repowering the equipment. The options with the greatest investment are operational efficiency, where repetitive processes are automated, and new technologies when the investment is for the purpose of changing the current equipment for more efficient ones. The use made of the machines and the way the production system is structured can increase the level of productivity, a well-defined production system strategy can maximize the organization's long-term results (Kim and Glock, 2018). For the case study an improvement in operational efficiency was made, by means of a conveyor belt the transport of the parts was automated.

This operational efficiency can be improved at four levels, performance, operation, equipment and technology (POET) (Xia and Zhang, 2010). In the case study a change in the production system is made by the installation of a conveyor belt, the process will change from the process illustrated in Figure 1 to the process outlined in Figure 3.

2. MATERIALS AND METHODS

A comparison is made between electric energy consumption and its production to evaluate the improvement due to the increase in production produced by the installation of the conveyor belt; the work crews are made up of three people, they carry out the activity under two production schemes with and without conveyor belt. For the productivity evaluation, the number of manufactured parts (NMPs) per month for one year before and after the installation of the conveyor belt was evaluated (Figure 5).

In relation to energy performance, the ISO 50006 standard was used as the basis for the development of energy performance

Figure 2: Energy savings according to the type of improvement made

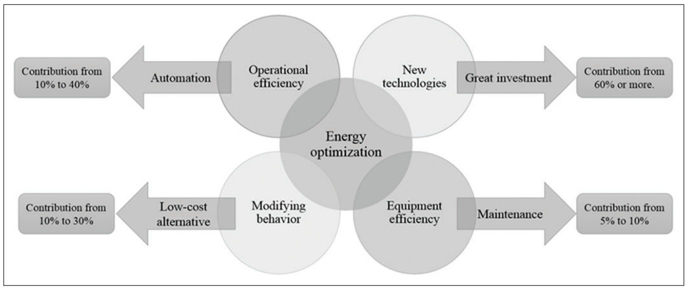
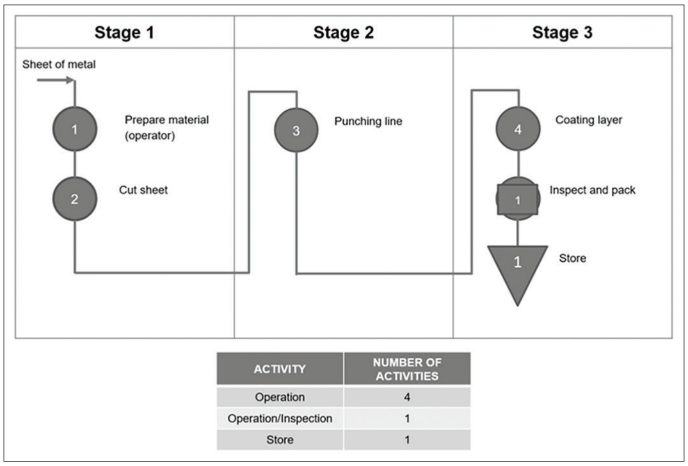


Figure 3: Operational diagram with conveyor belt



indicators (EnPIs) (energy baseline [EnB], energy consumption index (CI) and cumulative summation chart) (ISO, 2014; Cabello et al., 2016). The measurements were made from January 2016 to December 2017 and the used equipment was a power grid analyzer and 2 timers.

2.1. EnB

For the EnB development is established a linear correlation between electricity consumption and a variable, that influences it and its variability significantly in order to characterize the behavior and dynamics of the process with electricity consumption. The study analyses the monthly behavior of electric energy consumption and the NMPs.

$$E_nB = m \bullet NMP + E_0 \quad (1)$$

NMP=Number of manufactured parts per month,
M=Electricity consumption associated with the NMP per month,
E_0=Electricity consumption not associated to the NMP per month.

2.2. Energy CI

The energy CI or CI indicates the amount of energy in relation to production. Thanks to him, electric energy savings can be established by production planning and/or evaluating load indices to identify benefits of production volume as a function of electricity consumption. The theoretical CI is shown below:

$$CI = m + \frac{E_0}{NMP} \quad (2)$$

Figure 4: Photograph of the system with the installation of the conveyor belt

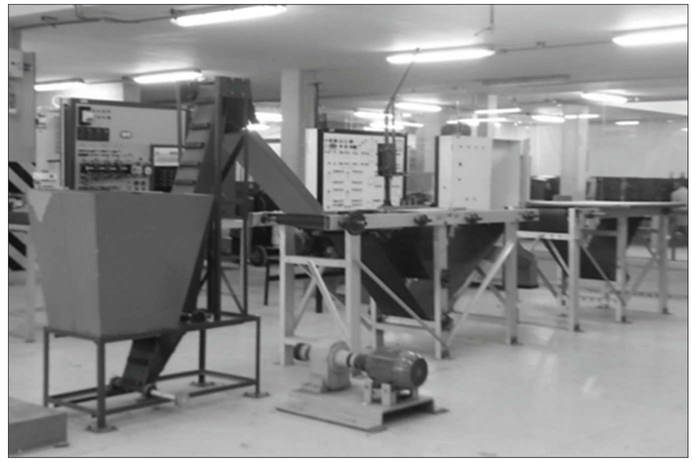
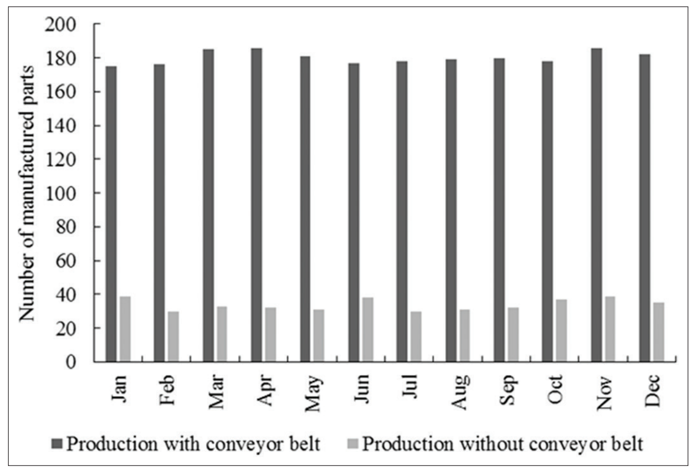


Figure 5: Comparison of the production between the two systems



The actual CI is made by dividing the electricity consumption by the actual NMP per month.

2.3. Trend Graph or CUSUM Graph

The graphical trend or cumulative sums indicator shows the variation in energy consumption regarding a period under study and thus to know the current amount of energy saved on the basis of the current production.

$$CUSUM = ((E_{real} - E_{baseline})_i + E_{real} - E_{baseline})_{i-1}) \quad (3)$$

If the indicator is >0, the indicator is in a non-conformity zone and therefore no electric energy is being saved.

3. RESULTS

In Figure 4 shows the conveyor belt installed according to the approved design.

Figure 5 shows that the implementation of the conveyor belt increased production by an average of 408% during the study period; this increase was made with the same number of workers and in the same operating time without the conveyor belt.

Figure 6 shows the monthly behavior of electricity consumption and the NMPs, from January 2016 to December 2016, a close relationship between electricity consumption and NMP can be seen, therefore, the relationship between these two variables can be used as an energy efficiency indicator.

Figures 7 and 8 present the electricity consumption baseline in the process of studying before implementing the conveyor belt and after implementing the conveyor belt.

Figure 7 shows that 58.3% of the data are below the baseline, which indicates that 58.3% was efficient considering their typical monthly behavior; however, in Figure 8 shows that 50% of the data are below the baseline. This change is explained by the fact that workers were faced with a new process and did not have much skill in handling the process with the belt.

The result shows the correlation between electricity consumption (kWh) and the NMP. The coefficient of determination for the process without conveyor belt is 0.7694 and with conveyor belt is 0.7235. The R^2 to the process without conveyor belt indicates that the model explains 76.9% the variability of electricity consumption in relation to the NMP and 72.3% is for the process with conveyor belt. Both correlations are based on actual operating data and the coefficients of determination are up from 0.6; the model can be considered valid and it allows the introduction of EnPI with suitable outcomes (Castrillón et al., 2013; Monteagudo and Gaitán, 2005).

With baselines the energy not associated with the NMP is identified, whose process without conveyor belt is 0.2011 kWh and with conveyor belt is 2.0624 kWh. The slope of the baseline represents the energy associated with the NMP, in other words, the energy per manufactured part, whose value without conveyor belt is 0.0143 kWh/NMP and with conveyor belt is 0.0047 kWh/NMP. This shows that the energy not associated with the NMP is greater with the conveyor belt than without it, because the introduction of this technology consumes electricity even without producing. On the other hand, the energy associated with production was much lower with the conveyor belt, as the operating times for the number of parts were more effective.

In Figure 9 shows that the consumption rate without conveyor belt, on several occasions, exceeded the corresponding theoretical

Figure 6: Monthly behavior of electricity consumption and the number of manufactured parts

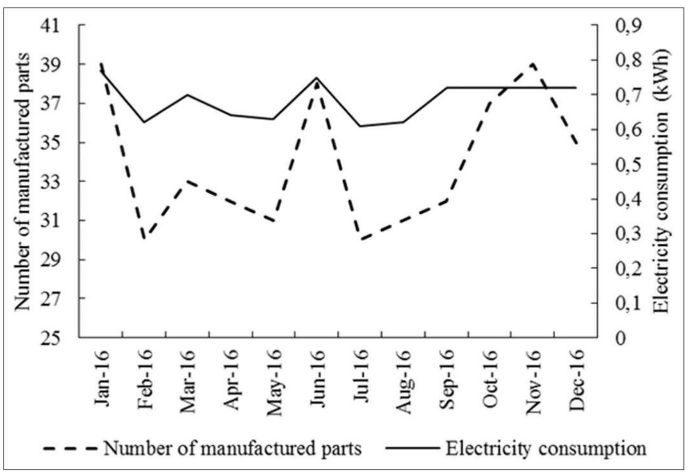


Figure 7: Baseline of electricity consumption in the process without conveyor belt

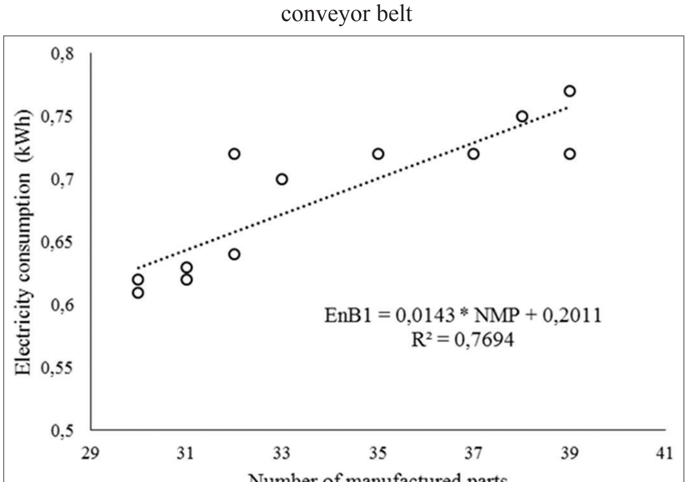


Figure 8: Baseline of electricity consumption in the process with conveyor belt

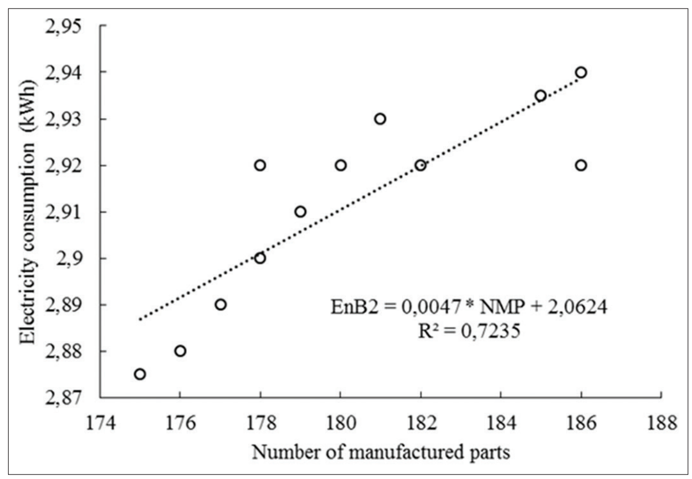


Figure 9: Comparison of the performance with and without conveyor belt

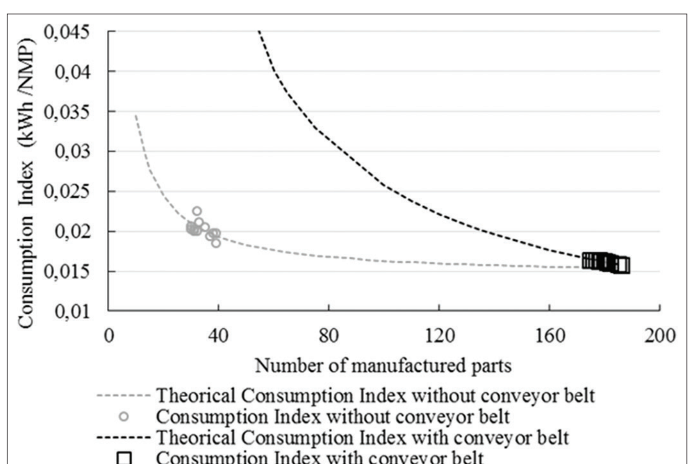
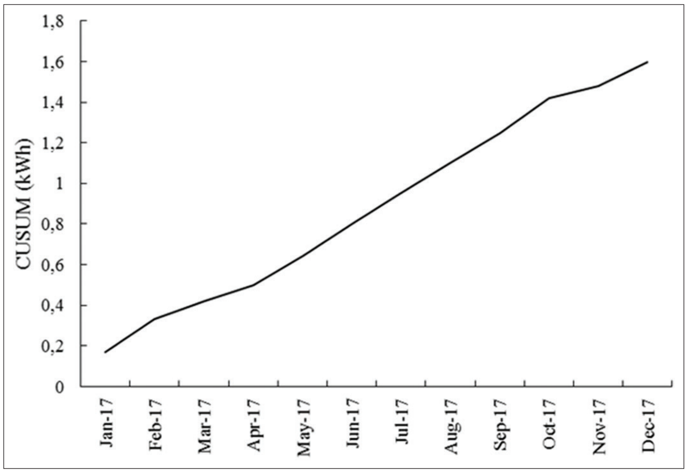


Figure 10: CUSUM graph



consumption rate. On the other hand, the consumption rate of the conveyor belt has a higher performance compared to the process without conveyor belt.

In Figure 10, the CUSUM graph is shown, it is observed that there is no energy saving during the study period, due to the fact that the CUSUM is above 0 and on the contrary it is increasing. Despite the fact that the consumption rate indicator was lower and the energy associated with the NMP was lower with conveyor belt compared to the process without conveyor belt.

The explanation lies in the fact that the energy is associated with the number of parts lifted and with the use of the conveyor belt, this one requires additional electricity for its operation during production downtime. In contrast, a significant increase in productivity is achieved (Figure 5).

4. CONCLUSIONS

This research employed a methodology to improve the transport of commodities using a conveyor belt. It particularly focused on improving production and operating efficiency in processes of feeding, drilling, inspection and packaging of finished products, which allowed reducing transportation times, increased production on average to 408%. There was a 67% decrease in electric energy associated with production, there was a 926% increase in electric energy not associated with production; it is concluded that there was no energy saving, but there was efficiency in the production and in the energy invested for the production of a part, but due to the installation of a motor for the movement of the conveyor belt, no energy saving is achieved.

The investment in the implementation of the conveyor belt allows the company to have an additional route to achieve greater competitiveness in the market; it also allows most of the work of operators to be devoted to production and not to activities such as the transport of metal parts, which in some cases can cause health problems in workers.

The literature indicates that there are alternatives to improve efficiency through POET. In the case study an improvement in the efficiency of the operation was made, achieving automation in the process of transporting products and showing an improvement in the energy cost of metal parts manufacture. For future research, energy efficiency evaluation studies could be developed to improve automation, belt speeds to avoid bottlenecks and to allow a more fluid operation for operators.

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