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# Water Retaining Nylon Rolling Application in the Automotive Industry with Collaborative Robot (COBOT)

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**Abstract**: This study focuses on the prototype design and preliminary experiments regarding the applicability of robots capable of collaborating with humans in the automotive sector. In standard factories, production is mostly carried out by humans. The use of robots is more suitable for tasks that require a certain standard. Performing operations with cooperative robots working alongside humans reduces costs and increases efficiency. A Cost/Benefit analysis was conducted in this study to assess the feasibility of using robots. The application will be carried out by a cobot. The surface beneath the upholstery on the side doors in the automobile body assembly line is covered with nylon to prevent liquid permeability. Currently, this process is performed by two operators for four doors. To validate the application in cases of quality issues, marking is done along the line with acetate and a pen during the rolling process. In the study, positioning for the doors on the conveyor line, moving at a speed of 3,2 m/min, was achieved using cameras mounted on two cobots equipped with grippers on the right and left sides. By applying a compressive force of 50N with the pressure roller at the gripper end, the adhesive on the nylon is ensured to bond with the sheet metal. The stability of the system was observed when comparing animation data with the application created in the experimental environment. As a result of all these processes, operational precision increased, and continuous robot-door synchronization was achieved. According to cost analyses, it is projected that the system will amortize itself within approximately 4 years.

**Keywords:** Collaborative robot technology, Human-robot interaction, Smart factories

## Introduction

Mass production is a manufacturing process that involves large-scale production of standardized products. It is characterized by the efficient production of high volumes of identical or similar goods, often using assembly line techniques to achieve economies of scale (Kumar et al., 2007). Mass production allows goods to be produced quickly and cost-effectively, leading to lower prices for consumers due to reduced production costs (Kumar et al., 2007). The concept of mass production has been a cornerstone of industrial manufacturing for decades and has revolutionized the way goods are produced and consumed. By optimizing production processes and standardizing components, mass production enabled the efficient production of goods on a large scale, contributing to increased productivity and economic growth (Kumar et al., 2007). The evolution of mass customization as a complementary strategy to mass production has further increased the ability of companies to meet consumer demands for personalized products within the framework of mass production (Kaplan & Haenlein, 2006). Mass production offers several advantages that have contributed to its widespread adoption in manufacturing industries. One of the key advantages is the ability to achieve economies of scale, leading to



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lower production costs per unit as the volume of output increases (Bunster & Bustamante, 2019). By producing large quantities of goods, manufacturers can spread fixed costs over a larger number of units, leading to cost savings that can be passed on to consumers through lower prices (Bunster & Bustamante, 2019). Another advantage of mass production is increased efficiency and productivity. Standardized production processes and assembly line techniques allow orderly and repetitive manufacturing of goods, reducing the time and labor required to produce each unit (Chang et al., 2022). This efficiency not only reduces production costs but also allows manufacturers to meet high demand and fulfill orders quickly (Chang et al., 2022). Additionally, mass production generally results in consistent product quality. By using standardized ingredients and processes, manufacturers can ensure that each product meets the same specifications and quality standards (Qi et al., 2020). This consistency is necessary to build consumer trust and loyalty, as customers can rely on the reliability and uniformity of mass-produced goods (Qi et al., 2020).

Smart factories, an important member of Industry 4.0, are highly digitalized and connected production facilities based on smart production techniques (Sadiku et al., 2021). These enhanced production environments leverage technologies such as big data, cyber-physical systems, and the Internet of Things to increase efficiency, productivity, and replication in production rates (Tomiyama et al., 2019; Wang, Wan, Zhang, et al., 2016). Smart factories are versatile; Increased data throughput leading to their performance through data analytics, agile response to failures and anomalies, as well as increased variability and flexible reconfigurability for smaller production volumes (Tomiyama et al., 2019). Smart factories offer increased process efficiency, reduced operating costs, improved product quality, enhanced safety and sustainability, and numerous benefits (Nwakanma et al., 2021). By integrating technologies such as artificial intelligence, robotics and cloud computing, smart factories can automate their work, optimize production workflows and enable real-time storage and control of parts of production (Heymann et al., 2018). These advances not only support improved support but also broaden the way for advanced product development and customization (Wang, Wan, Li, & Zhang, 2016). Moreover, the deployment of industrial wireless networks (IWNs) serves as a vital foundation for centralizing the architecture of Industry 4.0 and smart factories, ensuring continuous communication and coordination between various growths in the manufacturing economy (Volpi et al., 2023). The visual of Industry 4.0 components is shown in figure 1. Smart factories are expected to play a pivotal role in solving complex problems in manufacturing industries, achieving breakthroughs in factory operations, and promoting sustainable business registration (Yang et al., 2018).

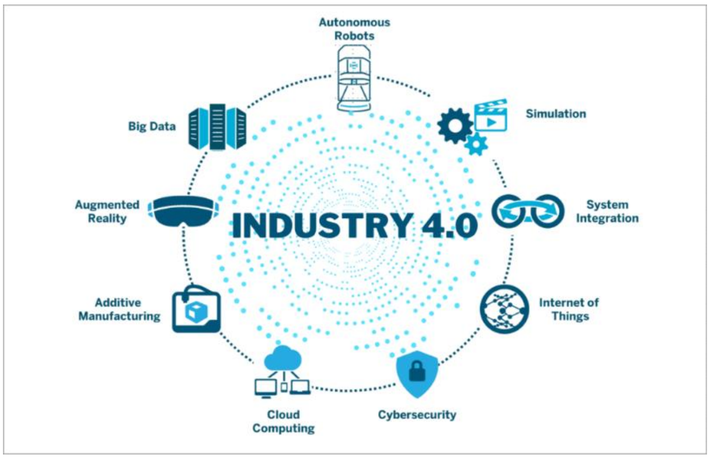


Figure 1. Industry 4.0 components

Collaborative robots, commonly known as cobots, are increasing in use in industrial environments, especially in smart manufacturing environments. These robots are specifically designed to work alongside humans, encouraging collaboration and shared workforce dynamics (Koh et al., 2019; Zakeri et al., 2023). The global adoption of collaborative robots is increasing, especially in smart factories, where they have largely replaced traditional industrial robots due to their improved performance and intelligent design (Indri et al., 2019; Wang et al., 2019). Collaborative robots provide innovative solutions for complex hybrid assembly tasks, especially in smart manufacturing contexts, by providing flexibility to production cells through close collaboration with humans (Matheson et al., 2019). These robots are effective in facilitating human-robot interaction, thereby increasing learning and comfort in collaborative spaces (Matheson et al., 2019). In addition, collaborative robots play an important role in restructuring production lines and ensuring flexibility and autonomy through their integration into the production ecosystem (Polenghi et al., 2023). Research on collaboration between humans and cobots in manufacturing applications has focused on improving productivity, safety, and efficiency in collaborative environments (Chromjakova et al., 2021). The cobot human working structure is shown in figure 2 (Publiteconline, 2024).

Figure 2. The Cobot human working

The automotive industry has been actively exploring and implementing collaborative robots (cobots) on assembly lines to enhance manufacturing processes. Studies have shown that the insertion of collaborative robots in automotive production lines can have a significant impact on production efficiency and competitiveness (Karabegović et al., 2021; Lima et al., 2019; Vido et al., 2020). These robots play a crucial role in smart automation within the automotive manufacturing sector, improving element manufacturing processes and car assembly operations (Karabegović et al., 2021). The use of cobots in the automotive industry aligns with the principles of Industry 4.0, facilitating smart manufacturing practices and advancing human-robot collaboration in shared workspaces (Lima et al., 2019). Manufacturers in the automotive sector are leveraging collaborative robots to optimize production workflows, increase flexibility, and drive innovation in manufacturing processes, ultimately enhancing the overall efficiency and competitiveness of automotive production lines.

In this study, a preliminary study was carried out to use robots to cover the surface under the flooring of the side doors in the automotive industry, in the automobile body assembly line, with nylon to prevent liquid permeability. The process, which is normally done by human hands, is planned to be performed by a collaborative robot. For this purpose, manual processing processes will be mentioned first in the second section. Then, the operations to be performed with the robot will be explained. The data obtained in these processes will be given in the results section. Finally, the conclusion will be given.

## Method

The method in the study consists of two parts. The manual assembly process and the operations to be performed with the cobot will be explained.

### *Manual Assembly Process*

Various processes are applied to the interior parts of the doors of passenger vehicles produced in the TOFAŞ Factory during assembly. One of these is the water retaining nylon rolling process that is adhered to the inner surface of the doors. This process is extremely important to minimize liquid and dust contact with the external environment.

The door line consists of a 60-meter long double-sided conveyor line moving at a speed of 3.2 m/min. Water retaining nylon rolling operation is carried out on 6 meters of it. Four personnel facing each other complete the process in two steps. In the first step, the first personnel attaches the nylon covering to the door by passing it over the cables. In the second step, the second personnel, using his rolu pliers, applies 50 N of pressure and bursts the hotmelt adhesive part on the water retaining nylon, allowing it to join with the door. After assembly, each door is rolled twice to ensure that the adhesive adheres well. The same operations are applied to the left and right for four doors in total. After the gluing process is completed, for quality control, marking is made along the rolled line with an acetate pen during the rolling process in order to verify the application. The rolling process and pen are shown in Figure 3.

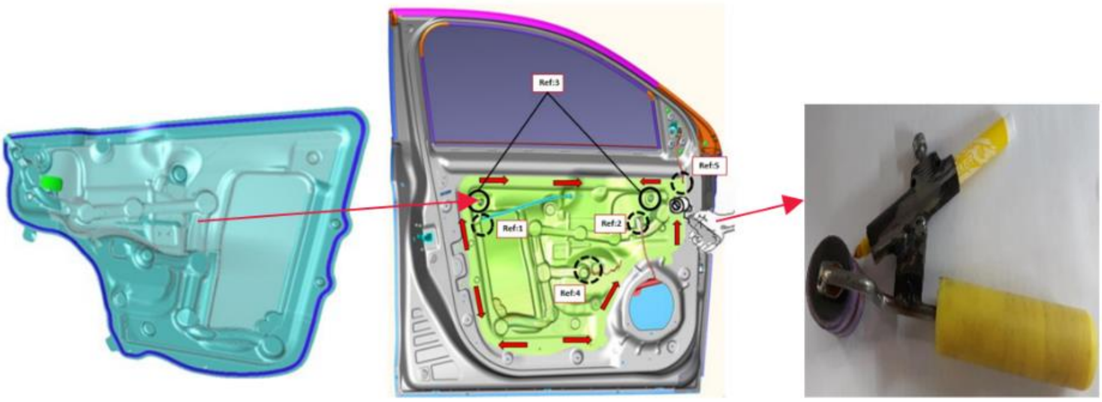


Figure 3. Rolling line and pliers

Table 1. Assembly chart workflow and times for front doors

| No | Process | Min/Vehicle |
|---|---|---|
| *1* | Take the right front door water trap nylon (a) from the line edge. Remove the protective paper from the nylon top. | 0,146 |
| *2* | Remove the mirror cable from the hole in the upper corner. Ref:5 | 0,025 |
| *3* | Remove the inner opening handle wire from the hole on the nylon. Ref:1 | 0,035 |
| *4* | Remove the speaker socket from the hole on the nylon. Ref:2 | 0,035 |
| *5* | Adhere the upper part of the nylon to the door, taking the dents on the nylon as a reference. Ref:3 | 0,095 |
| *6* | Remove the interior opening button installation socket from the hole on the nylon. Ref:4 | 0,035 |
| *7* | Remove the side and bottom protective papers of the water retaining nylon and adhere the nylon to the body by pressing it by hand. | 0,187 |
| *8* | Take the device from the side of the line. With the help of the apparatus, complete the rolling of the nylon, starting from the bottom point of the adhesive shade. | 0,287 |
| | *Total* | *0,845* |

Table 2. Assembly chart workflow and times for rear doors

| No | Process | Min/Vehicle |
|---|---|---|
| *1* | Take the right front door water trap nylon (a) from the line edge. Remove the protective paper from the nylon top. | 0,146 |
| *2* | Remove the inner opening handle wire from the hole on the nylon. Ref:1 | 0,035 |
| *3* | Position the reference points on the nylon and the door reference points together. | 0,095 |
| *4* | Remove the speaker socket and the internal release button socket from the hole on the nylon. Ref:3 | 0,070 |
| *5* | Remove the side and bottom protective papers of the water retaining nylon and place them in place by holding the ears next to them. | 0,187 |
| *6* | Take the device from the side of the line. With the help of the apparatus, complete the rolling of the nylon, starting from the bottom point of the adhesive shade. | 0,306 |
| | *Total* | *0,839* |

The assembly table workflow and times (min/vehicle) for the front doors are shown in Table 1 and for the rear doors in Table 2. In this table, the parts that the collaborative robot is planned to do are Step 8 at the front door and Step 6 at the back door. It seems that rolling takes the longest time in the operation. The time spent for a vehicle is front door: 0.845 min/vehicle - back door: 0.839 min/vehicle. Therefore, the applied process remains above the standard time in terms of process cycle time on the moving belt conveyor. Four packages of acetate pen, which is considered as an auxiliary material for this operation, are used per shift. The manual assembly process is shown in Figure 4.

Figure 4. The manual rolling process

*Assembly Process with Cobot*

The operations performed by two personnel in the current operation are planned to be performed by two collaborative robots. Robots will be positioned opposite each other on a fixed aerial line. The Universal UR5e Cobot selected for the demo application has 6 axes and has a reach radius of 850 mm and a carrying capacity of 5 kg. The gripper at the end of the robot will be such that the roller pliers can be fixed. Instant positioning, analysis and operation monitoring will be done with the data transferred to the software via the camera and sensors on it.

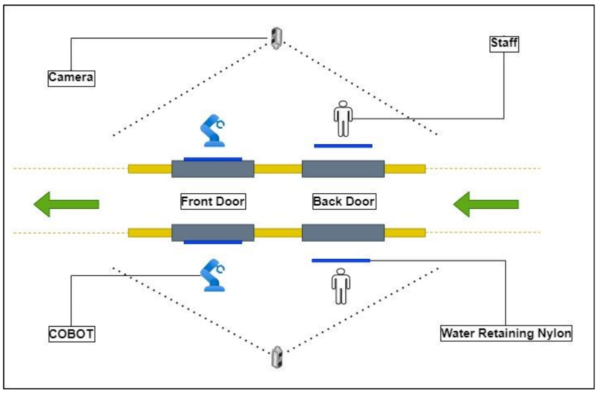


Figure 5. Diagram of the assembly process with cobot

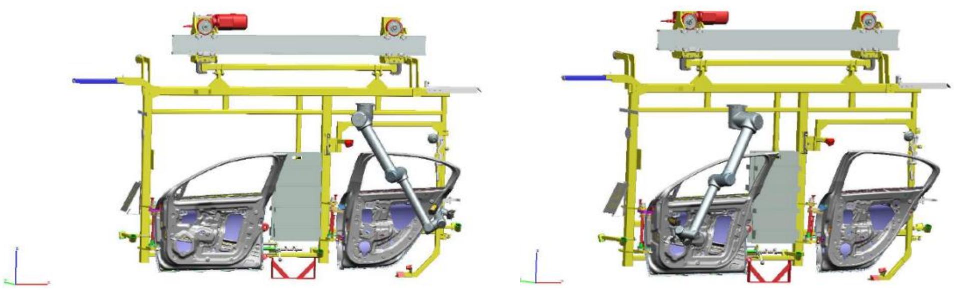

Figure 6. COBOTs on conveyor line

There are two separate conveyor lines for the right and left doors of the vehicle. The doors move on this line on a single carrier, front and back. Collaborative robots mounted on the overhead line will be able to work on two doors simultaneously. The working radius of the robots is programmed synchronously with the belt. A Keyence Vision series camera for each cobot detects the position at time t, and the speed information from the conveyor encoder goes to the robot. The cobot operating diagram is shown in Figure 5. This data is combined with the programmed g code (x, y, z) and the operation is performed. The 3D drawings below show the working scenario of the robots on the real field model. The system will work synchronously between Human and Robot in the same area at the same time. The design of COBOTs on the Conveyor Line is shown in Figure 6.

During the demo study, a single door and a single robot were used. Figure 7 shows the demo application. The system is modeled in both real and digital environments. By determining the distance and start-end points, a movement simulation and path were created through the software. Necessary load and gripper settings have been made. Sensitivity control was made by manually moving the line to which the door is connected. As a result of all these processes, the water retaining nylon adheres to the hot melt adhesive on the door without any problems. The overlap of application and simulation data and the stability of possible scenarios have been observed in many aspects.

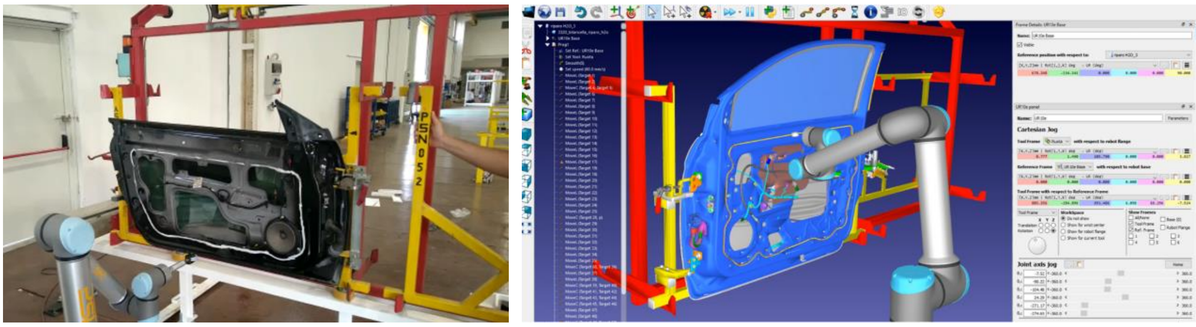

Figure 7. Demo application

## Results and Discussion

According to the results obtained as a result of evaluating the applicability of collaborative robots in assembly production lines and conducting demo studies, the following advantages can be obtained;

- Increased operational precision
- Shortening the operation time
- Elimination of quality loss
- Ergonomics improvement
- Demonstration of Quality Increase
- Process stability
- Reducing work accidents
- Creating alternatives

Table 3. Systemic advantages

| Systemic Advantages | Earnings (Euro) | |
|---|---|---|
| Standard time gain | € | 50.550 |
| Auxiliary material loss elimination | € | 11.124 |
| Non-additive loss of activity elimination | € | 13.782 |
| Ergonomics Gain | € | 5.524 |
| **Total Earnings** | € | **81.070** |

Table 4. Total Costs

| | *Commission* | |
|---|---|---|
| Cobot | k€ | 35 |
| Camera | k€ | 30 |
| Gripper-3P | k€ | 15 |
| Engineering - Automation. | k€ | 30 |
| Superstructure & line arrangement | k€ | 10 |
| Quality certificates | k€ | 14 |
| Workmanship | 20% | |
| ***Total Costs*** | ***k€*** | ***161*** |

The studies carried out and the gains from the systemic advantages to be achieved between manual operation and cobot operation are shown in Table 3. It is planned to earn a total profit of 81000 Euros. The costs incurred as a result of rolling with a cobot are given in Table 4. Commissioning includes installation. In this data, the most important value for operation optimization and applicability will be Benefit/Cost. In a system with a commissioning cost of 81/161, B/C = 0.5.

## Conclusion

Standardization is important for reasons such as increasing quality in mass production and ensuring the standardization of works. In production, working with human power is being replaced by machines. It is difficult to use standard machines to perform some production processes. Humanoid robots are used for this. Robot arms similar to the human arm structure are programmed and used in production. Robot arms that work together with humans have been developed with developing sensor, camera and software technologies. The re-planning of a production system with a collaborative robot (Cobot) was carried out within the scope of this study. Waterproof nylon rolling in the automotive industry is currently done by humans at the TOFAŞ factory. A preliminary study and the data obtained are presented to show how much this process can be improved by supporting COBOT. Considering the investment cost and the profit to be obtained, the system will amortize itself within 2 years. An increase in quality and customer satisfaction will be achieved in the annual production of approximately 240000 thousand vehicles.

## Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

## Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Basic Sciences, Engineering and Technology (www.icbaset.net) held in Alanya/Turkey on May 02-05, 2024.

* This study was developed to improve the production process at TOFAŞ Bursa automotive factory. The aim of the study is to determine the most suitable place to invest. Preliminary study data and demo application studies are presented.

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