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ORIGINAL ARTICLE

# Ergonomic Embedded in Designing Welding Assembly Tool for Automotive Manufacturing Process

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**ABSTRACT** – Ergonomics focuses on understanding how workers interact with their work environment, tools, and equipment. The proper ergonomics consideration in tool design will impact worker safety and productivity. Ergonomics-embedded knowledge is critical in designing welding assembly tools for automotive manufacturing. The study aims to improve the ergonomic issues faced by the automotive assembly welders. The methodology involves studying the existing welding assembly process in automotive manufacturing regarding RULA scores and simulating the postures using CATIA analysis. Based on the simulation, critical ergonomics issues should be identified and analyzed. Finally, the welding process is improved by designing the hand support for the workers to assemble parts. The results revealed that the RULA scores have improved from 7 (high risk at the existing condition) to 3 (medium risk) for both worker's hands after the support of the assembly tool. In conclusion, ergonomic embedding in welding assembly tool design has improved the automotive assembly worker's well-being. The findings of this study contribute to the growing body of knowledge on integrating ergonomics into automotive manufacturing processes, providing valuable insights for industry practitioners and researchers alike.

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## INTRODUCTION

Ergonomics focuses on human well-being and safety while working and educating people to understand how humans interact with work systems. Studies have been done looking at human-machine interaction and surroundings to prevent the relevance of the human component against machines and to develop techniques and boost employee productivity. Before World War II, the emphasis was on "designing the human to fit the machine" rather than building machines to fit people" [1]. It is vital to lessen aggressive motions and modify improper posture to increase work efficiency. [6]. Up to a point, proper ergonomic workstation design can boost efficiency, integration, worker comfort, worker variety, security, and safety. [2]. Traditional approaches to tool design often need to pay more attention to ergonomic factors, leading to sub-optimal tool functionality and increased worker fatigue and discomfort. However, there is a growing recognition of the importance of integrating ergonomics into the design process to create tools that enhance worker performance and well-being. For instance, ergonomic embedding principles in welding assembly tool design involve considering factors such as postures, force requirements, reach, and adjustability to minimize ergonomic hazards and promote optimal body mechanics.

The most crucial step in the manual assembly of automotive body parts is the welding process. By incorporating ergonomic principles, the automotive manufacturing industry can benefit from improved worker safety, reduced workplace injuries, increased productivity, and enhanced product quality. Ergonomic tools lessen the physical strain on workers, allowing them to perform tasks more efficiently and with reduced risk of musculoskeletal disorders. Additionally, designing intuitive and user-friendly tools enhances worker satisfaction and contributes to a positive work environment. Musculoskeletal disorders (MSDs) are one of the leading causes of occupational injury and impairment in the welding and fabrication industries [5]. The Rapid Upper Limb Assessment (RULA) is an ergonomic assessment tool used to evaluate the risk of developing work-related musculoskeletal disorders (MSDs) associated with the upper limb and neck regions. The assembly worker's physical, skills, and cognitive abilities are constantly tested during the manual assembly process. Designing welding assembly tools with ergonomics can enhance their compatibility, efficacy, safety, performance ease, and overall quality of life. Welders' body positions, appropriate planning, and ergonomically constructed workstations can help to some extent mitigate these issues [2].

The use of advanced software such as CATIA can be leveraged. CATIA offers powerful modeling, simulation, and analysis capabilities, enabling designers to create virtual prototypes, evaluate ergonomic factors, and make informed design decisions. This software integration facilitates the early identification and rectification of ergonomic issues before physical prototypes are developed, reducing the time and costs associated with tool design iterations. Hence, integrating ergonomics into the design of welding assembly tools for automotive manufacturing is vital to ensure worker safety, comfort, and productivity. By considering ergonomic factors throughout the design process and utilizing advanced software simulations, the automotive industry can design tools that optimize worker performance, reduce ergonomic risks, and promote a healthier and more efficient work environment. As the workers' complaints are increasing, this study aims to analyze automotive body parts welder postures using Rapid Upper Limb Assessment (RULA) analysis to improve comfort and safety.

## METHODOLOGY

This section explains the methodology of the study to increase workers' comfort while working at the manual automotive assembly welding line, as shown in Figure 1.

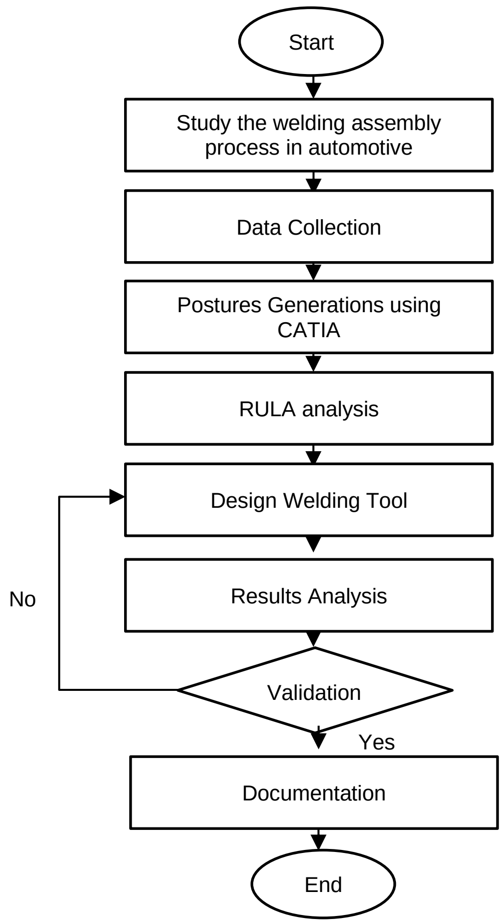


**Figure 1: Research Flowchart**

The study was conducted at Company X, which is an automotive manufacturing environment located in Malaysia. A wide variety of automobile body components are joined together using welding techniques. This study was performed in a welding assembly station at the production assembly line. The study of the welding assembly process involves examining the various postures used in welding to ensure that the process is performed safely and efficiently. The goal of studying the welding assembly process is to identify ergonomics issues that may arise during the welding process and to develop strategies to mitigate these risks. Ultimately, studying the welding assembly process can ensure that welding is performed with the highest quality and safety, resulting in a strong and durable finished product. Collecting data from a study involves systematically gathering and analyzing information to answer research questions and evaluate hypotheses. The data must be reliable and valid, meaning it accurately reflects the research questions and is free from bias or errors. Once the data is collected, postures using the CATIA software create a virtual representation of a person's posture. The data was collected through various methods, such as motion capture, photogrammetry, or manual modes. This process can be used to analyze a work's ergonomics and identify potential issues with posture and movement that could lead to injury or MSD. Once the data is collected and imported into CATIA V5, it can be used to create a three-dimensional model of the person's posture. The model can then be deployed and analyzed to identify any areas of concern, such as excessive bending or twisting of the spine or awkward positioning of the arms. This information can be used to make design changes or modify work practices to improve ergonomics and reduce the risk of injury.

The RULA technique was explicitly designed to assess and analyze the risks associated with repetitive movements and stationary positions in the workplace. Primarily utilized for evaluating ergonomic risks related to tasks involving the upper limbs, the RULA assessment entails observing the workers perform the job, measuring the anthropometric dimensions of the worker and the workstation, and analyzing the postures and movements employed during the task. Upon completing the RULA analysis, the evaluated task or workstation is assigned an overall score. This score indicates

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the level of risk associated with the required postures and movements during task performance. RULA scores range from 1 to 7, with higher scores signifying a more significant risk level. A score of 1- 2 indicates a low risk, 3-4 indicates a moderate risk, and 5-7 indicates a high risk. Suppose the overall RULA score falls within the low range (1-2), the postures and movements necessary for the task are acceptable. Suppose the score is moderate or high (3-7), corrective measures should be implemented to mitigate the risk of injuries or MSDs.

## RESULTS AND DISCUSSION

### Identify the posture problem

This identification method aims to determine the actual posture of a welder in an assembly station. The process of collecting data was using a camera or other imaging device to capture visual information. Once the data has been collected through picture taking, it can be analyzed using CATIA software. It may involve identifying image patterns or trends, extracting specific features or data points, and creating 3D models for visualizations.

**Figure 2: Welder's posture**

### CATIA RULA Analysis

CATIA RULA analysis is an ergonomic analysis performed using the CATIA software. The RULA method is used to evaluate the ergonomics of workstations or products regarding upper limb movements. Once the posture data has been integrated into the CATIA design project, it can be used to evaluate the ergonomics of the workspace or product design. By applying posture in CATIA, designers and engineers can create more effective and efficient products and workspaces that minimize the risk of injury or discomfort associated with poor postures and movements.

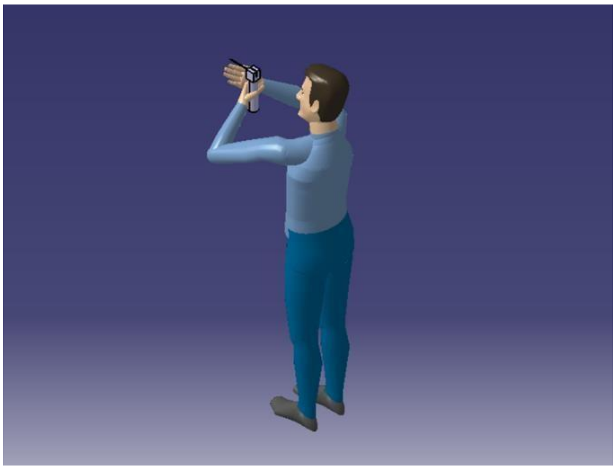

**Figure 3:** Digital model

The RULA analysis is processed once the digital model is ready, as shown in Figure 3. The analysis involves evaluating the user's upper limb postures and movements, including the neck, shoulders, upper arms, elbows, forearms, wrists, and hands. The postures and movements are assigned scores based on a predefined scale, and the scores are used

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to determine the level of risk associated with the movements and postures. The RULA results help designers to make changes to the assembly process and reduce the risk of injury or MSDs related to poor postures, as shown in Figures 4 and 5.

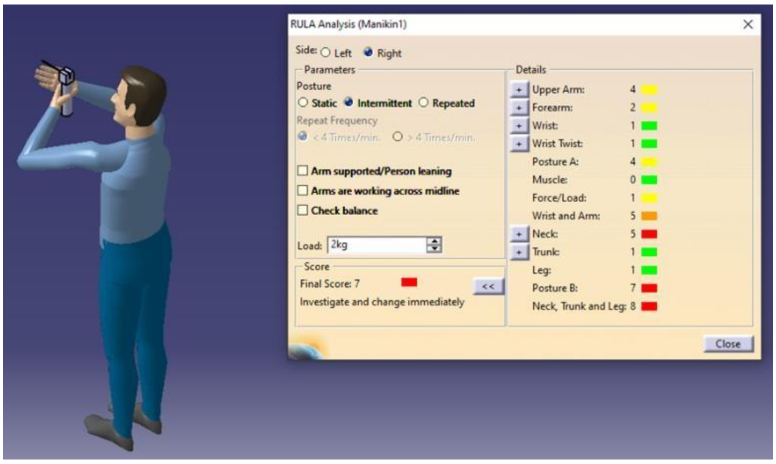


Figure 4: RULA Analysis for the right side

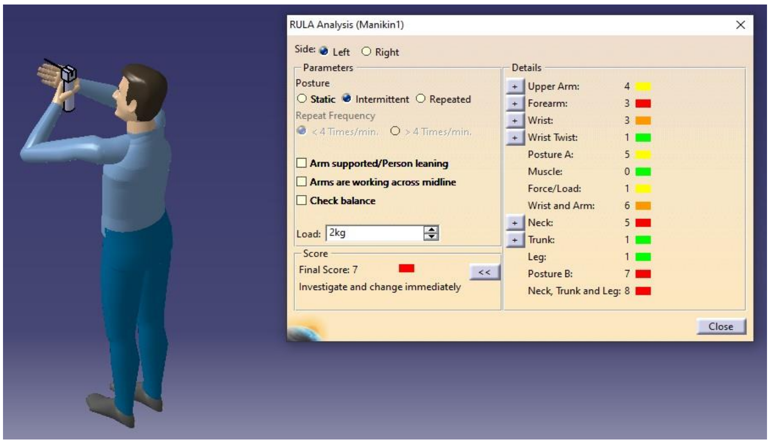


**Figure 5:** RULA Analysis for the left side

## Welding Design

The goal of designing welding assembly tools is to reduce ergonomic risks, which involves identifying potential issues and creating solutions. It was started by evaluating the welding assembly process by identifying potential issues based on the prior data collection. Then, investigate the cause of problems for the higher RULA scores and find ways to reduce the scores, which reflects the severity of the process. The solution started by sketching a design of a welding assembly tool to reduce the RULA score. It should mitigate excessive reaching by minimizing the need for workers to reach excessively by positioning tools and equipment within easy reach. It should also reduce excessive bending and twisting by avoiding setting workers in awkward positions that require them to bend or twist excessively. After that, support neutral postures by providing tools that allow workers to maintain neutral postures, such as straight wrists and relaxed shoulders.

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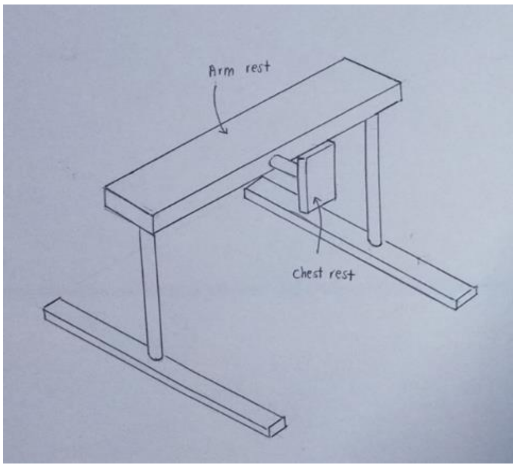


**Figure 6:** Sketch of assembly tool design

This study involves the integration of hand-drawn sketches into CATIA models, as in Figure 6. The sketch was the preliminary step in the design process, which can then be translated into digital models using CATIA software. The 3D drawing was also improved from the early sketch by including a wheel for effectiveness in the station, a chin rest for a proper neck posture, and a pad for arm rest. Then, the measurement of the model was based on the average anthropometric data of men in Malaysia. The study involves applying 3D drawing techniques to design welding assembly tools on a manikin model within CATIA software, as shown in Figures 7, 8, and 9. The objective is to manipulate 3D modeling and simulation to create and evaluate the welding assembly tool's ergonomics and functionality.

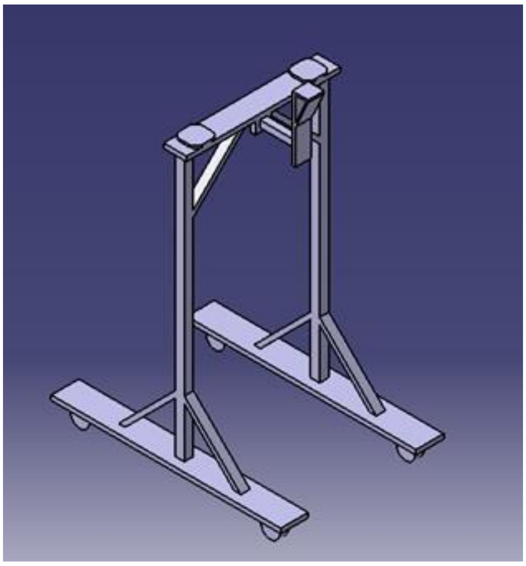

**Figure 7:** 3D drawing of welding assembly tools

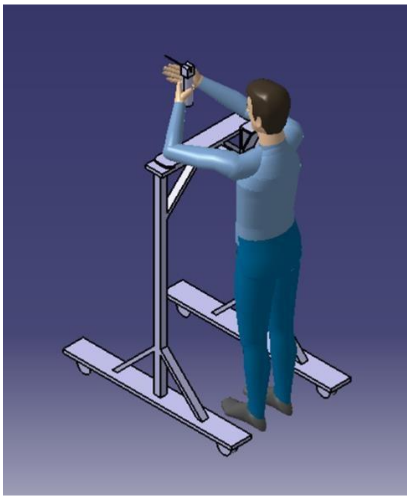

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**Figure 8:** 3D drawing of welding assembly tool

**Figure 9:** Side view of welding assembly tool

The simulations assessed how the proposed tool interacted with the manikin, considering factors such as reach, posture, and ease of use. By utilizing the capabilities of CATIA software, the study seeks to optimize the design of welding assembly tools by identifying potential issues and making necessary modifications. Integrating 3D drawing and manikin modeling in CATIA offers a comprehensive approach to designing ergonomic welding tools, providing insights into their performance and usability before physical prototyping and manufacturing.

## Results analysis

In this study, the scope involves collecting RULA data after applying welding assembly tools. It assessed the impact of the designed welding assembly tools on the ergonomic risks associated with the welding process. The study aims to measure and analyze the postures and movements of workers using the tools, utilizing the RULA methodology as shown in Figures 10 and 11. By comparing the RULA data before and after the implementation of the welding assembly tools, proper solutions should be implemented to reduce ergonomic risks and improve worker safety and comfort.

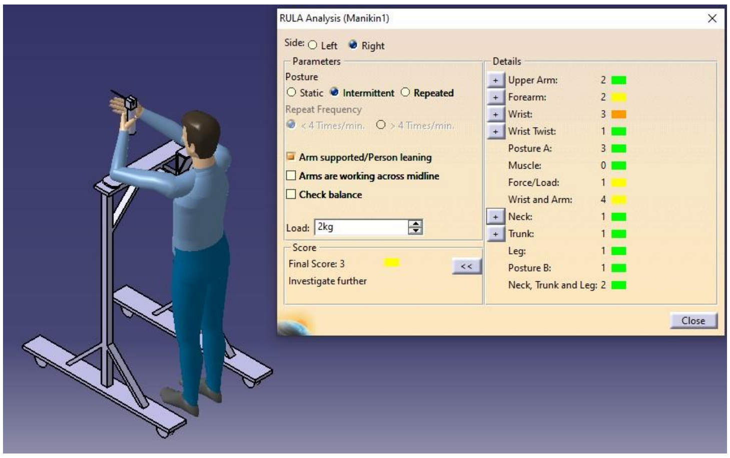


**Figure 10:** RULA Analysis after apply welding assembly tools for the right side

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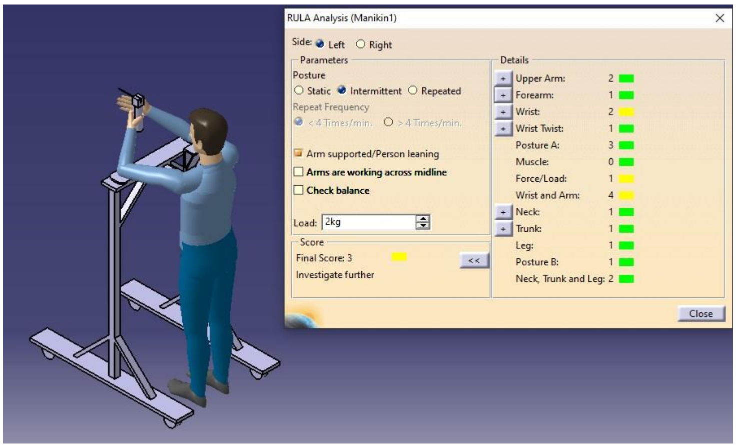


**Figure 11:** RULA Analysis after applying welding assembly tools for the left side

The comparison of data, as in Tables 1 and 2, provides valuable insights into the impact of the welding assembly tools on reducing ergonomic risks, enhancing productivity, and promoting a safer and more comfortable working environment. Table 1 shows the results for the right side of the worker, and it reveals that all the concern scores of medium risks (RULA 3-4) and high risk (RULA 5 and above) have been improved to a majority of low risk, except for Wrist and Arm score (reduced from 5 to 4). Consequently, the final score has significantly changed from high risk to low, medium risk. A similar study was also conducted for the left-hand side of the worker, and it revealed that all the concern scores of medium risks (RULA 3-4) and high risk (RULA 5 and above) had been improved to a majority of low risk, except for also Wrist and Arm score (reduced from 6 to 4). Similarly, the final score has significantly changed from a high risk to a low medium risk. The results manifest that the RULA scores have improved from 7 (high risk at the existing condition) to 3 (medium risk) for both worker's hands after the support of the assembly tool. The collected RULA data has provided valuable insights into the ergonomic performance of the tools, allowing for further refinement and optimization of the designs. Ultimately, this study will contribute to enhancing the overall ergonomics of welding assembly processes and promoting the well-being of workers.

**Table 1:** Comparison data results for the right side

| Details Score | Without tools | With tools |
|---|---|---|
| Upper Arm | 4 | 2 |
| Forearm | 2 | 2 |
| Wrist | 1 | 1 |
| Wrist Twist | 1 | 1 |
| • Posture A | 4 | 3 |
| • Muscle | 0 | 0 |
| • Force/Load | 1 | 1 |
| • Wrist and Arm | 5 | 4 |
| Neck | 5 | 1 |
| Trunk | 1 | 1 |
| • Leg | 1 | 1 |
| • Posture B | 7 | 1 |
| • Neck, Trunk and Leg | 8 | 2 |
| Final Score | 7 | 3 |

**Table 2:** Comparison data results for the left side

| Details Score | Without tools | With tools |
|---|---|---|
| Upper Arm | 4 | 2 |
| Forearm | 3 | 1 |
| Wrist | 3 | 2 |
| Wrist Twist | 1 | 1 |
| • Posture A | 5 | 3 |
| • Muscle | 0 | 0 |
| • Force/Load | 1 | 1 |
| • Wrist and Arm | 6 | 4 |
| Neck | 5 | 1 |
| Trunk | 1 | 1 |
| • Leg | 1 | 1 |
| • Posture B | 7 | 1 |
| • Neck, Trunk and Leg | 8 | 2 |
| Final Score | 7 | 3 |

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This study deliberates on the success of welding assembly tools in reducing RULA scores and mitigating ergonomic risks. The initial RULA data identified various ergonomic issues, but significant improvements were observed after implementing the tools with optimized designs. The tools' ergonomic features, including improved posture, reduced movements, and decreased strain, contributed to decreased RULA scores, indicating a lower risk of MSDs. Integrating worker feedback during the design process was crucial, ensuring the tool met specific ergonomic needs and preferences. The reduction in RULA scores highlights the positive impact on worker well-being, productivity, and job satisfaction. The findings emphasize the importance of ergonomic design and worker involvement in optimizing welding assembly tools to enhance worker safety and comfort in the automotive manufacturing process.

## CONCLUSION

This study concludes that the implementation of welding assembly tools has successfully reduced the RULA score based on the pre-existing RULA data. The initial assessment revealed several ergonomic risks associated with the welding assembly process, which elevated the RULA scores and indicated a higher risk of MSDs among workers. However, after the implementation of the optimized welding assembly tools, significant improvements were observed. The tools' ergonomic features, such as improved postures, reduced movements, and minimized strain on workers' upper limbs, were vital in reducing the RULA scores. Integrating worker feedback during the design process ensured the tool was tailored to their specific ergonomic needs and preferences. The reduction in RULA scores mitigated ergonomic hazards and enhanced worker well-being, productivity, and job satisfaction. These findings underscore the importance of considering ergonomics in designing welding assembly tools to create a safer and more efficient work environment for automotive manufacturing processes.

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