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Establishing Standard Methodologies To Improve The Production Rate Of Assembly Lines Used For Low Added-Value Products

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Abstract

Global competitiveness, mainly in the automobile sector, requires a constant focus on products and process innovation in order to provide consumers with a large variety of products of an excellent quality and at a low cost. In line with this philosophy, the study undertaken of the work method and its inherent activities has pointed to time measurement as a support tool of great potential in the optimization of the production process. The present case study aims to optimize the production process of an assembly line dedicated to the manufacture of control cables for the automotive industry. The ultimate objective was to adjust the output of the current line to that of the initial budget. By mapping all the activities and measuring the time spent on each of these, one was able to analyze the existing problems and inefficiencies. Subsequently, through the use of Lean tools and methodologies, one managed to find viable solutions, which resulted in a significant increase in productivity. The solutions implemented have allowed for an increase in line output of 43%, thus setting it within the values considered in the budget. One also achieved a reduction of 30% in assembly line use, which allowed for the addition of new product references on the assembly line in question. Since these gains are considerable for the company, the same methodology was standardized so that it could be applied to other assembly lines.

Keywords: Productivity improvement; Work study; Assembly line; Lean tools.

1. Introduction

In order to survive in today's competitive world, companies must find ways to reduce production costs, increase productivity and ensure efficiency in the execution of their operation processes [1,2]. In this industrial context, it has

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become imperative to implement methodologies which will enhance the daily productivity of assembly lines, as well as contribute to the greater efficiency of machines and their operators [3]. A study of the work at hand potentiates the optimization of processes through the chronological measurement of the times required for different tasks, enabling one to identify which of these constitute value-adding processes. The identification of non-productive times thus allows one to proceed with their elimination through the introduction of improvements [4,5]. The implementation of a methodology which combines a strategy of work analysis with Lean tools and principles constitutes one of the most powerful and efficient ways of eliminating waste, controlling quality and improving the general performance of any machine, system or process [6]. Since Lean methodology consists of various tools, one must know when and how they should be used in order to ensure successful implementation. These tools are frequently in the improvement of assembly line productivity, some of them extremely significant, such as standard work, visual management, 5S, SMED and the PDCA cycle [7,8,9]. The study described in this article was developed in a company which specializes in the production of mechanism-activating cables. Its main objective was to improve the production process of a seat-cable assembly line. The article is divided into five sections: section 1 consists of the introduction; section 2 presents a review of literature pertaining to the methods used in work analysis, as well as those of Lean Manufacturing techniques and tools; section 3 deals with the methodology adopted to carry out the work at hand; section 4 provides a comprehensive description of: the practical work developed; detected problems; proposals for improvement; and a comprehensive overview of the results obtained through the development of the work in question. Finally, section 5 presents the conclusions of the work undertaken.

2. Literature Review

Companies must possess the necessary processes, materials, people and technology if they are to guarantee a timely production of the quantities, products and/or services requested by customers. The ultimate outcome resides in customer loyalty and increased participation in the market [10,11]. In association with Lean tools, the implementation of a work-study enables any industry to achieve increased production, better quality and lower costs, which is ultimately translated into greater profits and higher levels of customer satisfaction [12]. The work study technique is fundamental in the improvement of process performance, since it consists of a research methodology. As such, it is developed in a methodical and systematic manner with the objective of enhancing the use of resources and establishing performance and quality patterns to support the development of activities [6]. With the dual purpose of finding a suitable method and determining the standard time required for its execution, the work-study technique is divided into two complementary areas: the study of the method and the measurement of times [5]. Studying the method essentially deals with establishing the best way to execute the tasks at hand, thus adding value and boosting efficiency. It promotes the elimination of unnecessary operations, waiting time and other forms of wastage [4]. The study of time comprises a set of procedures which are used to determine the time required – subject to certain conditions of standard measurement - for the execution of tasks which involve some human intervention [13]. Under these conditions, the time that is thus determined, is designated as standard time. This corresponds to the time required for a qualified and well-trained person, working at a normal pace and exerting an average effort, to execute a specific task, the method of which must be standardized previously [14]. In order to carry out the work study, a systematic structure must be followed. This consists of seven stages: select, register, examine, define, measure, implement and maintain. During the first stage, one makes a selection of the process or operation which will be the object of analysis. This is followed by a detailed recording of data and an examination of the entire process. Subsequently, a new method is defined, which could involve improvements in the processes areas, layout, equipment and work conditions, with the time associated with each task then being measured. The next step involves proceeding with the implementation of the new method and, finally, periodically verifying that procedures are being complied with, with the purpose of one can ensure that the standard method and times are maintained [6,15]. A study of both method and time provides one with the ideal conditions to directly observe the wastage affecting production. The essence of Lean manufacturing resides in this search for opportunities to reduce process operation times through the elimination of waste. It is by combining the aim of lean manufacturing with a study of times that the final objective for both of these can be successfully achieved, which is further reflected in an excellent rate of production [12,16]. Lean philosophy is a culture that involves training and practice; it resorts to methods and tools which eliminate waste, motivate staff, enhance equipment and increase productivity [10]. Its implementation first began in the automotive industry but it now guarantees the success of companies in a wide-ranging area of activities [17,18,19]. Lean philosophy essentially anchors on a mindset of sustainable improvement, which aims to eliminate wastage in the context of an organizational system and in processes involving people [20].

3. Methodology

The methodology which was adopted to carry out the work at hand consisted of five stages. In the first stage, one undertook a literature review, which was supported by scientific articles dealing with productivity enhancement methodologies. The purpose of this was to coherently support the empirical research presented. During the second stage, one essentially proceeded with the identification of the current situation of the process. This was accomplished by surveying the various tasks executed at each workstation, and the measurement of the respective times. The third stage consisted of a critical analysis of the determined standard times, which revealed various problematic aspects: the tasks with no added-value to the process; the existence of a bottleneck station; inadequate line balance; as well as the main problems and difficulties detected during the time measurement period. Based on this critical analysis, one was able to identify the points which can potentially be improved. In the fourth stage, and by harnessing Lean techniques and methodologies, one suggested various proposals for the process improvement. The fifth stage consisted of a presentation of the results and benefits ensuing from the implemented actions.

4. Analysis and optimization of an assembly line of low added-value products

The assembly line subjected to study is comprised of three workstations (station 1- punching station, station 2- cable assembly and trimming station, and station 3 – Zamak injection station) with a designated operator at each station (see Fig. **1**). The workstations are interconnected by means of a conveyor system which is responsible for transporting the subgroups from one station to the other. The final packing of the product is executed by the operator at station 3, who is also responsible for placing the packaged product onto the pallet, labelling and recording it. The components required to assemble the final product are supplied to the side of the assembly line (the lower section of the workbench) for the first two stations. In order to facilitate the action of reaching components during the running operation, these are decanted into smaller boxes, which are attached to the line. In order to visualize production status in real time, the station 3 operator registers the information hourly on a production board: the number of parts manufactured, whether they are compliant or non-compliant; and the failures which generated line stoppages and problems in quality.

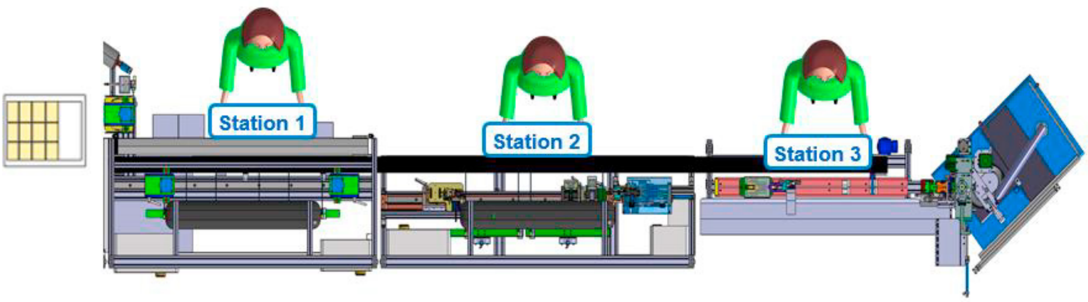

Fig. 1. The layout of the assembly line.

4.1. Study of the methods and times of the assembly line workstations

The assembly line studied emerged as a priority, due to its incapacity to reach the production level defined by the customer demand initially defined. Analysis began with the collection of data and the observation of workstation operations. These are presented in Tables 1, 2 and 3 for the workstations 1, 2 and 3, respectively. In the column for operation sequence, one can identify the tasks which are executed by the worker to accomplish the operations planned for his workstation, the sequence in which these are carried out, and the way the worker interacts with the machine/mechanism. The numbered tasks are cyclic, and the remaining circled ones only occur occasionally. The times spent on operations which present no added-value to the end product, since the customer does not pay for them, are marked in red. An analysis of these will be focused upon, so that they can be eliminated altogether or reduced to a bare minimum.

Table 1. Operation sequence and standard time for station 1.

Station 1			
Operation		Operation sequence	Time (sec/piece)
1	Countersinking/grinding of the spiral on both sides	○ Take a set of spirals from the box ○ Insert the spirals one by one on the countersinking/grinding mechanism ○ Rotate spirals 180° ○ Insert the spirals one by one on the countersinking/grinding mechanism ○ Place the set of spirals on the rail	2,6
2	Insertion of lubricant into the spiral	1. Take spiral from the rail 2. Insert it in the liquid-injection device 3. Remove from the liquid-injection device	2,7
3	Assembly of clip and assembly/punching of terminals	4. Take the clip and left terminal and mount it onto the spiral 5. Position spiral on the gig 6. Take right terminal, lift the spiral end, mount the terminal and position it on the gig once again 7. Activate the button control panel	8,3
4	Decanting	○ Decanting of the spiral terminal ○ Decanting of clips	0,4
Occupancy time			14,0
Added-value time			11,0

Table 2. Operation sequence and standard time for station 2.

Station 2			
Operation		Operation sequence	Time (sec/piece)
1	Mounting of the spring	1. Pick up spring and spiral subgroup 2. Insert the spring on the subgroup terminal	5,8
2	Mounting of the cable subgroup; cap crimping; thermo-engraving; cable trimming	3. Position cable on the subgroup terminal 4. Position subgroup on the mechanism. 5. Activate the button control panel	5,7
3	Decanting	6. Decanting of the cable subgroup 7. Decanting of the spring	0,4
Quality control		8. Check cable subgroup	1,0
Occupancy time			12,9
Added-value time			11,5

On analysing the standard time for each workstation, one verified that although station 3 is the bottleneck station, with a time of 15,7 seconds/part (see Table 3), the remaining workstations present times which exceed the objective of 11 seconds/part (see Tables 1, 2 and 3). This highlights the fact that successful intervention on this line will ultimately depend on the performance of all the workstations. In Table 4, one will observe that current output is set at 29% below the objective of 324 parts/hour; this is aggravated by the fact that there are a number of non-value adding tasks contributing to this result. Of these, one should highlight the tasks devoted to the spiral countersinking and grind, sprue removal, decanting, as well as those involved in quality and production controls.

Table 3. Operation sequence and standard time for station 3.

Station 3			
	Operation	Operation sequence	Time (sec/piece)
1	Cable trimming	1. Pick up the subgroup 2. Place on the cable trimming mechanism 3. Remove from the mechanism	3,9
2	Hammering the wire rope	4. Place on the hammer mechanism 5. Remove from the mechanism	2,5
3	Zamak into the 2nd terminal of the cable; traction test; measurement of the final length and corresponding validation	6. Position the subgroup on the mould and gig 7. Activate the button control panel	4,0
4	Sprue removal	○ Pick up a bunch of cables ○ Break sprue off manually	2,5
5	Packing	○ Place the bunch of cables in the box ○ Close the box ○ Open a new box ○ Report ○ Paste label on the box ○ Place box on the pallet	2,0
6	Quality control	○ Measure the final length (hourly)	0,5
7	Production control	○ Fill in the production table (hourly)	0,3
Occupancy time			15,7
Added-value time			12,6

Table 4. Indicators of the initial situation vs the objective.

	Target	Initial situation	Variation (%)
Output (parts/hour)	324	229	- 29
PPH (parts /person/hour)	108	76	- 29
Operator	3	3	0
Cycle time (sec/ part)	11,0	15,7	+ 43
Balance on assembly line (%)	95	90,4	- 4,6

4.2 Identification of problems and implementing solutions

Observation during the timing process, as well as interviews conducted with the operators involved, allowed for the identification of the main problems and sources of waste on the assembly line. Thus, one was able to pinpoint which operations constituted no added-value. In addition to these, there were problems associated with the reliability/robustness of the process itself. There was also a need to include more detail in the standardization process, in order to ensure more suitable work methods, which must be adopted by all the operators. Table 5 presents an overview of the problems detected on the line, as well as the solutions implemented to address those issues.

Table 5. Identification of problems and implementing solutions.

Problem	Description	Implemented solutions
Non-value-adding operations	Due to the cutting process, the countersinking/grinding operation must be carried out	This operation is now undertaken outside the line by means of an automatic process.
	Manual removal of sprue	The operation is now carried out by a device which was attached to the Zamak injection machine.
Unnecessary movements and transport	Inadequate work methods and each worker's criteria	The station file must provide more detailed information, especially when the tasks require greater skill.
	The pallet on which packing items for the finished product are placed is far from the packaging area	Since there is not enough room to move the pallet next to the 3rd workstation, the line was rotated by 180º, thus positioning the 3rd station next to the pallet.
	When reporting the number of final products manufactured on the system, and then printing the label to be placed on the package, the operator must cover an approximate distance of 15 metres to reach the printer.	Implementation of a system which allows the label to be printed on a printer which was placed on the assembly line.
Problems in product design	Failure in the insertion of the cable on the spiral terminal. The operator bypasses this difficulty by resorting to a method which is unsuitable for the operation in question	Elimination of the edges found inside the terminal
Process inefficiencies: Robustness and reliability of the process	Cable shifts from the clamp, forcing the operator to reinsert it.	Magnets and a funnel-shaped device were applied to ensure correct cable position
	After cutting, the surplus cable sticks to the clamp, which holds it in place	Use of a single stream of air and program clamps, which execute an open/close movement to shake off the cable tip
	The pressed clip does not align with the terminal	The cavity where the spring is positioned was widened to prevent torsion of the spiral during clip punching. This will also facilitate the positioning of the subgroup on the mechanism
	When incorrectly positioned, the clip is damaged during the pressing procedure	A poka-yoke was installed so that the clip will only fit if it is in the correct position
	Zamak sprue breaks inside the mould, so that the operator must use an airgun to remove it	Widening of the sprue channel so that it only breaks when the cutting device is activated
Line balance	Different station occupancy rates	Redistribution of tasks across the workstations in order to ensure that the times spent on the 3 workstations are balanced

4.3. Analysis of the results obtained

After the proposed solutions were implemented (see Table 5), one undertook a new study of the times, the result of which is presented in Table 6. The time dedicated to the assembly process decreased significantly: on station 1, times changed from 11,0 sec/part to 9,8 sec/part; on station 2, they went from 11,5 sec/part to 9,1 sec/part and on station 3, from 10,4 sec/part to 9,0 sec/part (see Table 6). The resolution of inefficiencies, which caused cycle interruptions, has thus produced a direct impact on the results. It should be pointed out that, during the measurement of times, one disregarded those cycles where irregular incidents occurred; consequently, the results of the implemented improvements are far higher than those presented. The calculated results only reflect the improvements proposed to address the reduction of fatigue and pace for the operator involved, since he is no longer subjected to constant cycle interruptions. A record is always kept of incidents for every hour of work: these pertain to the number of manufactured parts, OK and NOK, interruptions and the reasons for these, as well as other relevant production events. This task, which was previously undertaken by the station 3 operator, was transferred to the operator at station 2. Consequently, the bottleneck presents a time of 11,0 sec/part instead of 11,3 sec/part (see Table 6). Figure 2 illustrates the throughput achieved, which constitutes a direct result of the improvements implemented. Table 7 presents the results achieved through the implementation of the solutions presented in Table 5.

Table 6. Times before and after the implementation of the proposals for improvement.

	Time (sec/part) Before improvements			Time (sec/part) After improvements		
	Station 1	Station 2	Station 3	Station 1	Station 2	Station 3
Assembly process	11,0	11,5	10,4	9,8	9,1	9,0
Countersinking/grinding	2,6			Not executed		
Packing			2,0			1,5
Sprue removal			2,5			Not executed
Decantings	0,4	0,4		0,7	0,4	
Quality control		1,0	0,5		1,0	0,5
Production control			0,3		0.3	
Occupancy time	14,0	12,9	15,7	10,5	10,8	11,00
Time spent on non value-adding operations	3,0	1,40	3,3	0,7	1,7	0,5
Line balance	90,4 %			97,8 %		

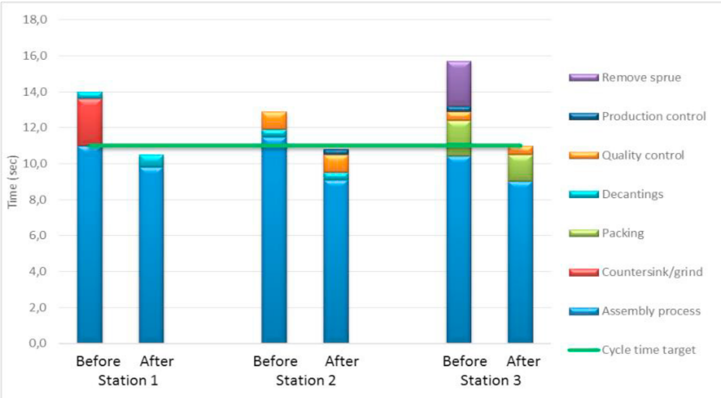

Fig. 2. Time spent on each task, before and after the implementation of solutions.

Table 7 – Results achieved through the implementation of the improvement solutions.

		Before the implementation of improvement solutions	After the implementation of improvement solutions	Variation (%)
Operators		3	3	0
Output (pieces/hour)		229	327	+ 43
Cycle time (sec)		15,7	11,0	- 30
PPH (pieces/person/hour)		76	109	+ 43
Balance in the assembly line (%)		90,4	97,8	+ 7,4
Time required to comply with customer demand (hours per week)		44	31	- 30
Occupancy rate	(1st shift)	100%	83%	- 17
	(2nd shift)	17%	-----	- 17

The objective of increased output was thus met, since the value reached (327 parts/hour) slightly surpassed the objective of 324 parts/hour (see Table 4). This is translated into a throughput of 43 % when compared to the initial value of 229 parts/hour. The line balance also showed a positive improvement: initially, this was set at 90,4% and reached a value of 97,8% at the end of the process (see Table 6). This demonstrates that the workload is now conveniently distributed across the various stations, which eliminates the hypothesis of the occurrence of the waste designated as “waitings”. The time required to meet weekly customer demand is now 31 hours per week, instead of the initial 44 hours (see Table7).

5. Discussion and conclusions

The main aim in the development of this study was to optimize the production process of an assembly line in order to approximate the real output to that considered in the budget and demand previously established. This objective was reached by eliminating non-value-adding tasks and by reducing the waste associated to the robustness and reliability of equipment, operator movements, task balance, as well as the definition and standardization of work methods, amongst others. This project allowed for an increase in production of 43% on the assembly line, from 229 parts/hour to 327 parts/hour. The occupancy rate was reduced by 30%, thus eliminating the need to partially activate the 2nd shift and freeing the occupancy of the 1st shift by 17%. The work undertaken on this assembly line was implemented on other lines at the same factory. Besides improving a rapid response to customer demand, new projects can now be integrated into the existing assembly lines. One should highlight that the work-study methodology played a major role in this process, since it allowed one to identify and quantify the main points of wastage. The same must be said with regard to the performance of Lean tools, which enabled a suitable response to the problems diagnosed. These methodologies provide a systematic approach, allowing one to find viable low-cost solutions which result in a significant increase in the reliability and efficiency of the processes in question. Furthermore, they do not overlook the important issue of investing in the human resources involved in the process, who invariably present suggestions and accept the improvements implemented.

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