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Continual improvement in the insert machining process at a metalworking facility

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Abstract

A certain metalworking company, leader in the manufacture and distribution of tools for the metallurgical industry, has had difficulties due to late deliveries and quality related problems in the powder metallurgy process. The areas with productivity problems are pressing and grinding, which present rework and, consequently, long process times and low throughput. This work describes the optimization of the manufacturing process of the inserts with the best sales in the company, and subsequent agent-based simulation, to determine the degree of improvement in the level of rework and the impact of the optimization. The simulation model was developed in Anylogic, considering raw materials and process machinery as agents, as well as additional elements such as transport trucks and inspection tables. As resources, the forklift and the process operators were considered.

The real contribution of this job was the possibility to analyze and demonstrate scenarios correspond to the state of the process before and after the improvement through a simulation and some statistical tools like Brainstorming, Ishikawa diagram, DOE (design of experiments) and a linear programing. The Productivity was found to be increased by 350% when using tungsten carbide powder with a density of 3.5 g/cm3, already agreed with the raw material supplier plants. Likewise, a correct allocation of personnel for the sandblasting operation, obtained through an integer programming model, leads to an improved productivity.

Keywords: Optimization, simulation, DOE (design of experiments), linear programming, Brainstorming, Ishikawa diagram

1. Introduction

This paper analyzes a company that has its roots in Sweden since 1942. It is a world leader in the distribution of tools, tool solutions and knowledge for the metalworking industry. Its plant in Mexico City is dedicated to the manufacture of inserts for lathe mechanization, the manufacture of rollers for the production of drilling tools, as well as cutting tools for the mining and oil and gas extraction industries. The methodology used to create its products is based on the powder metallurgy process.

Although the company has been in the market for a long time and is still a leader in its field today, it has started to have strong competitors who have struggled to deal with quality issues. Specifically, there have been complaints from internal and external customers, due to non-compliance with delivery times.

The areas with productivity problems are the pressing and grinding areas, since they present a low performance in terms of the number of worked hours and the backlogs of manufacturing orders. Total manufacturing time takes more days to process than is desired by sales and manufacturing managers.

The process times are found to be large, because defective parts require reprocesses and a 100% inspection for the next operation. This rework implies defects, delay, money, time and unnecessary effort leading to long and unacceptable lead times for customers.

The aim of this work was to implement a methodology based on the techniques of operations research to optimize the manufacturing process of the inserts with the best sales of the company and reduce the level of rework considerably. The project was focused on the proposal of a production system that reduces the manufacturing process time of the families of products with the most movement in the market and the optimization of the current process through quality tools and operations research.

2. State of the art

Parra (2006), aims to motivate the academic sector and small and medium-sized organizations to develop joint work in the area of dynamic simulation of systems that lead to a clearer and more reliable business management, and incidentally contribute to the training of better trained professionals to meet the needs of the environment. For this, the application of dynamic simulation of systems in a small company is presented, through the modeling and computational simulation of the metal bar lamination process for folders from FRAMECO SA (Bello-Antioquia), with particular interest in identifying the limitations of the system, the production capacity, the typical time of the process, the idle time of the labor and the time of unnecessary consumption of the gas used as an input in one of the equipment; Likewise, the sensitivity analysis of the process is illustrated in a general way. As a result, a simulation model is obtained that reasonably represents the dynamic behavior of the process and facilitates the manager, academic or analyst, the understanding, analysis and improvement of the production system. As a support tool to facilitate the proper addressing in this segment of companies, system dynamics can be used, a simulation technique that allows understanding the relationships between the elements of a certain system, and simulating their dynamic behavior in different scenarios without the need for be carried out on the real system, thereby facilitating a better understanding of it and the establishment of policies that are likely to lead to the most desired results.

Ilzarbe and Tanco (2008) present a case study carried out in a recognized company in the automotive sector, in which about 4,000 employees work to produce a single car model. The analyzed process is the laser welding applied to join the sides of the car and its roof, which is carried out in a closed cabin by means of two robots. This process presented quality problems, since the appearance of pores in both beads of the weld was frequent. Therefore, experimentation and specifically the Design of Experiments (DOE) were used to improve the process. The project achieved a 97% reduction in pores, as it started with an average defect rate of 3% and ended with an average defect rate of 0.09%.

The manager appointed the company's working group, consisting of four people: the factory manager, a person in charge of the planning department, a person in charge of the quality department and a representative of the maintenance department. On behalf of TECNUN (School of Engineering University of Navarra), the four authors of this article worked continuously. Once the work team was formed, it began with a preliminary analysis (Phase 0) to ensure that it made sense to resort to experimentation to solve the problem. Among other activities, a flow chart was constructed to clearly establish the process and delimit the study, as well as a "Brainstorming" and a root-cause diagram to identify the factors (variables) involved in the process.

A data collection sheet was designed to collect three weeks of pore information.

In conclusion, after a while, a confirmatory analysis was performed to verify that the results were maintained over time. After a two-month production analysis, the percentages of pores on the right side were 0.14%, while on the left side it was 0.03%. This means an average reduction of the pores of 97%. The experience was positive and very constructive. Ultimately, this project showed the usefulness of Experiment Design for process improvement and will serve as an example for new DOE application projects in this company.

3. Materials and methods

A process mapping of the insert manufacturing process was carried out as a diagnosis. Afterwards, the process was simulated in the Anylogic software to have the base scenario. Process data was collected, such as process times, and their statistical behavior was subsequently analyzed. This part was really important to find the type of distribution in each process to be set in the simulating software. In the Figure 1 is showed an example of these distributions.

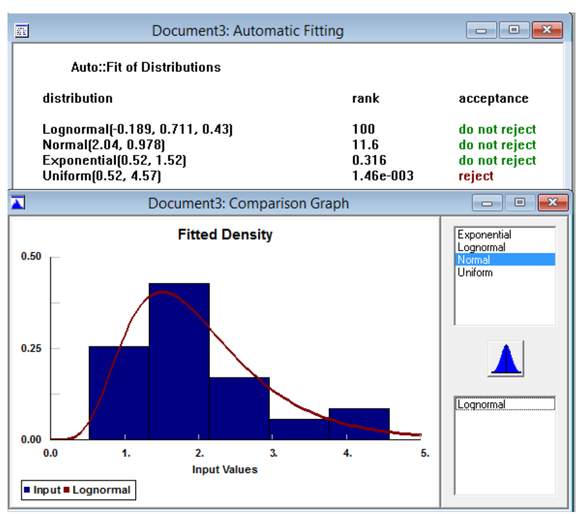

Figure 1. Type of distribution

Possible causes of delays in manufacturing orders were analyzed using quality tools such as the Ishikawa diagram, brainstorming and meetings with the involved production areas.

In the figure 2, we can see the Ishikawa diagram built according with the Brainstorming developed with different areas like Direction of operations, Engineering department, Quality department, Planning department, Lean manufacturing department, Maintenance department and some operators.

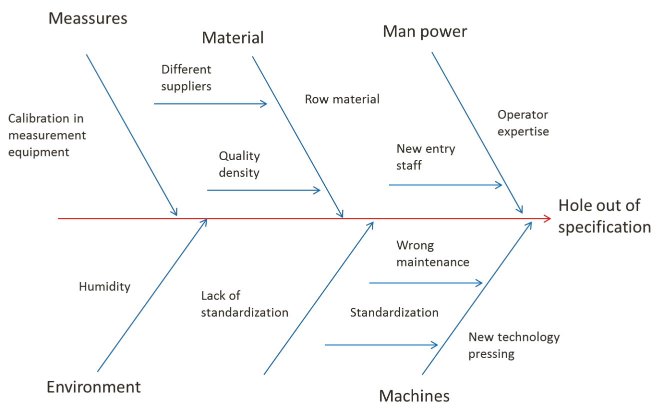

Figure 2. Ishikawa diagram

According to the Brainstorming and the Ishikawa diagram, machines pressing and the powder density are the main factors that cause the pieces out of specifications and as consequence the re workers in the process and the delivery late to the customers.

A design of experiments was carried out to determine possible variables that are affecting the operation more. The output variable was the Cpk and the Factors were the density and the machine with three different levels each one. Due to the fact, that the product can be manufactured with three different machines and with three different row materials (powder with different density).

A program lineal was developed as well in an specific process to be able to see the best combination and assignation of operators to maximize the productivity.

Finally, an improved scenario was constructed in the Anylogic agent-based simulation model, to compare the improvement proposals.

The simulation shows the current process showing the bottle necks in some process and the total quantity of orders that arrive to Warehouse in a period time of a week.

In the same way, a simulation was created with the improvements of the DOE and the assignation model to compare both scenarios.

4. Results and discussion

According to the results, the company should work with specific densities and machines to avoid getting pieces out of specifications. Is can be seen in the Figure 3, Cpk, a measure used to determinate if the pieces are in specifications, is bigger when the machine with ID = 100 and a powder density 3.50 g/cm^3 are used.

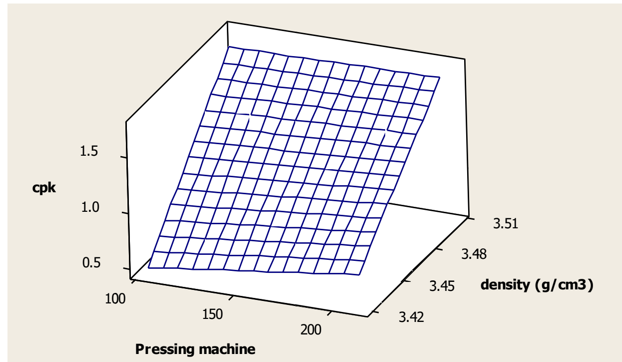

Figure 3. Surface plot for the press, Cpk vs. density

On the other hand, the comparison between the process before the research and the process after the optimization were simulated in Anylogic and it can be seen in Figure 4 and Figure 5.

In the Figure 4, there are marked in blue the process where the pieces go before finish all the process which are the process for rework pieces to adjust and inspection pieces out of specifications. The simulation was ran in a week period and at the end of the week, only two orders arrive to the warehouse.

In the Figure 5, there are marked in blue the process where the pieces go. As we can see, the orders don´t need to go to the rework process since they are within specifications. At the end of the period time, the total quantity was 9 orders arrived to the warehouse.

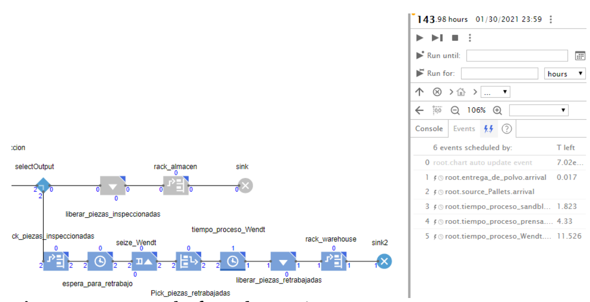

Figure 4. Process before the project

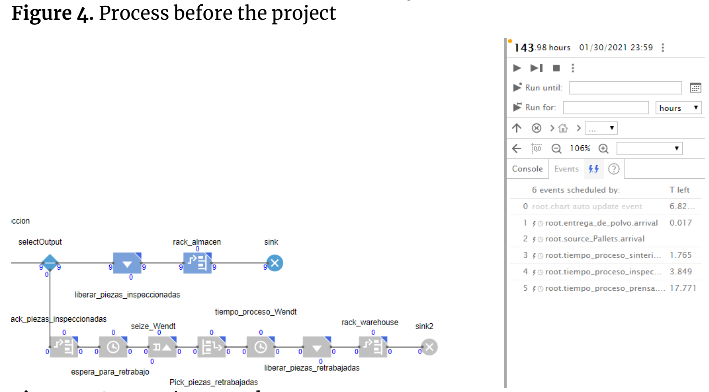

Figure 5. Process improved

The comparison can be seen in Figure 6. According with the results found, the number of the total orders that could be manufactured in a week with the improvements found is 9 and in the previous process is only 2. So, the productivity will increase in a 350%.

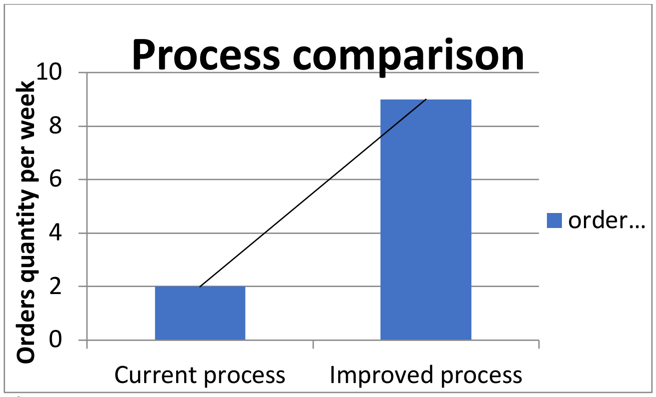

Figure 6. Process comparison

The estimated economic impact for a single product of a specific family of high runner products was three million pesos per year.

5. Conclusions

A fundamental part of process improvement is the analysis of the root causes that originate any deviation in efficiency, productivity or quality in the production process. Many tools can provide ideas to be able to decipher the cause that originates these deviations to the process. In this study, the cooperation between the operational and managerial personnel is essential. A discrete event simulation in Anylogic was able to determine optimal operating conditions, achieving a three million saving per year for one product family.

The plant management wants to develop these kinds of improvements for some other family products. In a future the simulation models will be an essential part of the company in the process engineering area.

6. References

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