DEVELOPMENT AND APPLICATION OF STANDARDIZED WORK TOOLS IN A FACTORY MACHINERY AND EQUIPMENT

Cassiano Rodrigues Moura (IFSC) cassianocrm@hotmail.com
Cristiane Ceratti Nunes (IFSC) ccerattinunes@gmail.com

The assembly process in companies is something that must be analyzed from the design of their products until assembly, because this directly affects the product cost, assembly time, shape or quality in the process. An important tool for these activities is the standardized work that went well for the assembly line of the companies can be a good alternative to contribute to improve the assembly process. The purpose of this study is to standardize the assembly process of a group of components to converting and packaging tissue. The research methodology applied in this study is bibliographic followed by action research, with practical application in a case study. Initially the company is presented and followed by a current assembly process identification. Subsequently the problems are identified and the development and application of the improvement tools for the standardization of the assembly process in a pilot group of components. Finally, the results are presented and can be observed that the development of the standardized work process reduced the receiving, warehousing and assembly parts, as well as a reduction of 7% in the internal assembly cost, which represents a saving in the annual purchases of $46,400.

Palavras-chave: Standardization, Control Plan, Process Plan, FMEA.
1. Introduction

The assembly process in the companies is something that must be analyzed from the design of its products to assembly, because it impacts in the product cost, in assembly time, form or quality process.

It is important that designer analyzes the manufacturing process, raw material and assembly in order to check if it is not impracticable for the company to manufacture this product.

According to the competitiveness of the market, the high demand of the customers to low cost with high quality and high variation of market demand, as companies need to expand their portfolio by opening physical space in the production line, reducing the lead time to assembly and simplifying the process.

The companies can use oriented design methodologies allowing to obtain a great amount of benefits in the assembly concept to the products, reducing the rework and adjustments in the components assembly process.

An efficient tool to improve the assembly process is the standardization of its processes, to achieve a quality assembly in the shortest time, a simplified structure of the product, the analysis of the potential failures, it results in a positive result for the company, contributing to the competitive increase.

Based on just-in-time philosophy the development of documents to improve the assembly process such as standard work, FMEA and Control Plan, followed by training among those involved can minimize failures and delays in the production line. Identifying sets that have problems such as rework and prolonged assembly, doing the analysis these processes in order to provide the modularization of the assembly process and its standardization.

As a result, improvements can be made to reduce nonconformities, as well as the analysis to replace components internally assembled to products manufactured by suppliers.

The purpose of this study is to analyze the assembly flow of a pilot assembly in a leading company in the supply of machines and services for converting and packaging paper and later propose an alternative to establish its standardization. Based on the problems identified,
solutions will be analyzed and suggested using standardized work tools to achieve higher productivity on the assembly line.

2. Theoretical reference

2.1 Just in Time

According to Shingo (1996) Just-in-time means that each process must be supplied with the necessary items, in the quantity needed and on time. In the same line Liker (2007) conceptualizes the Just-in-time as "a set of principles, tools and techniques that allow the company to produce and deliver products in small quantities, with short lead times, to meet specific customer needs."

Ohno (1997) points out that working with zero stock would be the ideal state, from the point of view of production management, however, it is very difficult to apply Just-in-time to the production plan of all processes in an orderly form for a product developed with many components, because the number of processes involved is high. With these concepts it is observed that one of the goals of this tool is to make the production work with reduced inventories, it is totally agree with the Toyota system's goal of eliminating all losses in the production process.

2.2 Standardized work

According to Pascal (2008) Standardized work is the safest, easiest and most effective way of doing the work that we know. For Fujimoto (1999) the concept of standardized work is to standardize all forms of carrying out activities in all the processes of the company. It is necessary to define the best way to do each work action and the appropriate sequence, using images and drawings to assist in understanding this planning. At Toyota, these visual documents make it an efficient tool for job improvement.

A standardization system creates, uses, and controls standards. Subsequently a system of process standardization will determine the systematic of actions and how the way to target achievement. According to Lucena (2006) this system is part of the Improvement Identification, followed by the elaboration and approval of the new standard and finalized by the training of those involved.

2.3 Elimination of Losses
The main purpose of the Toyota Production System is to look for the losses for its complete elimination. Due to the concept of non-cost that means the competitiveness of the market through reductions in operations costs and not increase in the value of the product, the losses needs to be eliminated.

Shingo (1996) writes about two types of operation that are divided among those that add value, transforming the raw material into components or products, increasing their value added through the greater efficiency of the transaction in the processing and those that do not add value, considered as losses referring any activity that does not contribute to the operations reducing the net operating efficiency. From this concept, non-aggregating value operations must be eliminated so that the increased efficiency of the operation as a whole is raised to the highest possible index.

Segundo Ohno (1997) Overproduction losses are the worst enemies because they help to hide other losses. Shingo (1996) claims that there are losses due to quantitative overproduction and losses due to overproduction by anticipation.

In the view of Liker (2007) processing losses can be by overprocessing or incorrect processing, these would be unnecessary steps to process the products. Inefficient processing resulting from a tool or design poor quality, causing unnecessary movement and producing defects can also be considered loss, as well as when products with higher quality than the one required are offered. For Liker (2007) the loss of defective products is due to the production of defective parts or rework in the correction its. The need to rework, discard or replace and inspect means loss of handling out, time and effort.

Unnecessary movements made by operators in the execution of an operation result in loss of displacement. According to Ohno (1997), moving does not necessarily mean working, which denotes a constant concern of the Toyota Production System with the work rationalization.

2.4 Tools for Process standardization

2.4.1 Process Plan
According to Monden (1998) the process plan is a working instruction document that defines the methods and resources used to make an operation.

It is important still that they show sketch and photos of the routes. And to describe the standardized activities to finalize the work. Process Plans are issued by planning and then are
constantly improved. They should be affixed to the assembly line in order to be visible to control the observation of the standard. (VILELA, 2007)

2.4.2 Control Plan

The control plan is a document that assists in the production process and should list the necessary tools, tests and process steps containing sketching and photos. (VILELA, 2007) Control plans are written descriptions of parts and process control systems. The Control Plan describes the actions required for each phase of the process, including receiving, the process itself and its results, and periodic requirements to ensure that all process outputs are under control. (MOURA, 2008)

2.4.3 Failure mode and effect analysis - FMEA

FMEA analysis according to Piluski (2015) is a methodology that its goal is to evaluate and minimize risks by analyzing possible failures, which includes determining the cause, effect and risk of each type of failure, followed by the implementation of actions to increase the reliability of the product or process (HELMAN & ANDERY, 1995; SAKURADA, 2001). There are basically two types of FMEA, the design and the process. Both have the same questions that are directed to their purpose as "How can this project / process fail to do what it should do" and "What we must do to prevent these potential failures."

The Project FMEA is used when project detailing is available, it involves analysis of specific causes of failures in individual components. (ROMEIRO FILHO, 2010).

Process FMEA is used to analyze manufacturing processes and assembly, conducted when the production process is already defined. It can also be applied to analyze quality problems related to the production process. (ROMEIRO FILHO, 2010).

4. Metodologia do desenvolvimento da pesquisa

The research methodology to be used in this work is a bibliography followed by action research, with practical application in a case study. The figure 1 shows the applied methodological flow.

Figure 1 - Methodological flow applied in this work
4.1 Case study

4.1 Company presentation

The company under study is a multinational company that has been operating in Brazil for 40 years, located in Santa Catarina, being a leader in the supply of machines and services to converting and packaging of toilet paper and towels. The company is in constant technological development to add value to the product and will be focus for this case study in the development of Standardized Work in the productive process of a set of pilot parts.

4.2 Current situation

4.2.1 Process analysis

The equipments to converting and packaging can be considered as large, it has about 72,000 items separated into 12 groups, as can be seen in table 1, which shows the components of each group as well as the percentage of each component in relation To equipment.

<table>
<thead>
<tr>
<th>Nº</th>
<th>Systems</th>
<th>Subsystems</th>
<th>Components</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>External Unwinder</td>
<td>22</td>
<td>1,793,00</td>
<td>3%</td>
</tr>
<tr>
<td>2</td>
<td>Internal Unwinder</td>
<td>28</td>
<td>2,345,00</td>
<td>3%</td>
</tr>
<tr>
<td>3</td>
<td>Embossing</td>
<td>62</td>
<td>6,745,00</td>
<td>9%</td>
</tr>
<tr>
<td>4</td>
<td>Rewinder</td>
<td>70</td>
<td>14,447,00</td>
<td>20%</td>
</tr>
<tr>
<td>5</td>
<td>Box core</td>
<td>17</td>
<td>2,804,00</td>
<td>4%</td>
</tr>
<tr>
<td>6</td>
<td>Corewinder</td>
<td>18</td>
<td>2,580,00</td>
<td>4%</td>
</tr>
</tbody>
</table>
The item n° 10, the Cutting Machine has about 5,200 components separated into 46 groups, representing 7% of the total equipment. Two of its groups are analyzed in this study. Each of these has components that are arranged in subgroups. The subgroups to be analyzed are the Internal grinding wheel subgroup and the External grinding wheel subgroup, which have 29 items.

Currently the assembly process is carried out by the company in several stages, as shown in figure 2. It begins in the planning and purchase of commercial and manufactured parts, which have different lead times, followed by their receiving, separation and direction their respective warehouses. When the design is in the assembly period the parts are separated and directed to the final machine assembly.

Figure 2 - Flowchart of the subgroup manufacturing process and assembly in study
Figure 3 presents a comparison of hours worked and rework in each system of the equipment. It can be observed that Cutting Machine has 8723 worked hours and 5.5% of these are reworked. It is important to note that the Cutting Machine is a representative item for the equipment occupying the 4th place in worked hours in the equipment, as can be observed in figure 3.

![Figure 3 - Total of hours x reworks 2016](image)

4.2.2 Problems identification

From the diagnostic performed in the previous step the problems can be identified in the current assembly process:

- a) Sets being purchased in separate parts for later internal assembly, generating an increase of assembly time and compromising the logistics flow;

- b) The lack of a documented assembly process hinders the development of external purchasing because the knowledge of the assembly process is dominated only by the current assemblers and as there is no work instruction it becomes difficult to develop a supplier or even a new internal assembler;

- c) The assembled set Grinding wheel group has its assembly time compromised due to rework and assembly adjustments causing delay in production. Its assembly time is 1h, but may have its assembly interrupted due to deviations in the tolerances and some parts are returned to your supplier for the adjustment process;

- d) Need to adjust some components to complete the assembly process;
e) High rework rate.

4.3 Improvement tools application

4.3.1 Standardized work development

To select the items to be analyzed to standardize the assembly of the pilot set this criterion was used: groups have rework in their assembly line, but have a considerable number in sales volume. The table 2 presents the sales volume of rework in 2016. It can be observed that items 3 and 4 have the highest percent of rework (6.1%), but do not have a considerable volume of sales.

<table>
<thead>
<tr>
<th>Item</th>
<th>Group</th>
<th>Annual volume (pç)</th>
<th>Equipment</th>
<th>Rework %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Internal grinding wheel</td>
<td>50</td>
<td>Cutting Machine</td>
<td>5.5</td>
</tr>
<tr>
<td>2</td>
<td>External grinding wheel</td>
<td>50</td>
<td>Cutting Machine</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Left punching</td>
<td>6</td>
<td>Rewinder</td>
<td>6.1</td>
</tr>
<tr>
<td>4</td>
<td>Right punching</td>
<td>6</td>
<td>Rewinder</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Roller support</td>
<td>24</td>
<td>Unroller</td>
<td>4.7</td>
</tr>
<tr>
<td>6</td>
<td>Roller guide</td>
<td>18</td>
<td>Bundler</td>
<td>3.5</td>
</tr>
<tr>
<td>7</td>
<td>Roller Transmission</td>
<td>6</td>
<td>Embossing</td>
<td>4.6</td>
</tr>
</tbody>
</table>

The process of purchasing components was changed, it was decided to buy the pre-assembled groups, optimizing their assembly process and minimizing their possible failures. The system of alteration and standardization can be observed in figure 4.

Figure 4 - Systematics of changing standards
### 4.3.2 Process plan

The data collection for the development of the Process Plan was carried out during the work shift observing the assembly of the Group. Photo registration and development process of the assembly process were carried out. Figure 5 illustrates the developed document that contains information describing the standard assembly planning, where you can observe information such as:

- **a)** Detail of assembled set, codes and photos of the components;
- **b)** Description (What?) - What is the process at that moment of assembly (assembling, checking) and which parts will be assembled;
- **c)** Key point (How?) - What will be the union of the pieces and what tools to use;
- **d)** Reason (Why?) - Why perform the assembly in the established way.
**Figure 5 – Developed process plan**

<table>
<thead>
<tr>
<th>SHEET OF ELEMENTS</th>
<th>Description (Whats?)</th>
<th>Key Point (How?)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test assembly of cylinders 224368 (ext) and 224390 (int) on the 394735 Motherboard in two positions, front and back</td>
<td>Manual angled assembly to check if the nut is mounting the part in the counter piece.</td>
</tr>
<tr>
<td></td>
<td>Mount o’ring 20505901 - 2 units in each cylinder</td>
<td>Manual assembly</td>
</tr>
<tr>
<td></td>
<td>Check shirt and bushing assembly if mounting without interference. Mount retainer shirt 224385, bushing DU 21171696 and bushing DU 21171633 on cylinders.</td>
<td>Use nylon hammer and device. Mounting needs to be without interference and bushing should be well at the end. Use vaseline if necessary to assist in assembly.</td>
</tr>
</tbody>
</table>
4.3.3 Control Plan

For the development of the Control Plan the data were collected in the final stage of the assembly, where the equipment devices are tested. Photos have been recorded and the details specified for the execution of these tests to ensure that the set is perfectly performing its purpose. Figure 6 shows the developed document, which contains the following data:

a) Characteristics of the operations: Describe the process (test, pass the dial indicator ...);

b) Operation descriptions: Specify tolerances, tools, etc;

c) Assembly: put the images that represent the tests to be done.
## CONTROL PLAN

<table>
<thead>
<tr>
<th>Operation Type</th>
<th>Device / Tool</th>
<th>Item Description</th>
<th>Specification</th>
<th>Responsible</th>
<th>Control Method</th>
<th>Sample Size</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting group</td>
<td>Comparator</td>
<td>Pass the dial indicator in the grinding wheel</td>
<td>(Acceptable 0.02)</td>
<td>Assembler and quality inspector</td>
<td>Measurement equipment measurements</td>
<td>1</td>
<td>Every final 10 each group of 1000</td>
</tr>
<tr>
<td>Testing pulse of cylinders</td>
<td>Comparator</td>
<td>Pass comparator watch in the grinding wheel assembled. Obs. Change the grinding wheel aside if it is varying greatly and the bolts should be tightened every 5 hours</td>
<td>(Acceptable 0.06)</td>
<td>Assembler and quality inspector</td>
<td>Measurement equipment measurements</td>
<td>1</td>
<td>Every final 10 each group of 1000</td>
</tr>
</tbody>
</table>

### REACTION PLAN:

Prepared by: Cristiane Ceratti Nunes

Revised / Approved by: XXXX

Date: XXXX
4.3.4 FMEA development

To develop this document, the data of the process were collected in the assembly of the study group, together with the knowledge of the assemblers and the quality control team, the FMEA document is shown, as shown in figure 6. The main failures pointed out were:

a) Variation in concentricity in the axis greater than 0,02 mm in the support of the grinding wheel and greater than 0,06 mm in the assembled set;

b) Cylinder with air leakage;

c) Set does not press;

d) Assembling with interference of sleeves and bushings;

e) Incorrect assembly of o-rings;

f) Inverted assembly of internal and external cylinders;

g) Cover does not fit.

The assemblers were identifying, while assembling, the possible failures that could occur in the assembly process and according to the knowledge of the quality sector, that followed the development of the manufacturing process of the items and can point the care in its manufacturing process.

Figure 6 – Developed FMEA

<table>
<thead>
<tr>
<th>Process</th>
<th>Function of the component</th>
<th>Possible faults</th>
<th>System</th>
<th>Indices</th>
<th>NPR</th>
<th>Preventive actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder Assembly</td>
<td>Assemble the cylinder 224398 (ex) and 224396 (ex) on the 304725</td>
<td>Incorrect assembly, inverted position</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>Assemble 2 O-rings 285605661 in each cylinder</td>
<td>Ring assembled out of position</td>
<td>6</td>
<td>10</td>
<td>7</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>Retaining spring shaft 21717656 and D.II bushing 21717656 on the cylinder</td>
<td>No interference</td>
<td>7</td>
<td>10</td>
<td>2</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>Use spring edge 21717656 (ex)</td>
<td>Bushings with tension</td>
<td>7</td>
<td>10</td>
<td>2</td>
<td>140</td>
</tr>
</tbody>
</table>
4.3.5 Description of the future process

Figure 7 shows a comparison between the previous process and the new assembly process adopted by the company. After implementation of the standardized process begins in the planning and purchase of the assembled subgroup, followed by its receiving, separation and directing to the project to be assembled in its due period.

4.3.6 Training

With the process standardization documents developed the company can train its operators and suppliers to carry out its assembly process with efficiency. To start the new flow they were trained to carry out the assembly according to the new process. The training of the assemblers was performed on the assembly line by the person in charge of the assembly. The training of the suppliers was carried out in two stages in order to obtain the homologation of the system. Such as:

a) On the assembly line with the already trained assemblers, exemplifying the process;
b) At the supplier, being observed the assembly and making sure that it exits suitable tools and specific space for the assembly of the groups.

5. Results and discussion

The development of the standardized work process has reduced, warehousing and assembly stages. The group is currently treated as an item, requiring less internal procedures to direct it to the assembly.

The analyzed groups pass to be purchased assembled and there were no more reworks, the assembly process was developed at the supplier to be carried out according to the new standard, adjusted and tested, arriving at the assembly line ready to be assembled to the equipment.

With the standardized work developed it was possible to create a better qualified supply source to manufacture the set at a lower cost, but with better quality. Table 3 presents a comparison of the cost for internal assembly and the assembly by external supplier. Quotations were made in three different suppliers, considering an annual volume of 50 units, compared to the internal assembly cost.

Table 3 – Comparison of the assembly cost

<table>
<thead>
<tr>
<th>Group</th>
<th>Supplier A ($)</th>
<th>Supplier B ($)</th>
<th>Supplier C ($)</th>
<th>Internal cost ($)</th>
<th>Variation</th>
<th>Reduction ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External grinding wheel group</td>
<td>7,776.00</td>
<td>7,257.00</td>
<td>6,640.00</td>
<td>7,104.00</td>
<td>7%</td>
<td>464.00</td>
</tr>
<tr>
<td>Internal grinding wheel group</td>
<td>7,776.00</td>
<td>7,257.00</td>
<td>6,640.00</td>
<td>7,104.00</td>
<td>7%</td>
<td>464.00</td>
</tr>
<tr>
<td><strong>Total ($)</strong></td>
<td><strong>15,552.00</strong></td>
<td><strong>14,514.00</strong></td>
<td><strong>13,280.00</strong></td>
<td><strong>14,208.00</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to table 7 the cost of production for the external assembly is 7% lower than the internal assembly cost. This calculation was carry out by comparing the cost of supplier C, which is the best quotation, with the internal assembly cost, resulting in a difference of 7%, being $464.00 lower by part and in the amount of annual purchases a saving of $46,400.00.

5. Conclusion
The present work developed a systematic actions for the standardization of the process of manufacture and assembly in a leading company in the supply of machines and services for conversion and packaging of paper.

During the analysis of the current process some improvement points were identified. These were treated through standardized work tools.

To ensure that the group performed its function efficiently, documents such as Process Plan, Control Plan and FMEA were developed for the standardization of the pilot component process.

It was possible to develop new supply sources for the assembled set, eliminating the rework that existed in assembling the components when purchased separately. The assembly began to be purchased externally, which will be delivered already assembled and tested, at a cost 7% less than internally assembled.

The result of standardizing the process with the purchase of the assembled set, optimized the assembly time and reduced workers because the assembly arrives done and tested on the assembly line. As well as the gain of physical space and cost, ensuring an efficient process and parts replacement fast in the customer.

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