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Design and Fabrication of Jig and Fixture for Panel Pin Assembly in Power Motor Side Mirror

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ABSTRACT

This research focuses on the design and fabrication of a jig and fixture to optimize the assembly process of panel pins for a car side mirror power motor. The current manual assembly method is inefficient, time-consuming, prone to frequent errors, and results in material wastage. To address these challenges, the study aims to develop a jig and fixture that enhances efficiency, reduces cycle time, and improves ergonomics. The methodology encompasses data collection, concept generation, CAD modeling using SolidWorks, and precision machining for prototype fabrication. Key analyses include time study, cost evaluation, and ergonomic assessment. The results reveal a significant 50.82% reduction in cycle time, from 4:04 minutes to 2:00 minutes, resulting in improved productivity and streamlined operations. Ergonomic analysis highlights enhanced operator posture and minimized physical strain, while cost analysis estimates the total fabrication cost at RM 156.26, emphasizing the design's cost-effectiveness. This project successfully demonstrates the potential of jigs and fixtures to address manual assembly inefficiencies, improve manufacturing outcomes, and serve as a practical model for broader industrial applications.

Keywords: Jig and Fixture Design, Ergonomics, Cost-effectiveness, Machining.

1. INTRODUCTION

The automotive industry continuously seeks innovations to enhance manufacturing efficiency and product quality. Power motor side mirrors are essential components of modern vehicles, providing convenience and safety through adjustable and motorized functions. However, assembling these components, particularly the panel pins, poses challenges due to the reliance on manual handling. Manual processes are prone to errors, inconsistencies, and operator fatigue. For instance, prolonged manual assembly increases the likelihood of component damage and extends cycle times, adversely affecting production targets. Moreover, repetitive actions contribute to worker discomfort, reducing long-term productivity. Addressing these challenges requires innovative solutions such as jigs and fixtures to streamline operations. Jigs and fixtures are critical tools in manufacturing, designed to enhance precision, repeatability, and operator efficiency [1]. Recent studies emphasize their role in reducing setup time and minimizing material wastage, particularly in precision-dependent assembly processes [2]. Furthermore, advances in CAD tools have enabled rapid prototyping and ergonomic optimization, ensuring user-friendly designs tailored to specific assembly requirements [3]. Despite these advancements, there remains a gap in their application to the assembly of power motor side mirrors. Previous studies focus largely on generic manufacturing processes, leaving specific challenges such as wire pin assembly in automotive applications underexplored. The manual assembly of panel pins in power motor side mirrors is inefficient and error-prone. Operators often struggle with proper alignment

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and secure installation, leading to frequent component damage and prolonged cycle times. Additionally, repetitive manual tasks exacerbate ergonomic challenges, increasing operator fatigue and the risk of workplace injuries. This study aims to design and fabricate a jig and fixture to optimize the assembly process of panel pins in power motor side mirrors. By addressing current inefficiencies, the study seeks to enhance productivity, reduce cycle time, and improve operator ergonomics.

2. METHODOLOGY

The overview of the overall research methodology and operation steps as shown in Figure 1 are required in achieving the objectives of this project.

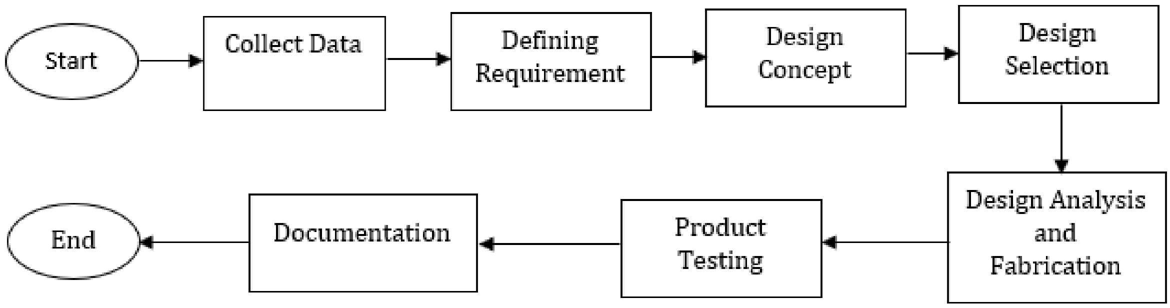


Figure 1: Research Methodology.

2.1 Collect Data

The product planning was based on data collected through observation of the current process. The process selected for improvement for the jig and fixture involved in the installation of power wires on the side-view mirror folding actuator, as shown in Figure 2.

Figure 2: Manual panel pins insertion.

The current process for installing power wires on side-view mirror folding actuators was inefficient, with issues like loose connections and pin damage. The task was a bottleneck, taking 4 minutes and 4 seconds to complete, while the target cycle time was under 2 minutes. Operators manually handled the motor part, increasing the risk of wire pin breakage due to a lack of stabilization. The process involved several steps, including preparing the actuator, cutting the power wire, attaching connectors, and connecting wires to the actuator's terminals. During observation, it was noted that the lack of a jig led to instability and frequent errors. Interviews with a production engineer and technicians identified these challenges and suggested implementing a jig to stabilize the motor during assembly. This change would improve efficiency, reduce errors, and enhance product quality.

2.2 Design Process

The engineering design process is critical for developing products that meet functional requirements while remaining cost-effective. In this research, the jig and fixture were designed to enhance the efficiency of panel pin installation on side mirror folding actuators by addressing issues such as stability, operator fatigue, and prolonged installation times. Key considerations included analyzing clamping positions, load distribution, material selection, and other essential parameters to ensure an optimal design. SolidWorks software was used to create the design.

2.3 Brainstorming

Brainstorming serves as a crucial step in transforming rough ideas into a structured design. One effective brainstorming technique involves benchmarking related products to guide the design process. Benchmarking involves studying existing products with functionalities similar to the one being developed or focusing on specific sub-problems that need attention. This process uncovers existing concepts that have been successfully implemented to solve similar challenges. By analyzing these products, designers can identify and adapt general concepts, integrating them into the development of innovative and improved solutions for the new product. This approach enhances creativity and ensures a more informed and efficient design process.

2.4 Design Selection

Design selection is the process of identifying and choosing the most suitable concept based on its evaluation against specific requirements and criteria [4][5]. By comparing the strengths and weaknesses of each concept, the most promising design is selected for further development. Generally, this process involves narrowing down alternative concepts that have been considered [6]. For this project, the screening method was employed to facilitate the selection of the final jig design [7]. This method supports designers in making informed decisions by systematically evaluating each concept. Initially, three different jig designs were developed, each with unique design concepts, and the screening method was used to identify the best design for further investigation.

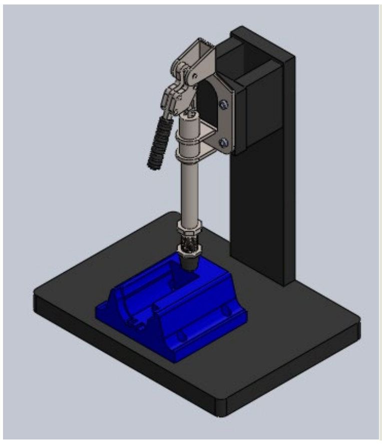
From Table 1, the result shows that the best option can be selected by choosing the highest rank. The third concept was the first rank which is the most acceptable for this requirement. Concept scoring is always used to select the final concept selection, which uses the rating score to rate the design. The concept scoring needs to be skipped for this design because the best design was selected from the design screening, which shows that the Third Design is dominant among others. So that, the Third Design will proceed for further research.

Table 1: Concept Screening Matrix.

Selection Criteria	Concepts		
	First Concept	Second Concept (Reference)	Third Concept
Ease of handling	0	0	+
Ease of use	0	0	+
Durability	+	0	+
Ease of manufacture	-	0	+
Portability	0	0	0
Cleaning ease	0	0	0
Maintenance ease	0	0	-
Production time	-	0	+
Sum +'s	1	0	5
Sum 0's	5	8	2
Sum -'s	2	0	1
Net score	-1	0	4
Rank	3	2	1
Continue?	No	No	Yes

2.5 Final Concept

The final design concept, as shown in Figure 3, is selected based on the decision made during concept selection. Here, the third concept is the best option. This final concept design, which is the insertion jig, is much better than the second design, which is the assembly part for this design and is also simpler.



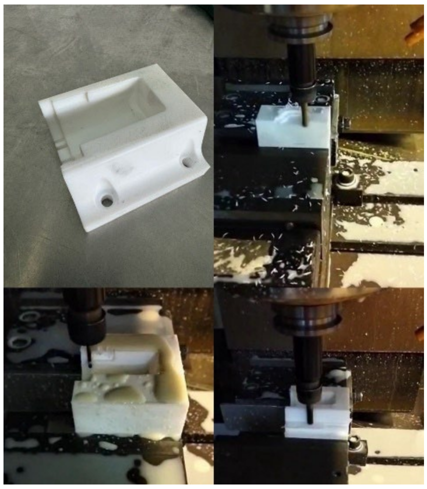
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Base Plate	Aluminium	1
2	Block	Teflon	1
3	Support	Aluminium	1
4	Spacer	Aluminium	2
5	Side Plate	Aluminium	1
6	M5 X 0.8 Hex Socket Head Screw	AISI 304	10
7	M6 X 1.0 Hex Socket Head Screw	AISI 304	4
8	Toggle Clamp	Galvanized Steel	1

Figure 3: Final Concept.

2.6 Fabrication Process

The jig and fixture fabrication process for the car mirror folding actuator assembly is designed to ensure precision, functionality, and durability. It begins with obtaining detailed dimensions of the actuator through 3D scanning for accuracy using 3D Peeler, and the prototype of the main fixture (Teflon Block) was created using 3D Printing using Polylactic Acid (PLA) material as shown in Figure 4a and tested to resolve design challenges, such as fit and alignment. Once the design is finalized, advanced machining techniques like face milling, end milling, ballnose cutting, drilling, and tapping are used to fabricate the main fixture at high precision as shown in Figure 4b. Other components, including the base plate, support, side plate, and spacers are also carefully fabricated as shown in Figure 4c. The toggle clamp is a standard component that functions as a lever mechanism to guide the panel pins for insertion. These components are assembled to create a robust tool that enhances the assembly process, ensuring proper alignment, stability, and consistent performance.

(a) 3D Scanning & 3D Printing.



(b) Machining Process of Teflon Block.

(c) Machined Components.

Figure 4: Fabrication process: (a) 3D Scanning and 3D Printing, (b) Machining Process of Teflon Block and (c) Machined Components.

3. RESULTS AND DISCUSSION

3.1 Time Study Analysis

The Time Study Analysis shows a significant improvement in assembly efficiency when using the jig and fixture. The total cycle time for assembling panel pins on the side-view mirror folding actuator decreased from 4 minutes 4 seconds during manual assembly to 2 minutes with the jig-assisted method, marking a reduction of 50.82%. This improvement was achieved by eliminating repetitive manual adjustments and providing a stable platform for assembly. The jig allowed operators to position the folding actuator securely and insert the wire pins efficiently using a toggle clamp. This streamlined the process, reducing errors and minimizing rework. The reduction in cycle time directly translates into higher productivity, enabling operators to complete more units within the same time frame while maintaining assembly quality.

3.2 Cost Analysis

The cost analysis compares the manual and jig-assisted assembly methods in terms of productivity, labor expenses, cost per part, total savings, and break-even point, highlighting the economic benefits of the jig-assisted method. Table 2 shows the material cost breakdown involved in fabricating the jig and fixture.

Table 2: Material Cost.

No.	Part	Quantity	Unit price (RM)	Price (RM)
1	Aluminium plate (40cm x 25cm)	1	RM 120	RM 120
2	Toggle clamp	1	RM 8.80	RM 8.80
3	Hex socket head screw (For base)	4	RM 0.40	RM 1.60
4	Hex socket head screw (For clamp and support)	10	RM 0.35	RM 3.50
6	Teflon	1	RM 21.00	RM 22.36
Total amount (RM)				**RM 156.26**

3.2.1 Parts per hour (Ph)

Parts Per Hour measures productivity, indicating the number of parts assembled per hour. A higher Ph reflects greater efficiency by optimizing resource utilization and reducing downtime. *S* in Equation 1 is known as Single Part Time.

$$Ph = \frac{1}{S} \tag{1}$$

Manual Insertion:

$$Ph = \frac{3600\ seconds}{244\ seconds}$$

$$= 14.75 \approx 15 \text{ parts per hour}$$

Jig Assisted Insertion:

$$Ph = \frac{1}{(2 \times 0.0167)}$$

$= 29.94 \approx 30$ parts per hour

Through this result, found that the jig-assisted method improves productivity by 100%, demonstrating its effectiveness in streamlining the assembly process.

3.2.2 Labor Expenses (L)

Labor expenses represent the cost of employing operators to complete the assembly process, as shown in Equation 2. *LS* is the lot size, *Ph* is parts per hour, and *W* is the hourly wage (RM7.21/hour).

$$L = \frac{LS}{Ph} \times W \tag{2}$$

Manual Insertion:

$$L = \frac{1000}{15} \times RM7.21$$

= RM480.67 Labor/lot

Jig Assisted Insertion:

$$L = \frac{1000}{30} \times RM7.21$$

= RM240.33 Labor/lot

The jig-assisted method reduces labor expenses by 50%, from RM480.67 to RM240.33, highlighting its economic advantage.

3.2.3 Cost Per Part (Cp)

The cost per part reflects the total cost of producing one unit and is calculated using Equation 3.

$$Cp = \frac{TC+L}{LS} \tag{3}$$

Manual Insertion:

$$Cp = \frac{0+480.67}{1000}$$

= RM0.481 cost per part

Jig Assisted Insertion:

$$Cp = \frac{156.26+240.33}{1000}$$

= RM0.397 cost per part

The jig-assisted method shows a lower cost per part by 17.47%, improving overall production cost efficiency.

3.2.4 Comparative Analysis

A comparative analysis of manual insertion and jig-assisted assembly, as summarized in Table 3, highlights the advantages of using the jig. While manual insertion involves no initial tool cost, it is limited by lower productivity and higher labor expenses. Despite an upfront cost of RM156.26, the jig-assisted method significantly increases productivity to 30 parts per hour and reduces labor expenses by 50%. These benefits result in a lower cost per part, making the jig-assisted method superior for high-volume production.

Table 3: Comparative Analysis.

Comparative worksheet		
Economic and Productivity factors	**Alternatives**	
	Manual insertion	**Jig-Assisted**
Lot size	1000	1000
Tool cost	0	156.26
Parts per hour	15	30
Labor/hour	RM7.21	RM7.21
Labor/lot	RM480.67	RM240.33
Cost per part	RM0.481	RM0.397

3.2.5 Total Savings and Break-Even Point

To determine the long-term feasibility of the jig, Total Savings and the Break-Even point were calculated. The total savings (TS) achieved by switching to the jig-assisted method were calculated using Equation 4:

Total savings for the part of the insertion by using the jig:

$$TS = LS \times (Cp\ 1 - Cp\ 2) \quad (4)$$

$$= 1000 \times (RM0.481 - RM0.397)$$

$$= RM84.00 \text{ total savings}$$

The break-even point (BP), representing the number of parts required to recover the jig's initial cost, was calculated using Equation 5:

$$BP = \frac{TC}{(Cp\ 1 - Cp\ 2)} \quad (5)$$

$$= \frac{156.26}{0.084}$$

$$= 1860.24 \approx 1860 \text{ parts to break-even}$$

The Break-Even Point is determined to be 1860 parts, indicating the minimum number of parts that must be produced for the tool to fully pay for itself.

3.3 Ergonomic Analysis

The ergonomic assessment using the Rapid Upper Limb Assessment (RULA) method was conducted to evaluate the manual and jig-assisted assembly methods for panel pin installation. The manual method revealed significant ergonomic risks due to unfavorable postures and repetitive motions. The RULA score for this method was 3, indicating moderate risk but highlighting areas of concern. The worker's upper limbs, particularly the arms and wrists, were subjected to strain with elevated arm positions, wrist flexion, and forceful manual actions, increasing the likelihood of musculoskeletal disorders (MSDs). Additionally, the forward bending of the neck and trunk and prolonged periods of static posture raised the risk of fatigue and discomfort, reducing long-term productivity.

In contrast, the jig-and-fixture-assisted method also received a RULA score 3, signifying moderate risk. However, the system improved the worker's posture by providing better support and minimizing manual alignment. The jig ensured a more neutral upper body position, reducing strain on the arms, wrists, neck, and trunk. Moreover, the toggle clamp system reduced the force needed for pin installation, alleviating the physical effort associated with the manual method. Despite receiving the same RULA score, the jig-assisted method proved more sustainable, reducing the cumulative strain from repetitive motions and minimizing the risk of long-term MSDs. While both methods showed moderate risks according to RULA, the jig-and-fixture approach offered a more comfortable and efficient solution, highlighting the need for further ergonomic assessments to fully understand the long-term benefits.

4. CONCLUSION

This research focused on the design and fabrication of a jig and fixture to optimize the panel pin assembly process for car side mirror power motors. The approach involved 3D scanning for accurate measurements, CAD design, prototyping, and machining processes, including milling, drilling, and tapping. The final jig and fixture resulted in a 50.82% reduction in assembly cycle time, decreasing it from 4 minutes and 4 seconds to 2 minutes, while increasing productivity from 15 to 30 parts per hour. Ergonomic evaluations confirmed improved operator safety and reduced fatigue. The total fabrication cost of RM 156.26 demonstrated the economic feasibility of the jig and fixture. The study emphasizes the critical role of customized jigs and fixtures in enhancing manufacturing efficiency, minimizing human error, and ensuring consistent production quality. Potential future improvements include integrating automation technologies, such as sensors or actuators, and using advanced materials like composites or reinforced polymers to enhance durability and reduce weight. These upgrades would make the jig and fixture more suitable for high-volume production environments. Overall, this research highlights the value of innovative and cost-effective design in achieving technical and economic advancements, offering a scalable solution for modern industrial applications.

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