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OPTIMIZATION AND DESIGN OF A MANUFACTURING LINE FOR AUTOMOTIVE PRODUCTS

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Abstract

This paper presents the results of the design and optimization of a manufacturing line for automotive products. The study focuses on optimizing a station to ensure that a shutdown of one manufacturing line does not affect other lines. The optimization process utilized KUKA robots for parts handling and implemented a rack-type station where automotive parts can be placed or picked up by two robots simultaneously. The station was designed to use modular design elements. The rack station is equipped with NOK define before abbreviate part identification sensors, resulting in a significant increase in production efficiency (28%), improved product quality (identification of scrap parts before welding the final product), and reduced operational costs. Future research may explore the long-term impact of optimization and its effects on employees.

Key words: optimization, production line, automotive, rack station, KUKA robots, modular design.

1. Introduction

The automotive industry is one of the most dynamic and competitive sector, requiring constant innovation and improvement in manufacturing techniques. With the rapid advancement of technology, there is a growing necessity to integrate automated processes that minimize human intervention. This drive for innovation is powered by the need to diversify and discover new methods to facilitate industrial processes and at the same time can be considered as a time, energy, cost saving method.

Previous research in the field has highlighted several approaches to optimizing manufacturing lines, including the use of modular design elements, the integration of robotic systems, and the implementation of advanced simulation techniques. Studies have shown that these methods can significantly reduce production time, improve product quality, and increase overall efficiency, as in [1].

For instance, the implementation of modular design elements allows for greater flexibility and adaptability in the manufacturing process. The integration of robots has been shown to enhance precision and consistency, leading to higher quality products. Advanced simulation techniques enable the testing and validation of different design scenarios, ensuring that the most efficient and effective solutions are implemented, as in [2].

This research paper aims to address the challenges and inefficiencies in the current manufacturing processes and propose a solution that enhances productivity, quality, and overall efficiency. In the rapidly evolving field of automotive manufacturing, there is a continuous need to improve production processes to meet the increasing demand for high-quality vehicles. The specific problem investigated in this study is the inefficiency and lack of optimization in the current production line where a stoppage in one of the production lines can stop all of them.

This study builds on the existing body of knowledge by applying these optimization techniques to a specific case study in the automotive industry. The proposed solution involves the design and optimization of a manufacturing line that incorporates modular elements, robotic systems, and advanced simulation techniques. This research aims to use modular design that helps to optimize and rapidly design a station and identify scrap parts in time for remanufacturing.

2. Materials and Methods

It has been received the 3D model of the finished body from our customer, EBZ Group, along with detailed information on which parts will be assembled and welded on each production line. After identifying all the processes and steps to be optimized in the manufacturing line, Figure 1 shows the extracted 3D model used on the production line.

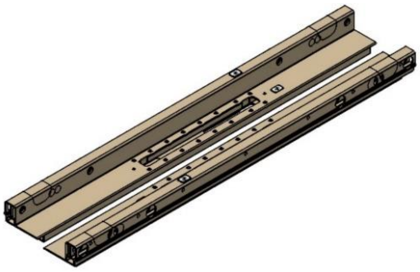

Fig. 1: Extracted 3D model

As shown in Figure 2, in the preliminary design phase, it was chosen to use 8 support points, made using standard parts and spacers provided by EBZ Group, along with parts designed in Catia V5, customized for our body. To enhance the stability of the body, it has been added 7 rough locators to ensure higher stability and precision when the robots place or retrieve the body. Given the advanced technology of the robots, it has been decided to maximize their use by incorporating 4 sensors for parts identification and rejection detection.

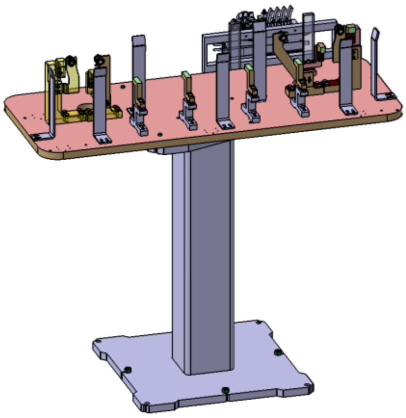

Fig. 2: The first designed station

This design was requested by EBZ Group, but after several discussions, it became clear that optimizing the production line was necessary. In the event of a failure in subsequent processes, it would be necessary to stop all lines. Therefore, the station was redesigned with a more optimized, modular design, repeating the support components and body identification for each body on the shelf station as illustrated in Figure 3.

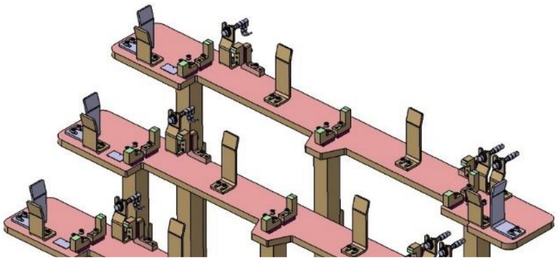

Fig. 3: Modular design

Figure 4 shows the optimized station used only 5 support points, made from simpler and fewer parts. The rough locators were optimized to reduce raw material usage, decreasing their number to 6 pieces, placed more evenly and at a lower height. New body identification points were identified, reducing the number of sensors from 4 to 3, with a simpler and more accessible support for easy replacement in case of failure.

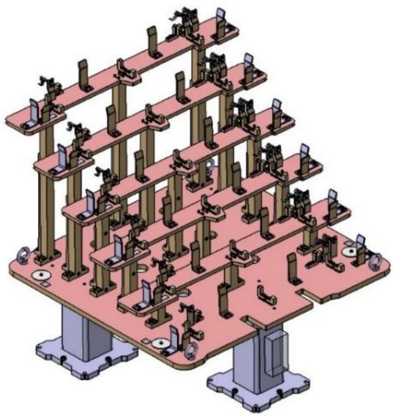

Fig. 4: Optimized station

After creating the rack-type station, storage stations were designed using the standards provided by EBZ Group as shown in Figure 5. In the event of a line stoppage, bodies from unaffected lines can be stored and subsequently produced/assembled. Four stations were designed to distribute each body type to the personal warehouse.

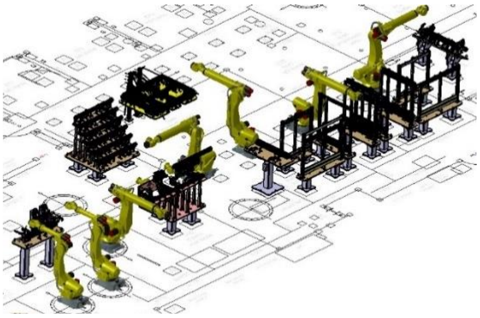

Fig. 5: Optimized production line

In order to avoid mixing inaccurately assembled or discarded bodies with the correct ones, emphasis was placed on designing a rework station as seen in Figure 6 where the worker can intervene to fix the problem and analyze why it occurred or determine if a recalibration of the robots is necessary.

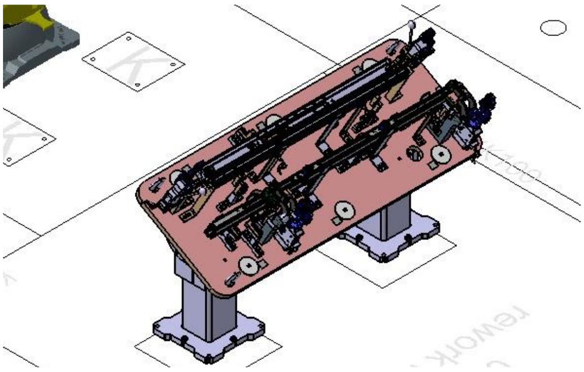

Fig. 6: The rework station

3. Results and discussion

The implementation of the optimization in the EBZ Group factory was evaluated through a detailed analysis of several performance indicators, including operational costs, product quality, production rates, and production time. Data was collected over a six-month period to ensure a realistic and comprehensive evaluation comparing the optimized versus non-optimized manufacturing line.

Analyzing Table 1 regarding operational costs, a significant reduction was observed after implementing the optimization. Before the optimization, the monthly costs ranged between 35,000 and 40,000 euros. After optimization, these costs consistently dropped below 32,000 euros per month. This constant cost reduction demonstrates the financial efficiency achieved by optimizing the station and the possibilities of continuous work without stopping.

Table 1: Operational costs (euro)

	Month					
	M1	M2	M3	M4	M5	M6
Total costs before opt.	35000	37000	38000	39500	40000	40000
Total costs after opt.	30000	32000	30000	31000	31500	32000

Table 2: Product quality

	Month					
	M1	M2	M3	M4	M5	M6
Defects before opt. (pc)	10	15	30	15	13	11
Defects after opt. (pc)	0	0	0	10	5	0

Table 3: Production rate

	Month					
	M1	M2	M3	M4	M5	M6
Parts produced before opt. (pcs)	5000	4750	4200	4750	4850	4950
Parts produced after opt. (pcs)	5250	5200	5350	5000	5100	5200

Table 4: Cycle time

	Month					
	M1	M2	M3	M4	M5	M6
Average cycle time before opt. (s)	65	68	80	68	67	66
Average cycle time after opt. (s)	59	60	55	65	62	60

In Table 2, the quality of the products was another essential aspect evaluated. Prior to optimization, the number of defects varied between 10 and 15 per month, indicating significant variability in quality standards. After implementing the optimization, the number of defects decreased significantly. This suggests that optimization through sensor detection and the implementation of the rework station allowed for timely repair or identification of problems, thus having a profound impact on product quality, completely eliminating defects and ensuring a consistent and high level of quality.

The production rates found in Table 3 have also seen notable improvements. Before the optimization, the number of parts produced per month varied between 4,200 and 5,000. After optimization, production increased steadily to 5,300 pieces per month. This increase in production rate reflects the enhanced efficiency of the optimized manufacturing line, allowing the factory to produce more parts within a consistent time frame.

The data in Table 4 reflected the production time, showing a significant reduction. The average production cycle dropped from 65-80 seconds per part before optimization to 55-65 seconds after optimization. This reduction in production time helps increase the overall efficiency of the manufacturing process, enabling the factory to produce more parts in less time and respond more quickly to market demands.

4. Research perspectives

Based on a comprehensive review of specialized literature and the results obtained in the present study, several promising research directions have been identified as underexplored and potentially valuable. This study utilized KUKA robots to optimize a manufacturing line in the automotive industry. However, several other technologies, such as different types of robots, artificial intelligence, and machine learning systems, could be equally or more effectively used. Future research should investigate these alternatives to enhance efficiency and productivity.

The findings of this study are specific to a single manufacturing line in the automotive area. Future research should explore the applicability of these optimization techniques in other contexts, including different industries and types of manufacturing lines. Additionally, while this study provides a snapshot of the short-term impact of optimization, it is crucial to examine the long-term effects. Future research should track manufacturing line performance over extended periods to determine the sustainability of performance improvements. It would also be valuable to assess the impact of optimization on other performance aspects, such as employee satisfaction and long-term profitability.

5. Conclusions

The optimization and design of the manufacturing line for automotive products, as detailed in this study, have demonstrated significant improvements in production efficiency, product quality, and operational costs. By integrating KUKA robots and implementing a modular rack-type station, the study achieved a 28% increase in production efficiency. The use of NOK part identification sensors played a crucial role in identifying scrap parts before the final welding process, thereby enhancing product quality and reducing defects.

The modular design elements allowed for greater flexibility and adaptability in the manufacturing process, which is essential in the dynamic and competitive automotive industry. The reduction in the number of sensors and support points, along with the optimized placement of rough locators, contributed to a decrease in raw material usage and operational costs. The study reported a consistent reduction in monthly operational costs from 35,000-40,000 euros to below 32,000 euros post-optimization.

Furthermore, the production rate saw a remarkable increase, with the number of parts produced per month rising from 4,200-5,000 to 5,300 pieces. The average production cycle time also decreased from 65-80 seconds to 55-65 seconds per part, reflecting the enhanced efficiency of the optimized manufacturing line.

Future research should explore the long-term impact of these optimizations and their effects on employees, as well as the applicability of these techniques in other industries and manufacturing contexts. Additionally, investigating the potential of other technologies, such as artificial intelligence and machine learning systems, could further enhance efficiency and productivity.

In conclusion, the study provides a robust framework for optimizing manufacturing lines in the automotive industry, demonstrating that strategic integration of advanced technologies and modular design can lead to substantial improvements in efficiency, quality, and cost-effectiveness.

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