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Improving the Assembly Time of a Plate Cover Product Through Fixture Design

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ABSTRACT

The welding process of a plate cover component in PT MCM has traditionally relied on manual methods, resulting in prolonged assembly time, inconsistent dimensional accuracy, and high operator dependency. To address these inefficiencies, this study proposes the design, fabrication, and implementation of a specialized welding fixture aimed at improving assembly time and product consistency. The research use an applied experimental methodology, start with the identification of production requirements through direct observation, interviews the operator, and document analysis. The fixture design was focus on principles of quick setup, structural stability, manufacturability, and safety standards. Technical modeling was performed using AutoCAD, then prototype fabrication using SPHC steel sheets (2 mm and 3 mm). The steel sheets shaped via precision laser cutting and assembled through MIG welding. The fixture was tested under real production conditions to evaluate its impact on setup time, weld quality, and geometric precise. Empirical observations revealed a significant reduction in average assembly time from 11.07 minutes to 8.46 minutes per unit. It's an improvement of approximately 2.61 minutes or 23.59%. Besides that, the fixture enhanced dimensional accuracy and reduced human error, its potential for broader implementation in similar manufacturing contexts. The results stated that fixture system has the critical role in improving process efficiency and product quality. It's feasible to apply in small and medium manufacture that seek transition from manual to standardized production workflows.

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1. INTRODUCTION

Welding is one of the most widely applied manufacturing processes in modern industry due to its ability to produce durable and permanent joints between metal components. Industrial sector that use welding such as automotive, aerospace, energy, and heavy machinery manufacturing. However, consistency and efficiency in welding operations is daily issue, especially in high-volume production settings. Fixture is one critical factor influencing the quality and reliability of welding. Fixture is a mechanical device designed to accurately hold, support, and position the workpiece during the welding process. The fixtures has function to minimize variation by ensuring proper alignment and securing the components in place. Its thereby reduce distortion, cycle time, and improve dimensional accuracy.

Many studies have explored fixture design strategies to improve production process performance. Carefully engineered fixtures can significantly reduce setup time and improve weld joint precision, particularly in elementary weld assemblies [1]. Monková et al. [2] stated the importance of customized fixtures in automotive manufacturing, where even minor misalignments can compromise component integrity. Additionally, Sikström et al. [3] explained how fixture forces can influence thermal distortion during gas tungsten arc welding. They stated the dual role of fixtures in component position and stress management. These studies demonstrate that welding fixture design is crucial for maintaining consistency, reducing operator dependency, and increasing product quality. Fixture design has advanced with focuse on able to reconfigure and smart technology. Seloane et al. [4] proposed an intelligent system to reconfigure fixture for rail car manufacturing, allowing for the accommodation of various component geometries within a single setup. This trend aligns with the growing demand for lean and flexible production systems. Computer-aided design and manufacturing tools have also enabled precision in the development of fixture prototypes, as noted by Zhang and Zhou [5], who introduced a database-driven approach for computer-aided welding fixture design. Meanwhile, experimental studies by Kaushik et al.[6] and Sabry & El-Kassas [7] showed that optimized fixture support plays a vital role in maintaining weld strength and minimizing microstructural defects, even in advanced applications such as friction stir welding of composite materials. Likewise, Muchtar et al. [8] designed a specialized fixture for welding cross-flow turbine runners, demonstrating the effectiveness of laser-cut SPHC steel components joined by MIG welding in delivering structural strength and dimensional reliability.

Another significant research direction focuses on virtual and digital enhancements in fixture development. Digital twin technologies, as discussed by Tabar et al.[9], offer simulation-based optimization for fixture design, enabling precise clamping sequence planning to avoid deformation and improve dimensional quality. Design frameworks such as the one proposed by Kadam et al.[10] for variable-angular-span locking fixtures further illustrate how design adaptability can meet diverse manufacturing needs. These innovations are supported by earlier foundational works, including robust pin layout strategies for sheet-panel assemblies [11] and reconfigurable locating layouts for compliant structures [12]. Simulation tools such as ANSYS have also been used to analyze welding deviations in automobile panels, confirming that computational methods can effectively predict and reduce geometric inconsistencies caused by improper fixture design [13]. Additionally, fixture-based optimization for robotic arc welding and small-series production has been explored by Bolmsjö and Ollson [14], contributing to reduced production time and labor costs. For high-precision applications like engine mounting bracket welding, studies such as Prassetiyo et al. [15] have shown that tailored fixture systems can significantly streamline the production of complex assemblies

Despite the breadth of existing research, a notable gap remains in the practical implementation of fixture design in small-to-medium-scale manufacturing companies, especially those still relying on manual assembly methods. At PT MCM, a metal fabrication company serving the automotive sector, the welding of Product 81410—a plate cover component—is performed manually without a standardized fixture. This results in prolonged assembly time, repeated measurement to achieve a specified 0.5 mm tolerance, and inconsistent welding quality. Therefore, this study aims to design and implement a specialized welding fixture for the plate cover product to reduce assembly time, eliminate repeated measurement, and enhance dimensional accuracy. By integrating industrial design principles, prototyping, and field testing, this research seeks to demonstrate how a simple but well-designed fixture can bridge the efficiency gap in conventional welding processes.

2. METHOD

Figure 1 illustrates a systematic workflow for the development and implementation of a fixture as a production aid, which closely aligns with the applied experimental approach employed in this study to improve the efficiency of plate cover production in a metal manufacturing and fabrication company serving the automotive industry. The process begins with the identification of production requirements, where key challenges in the existing system were determined through direct observation on the production floor, structured interviews with machine operators, and document analysis of production logs and technical drawings. These insights informed the concept design of the fixture, which was guided by principles derived from a comprehensive literature review—emphasizing quick workpiece installation, structural stability, manufacturability, cost efficiency, and occupational safety.

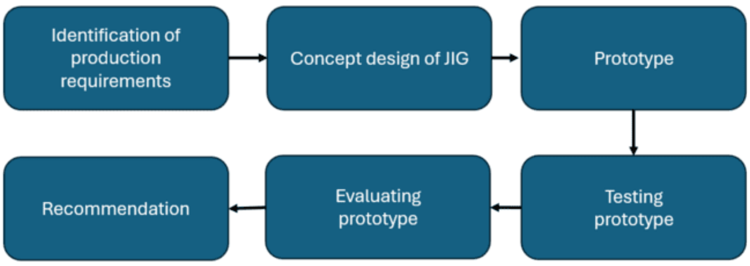


Figure 1. Workflow development of fixture

Subsequently, the fixture concept was translated into a technical design using AutoCAD, generating detailed engineering drawings to support accurate fabrication. The prototype was then constructed using 2 mm and 3 mm SPHC steel sheets, chosen for their availability and ease of processing. Components were laser-cut using oxide-based control to ensure dimensional precision, and assembly was performed using MIG welding for its structural integrity and industrial reliability. The testing prototype phase involved deploying the fixture under actual production conditions, measuring setup time, workpiece stability during welding, weld quality, and the fixture's operational lifespan. These data were used in the evaluation phase, where the new fixture's performance was systematically compared to the conventional method to assess improvements in efficiency, consistency, and final product quality. Based on this evaluation, a final recommendation was proposed, confirming the fixture's effectiveness and potential integration into full-scale production workflows.

3. RESULT AND DISCUSSION

Figure 2 illustrates the manual assembly process prior to the implementation of a dedicated fixture system. In this stage, operators relied on handheld measuring tools such as callipers and rulers to manually align and position components before welding. This approach is not only time-consuming but also highly operator-dependent, as the accuracy and consistency of the assembly process rely heavily on the skill, experience, and concentration of each individual operator. Variations in measurement technique or fatigue can lead to misalignment, dimensional deviations, and inconsistent weld quality. The lack of standardized guidance tools increases the likelihood of human error and rework, ultimately affecting production efficiency and output reliability. These limitations underscore the necessity of introducing a fixture system to reduce operator dependency and improve repeatability in the assembly process.

Figure 2. Manual assembly process

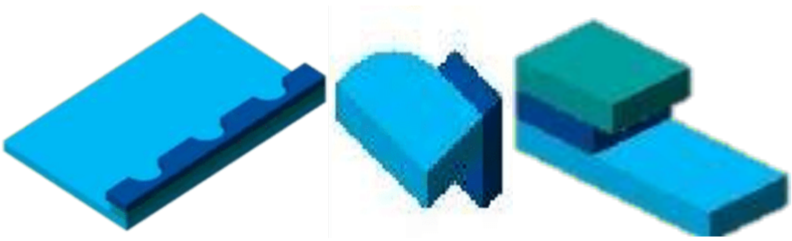
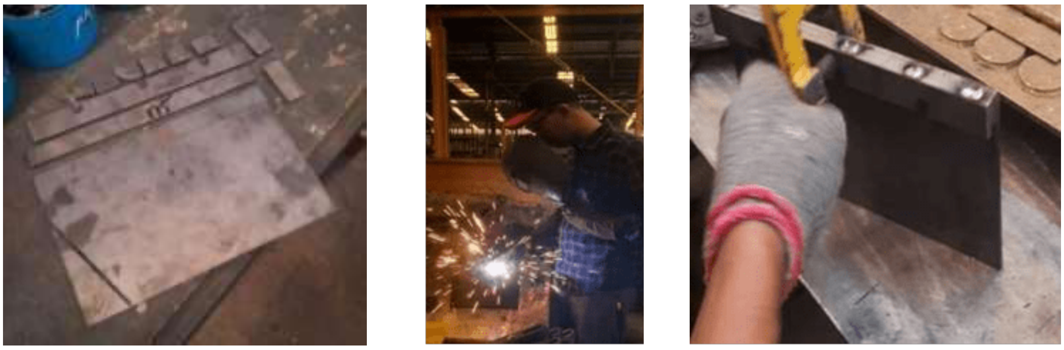


Figure 3. Concept design of fixture

Figure 3 is the illustration that showcases the conceptual design of the fixture components developed to improve the efficiency and accuracy of the plate cover assembly process. The fixture design consists of three elements: a base plate with contoured locating features, a V-block for cylindrical alignment, and a clamping unit to secure the workpiece during welding. The function of contoured locating features on the base plate to make sure the position precise. Base plate also provide consistent reference point for the workpiece led to reduce setup time and alignment errors. The V-block is designed to accommodate curved or cylindrical components, raising stability and alignment during the manufacture process. This is usefull for control geometric consistency in components that are tend to shift or rotate during welding. Additionally, the clamping mechanism applies distribution pressure in similar number to hold the parts firmly in place, minimizing the risk of displacement and ensuring weld accuracy. The modular nature of the fixture allows for adaptability to different part geometries and simplifies maintenance or replacement of individual components. This fixture design enhances operator ergonomics and safety, reduces reliance on manual measurements and operator skill dependent. This leads to improved productivity, higher dimensional accuracy, and overall consistency in the final product, which are critical factors in high-volume manufacturing environments.



(a) (b) (c)

Figure 4. Prototyping process

The sequence in Figure 4 illustrates the fabrication process of fixture prototype, start from material preparation to assembly then welding. Figure 4(a) show the laser-cut components made from SPHC steel sheets with thicknesses of 2 mm and 3 mm. SPHC steel use in this study due to their availability and ease of fabrication. These components were precisely cut using a high-powered laser machine, ensuring dimensional accuracy and minimal deviation. Figure 4(b) captures the MIG welding process, where a skilled operator joins the parts under controlled conditions to ensure strong, reliable welds, in line with industrial quality standards. Figure 4(c) shows the assembling stage, where individual components are aligned and held together prior to welding. This hands-on process demonstrates careful attention to fit and alignment, which is crucial for ensuring the fixture's structural integrity and functionality. Overall, the images represent fabrication approach that combines precision cutting, skilled welding, and careful assembly to produce a durable and presice fixture for production use.

(a) (b)

Figure 5. Finishing process

Figure 6. Painting

Figure 5 illustrate the finishing process of the fixture part. In Figure 5(a), a grinding operation is performed using a handheld grinder to remove burrs, sharp edges, and welding spatter from the metal surfaces. Its make sure the smooth contact areas and improved safety during handling. This step is critical for achieving precision and a professional finish. Beside that, it preparing the surface for potential painting or coating. Figure 5(b) displays the fixture part after grinding, laid out cleanly and ready for the final assembly or installation. The smooth surface finish contributes to better alignment, improved aesthetics, and enhanced durability of the fixture when used in production. Overall, the finishing process ensures that the fixture not only meets functional requirements but also adheres to industry standards for quality and safety.

Figure 6 illustrated coating with paint as the final step in the fixture fabrication. The fixture components have been painted in a bright yellow color, which not only enhances the aesthetic appearance but also serves as a protective layer against corrosion. This coating increases the durability and longevity of the fixture while also improving visibility and safety during operation. All parts get treatment powder coating or industrial spray painting methods to reach a well-controlled painting process. This step marks the completion of the fixture fabrication, ensuring that the product is both functionally reliable and compliant with industry standards for quality and maintenance.

(a) (b) (c) (d)

Figure 7. Assembly with fixture

The sequence of images in Figure 7 illustrates an inspection process utilizing a test fixture to verify the dimensional conformity of a fabricated cover plate. In this procedure, an operator equipped with protective gloves employs a precision-engineered yellow test fixture to assess the geometric accuracy and alignment of a bent metal component. The fixture is applied along various critical edges and features of the cover plate, such as bends, holes, and cutouts. It aims to ensure compliance with predefined design tolerances. The Figure 7(d) in the sequence demonstrates the full engagement of the component within the fixture, signifying that the part meets the specified dimensional and geometric requirements. This form of fixture-based evaluation is essential in manufacturing and quality assurance practices, as it facilitates consistent verification of component integrity prior to downstream processes such as assembly or welding. The gap between before and after the implementation of the fixture as an assisting tool is presented in Table 1.

Tabel 1. Observation time

Sampel (n)	The observation time before the use of the fixture (minute)	The observation time after the use of the fixture (minute)	Gap (minute)
1	11,39	8.59	2.80
2	10,93	8.72	2.21
3	12,10	9.49	2.61
4	10,35	7.55	2.80
5	10,78	8.07	2.71
6	11,20	8.24	2.96
7	12,40	9.55	2.85
8	10,17	7.48	2.69
9	10,24	8.03	2.21
10	11,15	8.87	2.28

Observation time in Table 1 presents empirical data comparing task completion times before and after the implementation of a fixture in a manufacturing or assembly process. Each of the ten samples reflects a distinct observation instance, with recorded times in minutes for both conditions—prior to and following the application of the fixture. The results demonstrate a consistent reduction in processing time across all samples, with the "Gap" column quantifying the time saved due to the fixture's usage. The observed time savings range from 2.21 to 2.96 minutes, indicating that the fixture contributes positively to operational efficiency by standardizing the task and reducing manual variability.

This consistent downward trend in task duration suggests that the fixture effectively minimizes procedural complexity and enhances task consistency, likely through improved alignment, faster positioning, or reduced need for manual adjustments. From a productivity standpoint, the time savings are significant; even marginal improvements at the unit level, when scaled to a larger production volume, can result in substantial aggregate time and cost reductions. The results affirm the value of integrating engineered aids such as fixtures within manufacturing workflows, particularly in settings where precision and repeatability are critical. Future work may include statistical validation (e.g., paired t-tests) to confirm the significance of the observed differences and a cost-benefit analysis to assess the economic impact of fixture implementation in long-term operations.

Figure 8. Final product

Figure 8 illustrate the final product resulting from the use of a fixture during the fabrication process. The component, a precisely bent and assembled metal enclosure, exhibits uniform geometry, accurate angular alignment, and consistent edge profiles, which are indicative of the fixture's effectiveness in ensuring dimensional accuracy and repeatability. The clean edges and well-aligned holes suggest that the fixture facilitated accurate positioning and secure holding during bending and welding operations, thereby minimizing human error and mechanical deviation. This outcome demonstrates the critical role of fixtures in improving both the quality and efficiency of production, especially in tasks requiring precision and structural integrity.

4. CONCLUSION

This study successfully demonstrated that the implementation of a newly designed fixture significantly improves the efficiency and accuracy of the welding process for product plate cover at PT MCM. By integrating predefined dimensional standards—specifically the 0.5 mm gap directly into the fixture structure—the need for repetitive manual measurements was eliminated, leading to a notable reduction in assembly time. Based on ten observation samples, the average welding time decreased from 11.07 minutes to 8.46 minutes, resulting in a time savings of approximately 2.61 minutes or 23.59%. Beyond time efficiency, the fixture contributed to improved consistency, reduced human error, and enhanced dimensional precision of the final product. The structured approach encompassing design, prototyping, and testing under real production conditions affirmed the fixture's operational reliability and manufacturability. These findings support the broader applicability of fixture-based optimization in high-precision, high-volume manufacturing environments. Future research may further explore scalability, statistical validation of efficiency gains, and economic impact analysis to strengthen the case for widespread adoption of such process innovations..

REFERENCE

[1] N. Kumar Jha and R. P. B, "Design and Analysis of Welding Fixture for Elementary Weld Joints," *CVR J. Sci. Technol.*, vol. 15, no. 1, pp. 90–95, Dec. 2018, doi: 10.32377/cvrjst1516.
[2] K. Monkova, P. Monka, A. Andrej, and M. Somsak, "Design of the Welding Fixture for the Rear Headrest Bracket of Audi," *Adv. Mater. Res.*, vol. 933, pp. 615–618, May 2014, doi: 10.4028/www.scientific.net/AMR.933.615.
[3] F. Sikström, A.-K. Christiansson, and B. Lennartson, "Role of Fixture Forces on Distortion in Gas Tungsten Arc Welding — An Experimental and Modelling Approach," *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.*, vol. 225, no. 1, pp. 140–148, Jan. 2011, doi: 10.1177/09544054JEM2048.
[4] W. T. Seloane, K. Mpofu, B. I. Ramatsetse, and D. Modungwa, "Development of intelligent reconfigurable welding fixture for rail car manufacturing industry." Apr. 21, 2022. doi: 10.21203/rs.3.rs-1474669/v1.
[5] Y. Zhang and Y. Q. Zhou, "Construction and Expression of Database for Computer-Aided Welding Fixture Design (CAWFD) Systems," *Adv. Mater. Res.*, vol. 323, pp. 141–145, Aug. 2011, doi: 10.4028/www.scientific.net/AMR.323.141.

[6] N. Kaushik, S. Singhal, R. Rajesh, P. Gahlot, and B. N. Tripathi, "Experimental investigations of friction stir welded AA6063 aluminum matrix composite," *J. Mech. Eng. Sci.*, vol. 12, no. 4, pp. 4127–4140, Dec. 2018, doi: 10.15282/jmes.12.4.2018.11.0357.

[7] I. Sabry and A. M. El-Kassas, "An appraisal of characteristic mechanical properties and microstructure of friction stir welding for Aluminium 6061 alloy – Silicon Carbide (SiCp) metal matrix composite," *J. Mech. Eng. Sci.*, vol. 13, no. 4, pp. 5804–5817, Dec. 2019, doi: 10.15282/jmes.13.4.2019.07.0463.

[8] M. Muchtar, S. Rasyid, and R. Nur, "Welding fixture design for the production of cross-flow turbine runner," 2018, p. 030020. doi: 10.1063/1.5042940.

[9] R. Sadeghi Tabar *et al.*, "Digital Twin-Based Clamping Sequence Analysis and Optimization for Improved Geometric Quality," *Appl. Sci.*, vol. 14, no. 2, p. 510, Jan. 2024, doi: 10.3390/app14020510.

[10] G. Kadam, B. Nagarajan, V. Mirji, and S. Sawant, "Design of Rigid-Locking Variable-Angular-Span Welding Fixture," in *IPDIMS 2023*, Basel Switzerland: MDPI, Jul. 2024, p. 35. doi: 10.3390/engproc2024066035.

[11] W. Cai, "Robust pin layout design for sheet-panel locating," *Int. J. Adv. Manuf. Technol.*, vol. 28, no. 5–6, p. 486, Mar. 2006, doi: 10.1007/s00170-004-2402-2.

[12] W. T. Seloane, K. Mpofu, B. I. Ramatsetse, and D. Modungwa, "Conceptual design of intelligent reconfigurable welding fixture for rail car manufacturing industry," *Procedia CIRP*, vol. 91, pp. 583–593, 2020, doi: 10.1016/j.procir.2020.02.217.

[13] L. Li and Z. M. Feng, "Deviation Analysis of Automobile Panels Welding Assembly Based on ANSYS," *Appl. Mech. Mater.*, vol. 121–126, pp. 3230–3233, Oct. 2011, doi: 10.4028/www.scientific.net/AMM.121-126.3230.

[14] G. Bolmsjö and M. Olsson, "Sensors in robotic arc welding to support small series production," *Ind. Robot An Int. J.*, vol. 32, no. 4, pp. 341–345, Aug. 2005, doi: 10.1108/01439910510600218.

[15] H. Prassetiyo, ~ Rispianda, and P. Dewi, "Rancangan Welding Fixture Pembuatan Produk Front Engine Mounting Mobil Suzuki Baleno," *J. Rekayasa Sist. Ind.*, vol. 4, no. 2, p. 97, Nov. 2015, doi: 10.26593/jrsi.v4i2.1631.97-105.