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Optimization of the Manual Insertion Process of Electric Motor Winders Using Lean Manufacturing Techniques

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Abstract:
Background*: During the development of the manual insertion analysis, it was possible to identify losses in the process, after using lean tools and data collection, gaps in the line balancing, due to low performance and desaturation in the insertion process.*
Materials and Methods: *Software (Auto card Simulation); Polyester Tapes; Steel plates S72; Conductor wires (Copper and Aluminum); Transfer Tweezers; Digital caliper; Ohmmeter; Continuity Test. Methods: Preparation of the area considering situations that should be in accordance with the standard, including: the installation and layout of machinery and equipment that employees handle during the execution of tasks, for excução and implementation of new layout was used Simulation Auto card, given the safety standards applied to NR-12, such as escape route and standards in force, spacing area for transit of operator and equipment.*
Results: *Some of the operations in its production process are: Operating mainly in the capital goods sector with solutions in electrical machinery, automation and paints, for various sectors, including infrastructure, steelmaking, pulp and paper, oil and gas, mining, among many others. The Organization stands out in innovation by constantly developing solutions to meet the major trends in energy efficiency, renewable energy and electric mobility. With industrial operations in 19 countries and commercial presence in over 38 countries.*
Implementation of process and improvement programs, among other Kaizen programs. Within the company, the Productivity Kaizen project in the Plant's winding and manual inserting centers was developed in the Manual Inserting Work Center in Brazil, Manaus. The company decided to start implementation on desaturation loss reduction in the winding and manual inserting work centers in Factory I, it is proposed to unify the winding, manual inserting and insulating material preparation work centers.
Conclusion:*This research aims to present through the application of the lean manufacturing tool, integrated with computer simulation, the various options for improvement and loss reduction that a manufacturing process can obtain. This result was achieved through the use of several tools that allowed the positive simulation. From the tools such as the spaghetti graph, a simulation was generated that allowed it to be used as a model for other areas of the Organization, with Global highlight of other Sites of the company, with recognition by the board of the head office. Global Perspectives for Production Engineering Manaus, AM, Brazil, the results achieved ensured a 30% average reduction in handling time, this change will bring positive impacts such as - Ergonomics: decrease in the paths, providing more safety and faster transitions. Organization: a planned physical arrangement facilitates access to machines and makes the environment visually more pleasant. Inventory: stocks, both final and in-process, can be reduced due to a shorter production lead time. In relation to what was presented, it can be concluded that the proposed change of the new layout brought to the planning a powerful tool that enables companies to visualize the results before investing time and resources in it.*
Key Word*:Chrono-Analysis, NVAA, WO, WCM, and Continuous Improvement.*

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I. Introduction

The opening of the market, driven not only by political forces, but also by a dynamic global movement, has put Brazilian companies under pressure from new competitive forces. This process has established a new environment, in which the continuous adaptation to changes presents itself as an essential condition for maintaining the ability to survive and develop organizations, behind the media, evidences and shows us that currently in the world economic scenario a volatile environment that constantly influences the organizations in a fierce competitiveness generating challenge for their maintenance, being extremely necessary the constant changes [1][2].

This study is based on the use of the concepts of WCM (World Class Manufacturing) methodology, implementation of continuous improvement tools, Spaghetti Diagram, Mura, Muri, Change, and Chrono-analysis, tools that aim to help in decision making through orientation, for the analysis and eventual application of improvements needed in the winding section of the Electric Motors company. With the transfer of one of the three product lines between the factories of the manufacturing unit, there was a need to review the process flow and the redistribution of the staff, aiming to maintain the productivity of the unit. For an in-depth analysis of the process in a systematic and organized way, with the objective of obtaining maximum benefits with minimum effort, the WCM [3-5] methodology was used.

In the use of the methodology in the study/analysis step of the cost matrix CD (cost deployment) it was observed the problems of real losses in productivity and in the process flow. After analyzing the work center loads, for this last scenario it was possible to concentrate the activities (winding, inserting and preparing insulating materials) in a single operator/shift, changing the load from 9% and 30% to 48%. With the new proposal it is suggested to modify the critical resource from 750 pieces/week to 157 pieces/week or 15 pieces/shift. The proposed scenario will meet 94% of the weekly schedule performed this year The choice of this specific sector was because it is the sector with the most waste and losses in the plant (engines), where we have uneven production flow affecting the assembler as a whole. Special emphasis was given to the use of the CD tool and focused improvement (FI) in the WCM philosophy. For the implementation of the feasible solutions.

For [6] show that this search for competitiveness can be observed in distinct moments in history, and of extreme importance for the emergence of new technologies, as for example, the development and fixation of the Fordist mass production system in the beginning of the 20th century. This model, which until then was the most efficient system presented - even with some problems related to losses and waste - gave rise to a study developed and led by Taiichi Ohno from Toyota. Through this study it was possible to understand the processes and strategies of competitors, recognizing their impact on organizational culture, and thus promote improvements and adaptations necessary to their own reality, with the goal of eliminating process losses. The so-called Toyota Production System (TPS) was born [6-9]. After a series of mapping in the production process and application of the NVAA, VAA and NVAA-N tools, along with a methodology known as kaizen, this methodology allowed to lower costs and improve productivity [10-11].

What are the possibilities of sharing the experience and knowledge within the whole methodology applied to this case study?

Considering the questions and objectives of the research project losses, the chosen research methodology is the Case Study. The paper describes the practical implementation of the project, which aims to reduce labor resources. after unification of the winding and manual inserting centers at Plant I.

II. Material And Methods

1) The methodology proposed in this work was developed as a goal of investigation of the losses presented in the process, which means an active role in analyzing the problem and developing solutions within the research environment (FLETCHER, 2017). In general, the investigation corroborated by adopting an analytical procedure and empirical knowledge connected to the process, and data survey, based on the methodologies. Chrono-analysis. Muda, Muri and Mudar and the Spaghetti Diagram, with application of other quality tools throughout the process.

3.1 Materials: Software (Auto card Simulation); Polyester Tapes; S72 steel sheets; Conductor wires (Copper and Aluminum); Transfer Clamps; Digital caliper; Ohmmeter; Continuity Test.

3.2 Methods: Preparation of the area considering situations that should be in accordance with the standard, including: the installation, and layout of machinery and equipment that employees handle during the execution of tasks, for execution and implementation of the new layout was used Simulation Auto card, attending the safety standards applied to NR-12, such as escape route and standards in force, spacing area for transit of operator and equipment:

1) Receiving raw material from the warehouse (Polyester Tapes, Sheets and conductor wire);

2) Preparation of the insulating machine, consisting of supplying with Polyester tape and adjusting the cutting and folding tools in manual mode.

3) Operate insulating machine in automatic mode for cutting and bending of the slot bottom insulator.

4) Check collar length and bend with digital caliper.

5) Preparation of the winding machine, consists of programming and supplying with copper and/or aluminum conductor wire.

6) Operate the winding machine in automatic mode to create the groups of coils in the clamps.

7) Check the Ohmic resistance of the coil with Ohmmeter.

Preparation of the inserting machine, consists of filling with Polyester tape and making adjustments to the height of the package and the cut length of the slot closure.Check the length of the groove closure with a digital *caliper. Operate the automatic inserting machine, which consists of positioning the clamp with the coil group plus the insulated sheet.Check the continuity of the coil groups with continuity test.*

3.4 Necessary Conditions

Table 1: Procedures.

Activity Sequences		Obsevations
What to Expect ?	**Stages?**	
Activity Sequences		
Mark as initials of the operators	Mark on the stator plates, use the atomic brush. Mark in sequence inserter, inserter assistant and winder operator	Mark the initials of the operators on the label of the reels who made the insertion.

Source: Authors, (2022).

Table 2. Stator winding check (Winding).

What to Excute ?	Stages?	Observations
Check the winding type of the wound stator.	- Confront the winding stator item with the winding set item.Check the label for the insertion pitch and winding type (mixed, double or single layers).	Check that the insulated stator is free of damaged or displaced plates, groove bottom insulating materials are displaced/damaged or missing.
Evaluate insulating materials, documentation/physical.	- Check the class of the insulating materials (F or H), correct sizing and necessary quantity. - Check that there is no damaged insulating material at the bottom of the groove and aligned in the same proportion before starting insertion.	Insulators withincorrect dimensions should be returned to the operator who supplies the incoming line, checking the materials in the production order as specified.
Set the step position of the coil insertion in a wound stator.	- Position the shielding materials (polyester) in the grooves making the insertion step, according to the attached label, to the coil assembly. - Set the insertion starting point to the slot that is in the same straight line as the guide channel on the clamped stator outer diameter. - Count the step to the left of the insertion operator making coil distribution.	Check that the polyester protections are not damaged during the process, and replace them immediately if the protections are damaged.

Source: Authors, (2022).

Table 3. Inserting the coils in the specified stator position.

Activity Sequences		Observations
What to Excute ?	**Stages?**	
Insert the coils in the specified stator position.	- Position the polyester materials in the slots by making the insertion pitch, as per attached label, to the coil set. - Insert the coils at the initial step position as specified in the drawing. - Define as initial insertion point the groove in the position above the groove, considering the right side of the groove with the groove facing down, counting the step to the left of the insertion operator that distributes the coils.	Check that the polyester protections are not damaged during the process, replace them immediately if the protections are damaged.
Insert coils into the stator.	Insert the coils and insulating materials manually, according to the sequence of the activity and the characteristics/ specifications of the coil.	Observe, that each coil is placed in its groove, avoiding that wires/wires from other coils are grouped in parallel grooves. Verify during winding that the coil is free of scratched or blistered wires.
	- Use the felt protection for II pole, double layer and interlocked winding stators, regardless of the pitch. - The other winding stators should use felt if the operators realize that the coil is going to touch the pallet, possibly damaging the coils.	
	Winding A and B. Double-wound winding stator, insertion starts with the winding with the largest pitch. Double-winding winding stator start the first insertion by the smallest polarity.	- The insertion of the 2nd winding of smaller pitch can start anywhere in the wound stator. - Wound stator with high filling, the insertion helper should place the closure at the end of the stator, preventing the copper wires from sticking out of the groove, generating material damage, scratched/damaged wires.

Source: Authors, (2022).

Table 4 Coil Centering and Coil Tying by Phase in Stators.

Activity Sequences		**Observations**
What to Excute ?	**Stages?**	
Center the coils.	Center the coils, proportionally on both sides, avoiding coil heads higher than specified in subsequent processes.	Take care not to damage the coils when rotating the stator under the pallet.
Take care not to damage the coils when rotating the stator under the pallet.	Use fiberglass tape, tying the 04 coils from the inside, separating them by phases in wound stator II poles, avoiding the occurrence of wires passed between the phases of the coils.	The purpose of the tape is to avoid the passage of yarn, that is, it does not have the need to tighten the coils, generating coil deformation (elbow) in the conformation of the coil heads.
Insert coils with wiring diagram.	**Motors with Tip Scheme:** Insert the 1st coils of each phase, mark with the atomic brush on the interlayer where the 1st insertion starts, remaining at the marked interlayer as reference, forming the insertion step of the 2nd phase to the left of the marked interlayer, following the same procedure of inserting the coils of the 3rd phase.	
Insert insulating tubes.	Insert the insulating tubes from the coil ends all the way into the bottom of the groove.	
Finishingthecoils.	Insert the coils so that they have a"combed" appearance, for all the coiled stators.	Center the insulators between phases in the coil. Keep the wires parallel to each other, in 100% of the wound stators, thus maintaining the quality of the product.
Insert coil outputs tips.	Insert the coil output ends into the inner diameter of the stator, taking care of the coil heads so as not to scratch them with the wire ends.	Distribute the tips on the inner diameter, preventing them from tangling, making it difficult to form the coil heads in the forming press the 1st time.

Source: Authors, (2022).

Table 5. Preforming the coils and cutting the excess between layers.

Activity Sequences		**Observations**
What to Excute ?	**Stages?**	
Preforming the coils.	Use the rubber hammer to lower the height of the coil heads, leaving them below the outer diameter of the stator.	Take care with possible damage (Deformations), in the coil heads, so as not to compromise the quality of the product.
Cut off excess interlayer (insulating) tips.	Cut the excess of the interlayer tips with scissors, taking care not to scratch the strands.	Rotate the winding stator, take care of the spools, preventing them from touching the pallet and spools with scratched wires.

Source: Authors, (2022).

Table 6. Result expected.

Control Items	**Control Frequency**	**Measurement Instrument or Method**	**Acceptance Criteria**	**Provision for Non-ConformingCharacteristic**
Copper Wire	100%	Visual	No scratched or banged copper wires / Dents.	Evaluate the possibility of insulating the copper wire, giving 04 turns of Kapton tape at the same point,otherwise wrap the QC.
Insulating Materials			No misplaced / damaged or missing insulating materials.	Exchange / when necessary and replace missing material.
Insertion of the coils.			No wires twisted, scratched, damaged, or misplaced.	Identify with card mod. 0073 - (WFR - 17583) to be evaluated by the QC.

Source:Authors, (2022).

3.4 Packaging and Identification

Table 7. Packaging and identification.

Activity Sequences		**Observations**
What to Excute ?	**Stages?**	
O estator bobinado deveseguir acondicionado empallets.	Use the appropriate suspension equipment and place on pallets. - Keep the rolling rings distributed on the mass, preventing the material from falling.	For safety's sake, insert the C-hook device on the entire inner diameter of the part.

Source: Authors, (2022).

Table 8. Identification of winding.

Identification	Where
Winding identification: On the label that is affixed to the stator's stapled plate. Note: Keep the identification legible for subsequent processes.	

Fonte:Autores, (2022).

Table 9. Environmental CareandWasteDisposal.

Waste	Internal Collectors	External Collectors	Final Destination	Observations
Insulating Materials	Blue container -Not recyclable-	Blue Bucket -Not recyclable-	Class II Industrial Landfill	Collected and Outsourced Company.
Insulating Material Polyester class B	Red Container -Polyester class B-	Red bucket	External Recycler	Scrap Storage
Waste PPE (Rubber, PVC, leather andmesh)	Blue container -Non-recyclable-	Blue bucket -Non-recyclable-	Class II Industrial Landfill	-
Sweeping/plant cleaning waste	Blue container -Non-recyclable-	Blue bucket -Non-recyclable-	Class II Industrial Landfill	-

Source:Authors, (2022).

*Note: For disposal of wastes not covered in this standard, consult WPS-6189 - (Industrial Waste Disposal), or section manager. Procedure in case of spills and leakages.

3.57 Contain the spill/leakage immediately. Collect with the help of shovel, sawdust, industrial towels or otherdevice appropriate to the situation.

3.58 Dispose of as described in the chapter on waste disposal of this standard or as directed by the area manager.

12.1.Energy Efficiency

Table 10. Equipment / process and energy care.

Equipment / Process	Energy Care
Lamps	Turn off the lights when you are not working in the area.
Fans	Turn off the central panel fans during meal breaks and meetings.
Winding Line	Shut down the winding line and machines / equipment on long breaks and weekends.
Microcomputer / Printers	Turn off microcomputers/printers on weekends
Compressed Air	Check for possible compressed air leaks in machine supply hoses; equipment and/or devices in your workplace.

Source: Authors, (2022).

IV. RESULTS AND DISCUSSIONS

This case study focuses on an organization that produces consumer goods. The company is a manufacturer of Electric Motors, which produces and sells products from over 100 brands in over 38 countries. This company produces, Electronic and industrial equipment. Manufacturing of low and medium voltage electric motors, industrial automation equipment and maintenance services, Power generation, transmission and distribution. Electric generators for hydraulic and thermal power plants, hydraulic turbines, wind turbines, transformers, control panels substations and systems integration services. Company name, job names, and program names are not disclosed for confidentiality purposes. The company has implemented sub-organizations called operations center to handle logistical, financial, master data, and purchasing operations. There are one or more locations to handle a continent. In Europe, and has a branch office in the industrial city of Manaus.Some of the operations in its production process are:- Operating mainly in the capital goods sector with solutions in electrical machinery, automation and paints, for various sectors, including infrastructure, steel, pulp and paper, oil and gas, mining, among many others. The Organization stands out in innovation by constantly developing solutions to meet the major trends in energy efficiency, renewable energy and electric mobility. With industrial operations in 19 countries and commercial presence in over 38 countries; - implementation of processes and improvement programs, among other Kaizen programs. Within the company, the Productivity Kaizen project at the Plant's winder and manual insertion centers was developed at the Manual Insertion Work Center in Brazil, Manaus. The company decided to start implementation on desaturation loss reduction in the winding and manual inserting work centers of Factory I, it is proposed to unify the winding, manual inserting and insulating material preparation work centers.

4.1 Brief description of the problem to be solved: This case study seeks to analyze and apply solutions to the design problems encountered during evaluation, after reviewing the manufacturing and setup times of the Factory's winding and manual insertion work centers, it was observed that the processes were exhibiting desaturation losses leaving the process sluggish, The main reason for this reduction is the mechanization of certain product families. Details of the production history from 2019 to 2022 are shown in Figure 9. The data wasextractedfromtheorganization's ERP.

Table 11. Process Flowchart Manual Inserting Winder.

Start
Step1= Receiving raw materials from the warehouse (Polyester Tapes, Sheets and Conductor Wire.
Step2= Preparation of the insulating machine, consists of filling with Polyester tape and setting the cutting and bending tools in manual mode.
Step3= Operate isolator in automatic mode for cutting and bending the bottom groove insulator.
Step4= Check the length of the collar and fold with a digital caliper.
Step 5=Winding machine preparation, consists of program and supply with copper and/or aluminum conductor wire.
Step6 = Run the winder in automatic mode to create the groups of coils in the clamps.
Step 7=Check Ohmic resistance of coil with Ohmmeter.
Step8 =Preparation of the inserting machine, consists of filling with Polyester tape and making adjustments to the package height and slot.
Step9= Check groove closing length with digital caliper.
Step10= Operating the automatic inserting machine, which consists, of positioning the clamp with coil group plus the insulated sheet.
Step11= Check continuity of coil groups with continuity test.
End

Source: Authors, (2022).

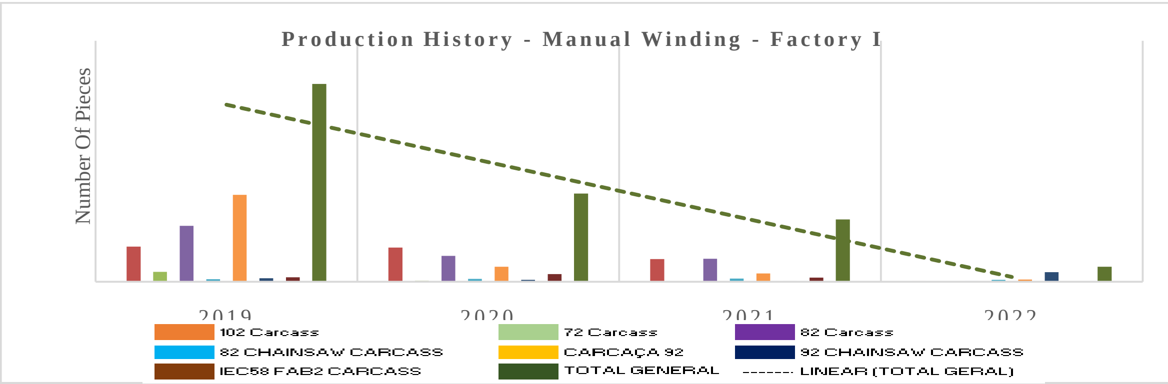


Figure 1. Production History - Manual Winding..
Source: Authors, (2022).

This problem brought productivity losses to the process. Initially, there was 1 operator/shift for the winder and 2 operators/shift for the manual insertion. As the workloads were low, 1 operator/shift was reallocated to other activities, leaving 1 operator/shift for the winder and 1 operator/shift for the manual insertion. After analyzing the work center loads for this last scenario, it was verified the possibility of concentrating the activities (winding, inserting and preparing insulating materials) in a single operator/shift, changing the load from 9% and 30% to 48%. Setup hours and hours necessary for coil recovery were added. With the new proposal it is suggested to change the critical resource from 750 pieces/week to 157 pieces/week or 15 pieces/shift. The proposed scenario will meet in 94% the weekly schedule performed this year according to Figure 2.

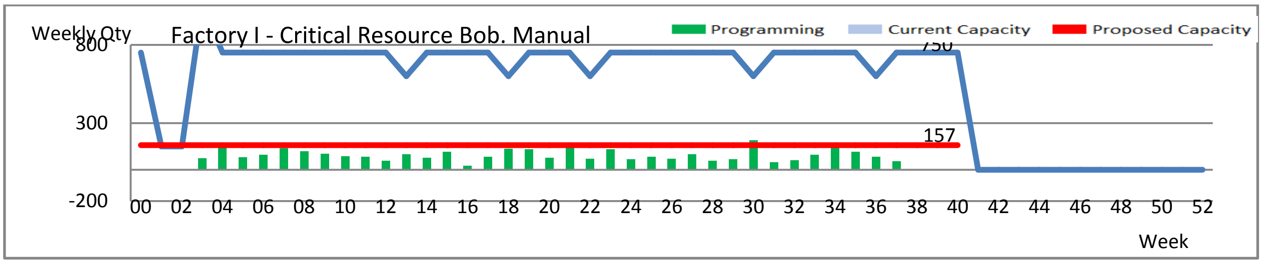


Figure 2: Critical resource manual winding.
Source: Authors, (2022).

For this scenario, it is proposed to create a Shared Capacity TC, which will encompass the following Work Centers: 01150116, 01150115 and 01150119. Besides the evaluations and loading, the analysis of the focused W.O. approach was also done for the Winder and Manual Winder, where it was possible to reduce R$ 5,454.76 of activities that do not add value (N.V.A.A.). The biggest wastes found were the waiting time for the winder and handling and rework for the manual winding. Practical tests were conducted during 2 weeks with the Industrial Engineering monitoring, where evaluations of the new method and new working times were made.

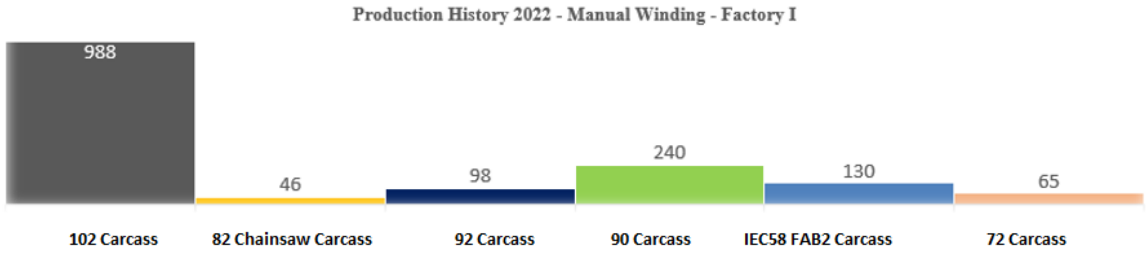


Figure 3: Production History in Manual Carcass winding.
Source:Authors, (2022).

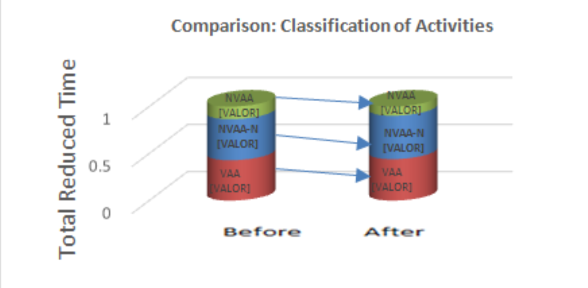
The chart indata analysis composed of a bar chart that sorts a given variable (frequency, volume, turnover, time, etc.) in descending order. It seeks to demonstrate the Pareto 80-20 principle (80% of the consequences come from 20% of the causes), that is, there are many unimportant problems in front of more serious ones. It allows visualizing and prioritizing the problems. It serves to concentrate efforts on the problems that present the greatest possibilities for improving results.

Table 12. Stratification of activities and their comparisons with the current and proposed situation after applying chrono-analysis on all activities that did not add value to the process.

Activity Stratification				
	Actual	Proposal	Difference	
VAA	378,6	368,2	10,4	2,7%
NVAA-N	385,5	385,5	0	0,0%
NVAAA	118,5	80,8	37,7	31,8%
Reduced Total Time			48,1	Seconds

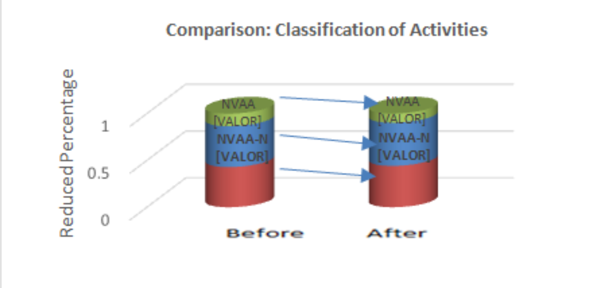
Source:Authors, (2022).

First some countermeasures are taken in relation to the sources of contamination so that they are contained or eliminated. To contain the water and oil sources, corrective and programmed maintenance was necessary in the fluid connections and piping and in the equipment's hydraulic units. In relation to metallic dust, it was fundamental to develop projects to reduce contamination, especially on the exit belts of the presses, where there was a high degree of dirt caused by the compacting of the raw material. Two devices were manufactured to reduce the spread: a suction device at the part exit belts and a dust collector box at the end of the belts, reducing the dirt that settled on the floor. At the end of the implementation of the devices we obtained a reduction of 6 minutes of cleaning per shift, corresponding to a saving of 13 thousand Reais per year and a B/C of 6.3. Afterwards the attention is turned to the process with the objective of improving the working conditions, in error reductions and consequently, productivity improvement, making an analysis relating all the operation activities and classifying them. Then, the Yamazumi Chart is used due to its visual representation to highlight the existing imbalance in the work cell, separating the activities that add and do not add value with their times. This chart is used to compare the takt time, that is, the time that a part or product must be produced based on the sales rhythm, to meet customer demand. It provides important information for the analyses of Muri, Mura, and Muda [37][38], whose purpose is to eliminate waste caused by activities that do not add value to the process. For this the activities are divided into three groups: VAA - activities that add value, generally activities of product transformation; SVAA - activities of semi-value added, do not add value, but are indispensable in the process, for example, positioning a part; NVAA - activities that do not add value, being these the cause of waste, for example, walking, transporting, waiting, etc. It is important to understand that these tools are complementary for the elimination of waste, using the filming of movements for better observation. Example: when a process is unbalanced or without pattern (Mura), we observe the occurrence of overloaded equipment and people (Muri) and consequently we will have the types of NVAA's, that is, 11 wastes (Muda). In figure 3 we show through the Yamazaki Chart the initial condition of the workstation relating the activities of the operators with the Cro-analysis.



Source: Authors, (2022).

Figure 4: Classification of activities with comparisons of the current and proposed situation after applying chrono-analysis on all activities that did not add value to the process.



Source: Authors, (2022).

Figure 5: Classification of activities with comparisons of the current and proposed situation after applying chrono-analysis on all activities that did not add value to the process.

Table 13 - Shows that behind the stratifications of Non-Value added activities (NVAA): Activity that does not transform the product directly or indirectly, and Value added activities - VAA (Value added activities), along with Non-Value added activities but necessary - NVAA-N (Non-Value added activities - Necessary), we were able to analyze the current and proposed scenario to these stratifications of these activities with 48.1 reduction in a total.

Table 13. Stratification of activities and their comparisons with the current and proposed situation after applying chrono-analysis on all activities that did not add value to the process.

Activities Stratification

	Current	Proposal	Difference	
VAA	378,6	368,2	10,4	2,70%
NVAA-N	385,5	385,5	0	0,00%
NVAAA	118,5	80,8	37,7	31,80%
Total Reduced Time			48,1	Segundos

Source: Authors, (2022).

Activities Stratification

	Current	Proposal	Difference	
VAA	0	0	0	0,00%
NVAA-N	184,5	184,5	0	0,00%
NVAA	458,4	344,1	114,3	24,90%
Reduced Percentage				

Source: Authors, (2022).

Table 14: Industrial cost calculation of motors (Costs section)

Material	Description	Industrial Cost (R$)		Variation	
		Current	Proposed	R$	%
13965792	MOTOR 4HP 2P 100LWFF2	$ 77,98	$ 77,72	-$ 0,25	-0,321%

Material	Description	Custo Industrial (R$)		Variation	
		Current	Proposed	R$	%
13322991	MOTOR 3cv 2P 100L WFF2	$ 74,08	$ 73,54	-$0,54	-0,732%

Material	Description	Custo Industrial (R$)		Variation	
		Current	Proposed	R$	%
10662446	MOTOR 5,5cv 2P IEC56 WBA1	$ 66,47	$ 60,79	-$ 5,68	-8,549%

Source: Authors, (2022).

Table 14 Process gains from the analysis of the main losses within the process, such as desaturation, after applying the NAAV tool - Activities that do not add value, we observed very important gains, not only in the reduction of product cost, but also efficiency in the process, this gain per pillar represents an annual reduction.

Table 15. Calculation of Process Gains.

Work Center	**Site Description**	**Total**	**Affected by the project**	**% Distribuição dos Ganhos**	**Comentários**
01150298	FI - Manual winding	$19.113,49	Yes	50%	Real Gain
01150299	FI- Winder Manual	$ 9.158,16	Yes	50%	
01150298	FI - Manual winding	$ 7.570,48	Yes	100%	PotentialGain
01150298	FI - Manual winding	$ 0,64	No		

Source: Authors, (2022).

Tabela 16. Desdobramento em perdas Anuais *x*Ganhos anuais oriundos após otimização do processo.

Breakdown into Losses						
Total Loss	**Loss**	**Pilar**	**CT**	**Gained (R$)**	**EarningsSummaryby Pillar**	
$ 28.271,65	Dessaturação	FI	01150298 e 9	$ 12.749, 77	FI	$ 12.749, 77
$ 7.570,48	NVAA	WO	"01150298	$ 253,26	WO	$ 253,26

Source: Authors, (2022).

Table 17. We identified that after mapping directly in the manual insertion process, using the current daily load, the average hours needed per day 1.44 with available hours of 15.83 brought reduction of average load 21% raising the service, thus activities directly linked to the process added increase in productivity zeroing the percentage.

Tabela 17. Programação não atendida.

Average hours required per day	1,44
Hours available per day	15,83
Average load	9%
Numberofdayswithunmet schedule	0
Percentageofdayswithunmet schedule	0%

Source: Authors, (2022).

Table 18. Reduction of 59% after implementing the workstation organization proposal, through studies and comparisons with the objective of reducing desaturation and increasing efficiency with real gains of $ 495,84

	Pilar	CurrentLoss (R$)	Reduction (R$)	%
Industrial engineering (Machine loads, process analysis, etc.	QualityControl	-	-	-
Environment (Environmental impact analysis, licensing, etc.)	PersonalDevelopment	-	-	-
InfrastructureandUtilities	Early Management	-	-	-
Safety and Occupational Medicine (PAME, Reports, etc.)	Logistics	-	-	-
	AutonomousMaintenance	-	-	-
Work Groups (Winding, Tooling, etc.)	Professional Maintenance	-	-	-
Quality Methodology (Indicators, analysis, etc.)	Environmentand Energy	-	-	-
	FocusedImprovement	-	-	-
Maintenance (Reports, comparisons, etc.)	Workplace Organization	$ 836,90	$ 495,84	59%
	Security			

Source: Authors, (2022).

4.3 Problem Analysis.

After a better understanding of the factors and causes surrounding the problem, a Spaghetti Diagram was drawn with the help of Chrono-analysis, where it was possible to map the losses, showing the probable causes, as shown in Figure 6. Table 18- Represents the budgeted framework of employees and their production capacity pieces/day, in the application of continuous improvement, Kaizen was possible to reduce 2 employees of 12 months, increasing the production capacity pieces/day from 5.79 per employee to 6.0 Productivity Piece/day/col. days.

Table 19. Evaluation of the events that pointed to a reduction in the number of employees in the operation, including an increase in productivity.

Event	**Data Deployment.**	**Number of Collaborators**				**Capacity Piece/day**	**Productivity. Piece/day/col.**
		Budgeted	**change of board**	**Approved**	**Real**		
Budget Factory I for 2022	-		-	616	612	3570	5,79
Productivity Kaizen Manual for Winders and Winders	out/22	616	-2	616	610	3570	6,00
Quadro Final	-		**- 2**	**616**	610	**3570**	**6,00**

Source: Authors, (2022).

The study of layout or physical arrangement involves the arrangement and physical location of processing resources. It deals with deciding where to place all the facilities: machines, equipment, and personnel. It determines the shape and appearance of workplaces and how processes will flow. Changes in layout imply changes in flow and productivity, affect costs and production efficiency. The goal of designing a good layout is to eliminate non-value-added operations (NVAA), facilitate the flow of materials and information, increase the efficiency of labor and equipment, and reduce the risk of accidents to workers. After changes in the layout we had expressive financial gains and mainly reduction in the time of execution of the activity.

3.4 Tool used

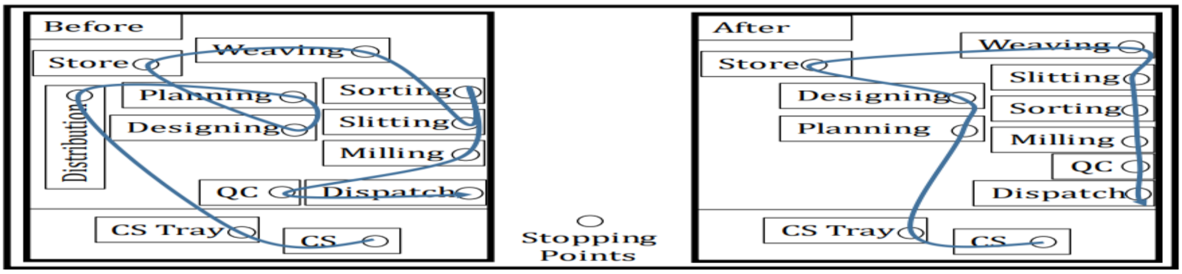


Figure 6. Spaghetti diagram.
Source: Authors, (2022).

Analyzing Figure 6, it can be concluded that the main causes of the problems are related to the problem of desarturation caused by lack of mapping of losses, the layout not suitable to the initial objective presented, described in the method and materials branches, respectively. Therefore, considering the need to make changes in the process layout, a small brainstorming was done with the technical teams, and some solutions were proposed as shown in Figure 7 and 8:

3.4.1 Spaghetti Diagram, 3M's and Chrono-analysis.

Spaghetti Diagram was used as the main tool for elaboration and data collection and evaluation of the results obtained, after treatment of all data and analysis, based on the ascertainment and tables with the main information found in the case study aimed at improving the production process in manual winding insertion.

4.5 Discussions

The applied method benefits from a combination of three effective continuous improvement methodologies. it can and should be adapted to the requirements of a company. The approach and the toolset are adapted to the needs of an organization. The paper presents how Kaizen can improve the processes of the manual winding insertion of manufacturing I, as well as their implementation to other areas of the company and thus improve customer satisfaction. After collecting data, it was possible to make an adaptation within the company and a special scheme was created. The company adjusted the Kaizen method and introduced four steps: Identification, Analysis, Conception, and Implementation. The team was motivated to use many adapted tools to find areas for improvement. Based on the studies and results presented, it is possible to use a cohesive and structured management system, allowing familiarization with lean practices, enabling the elimination of losses and productivity improvements in production plants, regardless of their size, as long as there is the involvement and commitment of the organization's top management and planning for the implementation of the management system, which is fundamental for the success of the philosophy and the change of the organizational culture.

V. CONCLUSIONS

This research aims to present through the application of the lean manufacturing tool, integrated with computer simulation, the various options for improvements and loss reductions that a manufacturing process can obtain. This result was achieved through the use of several tools that allowed the positive simulation. From the tools such as the spaghetti graph, a simulation was generated that allowed it to be used as a model for other areas of the Organization, with Global highlight of other Sites of the company, with recognition by the board of the head office. Global Perspectives for Production Engineering Manaus, AM, Brazil, the results achieved ensured a 30% average reduction in handling time, this change will bring positive impacts such as - Ergonomics: decrease in the paths, providing more safety and faster transitions. - Organization: a planned physical arrangement facilitates access to machines and makes the environment visually more pleasant. - Inventory: stocks, both final and in-process, can be reduced due to a shorter production lead time. In relation to what was presented, it can be concluded that the proposed change of the new layout brought to the planning a powerful tool that enables companies to visualize the results before investing time and resources in it.

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