OPTIMIZATION OF THE MANUFACTURING PROCESS OF CARDBOARD PACKAGING WITH FUZZY LOGIC: CASE STUDY COMPANY IN THE INDUSTRIAL POLO OF MANAUS

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ABSTRACT

This study arose from the need to meet the demand for manufacturing LCD monitors with cardboard packaging, with less assembly complexity, substantially reducing the amount of folds in the packaging, due to the use of a large number of collaborators involved in the assembly of standard cardboard boxes. The focus of the work is directly on reducing the amount of box folds, maintaining current factory layouts and complying with basic dimensional requirements, geometry, mechanical strength, and customer acceptance criteria (quality tests). The methods used for the purposes of the research were exploratory and descriptive, having as a research instrument applied in the form of observation and analysis in the various stages of the development of the packaging project, proposing a new approach to the concept of boxes that would meet the modern production and development needs. In this case, we propose, with Fuzzy logic, to validate the results obtained with the new layouts of boxes, as well as other recommendations relevant to the proposed study, creating subsidies to answer the problem raised.

INTRODUCTION

With the advent of globalization, the market has been undergoing intense transformations, becoming increasingly restless regarding innovations and reduction of raw material and labor costs, requiring companies to be more creative, agile, flexible and having to adapting to different types of cultures and customer needs is undoubtedly a challenging task for executives around the world, requiring greater efforts to survive in the market. And one of the great challenges of today's society is to produce goods and services at the lowest cost, with the lowest possible environmental impact, with high quality, generating employment and income, reducing the use of natural resources. The packaging is the link between the consumer and the product to be purchased by him, it is necessary that the packaging always present good conditions, a good design, being part of a set of factors that make people notice a certain product so that it is marketed (VIEIRA, 2016). Nowadays, there is an increasing need to produce packaging with less raw material, less assembly complexity, concomitantly with fewer possible folds, however, maintaining the physical integrity of the product, appearance and resistance to the various mechanisms involved, such as: relative humidity, handling, transport, storage time and stacking pattern (Selke et al., 2016). Identify points of improvement, referring to excess folds in the boxes, and develop changes in the layout aiming at optimization, reducing raw material and labor costs. These changes require quality tests for validation and the use of logic as a validation fact for the new layout.

MATERIALS

Os materiais utilizados no desenvolvimento das novas embalagens com menor quantidade de dobras, usamos softwares de desenvolvimento de embalagens e equipamentos de testes de qualidade conforme informado abaixo:
After the initial survey of the folds of boxes of all models of LCD monitors, we verified the average of folds to arrive at a standard value for the beginning of the works:

\[ M = \frac{\Sigma}{QMM} = \frac{4074}{12} = 339.5 \pm 340 \text{ folds} \]

Where
\[ \Sigma = \text{Sum of the amount of folds in all models of LCD monitor boxes.} \]
\[ QMM = \text{Quantidade de modelos de monitores.} \]

The result tells us the average amount of folds per monitors, where we carry out the analysis of the production process for the survey of necessary manpower and layout for the execution of this activity. The figure below demonstrates the result of the Process Engineering study:

Source: Author (2021).

Figure 1. Production Flow Schematic Diagram of Standard Fold Quantity Boxes

After the study of times and methods prepared by Process Engineering, we observed that the average workforce needed to assemble the packaging was 45 employees, considering an average production line of 51 employees for the assembly of each monitor model, we can say that for each monitor assembly line, we have to have a box assembly line. Considering the amount of labor allocated for the assembly of boxes within the company, which was 08 people (value stipulated considering the standard of labor for the assembly of TV boxes, less complex than the boxes of LCD monitors in the same company), there was a need to reduce the complexity of the boxes, otherwise we would significantly increase the number of operators and layout area and there would be a great loss in the production setup (change from monitor assembly to TV and vice versa). We consider that the project should respect the standard layout for assembling boxes as shown in the photo below:

Source: Author, (2020).

Figure 2. Production Flow Schematic Diagram for assembling TV boxes

The layout shown above, considered standard for assembling TV boxes within the company, considers 08 operators in the assembly of boxes. To respect this standard, there would be a need to modify the
design of the LCD boxes, where the bending values would have to be reduced to adapt the boxes to the assembly process. Considering that to achieve the values of "folds x amount of labor x production layout", the number of folds would be needed according to the table below:

\[ QD = \frac{QMD}{QPO} = \frac{340}{8} = 42.5 \pm 43 \]

Where

QMD = Average amount of creases per LCD monitor.
QPO = Standard number of operators on the packaging line

Considering the production volume factors, differentiated by model, monitor geometry, micro pauses in the process, ergonomic analysis of the SDESMT and quantity of accessory sets (varies according to the model), the maximum value of 50 folds per unit of packing box. Considering values above 42 as disapproved.

Table 3. Criteria for evaluation of bends of the box/shim set

| FOLDS    | VALUES     |
|----------|------------|
| APPROVED | 13 – 36    |
| ACCEPTABLE | 36 – 42 |
| DISAPPROVED | 42 – 50 |

From the table we created the inference rules for the study of Fuzzy logic.

Table 4. Inference Rules for Bends

| Item | CASHIER | SHIM | RESULT |
|------|---------|------|--------|
| 1    | Low     | Low  | Approved|
| 2    | Low     | Low  | Acceptable|
| 3    | Low     | Medium | Approved|
| 4    | Low     | Medium | Acceptable|
| 5    | Low     | High  | Disapproved|
| 6    | Low     | High  | Approved|
| 7    | Low     | Medium | Disapproved|
| 8    | Low     | Medium | Disapproved|
| 9    | Low     | High  | Acceptable|
| 10   | Low     | Medium | Acceptable|
| 11   | Medium  | Low   | Acceptable|
| 12   | Medium  | Medium | Approved|
| 13   | Medium  | High  | Disapproved|
| 14   | Medium  | High  | Acceptable|
| 15   | Medium  | Medium | Disapproved|
| 16   | Medium  | Low   | Disapproved|
| 17   | Medium  | High  | Approved|
| 18   | Medium  | Low   | Approved|
| 19   | High    | High  | Disapproved|
| 20   | High    | High  | Acceptable|
| 21   | High    | Medium | Disapproved|
| 22   | High    | Medium | Acceptable|
| 23   | High    | High  | Approved|
| 24   | High    | Low   | Disapproved|
| 25   | High    | Low   | Approved|
| 26   | High    | Medium | Acceptable|
| 27   | High    | Low   | Approved|

Considering the evaluation functions of the input and output variables, the inference ones are assembled according to the formula below:

The equation: \( R = Nv \)
\( R \) is the number of rules
\( N \) is the number of inferences
\( V \) is the number of variables

Then:

\[ R = 3^5 \cdot R = 27 \]

RESULTS AND DISCUSSION

In the study of the results, we can evaluate in figure 3 through fuzzy logic, that by changing the number of folds of the box, to a greater value, we have to compensate for this variation in the box shim, considering that values above 50 folds must be respected during the analysis of the project, avoiding very high values and always making the compensation of the folds as far as possible, in case there are high values in one or another item of the box.

![Figure 3. Fuzzy System for the evaluation of box folds](source)

Figure 4. Shape of the output variable

![Figure 4. Shape of the output variable](source)

Figure 5. Result Fuzzy System Inference Rules

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Figure 6. Result Fuzzy System Inference Rules

Source: Author, (2021).
FINAL CONSIDERATIONS

A fuzzy logic approach was proposed to optimize packaging box folds. Minimizing the different types of problems in companies and in any segment is very important, especially when there are tools that allow it, as was verified in the study in question. The work aimed, among others, to present a study of optimization and development of cardboard packaging for LCD monitors, reducing the amount of folds and using Fuzzy logic in the process. Meeting the requirements stipulated by suppliers, internal and external customers considering the manufacture of new cardboard packaging with a new design. It is assumed that the presented study contributes satisfactorily to strategic decision making. The fuzzy system demonstrates great capacity for analysis and evaluation studies of packaging processes, where reducing the amount of folds makes a difference, adding value to the business, reducing labor costs and reducing time with process setup.

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