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Analysis of the implementation of changes on an assembly line in the auto industry

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Abstract: The present paper aims to present the solving of problems registered in an assembly production line for a given product, problems that led to the appearance of defects identified by the customer. It starts from the analysis of the functional and quality indicators of the assembly line. Also, the complaints coming from the client are analyzed for 2 types of defects that appeared in the assembly process, using the AMDEC method. It is also analyzed the working time for each workstation, in order to be able to identify the possible blocking position. It then proceeds to the establishment of a revised AMDEC, from which it is expected to establish corrective actions and find solutions. Next, the action plan for the process is established, following the risk analysis. The proposed solutions are implemented, in order to be able to evaluate their impact and the changes that have occurred in the production flow. Finally, after analyzing the obtained results, it is found that the complaints from the customer - on the one hand - were eliminated and an increase in the production capacity of the line was obtained - on the other, both results contributing to the increase of the profit of the organization.

Keywords: quality, assembly, AMDEC, workstation, production flow.

1. Introduction

The product studied in this paper will be referred to as product X. Product X is obtained as part of a production process, which is a technological assembly process, which is composed of a series of operations. These operations aim at the placement and fixing of various components, in order to obtain the final system that makes up the product X. The form of production organization in this case is the flow organization, on the assembly line, with specialized positions for performing certain assembly operations, the final purpose being the product of X [1]. The characteristics of the assembly line are [5]:

- the division of the assembly process is on 6 positions - plus final control - approximately equal in terms of time, respectively of work volume;
- the grouping of operations by stations was not carried out taking into account the rhythm of the line;
- the specialization of the workstations is achieved by training the operators;
- multiple operations are performed at each station;

- the positioning of the workstations is in the order imposed by the execution of the assembly operations, which ensures a one-way movement for the final product X, respectively: lubrication, assembly of the components, screwing, checking and final control;
- the movement of the assembly is carried out from one station to another with the help of sleds that move on the guide of the assembly line;
- from the point of view of the number of operators, this may vary depending on the desired capacity on the line at that time - between minimum 1 operator or maximum 7 operators.
- the capacity of the assembly line differs depending on the number of operators, this being influenced by the station with the highest time - in station 3 (50 ") - and can vary between a minimum of 85 pieces (with 1 operator) and a maximum of 405 pieces (with 7 operators).
- 20 a total of 20 references can be produced that differ by different characteristics, but the production process remains the same.

2. Analysis of the assembly line problems and solution finding

Initially, the functional indicators of the assembly line are identified, but also the quality indicators - Table 1.

Table 1 Assembly line indicators in the initial situation

Functional indicators of the line							
No. operators	*Td - time available*	*Q - quantity*	*T - tact*	*KOSU - cycle time*	*CP - max. capacity of the line*	*G_{il} - degree of loading*	*P - workstations*
[pers.]	*[min/ch]*	*[pieces/ch]*	*[min/ pieces]*	*[min/ piece]*	*[pieces /year]*	*%*	*-*
Min 1 Max 7	450	Min 85 Max 405	0,9	Min 0,9 Max 6,33	342.630	90	6 + 1
Line quality indicators							
Rc - customer complaints				*TLR* - total waste off the line (target)			
[complaints/year]				*[pieces /work shift]*			
9				9			

A complaint received from the customer for product X refers to an unusual noise during its operation. Following the analysis done by the customer, it was found that the main cause of this noise is the existence of a screw inside the housing, which produces a noise when the mixing function is used, due to the movement of the screw between the housing and the mixing flap - Figure 1 .a.

A second complaint received from the customer for product X is related to the lack of the screw for the radiator hatch assembly on the housing - Figure 1.b.

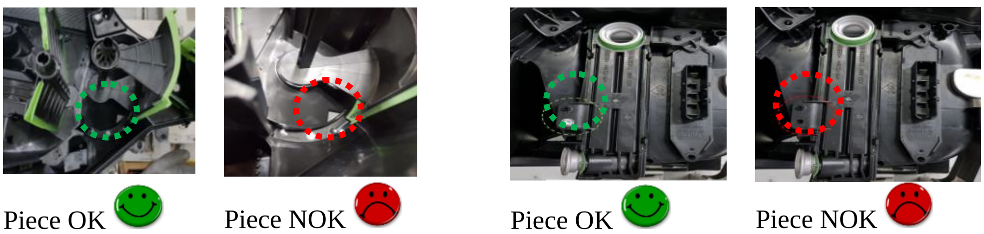

Figure 1. Complaints received from the client

a. the existence of a screw unfixed b. lack of assembly screw

An AMDEC was opened [7], introducing the new defect received from the customer - table 2.

Table 2 Initial AMDEC (selection)

Operation	***Defect***	***Description defect***	***Effect***	***Type detection***	***O***	***S***	***D***	***RPN***
Screwing semicasings	missing screws no. total screws	Mode of operation not respected	The landmark is operable, functionally, it can degrade, nonconforming product	numbering screws	3	7	7	84
	removing screws in the open area	Manipulation wrong	Inoperable landmark, reduced performance level, without affecting the safety of the product.	Visual	3	6	8	144

The analysis of the working time for each workstation is highlighted in table 3, which shows that the workstation 3 is a blocking station [1].

Table 3 Initial analysis of working time

No. workstation	workstation 1	workstation 2	workstation 3	workstation 4	workstation 5	workstation 6	Control
Time (sec)	42	43	54	43	45	43	48

3. Implementation of the solution on the assembly line for defection elimination

The existing AMDEC has been revised. The AMDEC analysis must necessarily contain a good definition of the actions, the dates of implementation, as well as the persons responsible for the implementation of the actions - tables 4a and 4.b.

Table 4.a revised AMDEC (selection**)**

Defect	***Effect***	***Corrective actions***	***Date of planning***	***Date of achievement***	***Pilot***	***The result of the actions***
missing screws no. total screws	The landmark is operable, functionally, it can degrade, nonconforming product	Implementation of a permanent semi-casing assembly solution: ultrasonic and thermal welding machine	08.2019	09.2019	Project engineer and methods engineer	Solved ☑
removing screws in the open area	Inoperable landmark, reduced performance level, without affecting the safety of the product.		08.2019	09.2019		Solved ☑

Table 4.a revised AMDEC (selection)

Defect	***Effect***	***Corrective actions***	***O***	***S***	***D***	***RPN***
missing screws no. total screws	The landmark is operable, functionally, it can degrade, nonconforming product	Implementation of a permanent semi-casing assembly solution: ultrasonic and thermal welding machine	3	7	2	42
Scăpare șuruburi în zona deschisă	Reper inoperabil, reducere nivel performanță, fără afectarea siguranței produsului.		3	6	2	36

The action plan defined for the process following the risk analysis, is the implementation of a permanent solution for the assembly of the semi-carcasses, namely by ultrasonic and thermal welding. This solution involves the introduction into the process of a new machine, a welding machine.
The ultrasonic and thermal welding machine was designed to be integrated into the assembly production line studied - figure 2.a. The points impacted by this modification of the assembly process are those presented in figure 2.b.

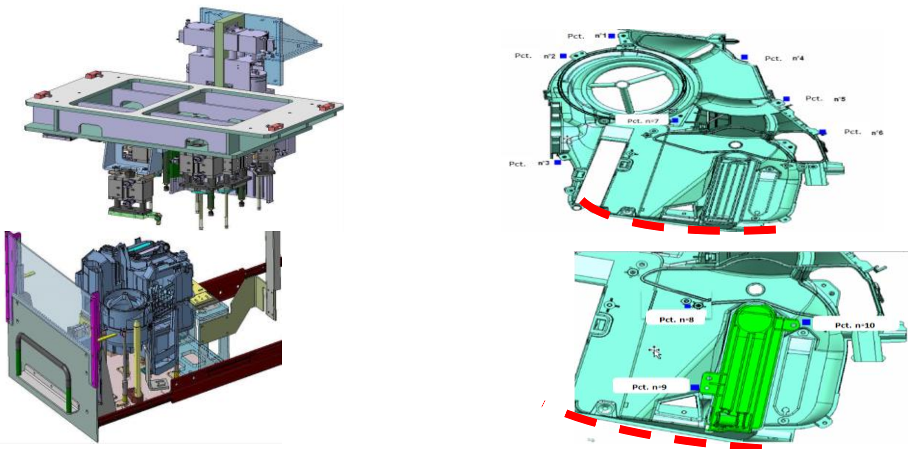

Figure 2. Applying the solution for the assembly line
a. ultrasonic and thermal welding machine b. weld points

At the beginning of the implementation of the new welding machine in the assembly line of product X, the first problems were identified. These problems were aimed - mainly [3]:

- ❐ the incorrect position of the operator when loading and unloading the part from the welding machine,
- ❐ rotating the operator by 90 degrees at each operation to perform the same movements.

The solution found to solve these problems is to implement an automatic robotic mechanism for loading / unloading the welding machine - Figure 3 [6].

Figure 3 Automatic robotic mechanism implemented

The automatic robotic mechanism implemented, in addition to the ergonomic advantage, also contributed to the reduction of the cycle time from item 3 - table 5. Thus, after the sled reaches the welding station, the piece is loaded / unloaded by the automatic robotic mechanism, and the operator - while performing these operations - will go to the next item, to perform the following operations. A comparison between the two situations was made in Figure 4.

Table 5 Analysis of the modified working time

No. workstation	workstation 1	workstation 2	workstation 3	workstation 4	workstation 5	workstation 6	Control
Time (sec)	42	43	49	47	45	43	48

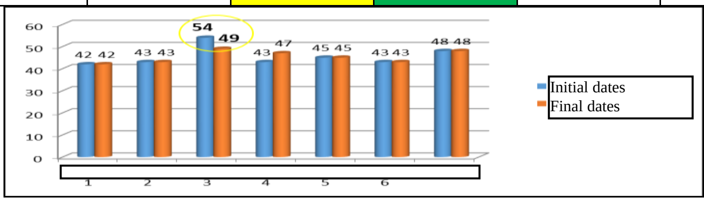

Figure 4. Comparison between working time in the 2 situations

In workstation 3 the following modifications of the operations performed [4] took place:

- loading of the welding machine by the automatic robotic mechanism on the sled on the support of the welding machine;
- the assembly of 2 semi-finished products by thermal and ultrasonic welding;
- unloading of the welding machine by the automatic robotic mechanism from the back of the welding machine back on the sled;
- moving the sled to the next workstation;
- clips the clamping assembly operation that was initially performed in this workstation, was transferred to the next workstation, namely to station 4;
- the interval between 2 successive pieces is now 49 sec. compared to 54 sec. initially, so a 5 sec reduction was obtained.

The indicators of the assembly line after the improvement are - table 6:

Table 6 Assembly line indicators in the modified situation

Functional indicators of the line							
No. operators	*Td - time available*	*Q - quantity*	*T - tact*	*KOSU - cycle time*	*CP - max. capacity of the line*	*G_{il} - degree of loading*	*P - workstations*
[pers.]	*[min/ch]*	*[pieces/ch]*	*[min/ pieces]*	*[min/ piece]*	*[pieces /year]*	*%*	*-*
Min 1 Max 6	450	Min 86 Max 540	0,833	Min 0,833 Max 5,233	456.840	90	6 + 1
Line quality indicators							
Rc - customer complaints				*TLR* - total waste off the line (target)			
[complaints/year]				*[pieces /work shift]*			
0				0			

4. Results analysis

The comparison of the initial situation in which the assembly line was located and the one in which the proposed modifications were introduced will be carried out from the organizational, functional and quality indicators point of view.

Thus, from the organizational point of view, in the improved situation the following changes have taken place:

- a new machine, namely thermal and ultrasonic welding machine, was introduced in workstation 3;
- an automatic robotic mechanism for loading / unloading the welding machine, necessary for performing the operations of the manipulated subassemblies, was introduced in the workstation 3;
- the operations from workstation 3 were reorganized by: performing the thermal and ultrasonic welding by the thermal and ultrasonic machine and introducing the manipulation operations performed by the automatic robotic mechanism - loading / unloading;
- the operations from workstation 4 were reorganized by transferring the assembly operation via clip - from workstation 3 where it was initially performed. Thus, the working time for this operation increased by 4 seconds, because this operation did not exist in the initial situation in the workstation 4.

From a functional point of view, the indicators associated with the 2 situations are presented in table 7.

Table 7 Evolution of the functional indicators of the assembly line

	Functional indicators of the line							
Assembly type	*No. operators*	*Td - time available*	*Q - quantity*	*T - tact*	*KOSU - cycle time*	*CP - max. capacity of the line*	*G_{il} - degree of loading*	*P - workstations*
	[pers.]	*[min/ch]*	*[pieces/ch]*	*[min/ pieces]*	*[min/ piece]*	*[pieces /year]*	*%*	*-*
screw	Min 1 Max 7	450	Min 85 Max 405	0,9	Min 0,9 Max 6,33	342.630	90	6 + 1
welding	Min 1 Max 6	450	Min 86 Max 540	0,833	Min 0,833 Max 5,233	456.840	90	6 + 1

The analysis of the functional indicators of the assembly line shows the following changes:

- the maximum number of operators decreased from 7 to 6, so a reduction was obtained with 1 operator / exchange of work;
- the maximum quantity of products realized on the exchange of work has registered an increase from 405 pcs / exchange of work 540 pcs / exchange of work with + 135 pcs / exchange of work;
- the tact of the line decreased from 0.9 min / pcs to 0.833 min / pcs with - 0.067 min / pcs;
- the KOSU indicator fell from 6.33 min / pcs to 5.233 min / pcs, so a reduction of 1,097 was obtained for the maximum number of operators;
- the production capacity of the assembly line increased from 342,630 pcs / year to 456,840 pcs / year, so it increased by 114,210 pcs / year.

From the point of view of quality indicators, the results of the 2 situations are presented in table 8.

Table 8 Evolution of the quality indicators of the assembly line

Assembly type	*Rc* - customer complaints	*TLR* - total waste off the line (target)	*RPN [Defect 1 & Defect 2]*
	[complaints/year]	*[pieces /work shift]*	*[point]*
screw	9	9	84 & 144
	0	0	42 & 32

The analysis of the quality indicators of the assembly line shows the following changes [2]:

- the Rc value respectively of the complaints from the client decreased from 9 complaints / year to 0 complaints / year, so all the complaints from the client could be eliminated;
- the TLR value of the total number of rejects on the line also decreased from 9 pieces / work exchange to 0 pieces / work exchange, so all the rejects could be eliminated;

- the value of the RNP dropped significantly from 84 points to 42 points for Defect 1, so by 42 points for Defect 1;
- the value of the RNP dropped significantly from 144 points to 32 points for Defect 2, thus 112 points for Defect 2.

5. Conclusions

As a first conclusion of the modifications and reorganizations carried out, it can be seen that a workstation 3 has been automated, eliminating certain manual assembly operations, thus eliminating two of the defects identified in the AMDEC analysis.
A second conclusion concerns the many advantages that this solution brings, namely:
- the quality of the assembly subsystem obtained for the screw operation;
- during the shorter cycle;
- improving the ergonomics of the workstation 3;
- continuity without bottlenecks of the flow of assembly of the obtained subsystem;
- synchronization of the assembly process, therefore balancing the assembly line;
- performing this operation on a single machine;
- eliminating an operator, thus reducing costs;
- area eliminating expectations;
- removing a certain number of screws from the composition of the assembly subsystem;
- lowering the RPN.

In the end, it can be considered that the implementation of the automatic robotic mechanism and the reorganization of the operations from workstation 3 and from workstation 4 ultimately led to the elimination of the complaints coming from the client - on the one hand - but also to the increase of the production capacity of the line - on the other hand, both results contributing to increase the profit of the organization.

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