And., Intl.,J., Appl Sci., Eng., Tech, Vol 06, No 02, July 2026
e-ISSN: 2797-0442

Engineering Design and Five Whys–Based Analysis for Jig Redesign in a New Auto Press Pin Machine

Armijal*, Muhammad Hamdan Fadhlani, Alfadhlani, Prima Fithri, Reinny Patrisina
Department of Industrial Engineering, Faculty of Engineering, Universitas Andalas, Padang, Indonesia
*Corresponding author: armijal@eng.unand.ac.id

Abstract— PT ABC is a major automotive manufacturer in Indonesia producing NR-series and hybrid engines. To address limitations of the manual press pin machine, an auto press pin machine was developed. However, operational issues emerged during the load–unload process due to instability of the jig path, leading to workpiece misalignment and reduced process reliability. This study aims to identify the root causes of the jig path instability and propose an engineering-based improvement. Root cause analysis was conducted using the five whys method based on field observations and discussions with operators and technicians. The analysis indicated that geometric incompatibility between the jig track and the cylinder block was the primary cause of instability. Based on these findings, the jig path was redesigned using computer-aided design (CAD) with SolidWorks, followed by motion study simulations to evaluate stability and potential interference. The redesigned jig path demonstrated improved positional stability and smoother workpiece movement during simulation. Although quantitative performance indicators were not evaluated, the proposed design provides a technical foundation for future performance-based assessments.

Keywords: Auto and manual press pin machine, Root cause analysis, Manufacturing equipment improvement.

This article *is licensed under the CC–BY-SA license.*

1. Introduction

The automotive manufacturing industry in Indonesia is experiencing rapid growth and plays a significant role in driving national economic development. In an increasingly competitive environment, companies are required to achieve an optimal balance between efficiency, quality, and reliability in their production processes. The principles of the Toyota Production System (TPS) and the philosophy of lean manufacturing serve as key references for achieving operational efficiency through waste elimination and continuous improvement across all production lines [1], [2].

PT ABC is one of the largest automotive manufacturers in Indonesia that consistently applies TPS principles in its operations. One of its production facilities focuses on manufacturing NR series engines and hybrid engines. To maintain competitiveness, PT ABC routinely invests in technology through capital expenditure (CapEx) programs, including replacing manual machines with automated systems to improve efficiency and work safety [3], [4]. One of the implementations of this program is the replacement of the manual press pin machine with the auto press pin machine, which is expected to reduce cycle time and increase productivity. The stages of designing PT ABC's new tool can be seen in Figure 1.

Received: January 19, 2026, Revised: March 6, 2026, Accepted: April 1, 2026
https://doi.org/10.25077/aijaset.v6i2.322

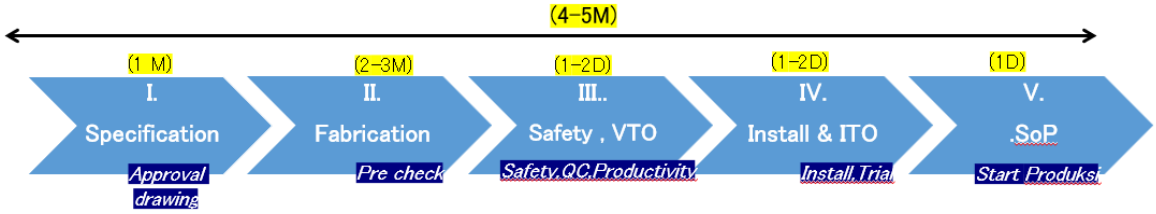

Figure 1. New Equipment Design Stages at PT ABC

Problems were identified during the fabrication stage, in which the manufacturer builds the machine according to the specifications defined in the initial design phase. Preliminary observations indicate instability in the jig trajectory during the load–unload process of the cylinder block on the auto press pin machine. As a result, the workpiece frequently experiences misalignment [4], [5]. Such issues are commonly encountered in assembly lines involving complex mechanical interactions among clamping components (fixtures), guide pins, and workpiece positioning systems. In this case, the misalignment during the load–unload process originates from the machine fabrication stage, as illustrated in Figure 2 and Figure 3.

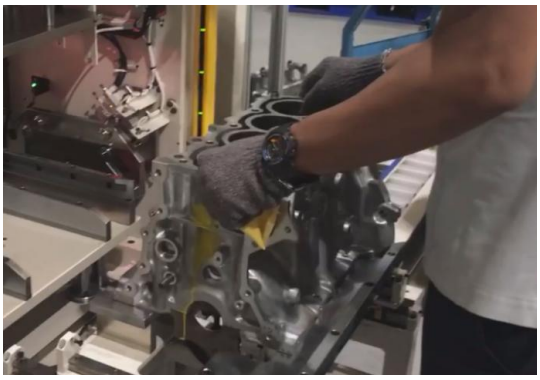

Figure 2. Misalignment Conditions During the Cylinder Block Loading and Unloading Process

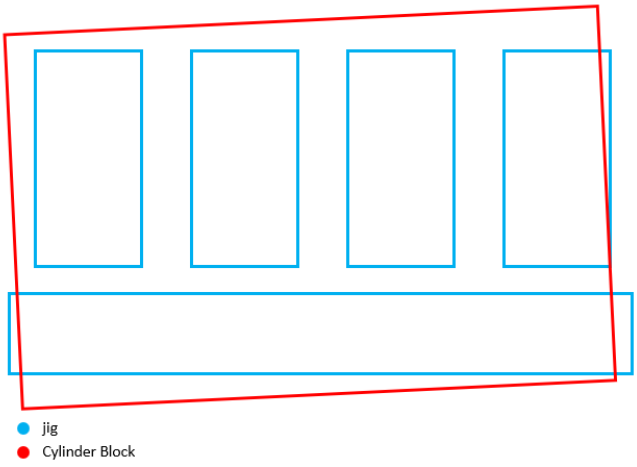

Figure 3. Top-view Illustration of the Observed Misalignment

In the context of production equipment design, jig stability is influenced by a combination of geometric factors, fulcrum determination, and assembly tolerances. A review of the literature indicates that the application of computer-aided design (CAD) and motion simulation can support interference analysis and mechanical function validation prior to physical implementation [6], [7]. In addition, root cause analysis (RCA) methods, such as the five why analysis, are effective for systematically

identifying the underlying causes of production problems using field data [8], [9].

The challenges faced by PT ABC are of particular interest because they involve both technical aspects (incompatibility in trajectory design) and systematic issues (the absence of thorough root cause evaluation during the machine development stage). Accordingly, this study aims to apply the five why analysis method to identify the root cause of inefficiencies in the load–unload process of the auto press pin machine, followed by a CAD-based redesign of the jig track to enhance positioning reliability and reduce operational disruptions.he problems faced by PT ABC are interesting to study because they contain technical elements (trajectory design incompatibility) as well as systematic elements (lack of root cause evaluation at the machine development stage). Therefore, this study focuses on applying the five why analysis method to find the root cause of the load–unload process inefficiency in the Auto press pin machine, followed by redesigning the jig track using CAD to improve position reliability and reduce operational disruptions.

2. Method

This study employed a structured methodological framework to identify operational issues in the Auto press pin machine, determine their root causes using the five why analysis method, and develop a CAD-based redesign of the jig track to improve process stability.

2.1 Research Stages

The research was conducted in sequential stages. First, the problem was identified through direct observation of the Auto press pin machine at one of the PT ABC Plants, focusing on the cylinder block load–unload process. The observation revealed recurrent misalignment and jamming of the workpiece along the jig track, resulting in increased cycle time and reduced machine effectiveness.

Based on the identified root causes, the jig track was redesigned using computer-aided design (CAD) software to improve guide pin geometry and positioning. The redesigned jig was validated through motion study and interference analysis to ensure collision-free operation [7], [10]. The redesign's effectiveness was evaluated by comparing machine performance before and after implementation motion study simulations. The methodological flow of the study is presented in Figure 4.

2.2 Research Location

The research was conducted at one of the PT ABC Plants, a major production facility for NR series and hybrid engines. The study focused on the Auto press pin machine area, specifically the cylinder block load–unload process, where a trajectory instability in the jig was observed. Data collection and observations were conducted on site with support from operators and technicians to ensure accuracy and reliability.

2.3 Data Collection Techniques

Primary data were obtained through direct observation of machine operation, including cycle time measurement and visual assessment of jig movement during the load–unload process. In addition, interviews with operators and technicians were conducted to gather qualitative insights regarding equipment behavior and previous corrective actions.

Secondary data were collected from internal company documentation, including daily overall equipment effectiveness (OEE) reports, work instructions (WI), standard operating procedures (SOP), and technical drawings of the cylinder block and jig components. OEE was selected as the primary performance metric, as it provides an integrated evaluation of availability, performance, and quality [5], [6], [11]. These data were used to compare machine performance before and after the redesign of the jig.

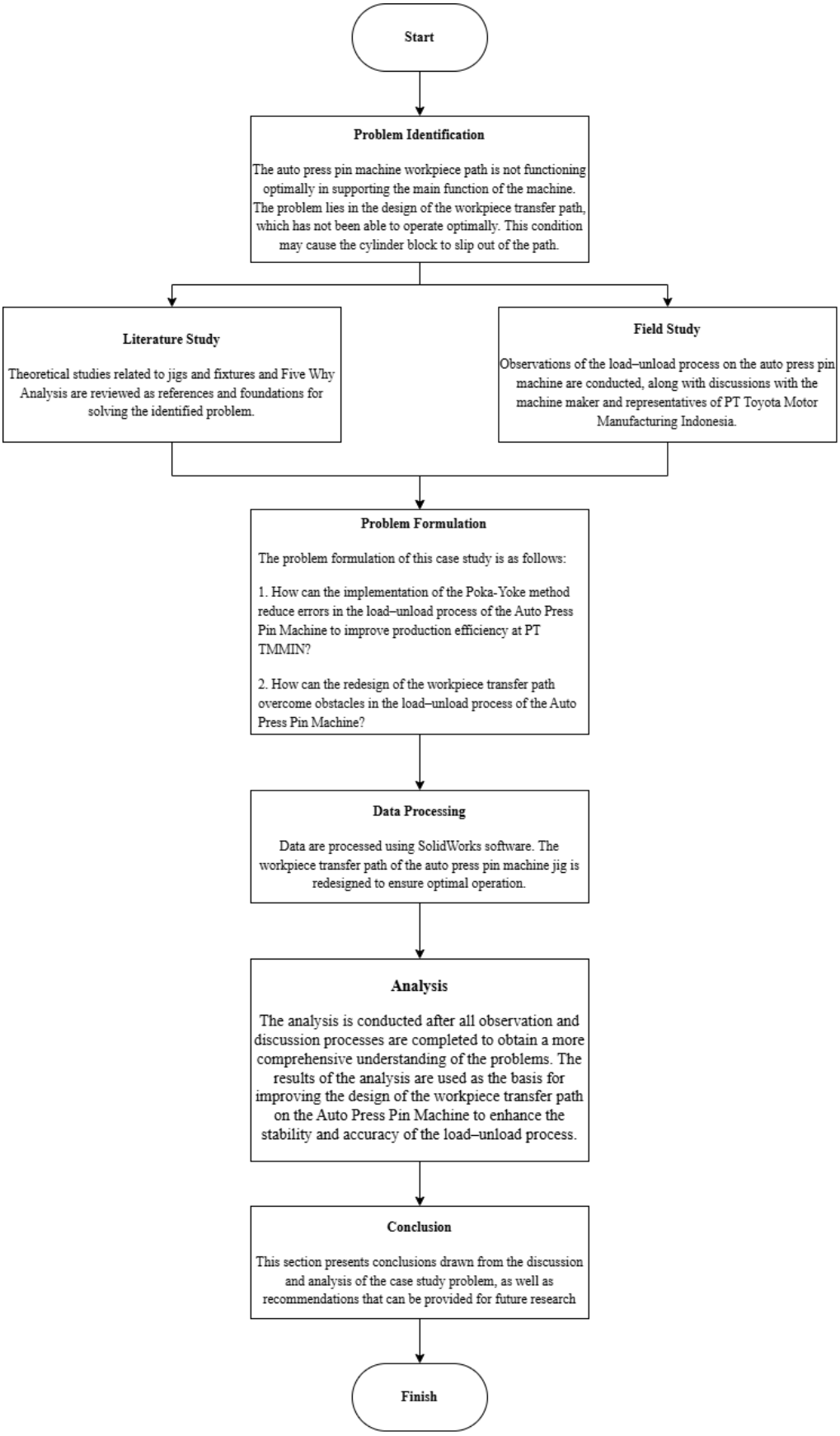

Figure 4. Research Methodology Flowchart

2.4 Data Analysis

Data analysis consisted of two main stages. First, a root cause analysis was conducted using the five whys method through structured discussions with operators, technicians, and engineers. The iterative questioning process identified improper guide pin alignment relative to the cylinder block geometry and tolerance deviations during jig fabrication as the primary causes of misalignment [8], [9], [12].

Second, the jig track was redesigned in SolidWorks for 3D modeling. The redesigned jig incorporated principles of locating, clamping, and supporting to ensure accurate workpiece positioning during the load–unload process [6], [7]. Motion study simulations were then conducted to evaluate jig movement and detect potential interference. The simulation results indicated improved trajectory stability and reduced collision risk during machine operation [10], [13].

3. Result and Discussion

Field observations revealed that the cylinder block load–unload process on the auto press pin machine did not operate smoothly. During operation, the workpiece frequently shifted in position along the jig track, leading to intermittent contact between components and occasional jamming. Operational disturbances such as intermittent contact and jamming during the load–unload process may contribute to equipment downtime, which in turn affects machine performance indicators such as OEE [4].

Visual inspection of the jig track indicated geometric discrepancies between the guide pin position, the support groove, and the cylinder block geometry. As a result, the workpiece did not maintain a consistent orientation during transfer, increasing the likelihood of misalignment and impact. The condition of the jig track prior to improvement is shown in Figure 5.



Figure 5. Condition of the Jig Track Before Improvement

3.1 Analysis Using the Five Whys Method

To determine the underlying causes of the observed disturbances, a root cause analysis was conducted using the five whys method. This analysis was conducted through structured discussions with machine operators and technicians who were directly involved in daily operations and maintenance.

The analysis results indicate that the primary cause of jig track instability was the misalignment of the guide pin relative to the cylinder block geometry and center of mass. This condition caused the workpiece to shift during the load–unload process. Root cause analysis using cause–effect identification techniques revealed that this misalignment originated from dimensional deviations introduced during the jig fabrication stage [9], where applied tolerances did not fully comply with the design specifications. In jig and fixture systems, dimensional inaccuracies during fabrication may lead to geometric inconsistency between the locating element and the workpiece interface, thereby

affecting positioning stability during operation [7].

The complete five whys analysis is presented in Table 1. Overall, the results demonstrate that the instability issue is geometric in nature and is directly related to fixture design and manufacturing accuracy.

Table 1. Five Whys Analysis on Auto Press Pin Machine.

No	Question	Responds
1	Why is the workpiece transfer path not optimal?	Because there are obstructions during the load–unload process.
2	Why do obstructions occur during the load–unload process?	Because the workpiece movement along the path is not smooth during operation.
3	Why is the movement along the path not smooth?	Because there is a mismatch between the designed path and the actual conditions in the field.
4	Why is there a mismatch between the design and actual conditions?	Because the design validation did not fully consider all operational variations, such as workpiece dimensional tolerances and actual positioning conditions.
5	Why did the validation process not cover all operational conditions?	Due to resource limitations and the initial assumption that the design was sufficiently robust for field implementation.

3.2 Jig Track Redesign and Simulation Results

Based on the identified root causes, the jig track was redesigned using SolidWorks to improve geometric compatibility between the jig components and the cylinder block. The redesigned configuration focused on adjusting the guide pin position and refining the track geometry to better support the workpiece during the load–unload process.

The redesigned jig track was evaluated using motion study simulations conducted under operating conditions representative of actual production. The simulation results showed smoother workpiece movement along the redesigned path, with consistent clearance maintained between interacting components. No interference or collision was detected throughout the simulated load–unload cycle. The proposed jig track design and the condition of jig track improvement are shown in Figure 6 and Figure 7.

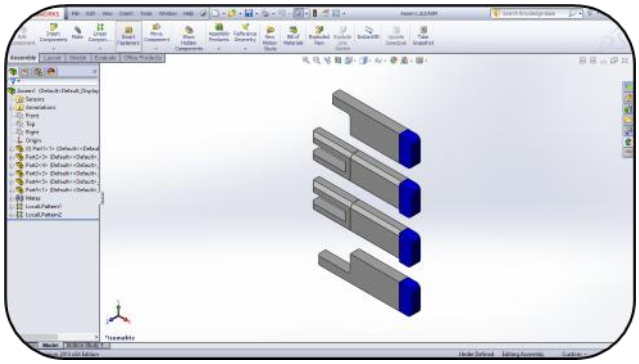

Figure 6. Proposed Design for Improvement of Auto Press Pin Machine Track



Figure 7. Condition of the Jig Track After Repair

3.3 Discussion

The results confirm that geometric incompatibility between the jig track and the cylinder block was the dominant factor contributing to instability during the load–unload process. The application of the five whys method enabled the systematic identification of the problem's fundamental causes, highlighting the critical roles of guide pin positioning and dimensional control during jig fabrication [8], [9]. This finding is consistent with previous studies emphasizing that geometric accuracy and tolerance control are essential considerations in jig and fixture design to ensure proper positioning and operational stability [7].

The CAD-based redesign, supported by motion simulation, demonstrates the effectiveness of virtual validation in identifying and mitigating potential mechanical interference before physical implementation. Similar conclusions have been reported in previous research, which indicates that CAD simulation can significantly reduce design-related errors and improve fixture reliability in automated assembly systems [7].

Although this study did not include quantitative evaluation of operational performance indicators such as cycle time reduction or overall equipment effectiveness (OEE), the analytical and simulation results suggest that the proposed jig track redesign has the potential to enhance process stability and operational reliability. Future research is therefore recommended to implement the redesigned jig in actual production conditions and to evaluate its impact using measurable performance indicators, including cycle time, downtime, and OEE.

Overall, the integration of qualitative root cause analysis with simulation-based design validation provides a systematic and practical framework for resolving fixture-related instability in automated manufacturing systems. This approach can be adopted in similar industrial contexts to support more reliable equipment design and continuous improvement initiatives.

4. Conclusion

This study investigated instability in the cylinder block load–unload process of the auto press pin machine at one of the PT ABC’s Plant by applying a structured problem-solving approach. Through direct observation and root cause analysis using the five whys method, the primary cause of jig track instability was identified as geometric incompatibility between the guide pin position and the cylinder block geometry, compounded by dimensional deviations introduced during the jig fabrication stage.

Based on the identified root causes, a jig track redesign was developed using computer-aided design (CAD). Motion study simulations of the redesigned configuration demonstrated improved trajectory stability and the absence of mechanical interference during the simulated load–unload process. These results indicate that CAD-based validation is an effective tool for addressing geometric design issues in production equipment prior to physical implementation.

Acknowledgment

The authors would like to express their gratitude to the Faculty of Engineering, Universitas Andalas, for providing financial support for this research through the Industrial Engineering Lecturer Research Scheme (Skema Penelitian Dosen Teknik Industri), Grant No. B/37/UN16.09/SPK/PT.01.03/RKAT-UNAND/2025.

References

[1] J. K. . Liker, *Toyota way : 14 management principles from the world's greatest manufacturer*. McGraw-Hill, 2013.

[2] Ohno, T. Toyota Production System: Beyond Large-Scale Production. Portland, OR: Productivity Press, 1988.

[3] H. Ariyah Jurusan Teknik Industri, F. Sains dan Teknologi, U. H. Sultan Syarif Kasim Riau Jl Soebrantas No, and S. Baru, "Penerapan Metode Overall Equipment Effectiveness (OEE) Dalam Peningkatan Efisiensi Mesin Batching Plant (Studi Kasus: PT. Lutvindo Wijaya Perkasa)," *Jurnal Teknologi dan Manajemen Industri Terapan (JTMIT)*, vol. 1, pp. 70–77, 2022.

[4] P. Dobra and J. Jósvai, "Prediction of Overall Equipment Effectiveness in Assembly Processes Using Machine Learning," *Strojnicky Casopis*, vol. 74, no. 2, pp. 57–64, Nov. 2024, doi: 10.2478/scjme-2024-0026.

[5] A. A. T. Panudju, "Peningkatan Efektifitas Mesin dengan Metode Overall Equipment Effectiveness," *RIGGS: Journal of Artificial Intelligence and Digital Business*, vol. 4, no. 1, pp. 428–436, Apr. 2025, doi: 10.31004/riggs.v4i1.423.

[6] Serope. Kalpakjian, S. R. . Schmid, and K. S. Vijay. Sekar, *Manufacturing engineering and technology*. Pearson Education South Asia Pte Ltd, 2014.

[7] A. D. Ibrahim, H. M. A. Hussein, I. Ahmed, E. A. Nasr, A. Kamrani, and S. A. Abdelwahab, "Computer-Aided Design of Traditional Jigs and Fixtures," Jan. 01, 2022, *MDPI*. doi: 10.3390/app12010003.

[8] M. A. . Barsalou, *Root cause analysis : a step-by-step guide to using the right tool at the right time*. CRC Press, 2015.

[9] A. Kumah *et al.*, "Cause-and-Effect (Fishbone) Diagram: A Tool for Generating and Organizing Quality Improvement Ideas," *Global Journal on Quality and Safety in Healthcare*, vol. 7, no. 2, pp. 85–87, May 2024, doi: 10.36401/JQSH-23-42.

[10] H. Radhwan, M. S. M. Effendi, M. Farizuan Rosli, Z. Shayfull, and K. N. Nadia, "Design and Analysis of Jigs and Fixtures for Manufacturing Process," in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Aug. 2019. doi: 10.1088/1757-899X/551/1/012028.

[11] T. Ilham Berdotu, R. Nanda Kartika, dan Heribertus Rudi Kusumantoro, T. Rekayasa Cetak Dan Grafis, T. Grafika Dan Penerbitan, and P. Negeri Jakarta, "Penerapan Metode OEE Untuk Menilai Efisiensi Mesin Cetak Digital AccurioPress 6100," vol. 4, no. 1, 2025.

[12] A. Kumar, G. P. S. Jadon, and P. P. Pandit, "Design, Optimization, and Analysis of Machining Fixture Layout under Dynamic Conditions," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 11, no. 4, pp. 4022–4038, Apr. 2023, doi: 10.22214/ijraset.2023.51115.

[13] F. Kurniawan, A. K. Faizin, M. A. S. Atmojo, and M. D. Lisanto, “Desain dan simulasi uji pembebanan statis pada jig and fixture bor dan gerinda portable,” *Dinamika Teknik Mesin*, vol. 14, no. 2, p. 145, Oct. 2024, doi: 10.29303/dtm.v14i2.879.