ISSN No:-2456-2165

Impact of Human-Robot Collaboration in the Automotive Industry

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Abstract:- The use of automation and robotics in the automobile industry has transformed manufacturing practices, where humans and robots now collaborate to boost productivity and efficiency. This paper aims to analyse the impact of the evolution in the collaboration between humans and robots on the automotive industry. This study examines the benefits of human-robot collaboration by analysing the productivity ,flexibility and safety of the workers in various levels of human-robot collaboration. The paper also dives into the complications which occur during the collaboration between humans and robots such as training and work distribution. Human-robot collaboration is essential in the modern world, and research studies show its effectiveness in various industries, including healthcare, industry, transportation, and agriculture. The increasing amount of research on this topic suggests that human-robot collaboration is an important aspect of modern industrial development.The study's findings contribute to a wider discussion on the future of work and the appropriate implementation of human-robot collaboration in industrial settings such as the automotive industry. Finally, the goal of this research is to allow a peaceful and efficient collaboration between humans and robots, opening up new paths for innovation and growth in the automobile industry.

Keywords:- *Automation, Robotics, HMI, Human-Robot Collaboration.*

I. INTRODUCTION

Robotics is one of the key branches of automation, and not only in the mechanical engineering industry [1]. Industrial robots and manipulators have found their application in a wide range of tasks that can replace human operators [1].

By incorporating automation and robots, the automobile sector underwent a significant transformation [8]. The usage of these robots in the automobile sector has resulted in a shift in manufacturing practices, where humans and robots now collaborate to boost productivity and efficiency [8]. The advancement of human-robot collaboration has had a significant influence on the automobile sector. This work will focus on analysing how the evolution in the collaboration between humans and robots has impacted the automotive industry.

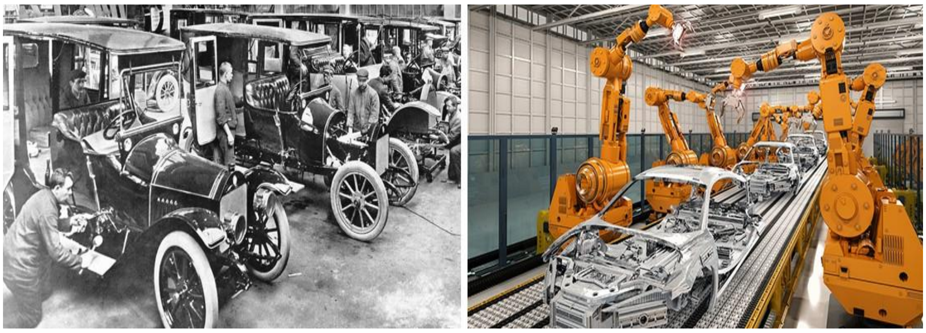

Fig. 1: Then vs Now production methods, respective 1

[source: Global Electronic Services]

II. STATE OF ART

The evolution of cars started way back in 1672, with the first invention being the steam-powered vehicle. However, it wasn't until 1769 that Nicolas-Joseph Cugnot created the first steam-powered car that could transport people [8]. The automobile industry was really revolutionised with the introduction of the Ford Model T, developed by the Ford Motor Company, which became the first vehicle to be mass-produced on a moving assembly line, marking a significant moment in history as it made cars more widely accessible and affordable to the common person [8]. As a result, there was an increase in car ownership, and by the 1920s, cars had become an integral element of the American lifestyle [8].

The use of human-robot collaboration in the automobile industry has undergone a significant revolution, from the early days of manual labour to the modern day of automation and robotic systems [4].

In the olden days of car manufacturing, humans played a significant role in the production process, being responsible for everything from designing to assembling the vehicles. Henry Ford created an assembly line production method that solely relied on human labour to keep it running smoothly [4]. This production method allowed a large number of cars to be produced in a short period of time, reducing costs and making them more affordable.

Robots were first adopted in the production of automobiles in the 1960s due to the growing demand for cars, which required an increase in production efficiency [3]. The first robots implemented in car production were hydraulic and were used to perform only repetitive and physically demanding tasks such as welding car bodies and painting [4]. However, these robots had only limited capabilities and were not flexible, but they were more efficient than human labour in specific tasks.

More advanced robots started to get adopted in the 1970s and 1980s because of the development of microprocessors and computer technologies [3]. These robots were electric and were more accurate and flexible than the previous generation, which made them more useful for a wider range of tasks. Because it is now easier to programme the manufacturing process, it can be easily changed in response to changes in demand or automobile design [3].

In today's world, robotic systems and automation have now become an essential part of the car production process and are used in almost every stage of production [4]. Humans have not been eradicated, they are still involved in the production process, but their role has shifted to monitoring and maintaining the machines, making sure the production process runs smoothly and efficiently, while humans also focus on the tasks that require creativity and decision-making skills [3].

III. METHODOLOGY

The use of robots in the manufacture of vehicles involves several different variables. Costs, system integration, safety, manufacturing capacity, consistency and quality, and flexibility are some of such factors [1].

The implementation of robots can prove beneficial in a variety of areas, such as improving the safety of humans since robots can carry out risky activities under hazardous conditions without putting humans at risk of injury [6]. Robots are capable of producing at a higher rate with a higher level of consistency while also reducing human error. Robots are also simpler to reprogram, allowing firms to easily alter the design or manufacturing process of automobiles [1].

However, not all of these aspects of the implementation of robotic systems are favourable; some are undesirable. The deployment of the robotic system would result in an increase in initial expenses for the firm, raising its costs of production [ADD1]. Training personnel would be required to operate and regulate the robotic system, increasing costs yet again. Integrating these systems with humans could be challenging due to human-robot collaboration unless a specialised system is devised to smooth out the collaboration. Using robots would result in the loss of jobs for the human workforce that previously performed the same tasks now done by robots [2].

Human-robot collaboration is incredibly significant in today's world, as seen by the surge in the number of studies on the subject. This study was carried out in a variety of industries, including healthcare, industry, transportation, and agriculture.

Numerous studies have found that human-robot collaboration in the workplace improves efficiency and production [1]. According to research published in the International Journal of Advanced Manufacturing Technologies, human-robot collaboration increases efficiency by 22% when compared to traditional production methods [2]. Further studies also show that human-robot collaboration in a healthcare workplace reduces the risk of physical injuries to workers, and another research study shows that it also reduces the risk of musculoskeletal disorders in workers. There are many such studies that prove the importance of human-robot collaboration in different fields while stating its benefits [1].

In terms of the number of research papers published on the topic of "human-robot collaboration," a search on Google Scholar [5] yields over 34,000 results. This can show the relevance and significance of this study. Many of them report on empirical studies and provide theoretical insights that contribute to our understanding of the benefits and challenges of human-robot collaboration [5]. Overall, the increasing amount of research on this topic suggests that human-robot collaboration is an important area for further study and has the potential to transform many industries in the coming years.

IV. ANALYSIS

More than 2,800,000 of these machines have been sold globally since the first industrial robot entered production in 1967 [8]. Later, robots of the most recent generation took the place of this machine series [3]. Contrary to the older generation, they are more effective, highly capable (e.g., a payload-to-weight ratio up to ten times higher), and have complex handling/technological devices [3]. They are typically equipped with various cognitive and "intelligent" sensors that can help robots navigate challenging environmental conditions or processes and prevent potential damage to manipulated items or the robot itself [3].

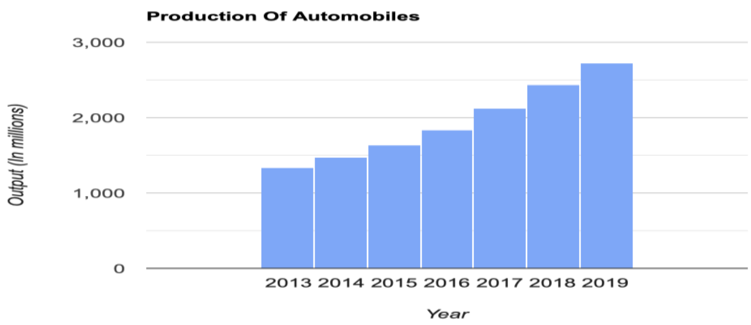

Fig. 2: production of automobiles, trends from 2013 - 2019 [3]

Robots have grown common in ordinary engineering and consumer product production [3], but robotics in electronics is now witnessing the most rapid growth. According to the International Federation of Robotics (IFR), global output and sales in this field have surged by 114% in the previous six years. According to published statistics (IFR, 2020), the robot market is predicted to increase at a 14 percent annual rate by 2024, with 600,000 robots manufactured yearly. In comparison, around 80,000 of them were made annually at the turn of the millennium. In 2018, Europe had an average of 106 robots per 10,000 industrial employees, the United States had 91 robots, and Asia had 75 robots per 10,000 industrial workers.

It is commonly known that the automobile industry has one of the greatest implementations of robots in production, with 33% of the total supply of robots in 2019 [3]. Manufacturing of passenger vehicles and cars, whether with a traditional internal combustion engine or more popular vehicles with hybrid drive and electric drive systems, has become increasingly difficult in recent years [2].

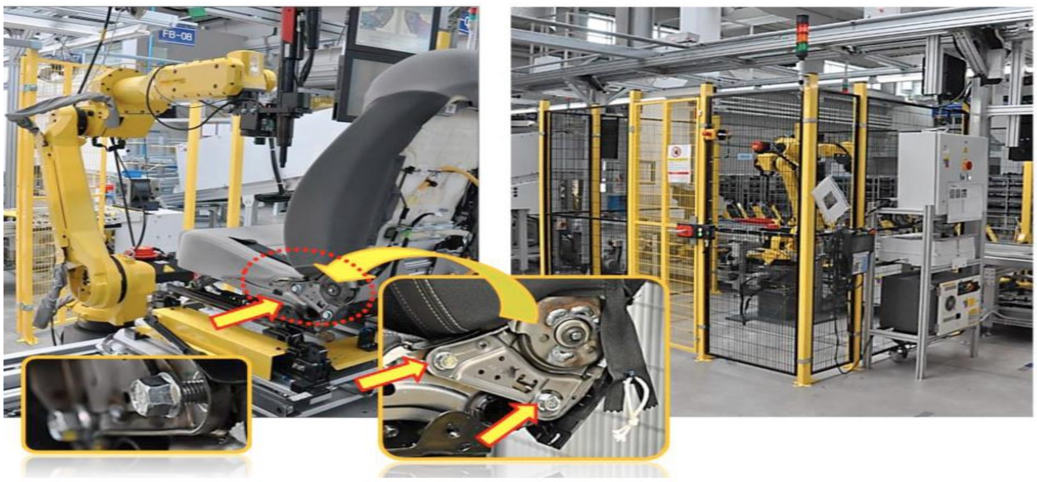
Fig. 3: View Of Solved Bolting Station [3]

The major goal is to create a robotic cell that will replace a human operator at the workplace of bolt tightening on the car seat assembly line at a car factory's external supplier. It is a technique of tightening four screws that connect the lower (seat portion) and rear (backrest) parts of the front seats of a passenger automobile, always a pair of seats - left (marked as LH) and right (marked as RH) (marked as RH). The line's average production capacity is roughly 1000 pairs of seats per day, which equates to around 8000 tightening cycles per day.

V. A LEVELS OF HUMAN-ROBOT COLLABORATION

There are several levels of human-robot collaboration, which can be categorised based on the degree of interaction and communication between humans and robots.[7] These levels are:

A. Low Level

Figure 4 depicts a body shop work cell in which an operator feeds various body components into a rotary table fixture. The operator departs the light-curtain-protected area and presses a push button to start the welding cycle. The welding robots spot-weld the components as the rotating table rotates into the welding position.

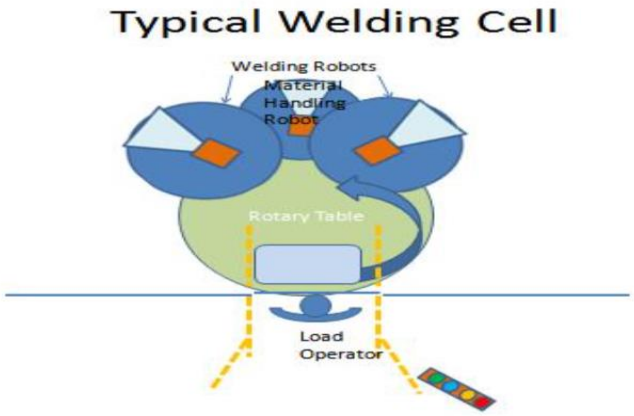

Fig. 4: An Automotive Body Shop Example of Low-Level Human and Robot Collaboration [7]

The operator is placing an extra fixture onto the rotary table while the robots continue welding. After the welding cycle is finished, a material handling robot takes the welded subassembly and transports it to the next process.

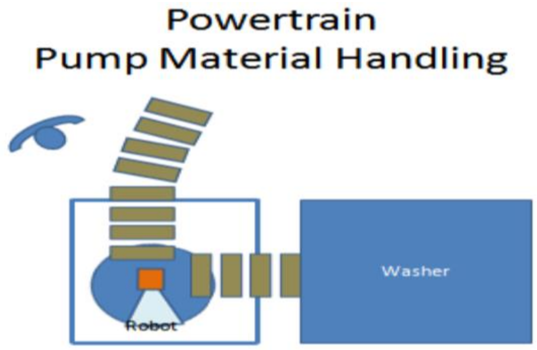

Fig. 5: An Automotive Power train Example of Low-Level Human and Robot Collaboration [7]

The employment of intermediary hardware, such as a rotary table or an input conveyor, to buffer and transport components between the operator and the robots is one of the main aspects of this low-level human and robot collaboration. (shown in Figure 5)The hardware helps to prevent direct human-robot interaction by

- Allowing the person to operate outside the robot's working perimeter
- Allowing the human to do his or her own duties asynchronously with the robot.

The hardware transfer device, such as the rotating table or the input conveyor, on the other hand, adds expense, takes up extra space, and makes the work cell less adaptable to new product modifications.

B. Medium Level

Figure 6 shows a body shop work cell in which the operator feeds the outer bumper panel directly into the robot's end-of-arm tooling. The operator then feeds more bumper assembly components directly into the EOAT. The robot is stretched to its maximum operating range during this loading phase, and the servo drives are de-energized.

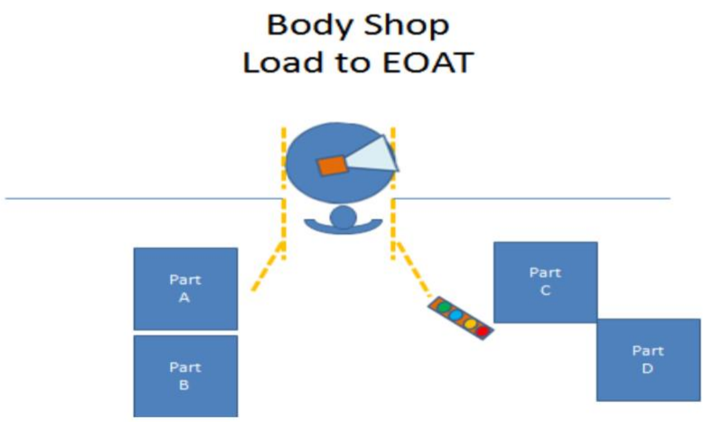

Fig. 6: An Automotive Body Shop Example of Medium-Level Human and Robot Collaboration

ISSN No:-2456-2165

When all loading is completed, the operator steps outside the light curtain-covered area and presses a button to start the EOAT clamping. The servo drives on the robot are activated, and the robot moves into the welding position. When the welding is finished, the robot transfers the fender assembly to the next cell for further processing.

Figure 7 illustrates a power train application in which the operator opens the robot enclosure's sliding door and puts a front engine cover onto a fixture. The fixture is situated within the robot's operational area. The operator places the part in the fixture when the robot's motor drives are de-energized and the robot is at its maximum working range.

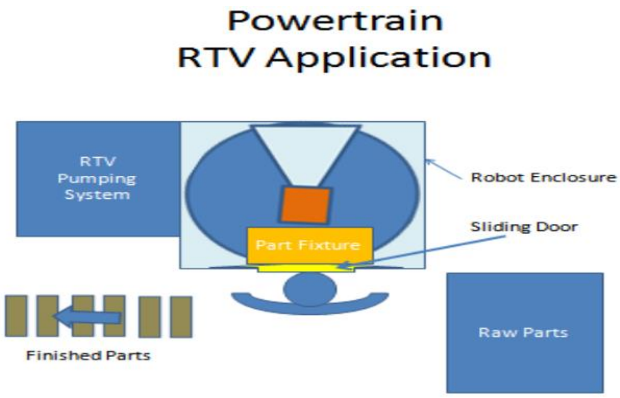

Fig. 7: An Automotive Power train Example of Medium-Level Human and Robot Collaboration

The robot's operating condition while the human operator is in its working environment is one of the fundamental aspects of this medium-level human and robot collaboration. Intermediate hardware may or may not be employed, such as a fixture to hold a part for the robot to pick up from. The operator will interface with the robot directly within its working environment without the use of hardware. The operator works simultaneously with the robot to complete his or her own tasks. This means the robot will not go on to the next job items until the operator starts motioning through a secondary input.

C. High Level

There are currently no applications in automobile body shops or powertrain manufacture that enable high-level human-robot collaboration with typical industrial robots. Fig. 8: Shows the single use of "Intelligent Lift Assist" in automobile general assembly.

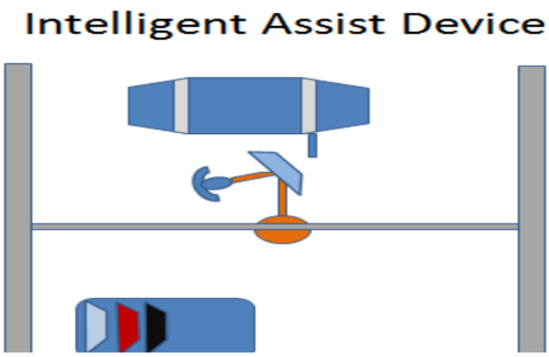

Fig. 8: An Automotive General Assembly of High-Level Human and Robot Collaboration

In this case, an operator is connected to and directly controls a robotic arm (an intelligent assist device - IAD). The interaction between the operator and the robotic arm works similarly to a robot teach pendant. The operator must keep pressure on the control device, the robot's speed is controlled, and sensors detect sudden movements of the operator and/or the robotic arm. These devices combine the power and precision of a robotic manipulator with the route flexibility and decision-making abilities of a human operator.

The degrees of human-robot collaboration, in conjunction with an examination of existing safety perceptions and interviews with technology implementers and users, provide us with a framework for determining the possibility for the effective deployment of various fenceless robotics systems. This part also assesses the likelihood of the effective adoption of fenceless robotic systems and enhanced human-robot collaboration.

VI. DISCUSSION

A. Factors influencing productivity

➢ *Stress*

Working beside a robot might raise human mental stress, due to the physical features of the robot, such as its look, in terms of size or form, and mobility. Operator stress is linked to situational awareness, which can be impacted by physical or psychological stresses. The former pertains to noise and illumination settings, whereas the latter alludes to fear, uncertainty, and event repercussions. As a result, the operator must be aware of the situation; otherwise, the likelihood of dangerous incidents increases. When the robot approaches close to the operator at a fast speed and without warning of motion, the operator's emotional tension may increase, overall lowering productivity.

- *Workload*

Workload refers to the effort used by a human operator during a job and may be assessed using the NASA-TLX, a tool that consists of a questionnaire with six items to assess: mental demand, physical demand, temporal demand, effort, frustration, and performance. The introduction of collaborative robotics results in a reduction in physical burden since the robot assists the operator in heavy and repetitive operations.

Nevertheless, because the job activity is less physical with fewer repeated motions and the operator must handle new responsibilities such as robotic monitoring and supervision, the physical burden lowers, making the operator feel less stressed and tense, less exhausted at the end of the day, hence raising productivity.

- *Trust*

Trust is an important factor for successful Human-Robot Cooperation since, in the absence of it, operators may underutilise the robot, potentially resulting in performance decreases, or perhaps not employing it. The morphological feature of the collaborative robot may impact trust; in fact, some designs may induce a stronger proclivity to interact. A large robot, for example, may discourage humans from collaborating, but a smaller robot or one with social indications may make the operator feel more at ease.

B. Safety

The majority of the studies chosen focused on human-robot collaboration safety. In general, safety is concerned with the identification of the risks and hazards involved in the activity, as well as the implementation of the necessary safety measures. It becomes a significant topic to address when integrating collaborative robots into the industry since a collaborative system is designed to allow physical connection with people in hybrid and fenceless work cells, eliminating the need for robot isolation.

Safety was considered to be the most important need for the adoption of collaborative robots in one of the research, followed by usability, adaptability, and efficiency. Because collaborative systems allow and require task sharing in a fenceless workspace, the main hazard category will be mechanical: potential non-functional physical interaction between the operator and the mobile parts of the machine, particularly the robot arm and various types of end-effectors. Because the environment is dynamic, safety systems for collision avoidance and/or contact mitigation, as well as safety precautions linked to work cell design, must be effectively integrated into collaborative robots. Because Human-Robot Collaboration typically takes place in a dynamic environment, and the coexistence of humans and collaborative robots in a shared space creates a hazardous situation, appropriate mechanisms to ensure the safety of humans and robots are required, and the design of safety mechanisms must meet the corresponding industrial standards.

C. Limitation

Writing a research paper on the impact of human-robot collaboration in the automotive industry poses several challenges. Firstly, the topic is broad, and extensive research is required to collect relevant data from various sources. The research requires an in-depth understanding of the history of the automobile industry, the role of humans and robots in the production process, and the evolution of robotic systems in the industry. The research must also address the challenges and benefits of human-robot collaboration, including costs, safety, flexibility, system integration, and quality consistency. The study must also analyse the impact of human-robot collaboration on the workforce, specifically the loss of jobs for humans. Lastly, the research paper must be written with scientific accuracy and a thorough analysis of the data collected, which requires expertise in the field of automation, robotics, and mechanical engineering. These challenges must be addressed by the researcher to create a comprehensive and informative research paper on the impact of human-robot collaboration in the automotive industry.

To understand how people working with robots affect work, a survey was done by the International Federation of Robotics in 2019. The survey looked at how productive and safe workers were when they worked together with robots, and whether it was cost-effective.

VII. ANALYSIS

A. Productivity Analysis

To see how humans working with robots affected productivity, we studied data from car factories that used robots from the IFR report. We looked at things like how much they produced, how long it took, and how many mistakes they made.

The study showed that productivity went up a lot when humans collaborated with robots. On average, they produced 35% more, which means they made production a lot faster.[9] The robots helped with different parts of making the cars, so assembly got done more efficiently.

Using robots also made the production time shorter. Robots could do their tasks faster than humans, so the time it took to make an automobile decreased by 25%.[10] This meant they could produce more cars in the same amount of time.

Another benefit was that the number of mistakes went down. Humans are prone to make errors, especially when attempting a repetitive task. But when robots took over those repetitive tasks, there were 40% fewer mistakes and damages to the products. This improved the quality of the products and reduced the need for fixing mistakes, further increasing the production rate.

B. Safety Analysis

Safety is really important when humans and robots collaborate in car factories. We looked at reports of IFR which include accidents and incidents in factories that used robots to determine the safety hazard.

The study showed that safety improved when people worked with robots. Accidents and injuries decreased by 60%, which means it became a safer place for workers.[9] The robots had advanced sensors and could detect possible dangers, so they helped to make sure that people were safe around them.

Using robots also reduced physical risks. Tasks that were tiring and repetitive for people were done by robots instead. This helped to decrease problems like muscle and bone disorders and injuries. Overall, improving human safety.

C. Cost-effectiveness Analysis

The results showed that even though using robots required a big investment at first, it saved money in the long run. Automating repetitive tasks and making production more efficient reduced the costs of labour and increased the number of cars they could make in a given time period.

We also found that the investment paid off quickly. On average, factories earned back the money they spent on robots within two years.[9] This showed that using robots was a good financial decision in the car industry.

Hence, working with robots had a positive impact on productivity, safety, and cost-effectiveness in the car industry. It increased production by making the process faster, improved product quality, made the workplace safer, and was financially beneficial.

These findings show that using robots alongside humans can revolutionise car manufacturing by making it more efficient, safe, and economically viable.

VIII. CONCLUSION

The use of robotics and automation has had a profound impact on the automobile industry. Human-robot collaboration has revolutionised the way cars are manufactured, leading to increased efficiency, productivity, and safety in the production process. The integration of robots has allowed for a higher rate of production and improved quality, while humans can now focus on tasks that require creativity and decision-making skills.[9] However, the implementation of robotic systems in the automobile industry also presents challenges, such as the initial cost of investment, the need for trained personnel, and the potential loss of jobs for the human workforce. Nonetheless, the benefits of human-robot collaboration are numerous, making it an essential component of modern manufacturing.

Furthermore, the increasing amount of research on human-robot collaboration across various industries highlights the significance of this field. Research has demonstrated that human-robot collaboration improves efficiency, reduces the risk of physical injuries, and enhances the overall performance of the manufacturing process. As technology continues to advance, the potential applications for human-robot collaboration are likely to expand, and the benefits will only increase. The success of human-robot collaboration depends on the ability to overcome the challenges of integrating robots into the manufacturing process. This requires the development of specialised systems that ensure smooth collaboration between humans and robots. Additionally, training personnel to operate and maintain robotic systems is necessary to ensure their proper functioning and safety.

The automotive industry has come a long way from the days of manual labour to modern-day automation and robotic systems. The use of robots in manufacturing has enabled the industry to improve production, reduce costs, and enhance product quality. Furthermore, human-robot collaboration has made it possible to achieve tasks that were once impossible or too risky for humans to perform. The future of the automotive industry is closely linked to the continued development and integration of robotic systems. It is essential that companies invest in the latest technology and properly train their personnel to ensure that they are well-equipped to work with these systems. By embracing human-robot collaboration, the automobile industry can continue to evolve and stay at the forefront of technological advancement.

As technology continues to evolve, it is likely that the role of robotics and automation will expand in the automobile industry and beyond. Human-robot collaboration has the potential to revolutionise the way we work, live, and interact with technology. It is up to us to embrace this technology and use it to its fullest potential.

ACKNOWLEDGEMENT

Thank you for the guidance of Claudia D'Ettorre mentor from University College London in the development of this research paper.

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