v. 3, n. 24, 2023

Journal of
Engineering
Research

ERGONOMIC RISK REDUCTION OF THE LINER OPERATION OF THE PUSHER ONE PRODUCTION CELL THROUGH SEMIAUTOMATION IN A MEDICAL COMPANY

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Abstract: In this research, the use of semi-automation is proposed to reduce ergonomic risk in production operations. To do this, a case study is presented regarding a medical company, in which a high ergonomic risk is detected in a production cell, in which a catheter is manufactured to treat brain aneurysms. This production cell is called Pusher One and the study focuses on the Liner operation.

The research also arises, because the need to improve some productivity metrics is detected. Faced with bottlenecks, high production times, stress and fatigue in the personnel and not reaching the daily production goals, as well as a lack of quality in the finished products, it is concluded that there is a high ergonomic risk in the operation. With the situation described above and in view of the company's goal of transcending towards greater maturity, the hypothesis was raised as to whether semi-automation could improve the production process, but above all reduce the present ergonomic risk. As the hypothesis is affirmative, the project would have great potential when replicated in other production lines of the same company. In addition to this, it could demonstrate the importance of automation as a tool for reducing ergonomic risks.

The results of the investigation reflect that the favorable results for the company were evident and the goals set were exceeded. Above all, the main objective was to make the operation in question safer for its collaborators. The ergonomic analysis carried out contributed to improving production standards while benefiting the operators. For the company, it represents a contribution to its safety policy, as well as to occupational risk control regulations.

Keywords: ergonomic risk, semi-automation, Work effort index (JSI), production, medical sector.

Work areas: Work evaluation, work design and analysis.

Relevance for ergonomics. This project shows that, in the present case study, semi-automation made a radical change not only in the improvement of the process, but also in the main objective, which was the reduction of ergonomic risks in the operation in question. The hypothesis raised was verified and it is considered that this work can help to bring to the table the debate about the advantages of automation in ergonomics.

INTRODUCTION

This project was carried out in a medical business, located in Tijuana Baja California. Taking into account that the company is constantly growing and in search of continuous improvement, the improvement of the processes was derived by converting the lines to production cells. This led to the detection of some areas of opportunity that gave rise to this investigation. One of the overriding factors was the safety of its employees. Considering that operations are carried out in a safe work environment with a low risk of occupational diseases. In addition to this, the need to improve some productivity metrics is considered.

The general objective was to reduce the ergonomic risk of the Liner operation of the Pusher One production cell and to improve the productivity metrics through semi-automation. For this, the application of the JSI methodology to determine the ergonomic risk and reduce it were considered as short goals, as well as to analyze the production process to determine the level of semi-automation. The JSI method is chosen because the occupational safety regulators consider it a valid method. In the same way, it was planned to contribute to the productivity metrics, reducing the productivity time of the operation by 30% and reducing waste due to poor material handling by 40%. Therefore, and in the same vein of continuous improvement, it was considered to apply the DMAIC methodology as a basis for the development of the project.

The project had a greater scope than the proposed objective since it will be replicable for other areas of the company. Its application went to the Pusher One cell station of the operation called Liner and it demonstrates in the area of ergonomics how automation can benefit companies and their employees together to make work safer on the one hand and on the other hand the other, to raise their productivity rates.

DELIMITATION

The project was carried out in a company of the medical sector. It was focused on an operation called Liner of the Pusher One production cell. The project was limited to developing in six months and was applied as a professional residence for the Industrial Engineering career at the Tecnológico Nacional de México, Tijuana campus.

METHODOLOGY

The research was carried out from two axes, on the one hand, the use of the JSI methodology for ergonomic assessment, and on the other, through the DMAIC methodology. In addition, various industrial engineering tools were used to complement the resolution of the problem. Figure 1 shows the strategy used in a schematic way.

JSI METHODOLOGY

On this occasion, the company decided to use the JSI method because the occupational safety regulators in the context in which it is found, consider it a valid method.

The JSI method "[…] is a job evaluation method that allows assessing whether the workers who occupy them are exposed to developing cumulative traumatic disorders in the distal part of the upper extremities due to repetitive movements. Thus, the hand, wrist, forearm, and elbow are involved in the assessment. The method is based on the measurement of six variables, which once assessed, give rise to six multiplying factors of an equation provided by the Strain Index. This last value indicates the risk of appearance of disorders in the upper extremities, the risk being greater the higher the index. The variables to be measured by the evaluator are: the intensity of the effort, the duration of the effort per work cycle, the number of efforts made in one minute of work, the deviation of the wrist with respect to the neutral position, the speed with which the task is carried out and its duration per working day" (Diego-Mas, José Antonio, 2015).

DMAIC METHODOLOGY

The DMAIC methodology is a methodology used for improvement that addresses problems in a systematic and scientific way also known as Six Sigma and derived from it. The DMAIC methodology studies the processes to eliminate the different types of waste in a production process that do not add value to the customer, control the variation of the data and focus the process to the customer's specifications. In general, any methodology requires a general projection with specific tools for its application, with Six Sigma not being an exception. For this reason, this part will analyze the general methodology that it uses and the statistical methods necessary for its application. Any process within an organization can be understood as a function that, applied to certain input variables, provides a set of result variables. The Six Sigma methods propose to work to improve the processes, on those input variables that significantly influence the outcome variables. To decide on these issues, it is recommended

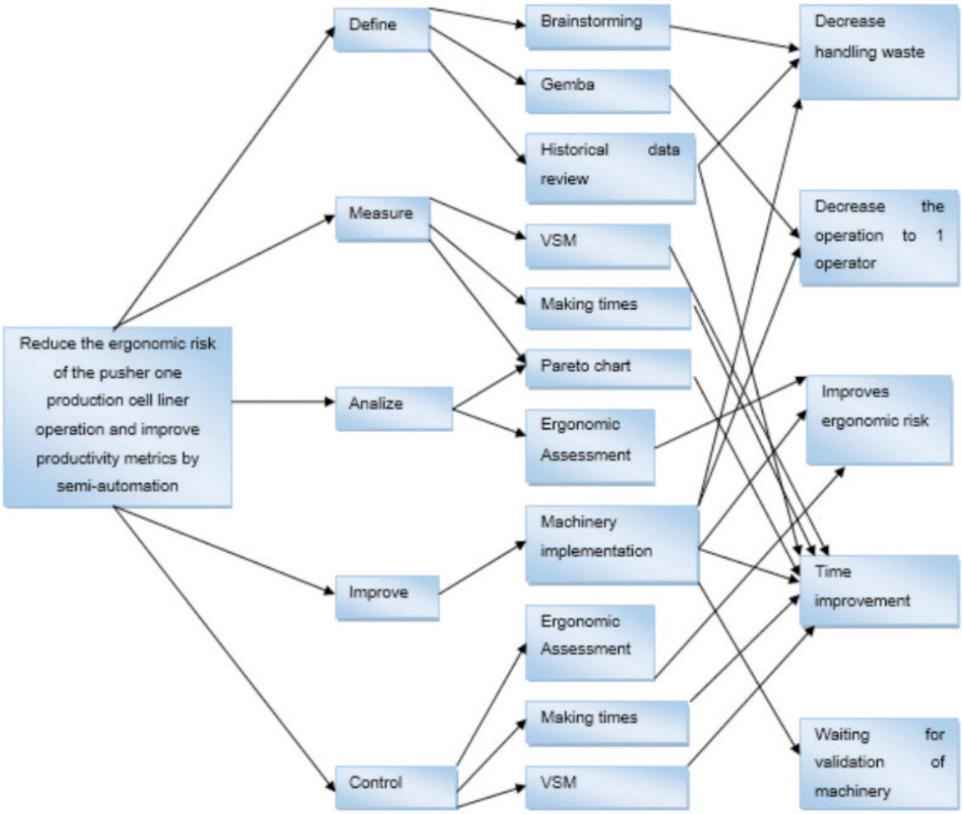


Figure1. Represents the strategy for the development of the project.

Source: Prepared by the authors.

Time Measurement Sheet

PROCESS:	Pusher One	RECORDED BY:	Luis Mendoza
SHIFT:	1	DATE:	feb 18 2021

No.	Element	1	2	3	4	5	6	7	8	9	10	Low Repeat (3)	Adjust	Adj. Low Repeat	MANUAL Wait	MANUAL Walk	MANUAL Work	AUTO (Unattended Machine)
1	Inser Outer Jacket	13.00	11.00	12.00	13.0	10.0	13.0	12.0	13.0	13.0	12.0	12.0		12.0	2.0	0.0	0.0	0.0
2	Inser Sac witre on liner	15.00	16.00	74.00	14.0	15.0	14.0	13.0	16.0	15.0	14.0	14.0		20.0	7.5	0.0	0.0	N/A
3	Strech and cut liner	13.0	9.0	39.0	10.0	13.0	13.0	10.0	11.0	11.0	12.0	11.0		11.3	5.6	0.0	0.0	0.0
4	Liner inserter	74.0	75.0	66.0	69.0	73.0	79.0	77.0	71.0	73.0	72.0	73.0		72.9	36.5	0.0	0.0	N/A
5	Inserter outer jacket tool	57.0	59.0	36.0	58.0	59.0	57.0	58.0	59.0	57.0	57.0	57.0		57.5	28.8	0.0	0.0	N/A
6	Shrinkage, cut and measure	56.0	53.0	116.0	53.0	54.0	51.0	53.0	59.0	56.0	52.0	53.0		54.1	27.0	0.0	0.0	N/A
	Total Best of 3											220.0	0.0	227.8	107.4	0.0	0.0	
	Total of Observations	228.0	223.0	343.0	217.0	224.0	227.0	223.0	229.0	225.0	219.0							
														Total Man	107.4			

Table 1. Time taken from the cell.

Source: Prepared by the authors.

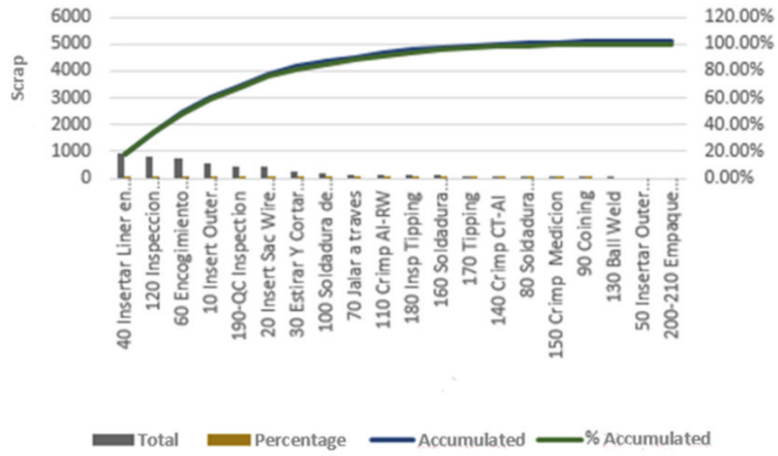


Figure 2. Shows the Pareto Waste-Operations Diagram, observe the Liner operation.

Source: Prepared by the authors.

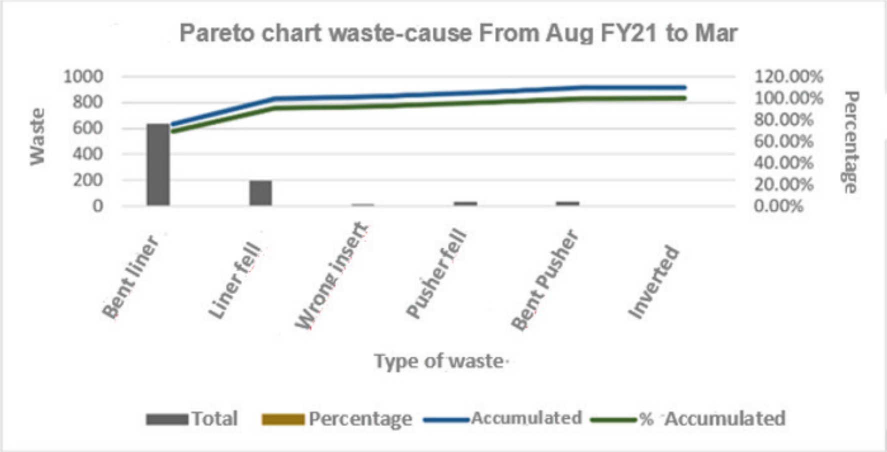


Figure 3. Pareto Waste-Operations Diagram, shows the types of defects.

Source: Prepared by the authors.

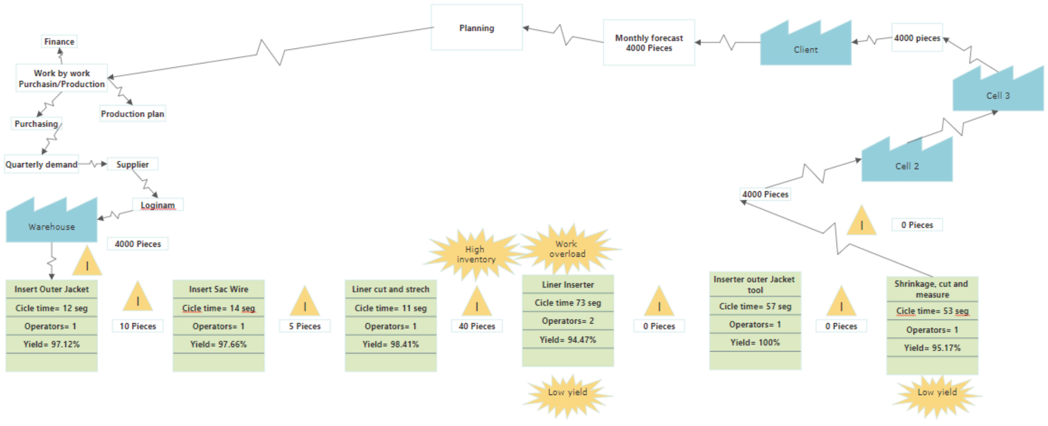


Figure 6. Cell value flow map before enhancement.

Source: Own elaboration with company data.

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.317324231407

not to be based on subjective criteria, but on objective facts deduced from the analysis of existing information or collected for that purpose. The development of a Six Sigma continuous improvement project arises from five basic and well differentiated stages, which constitute what has been called DMAIC Methodology (García, 2014, pg. 28).

The DMAIC methodology helps us to make decisions based on objective data for the improvement of processes, where with the help of quality tools the root cause of the problems is justified, as long as all the phases of DMAIC are used since a decision An unfounded decision does not allow you to visualize beyond your knowledge and experience, on the contrary, if DMAIC is used correctly, you can visualize a broader picture and make a decision that is not biased by the ideas of the person.

Regarding the aforementioned, Gutiérrez and De la Vera, 2009 argue that the data alone does not solve the problems of the client and the business, therefore a methodology is necessary. In 6σ, projects are rigorously developed with the five-phase methodology: Define, Measure, Analyze, Improve and Control.

RESULTS

The results are presented following the DMAIC methodology in each of its stages. Likewise, according to the diagram of the methodological strategy, ergonomic evaluation is presented from the stage of analyzing and improving.

DEFINE

The main problems in the area were low productivity, waste due to material handling and possible fatigue of the right wrist of the person in the Liner operation, which could result in an injury, which would lead to an ST7 leading to an ST9 or illness. of work. A Gemba was used around the area and brainstormed.

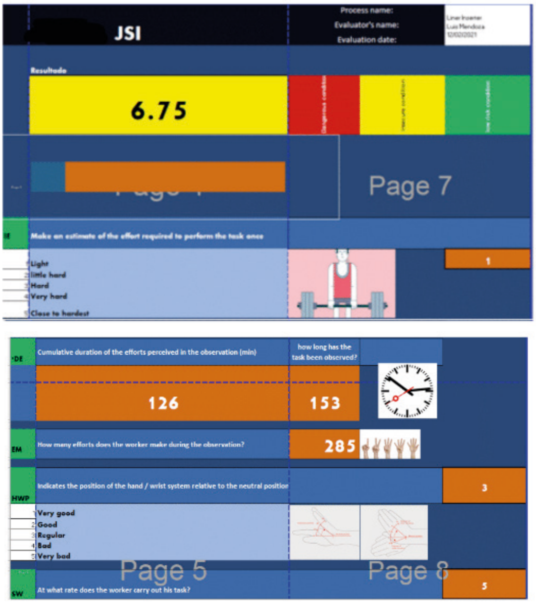
MEASURE

The analyzes were carried out by means of graphs and time taking to measure the current state of the cell and its operation. Table 1 shows the measurements.

Waste is shown in Figure 2. Through a Pareto diagram by seasons, it can be observed that the Liner operation is the largest contributor to waste, hence the object of study.

When making the previous Pareto Chart, with the operations with the most waste, it was decided to make another Pareto Chart with the types of defects, as shown in Figure 3.

For its part, due to the repetitive movement of the wrist, which was demonstrated in the operation and complaints from the workers. It was decided to carry out an ergonomic evaluation and use the JSI method, supported by the company's recommendations since it is considered a valid method by the authorities in the area of occupational safety. When carrying out the evaluation, which was carried out with the criteria of the company and the researcher, it was concluded that this operation produced an unsafe condition for the worker, as can be seen in Figure 4.



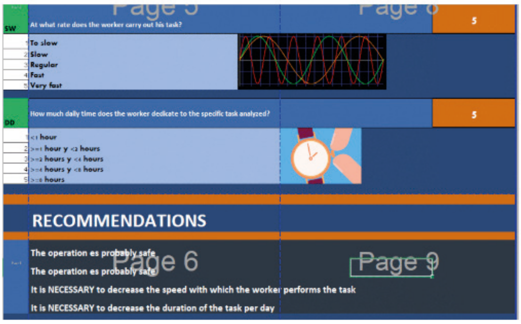


Figure 4. Ergonomic evaluation before improvement.

Source: Format extracted from the company and evaluation carried out by author.

Figure 5 shows the operation in its initial state, in which the position of the wrist and hand can be appreciated, denoting the repetitive movement in the left hand.

Figure 5. Shows the Liner feature where the repetitive wrist movement is found.

Source: Image taken at the medical company in question.

Figure 6 shows the current value flow of the cell, that is, before the improvement, where the points to be attacked are identified.

ANALYZE

According to the variables raised in the research, it was decided to carry out a 5 whys, considering it as the initial method to reach the root cause of the problem. It is presented in Table 2.

After the implementation of the semi-automated machinery, it was decided to perform the ergonomic evaluation again with the same operator, to analyze the changes and the relationship between these two variables, that is, between the Liner operation and the implemented machinery. Thus, with the implementation of the insertion machinery, the results were analyzed and presented in Figure 7.

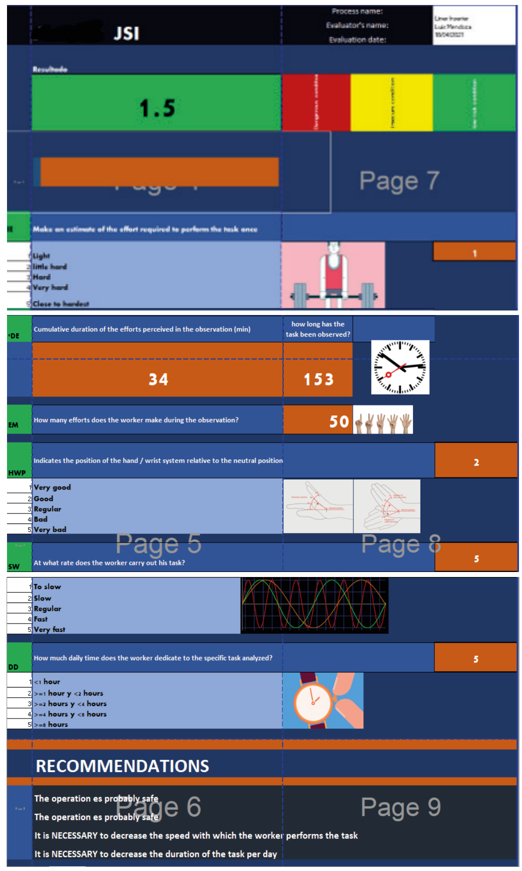


Figure 7. JSI ergonomic evaluation after improvement in Liner operation.

Source: Format extracted from the company, evaluation carried out by the author.

IMPROVE

In this phase, the metrics that were improved through the implementation of the machinery and that have their relationship with productivity are graphically presented. Figure 8 shows the improvement in terms of cycle time.

	W1	W2	W3	W4	W5
High lead time	High waste by rework	Fragile and small material	Material is bent or thrown	High speed to meet the goal	Lack of fixture to insert it
	Uneven workload	Long liner process	By inserting liner into pusher	It has to be done carefully	Lack of machinery to assist operator with insertion
	Tiredness due to dysergonomics	Perform the operation around the clock every day	Perform repetitive wrist movement	Lack of machinery to help insert the liner	N/A

Table 2. The 5 whys of the variables found in the measurement phase.

Source: Prepared by the authors.

Time Measurement Sheet

PROCESS:	Pusher One	RECORDED BY:	Luis Mendoza
SHIFT:	1	DATE:	Apr 18 2021

No.	Element	1	2	3	4	5	6	7	8	9	10	Low Repeat (3)	Adjust	Adj. Low Repeat	MANUAL Wait	MANUAL Walk	MANUAL Work	AUTO (Unattended Machine)
1	Inser Outer Jacket	13.00	11.00	12.00	13.0	10.0	13.0	12.0	13.0	13.0	12.0	12.0		12.0	2.0	0.0	0.0	0.0
2	Inser Sac witre on liner	15.00	16.00	74.00	14.0	15.0	14.0	13.0	16.0	15.0	14.0	14.0		20.0	7.5	0.0	0.0	N/A
3	Strech and cut liner	13.0	9.0	39.0	10.0	13.0	13.0	10.0	11.0	11.0	12.0	11.0		11.3	5.6	0.0	0.0	0.0
4	Liner inserter	43.0	45.0	44.0	48.0	46.0	46.0	47.0	46.0	46.0	47.0	46.0		58.0	22.9	0.0	0.0	N/A
5	Inserter outer jacket tool	57.0	59.0	36.0	58.0	59.0	57.0	58.0	59.0	57.0	57.0	57.0		57.5	28.8	0.0	0.0	N/A
6	Shrinkage, cut and measure	56.0	53.0	116.0	53.0	54.0	51.0	53.0	59.0	56.0	52.0	53.0		54.1	27.0	0.0	0.0	N/A
	Total Best of 3											193.0	0.0	212.9	93.8	0.0	0.0	
	Total of Observations	197.0	193.0	321.0	196.0	197.0	194.0	193.0	204.0	198.0	194.0							
														Total Man	93.8			

Table 3. Liner time taken with improvement implementation.

Source: Prepared by the authors.

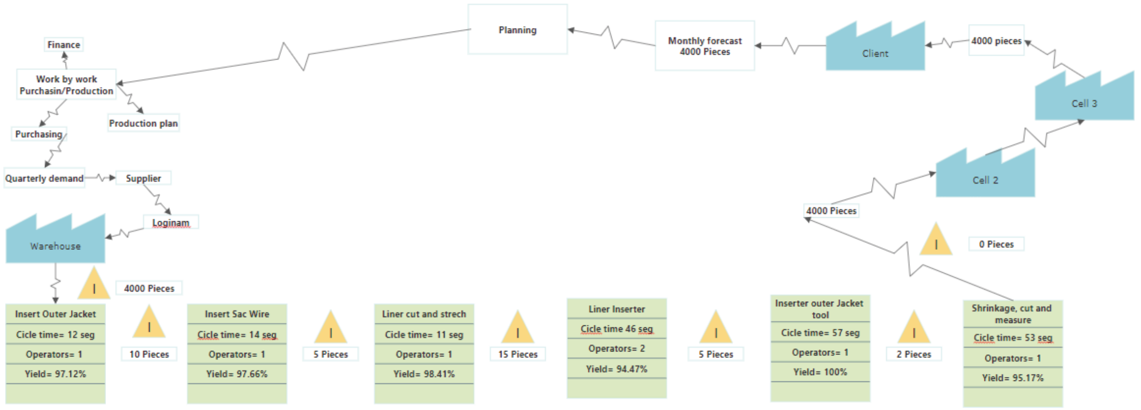


Figure 9. Value stream map with the Liner insertion machine implementation.

Source: Prepared by the authors.

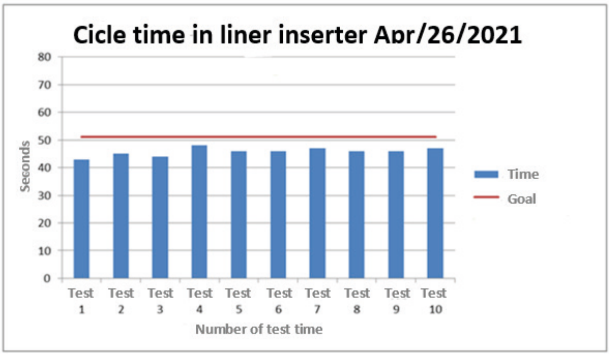


Figure 8. Graphic representation of the improvement in the cycle time to Liner.

Source: Prepared by the authors.

Table 3 shows the measurement of the time taken already with the operation of the semi-automated machinery.

In Figure 9 you can see the value flow map with the implementation of the machinery, where you can see the difference to the one previously presented.

CONTROL

The fulfillment of the objectives was demonstrated by means of the graphs previously analyzed. To keep control of this improvement and visualize the variability of the process, measurements of the metrics will be carried out daily and the procedure will be changed to add the new correct steps.

Thanks to the semi-automated design shown in Figure 10, the insertion point of the component is easier and variable and erroneous movements are eliminated, all this contributes to the elimination of waste, but above all to the ergonomic part that was wanted to improve in this project.

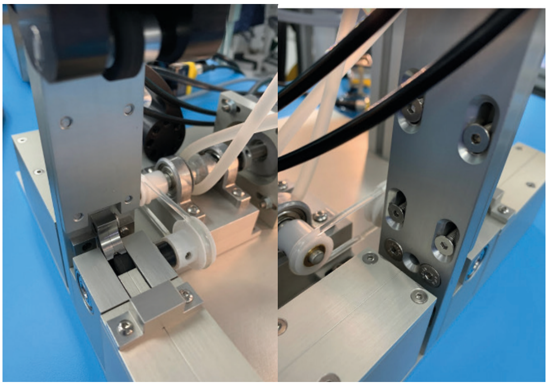


Figure 10. Shows the machinery for the semi-automated process.

Source. Own elaboration taken from the company.

In Figure 11 you can see the performance of the Liner operation and the fulfillment of the objective of eliminating 40% of waste, which has remained constant.

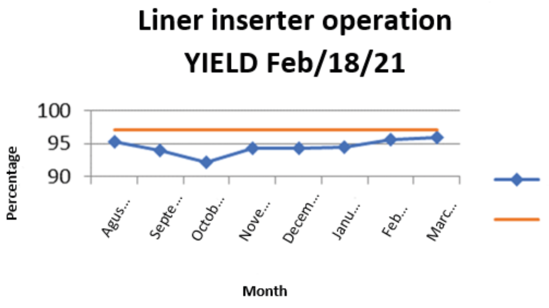


Figure 11. Graphical representation of the last months of the Liner operating performance

Source: Prepared by the authors.

Another objective was to reduce the cycle time by 30%, which led to a 37% reduction in time. In Figure 12 you can see how the goal was reached and is being maintained.

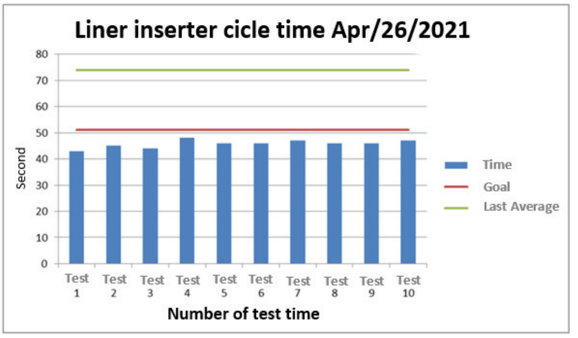


Figure 12. Graphic representation of current times.

Source: Prepared by the authors.

In Figure 13 an improvement in the Yield is observed, it is concluded that the improvement implemented was successful.

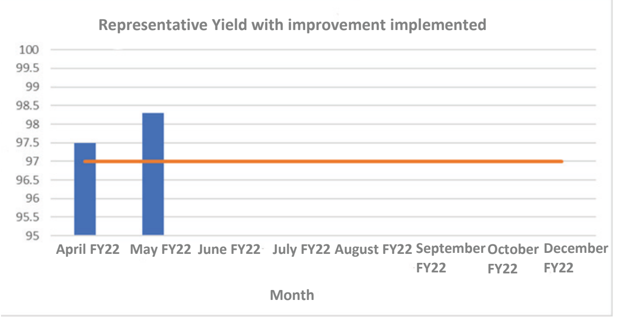


Figure 13. Representation of the Yield increase exceeding the goal

Source: Prepared by the authors.

For the results of the ergonomic analysis, the risk for wrist fatigue was reduced to 1.5 as shown in Figure 7, the risk low from medium almost high to very low fulfilling the main objective.

CONCLUSIONS AND RECOMMENDATIONS

This research represented a plausible project for the company since the results were evident and the goals set were exceeded. Above all, the main one that was to carry out the safest operation for its collaborators. In addition, it is a project that, given the results, will be replicable.

The ergonomic analysis carried out contributed to improving production standards while benefiting the operators. For the company, it represents a contribution to its safety policy, as well as to occupational risk control regulations.

For the ergonomic analysis results shown, the risk for wrist fatigue was reduced to 1.5, which means that the risk was low from medium to high to very low meeting the objective of the investigation. In general, it is considered that thanks to the performance of the objectives achieved, the production process was improved by the implementation of a semi-automated machinery, which makes the Liner operation a safer and more efficient operation. Specifically, in the insertion time, the objective of which was to reduce the cycle time by 30%, with the implementation of the machinery the insertion speed was greatly increased. It is worth mentioning that the insertion time takes most of the liner process, therefore this led to a 37% reduction in time.

Regarding the cell performance metric, this was below the expected goal, the measurement of the last months before implementation was taken and it can be concluded that the performance of the line is affected and thanks to the implementation of the DMAIC methodology, it was possible to get to the root of the problem. In addition, an implementation was made to root out what was causing the poor cell performance.

To verify compliance with the goal of minimizing waste by 40%, in the tests carried out with the insertion machine, no waste due to handling (bending or pulling) was observed, thanks to the design of the machinery where the Liner is inserted. It is conical in shape, this way makes the insertion point easier. In addition, due to the rollers that move the component in a uniform and fluid way, the hem is eliminated, due to variable and erroneous movements, all this contributes to the elimination of waste that was mainly due to handling.

Thanks to the improvement, it was concluded that the waste due to handling does not always belong to the operator; in this case, it was the need for an implementation that helps the operator to carry out his work. Which brings us to the ergonomic part of the project and on which the hypothesis is raised. It was stated that semi-automation could improve the production process, but above all reduce the present ergonomic risk, which was verified when the project was developed.

This research also shows that through the DMAIC methodology any production process can be improved, reaching the root cause of the problem, which in this case, has a direct relationship with the low effectiveness of how the process was carried out. Also that through this methodology each objective set out in the project was met. Improve production times, specifically reduce cycle time by 30%, which was achieved and not only that, but the goal was exceeded, reaching a reduction of 37%.This contributed to the improvement of several factors such as, firstly, the stress of the operator, being pressured to reach the daily production standard. The same situation that forced the operator to do the job with low care and poor quality, focusing only on the goal, this led us to another factor for improvement, which was waste.

One of the main recommendations is that given the importance of occupational safety and also having found areas of opportunity in the company, do not let yourself be overlooked by replicating this research, or, where appropriate, applying ergonomic methods according to the context of work cells. It is also recommended to look at other ergonomic methods that, although they are not yet considered by the regulatory authorities, if their effectiveness and plausible results have been demonstrated.

Another recommendation is to carry out control actions, since in this way the production process can be monitored and followed up, in order to meet and maintain production standards.

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