AUTOMATION OF PRODUCT CONTROL IN THE AUTOMOTIVE INDUSTRY WITH QUALITY ASSURANCE

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ABSTRACT
In this paper, the optimization of the workplace and quality control of production components in the automotive industry was carried out. In addition to improvements from the aspect of production, improvements to the process of quality control, safety at work and the quality of the manufactured piece were also shown. Statistical analyzes were performed with the help of quality assurance tools and a comparison was made between the current state of the production process and the conceptual solution. The goal is to show the impact of mechatronics in the quality management process in the automotive industry.
Keywords: quality assurance, automotive industry, automation, productivity.

1. INTRODUCTION

The European automotive industry employs more than 12 million people directly or indirectly, therefore it is one of the largest contributors to the economy of modern society. Automotive businesses have recently been driven to raise quality and efficiency due to increased worldwide competition. The IATF 16949:2015 standard, which prioritizes procedures and customer satisfaction with the involvement of both employees and suppliers, serves as the foundation for quality management in the automobile industry [1].

Figure 1. IATF:16949 model. [1]

The topic of this work is the automation of the production process with the use of quality tools, in order to enable the satisfaction of the defined criteria. Automation aims is to facilitate the work of the operator himself, to speed up the production time (production) and to ensure the achieved product quality. The goal is to bring other aspects closer to mechatronics. Automation is often understood only to improve the production process and financial savings, without analyzing the consequences on other aspects, such as human resources and quality. In the following text, the benefits of fulfilling the requirements of certain aspects and the advantages they bring are explained.

2. THE RELATIONSHIP OF MECHATRONICS WITH QUALITY, PRODUCTION AND HUMAN RESOURCES

There is an opinion that "automation is the future", but this is a slogan that is quickly becoming outdated. Automation is not the future; it is the present. As artificial intelligence technologies become commonplace, fully automating production lines is no longer ambitious, complex or expensive - it's practical and affordable. Ultimately, automation allows companies to reduce risk, save money, and achieve significant efficiencies in the manufacturing environment. The thought of mechatronics in the automotive industry brings to mind robots and manipulators used to manipulate car assembly, painting, welding, etc. It is often forgotten that mechatronics is also present in those processes where smaller components and systems are involved. Mechatronic systems are characterized by a high degree of integration and very good performance, as a result of cooperation in the fields of mechanics, electronics, automation systems and IT [3].
Quality control is one of the most important parts of the production process for most companies and industries. Especially if a small manufacturing error can result in a huge loss for the company, it becomes imperative to invest in better quality control systems. Automation is key in production quality control. It allows certain limits or criteria to be set for the products being produced. Then it also helps to monitor the production process in real time. Early detection of errors or damage in the production process can save from large losses. Therefore, automated quality control ensures the production of only the best quality products.

3. CURRENT ASSEMBLY PROCESS OF WORKPIECES

The manufacturing of a single plastic pipe for the automotive industry is the topic of this paper's research. Air conditioners, propulsion (diesel or gasoline) engines, or the fuel delivery system for those engines all employ these pipes to carry fluids. Figure 2 shows a straight plastic pipe as well as a plastic corner connection, along with all the components that went into its final construction.

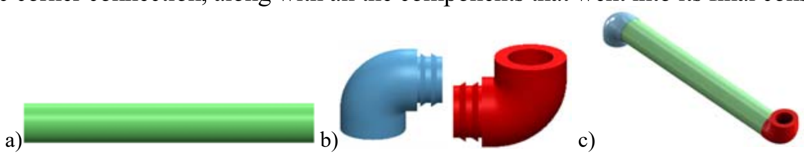

Figure 2. Parts for assembly: a) tube; b) corner connect - coupling; c) final assembly.

Assembly requirements include a component without surface damage (creases, lack of/excessive material), and a gap no greater than 0.8 [mm]. The connecting outlet openings' axes must be parallel and pointing in different directions. There are two electro-pneumatic assembly stations where the manufacturing process occurs. Both assembly stations operate on the same principle: one machine is used to assemble one coupling, and the other station is used to assemble the second coupling. In order to push the coupling with the final stroke and expand the side of the pipe where it is pressed, the assembly station's operating principle requires the mechanical force of the operator. Three components in the electro-pneumatic assembly station move; all the other components are fixed and immobile.
A clamping arm, the first moving group, is used to secure the pipes in the tool's jaws. In addition to the mechanical component, an inductive sensor is fitted in the fixed portion of the tool that is attached to the handle and can detect whether the handle is being lowered or elevated. A pneumatic cylinder and a metal wall make up the second moving group. The tool's jaws are right next to the metal wall. There is a light curtain on the metal wall, whose rays are interrupted by a pipe if it is of the appropriate length.

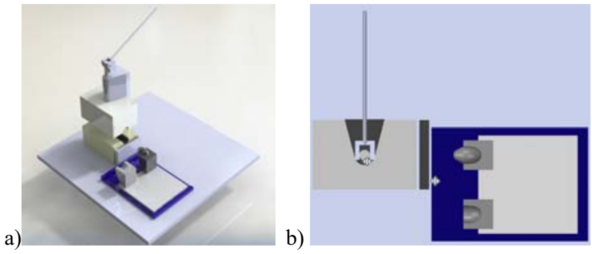

Figure 3. a) The electro-pneumatic assembly station's layout b) The electro-pneumatic station's model with the sensors' schematic markings

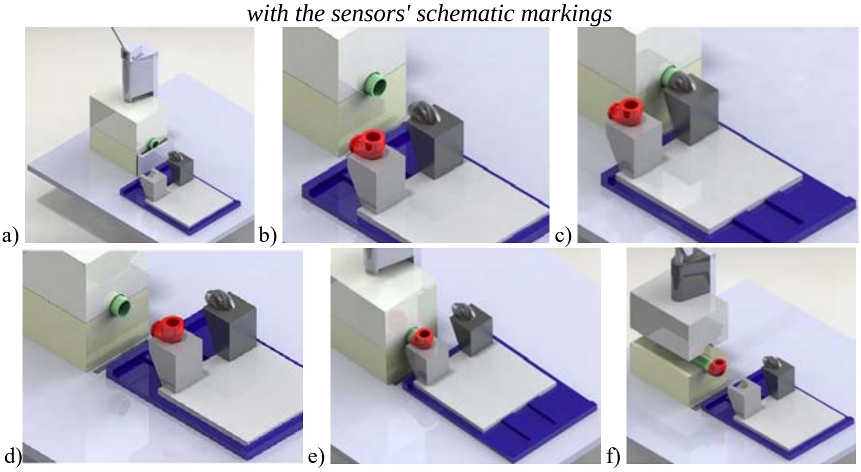

Figure 4. a) Lowered clamp after the pipe has been inserted (plan and isometric). b) Installed corner connect - coupling. c) Expanding the coupling. d) Moving the main moving plate back. e) Pressing the coupling. f) Completed process of pressing the coupling.

Two metal plates make up the third moving group, and one of them has an expander and a connector holder. The pipe axis and the axes of the expander and connectors must be coaxial. The pipe expander, which has a conical shape, has the function of widening the entrance to prevent collisions between the coupling and the pipe's walls, which could result in breakage. The coupling holder, expander, and base are all attached to the hand lever, while the pneumatic cylinder is attached to the base below. The procedure for lowering the clamp and turning on the inductive sensor is shown graphically in Figure 4. The procedure for attaching the coupler is shown in Figure 4.b. It is necessary to set the connection so that it is fixed in place. Otherwise, pressing could cause the coupling to break. The coupling expansion procedure is shown in Figure 4.c. The inductive sensor is turned on because the white plate is at the final position. Figure 4.d shows the movable plate moving back to its initial position. Pressing the connection is the last stage in the production process, as shown in Figure 4.e. After that, the components return to their original positions. Once one coupling has been pressed, another coupling must be pressed using the same methodology but on a different machine. Three employees are needed to complete the process: two at the electro-pneumatic assembly stations, and one at the checking station who performs a visual inspection of the final product and a clearance check.

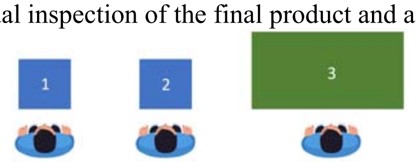

Figure 5. Production line of the functional component.

3.1. The process of testing the machine capability of the electropneumatic station

A gap forms when the connector presses into the pipe. The gap must, as was already mentioned, not be greater than 0.8 [mm]. The values that are useful for testing are the gaps between each of the 50 pieces that a single worker created in a row. Table 1 displays the results of the piece measurements that were performed at the electro-pneumatic station. Minitab is the program used to determine a machine's capabilities.

Table 1. Clearance between pipe and fitting.

	Sample number	Size [mm]		Size [mm]		Size [mm]		Size [mm]		Size [mm]
	1	0,15	11.	0,15	21	0,15	31	0,05	41	0,15
	2	0,15	12.	0,1	22	0,15	32	0,15	42	0,15
	3	0,15	13.	0,15	23	0	33	0,15	43	0,15
	4	0,05	14.	0,15	24	0,05	34	0,05	44	0,05
	5	0,05	15.	0,15	25	0,05	35	0,15	45	0,05
	6	0,05	16.	0,15	26	0,15	36	0,15	46	0,15
	7	0,15	17.	0,1	27	0,15	37	0,15	47	0,15
	8	0,15	18.	0,2	28	0,15	38	0,15	48	0,15
	9	0,1	19.	0,15	29	0,15	39	0,15	49	0,15
	10.	0,15	20.	0,15	30	0,05	40	0,15	50	0,15

According to the analysis and diagram, the C_m index of 2.93 satisfies the requirements for machine capability; however, the C_{mk} = 0.92 value informs us that a low index indicates that results are in a wide range in the tolerance domain, which means that the process can be unstable and it is possible that out-of-spec pieces will be produced. There is a potential for creating a gap that is not within specification if there is a mistake made during the manual bending procedure.

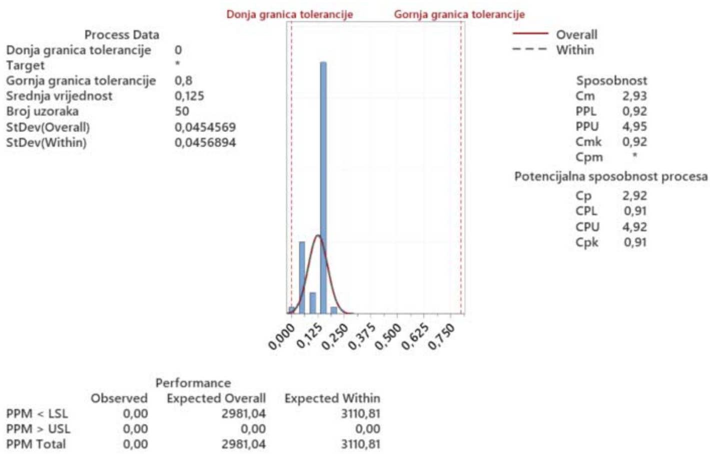

Figure 6. The results of calculate machine capabilities.

4. CREATION OF A NEW ASSEMBLY PROCESS

In contrast to how the production process is currently set up, the new approach emphasizes less labor-intensive operations, safe operations, higher product quality, a decrease in waste rates, and less product variability. Due to the machine's limited workspace and light curtain security, the new assembly station is physically different from the existing one. A significant number of inductive sensors are present. Similar principles control assembly, but with a higher degree of automation that makes it possible for quick and safe operation. One of the primary changes is that the new approach uses an electric cylinder that expands and pushes the coupling automatically rather of the manual metal handle that is now utilized for the pressing process. Various sensors and mechanical stops control its operation. In order to prevent the pipe from moving at this stage of setup, the operator must manually lower the handle. With the new approach, a pneumatic cylinder helps this process operate automatically.

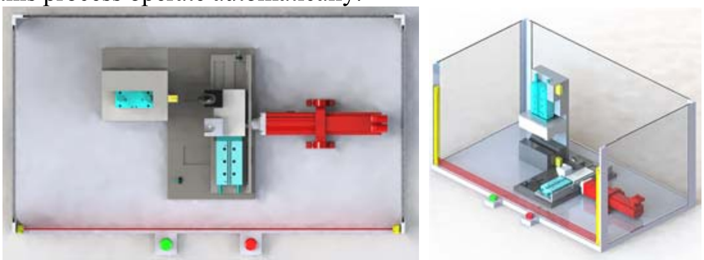

Figure 7. Design of the new fully automated assembly station.

Briefly described, the process goes as follows: The user inserts the pipe into the tool's jaws and checks the sensor indicator; if it is green, the tube is positioned correctly. The operator inserts the coupler into the coupler holder while keeping an eye on the inductive sensor's indicator. When the START button is pressed, the assembly process starts. The operator must not enter the machine's working area in order to avoid interrupting the light curtain. By pushing the RESET button, the components are brought back to their original positions when the operator removes the piece from the work area and places it in the packaging that is provided. Detailed description of the process in present on a figure 8. and visualized below.

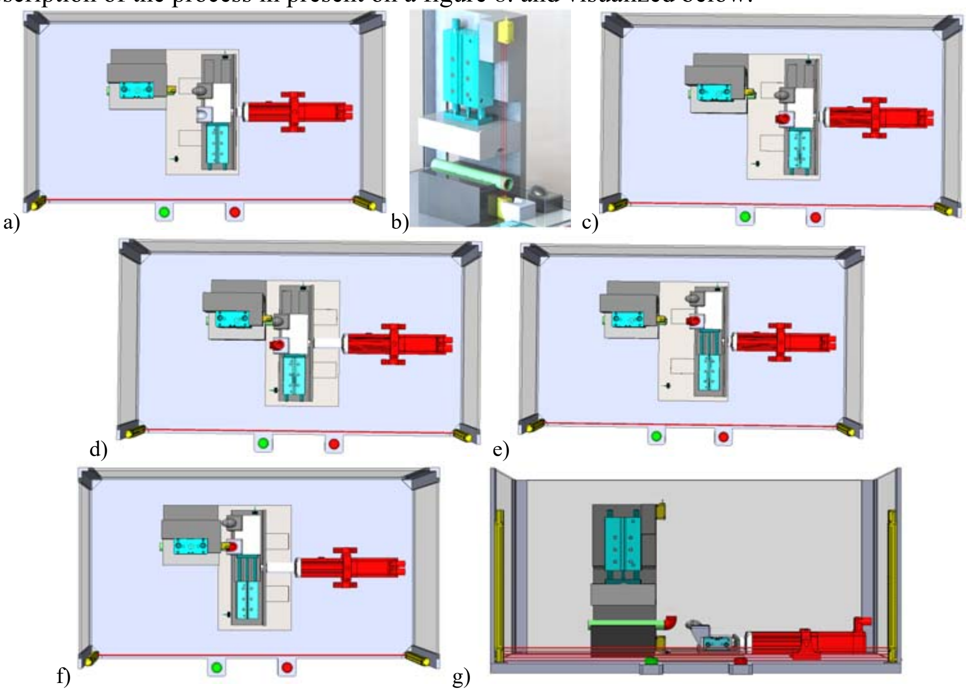

Figure 8. a) Placed pipe in tool jaw. b) Activated CCD sensor by the presence and correct position of the pipe. c) The coupling is installed and the inductive sensor is activated to check the presence of the coupling. d) Pipe expansion process. e) Activation of the pneumatic cylinder to move the coupling holder and expander. f) Pressing the coupling. g) Completed coupling assembly process.

The CCD sensor is turned on when the pipe is inserted into the tool's jaws. The process can go on while the machine is running since the CCD sensor is activated by the pipe's edge. The CCD sensor won't work if the pipe isn't in the right place. The sensor's indicator helps know if it's been installed properly. The new production process model, in contrast to the current situation, guarantees the coupling's presence and location. The sensor won't function if the connector is not in the right place. The assembly process begins with the placement of the pipe and coupling. The cylinder that lowers the tool handle is turned on by pressing the star button. The electric cylinder is turned on after being extracted to the end position (the inductive sensor), at which point the pipe is expanded. The inductive sensor for the piston's end position activates after the electric cylinder is turned on. The coupling holder and expander are moved by the pneumatic cylinder after this sensor is turned on. The pipe and any moving functional components could get damaged if the coupling's and the pipe's axes are not coaxial. In addition to this require, it's critical that the coupling holder not interfere with pressing and that, following completion of the pressing operation, the coupling holder and coupling may be detached without incident. When it reaches its end position, the coupling and expander holder are moved, the cylinder's piston is activated, and the electric cylinder is activated as well, bringing the working plate and pipe back together. The piston's action, which is controlled physically and electrically, presses the coupling. It is important to clear the area around the work piece when the assembling process is complete. The operator separates the finished product and places it away once the operation is finished.

4.1. Electro-pneumatic scheme

It is important to understand the relationships between input and output signals because the system is closed and contains both electronic and pneumatic components. These are the input factors: Inductive sensor of the pneumatic cylinder 1's end position (figure 9a). Inductive sensor of the end position of the pneumatic cylinder 2 (figure 9b). Inductive sensor for checking the presence of the coupling. (figure 9c). Inductive sensor of the end position of the electric cylinder (figure 9d). Light curtain signal: The purpose of the light curtain is to prevent the operator from coming into contact with the moving actuators during the assembling process. (Figure 9e). CCD camera (figure 9f). The following output components: 1) The tool jaws' pneumatic cylinder 1, 2) Pneumatic cylinder 2 (coupling holder and expander), 3) The electric cylinder.

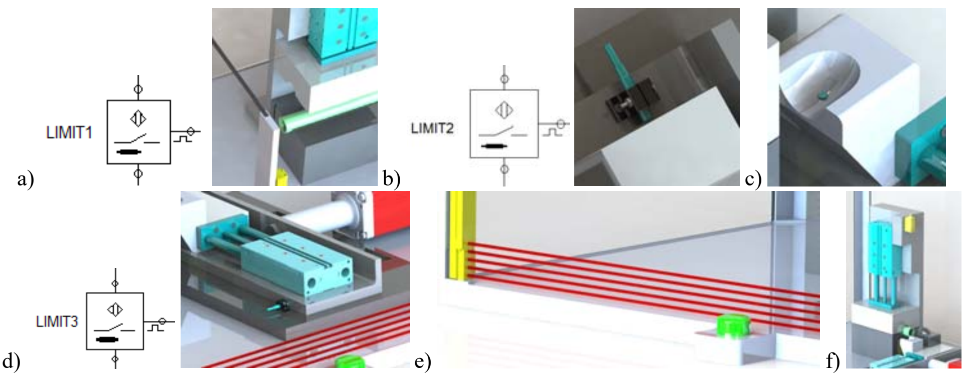

Figure 9. a) Schematic representation of the inductive sensor of the end position of the pneumatic cylinder 1. and position of the inductive sensor. b) Schematic representation of the inductive sensor of the pneumatic cylinder 2. and position of the inductive sensor. c) Schematic position of the inductive sensor in the coupling holder. d) Schematic representation of the inductive sensor of the end position of the electric cylinder and position. e) Light curtain. f) Schematic view of the CCD sensor.

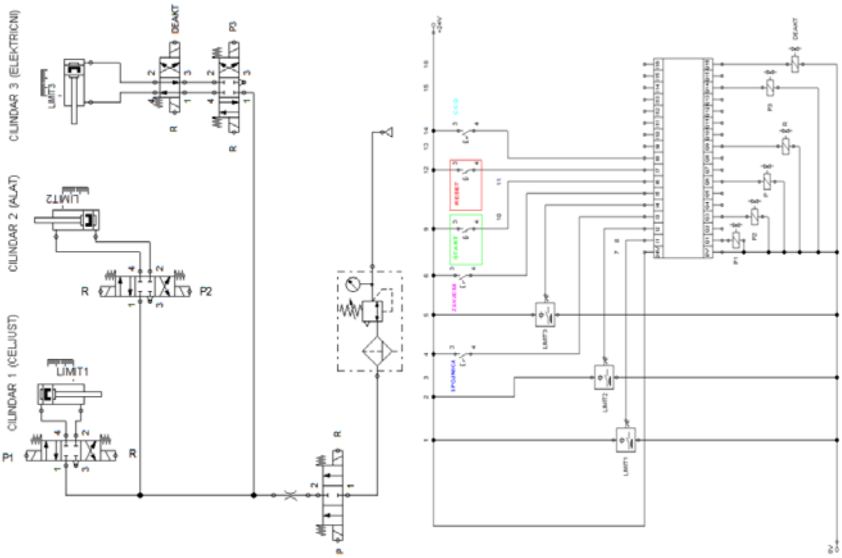

Figure 10. Pneumatic and electronic scheme.

4.2. Results of the duration of the new assembly process

These aspects of the conceptual solution are different: The speed of the operator is currently a factor in several process phases, including lowering the handle, extending the pipe, and lastly pushing the connection. These actions become automated by the conceptual solution. Additionally, the piece control time is completed while creating the next part, maximizing the machine's efficiency and eliminating waiting time. The pneumatic cylinder moves at a speed of 0.8 [m/s], and the electric cylinder moves at a speed of 0.15 [m/s]. When comparing the results of the current assembly process's duration with that of the new one, it can be determined that the new solution resulted in a 37% reduction in process duration. As a result, more pieces will be produced during a single shift or, if quantity is not a crucial consideration, the operator will spend less time at that machine.

	Process step	Process time that adds value	Process time that does not
1	Placing the pipe in the machine 1		4
2	Installing the coupling in the machine 1		6
3	Exit the working area of the machine 1 and press the Start button		2
4	Jaw lowering (cylinder 1)		0.1125
5	Coupling expanding process (Cylinder 3)		0.6
6	The process of retracting piston 3 and extraction piston 2		0.6
7	Coupling pulling process (cylinder 3)		0.6
8	The process of press coupling	0.05	
9	The process of returning (all cylinder) piston back		0.6
10	The process of separating the product from the machine		2
11	Inspection of the processed piece (inspection during the assembly of the next pipe)		0
12	Placing the producet piece in the control box		2
13	Placing the pipe in the machine 2		4
14	Installing the coupling in the machine 2		6
15	Exit the working area of the machine 2 and press the Start button		2
16	Jaw lowering (cylinder 1)		0.1125
17	Coupling expanding process (Cylinder 3)		0.6
18	The process of retracting piston 3 and extraction piston 2		0.6
19	Coupling pulling process (cylinder 3)		0.6
20	The process of press coupling	0.05	
21	The process of returning (all cylinder) piston back		0.6
22	The process of separating the product from the machine		2
23	Inspection of the processed piece (inspection during the assembly of the next pipe)		0
24	Placing the producet piece in the control box		2

	Current state		New solution	
	Time	%	Time	%
Process time that adds value	1	0.016942	0.02	0.0005399
Process time that does not add value	58	0.9830508	37.025	0.9994601
Waiting or transport time	0	0	0	0
Total time	59	1	37.045	1

Figure 11. Process phases and a time comparison between the present and new assembly processes.

5. CONCLUSION

The term "automation" frequently connotes both the removal of humans from the production process and an improvement in productivity, but in this case, it is obvious that automation includes much more. By integrating automation and the principles of quality management, successful results, capable and stable production processes, and fewer defective products—all of which have a positive impact on the company's financial situation and reduce customer complaints—can be achieved. The research conducted has shown that automation using mechatronic components has improved conditions in a number of areas, including quality, productivity, and human resources. By making the parts almost identical, quality is ensured and there are no deviation samples that might be off-spec. One of the requirements for the process to be successful is production stability. Error possibilities are reduced if a process is steady, controllable, and independent of the human aspect. Along with the automatic assembly, the piece's quality is also verified as the next one is being made. As a result, the operator can concentrate more closely on the piece itself rather than racing to prepare for the next manufacturing step. Additionally, because it is an automatic process as opposed to the current state, where the operator can use variable pressing force and speed, the pressing force is always the same. Automation increases workplace safety from a human resources point of view. Automation facilitates maintenance on the machine itself in addition to the safety feature. Because many processes are taking place simultaneously in the new solution as opposed to the current state, where each process was running sequentially, the norms for production show that productivity has increased significantly. Innovating with an automated solution helps to increase productivity, process efficiency, workplace safety, and product quality, which makes it easier to deliver the required amounts to the customer.

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