SINTEK JURNAL: Jurnal Ilmiah Teknik Mesin
ISSN: 2088-9038, e-ISSN: 2549-9645
Homepage: http://jurnal.umj.ac.id/index.php/sintek

DEVELOPMENT OF A SPECIAL SERVICE TOOL FOR HYDRAULIC PISTON MAINTENANCE ON EXCAVATOR PC 210-10M0

Reza Febriano Armas[1,*], Hendro Purwono[1], Thomas Junaedi[1], Alfauzi[2], Lintang Fuji Santosa[2]
[1]D3 Automotive & Heavy Equipment Engineering, Universitas Muhammadiyah Jakarta,
Jl. Cempaka Putih Tengah XXVII, Cempaka Putih, Jakarta Pusat, DKI Jakarta, 10510, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Universitas Muhammadiyah Tegal,
Jl. Melati No. 27, Kejambon, Tegal, Jawa Tengah, 52124, Indonesia
[*]E-mail: reza.febriano@umj.ac.id

Accepted: 13-09-2024 Revised: 11-11-2024 Approved: 01-12-2024

ABSTRACT

Excavators are essential machinery widely utilized in mining, construction, plantation, and other industries. The Komatsu PC210-10M0, a small-sized excavator model, performs critical operations such as material digging and transportation. However, during component overhauls, particularly for the boom cylinder, bucket, and arm, significant challenges arise due to the absence of suitable tools for efficiently removing and installing hydraulic cylinder pistons. The current reliance on generic tools such as screw wrench sets (L-keys) is suboptimal, leading to inefficiencies, increased risks of workplace accidents due to tool slippage, and longer processing times. This study addresses these limitations by employing the Seven Up++ method to develop a specialized service tool specifically designed for hydraulic cylinder piston maintenance. The methodology encompasses three critical phases: Analysis, Solution, and Results, ensuring a systematic and innovation-focused approach. The developed tool securely positions itself on the piston cylinder, utilizing two pins inserted into pre-existing holes on the piston surface. The results demonstrate significant improvements: maintenance processing time is reduced by up to 70%, operational safety is enhanced due to the tool's secure attachment, and labor requirements are halved, with manpower reduced from two operators to one. These findings highlight the tool's potential to optimize maintenance operations and improve overall efficiency in the use of Komatsu PC210-10M0 excavators.

Keywords: special service tools; hydraulic excavators; maintenance efficiency; Seven Up++ method

ABSTRAK

Excavator merupakan alat berat penting yang banyak digunakan di pertambangan, konstruksi, perkebunan, dan industri lainnya. Komatsu PC210-10M0, model excavator berukuran kecil, melakukan operasi penting seperti penggalian dan pengangkutan material. Namun, selama perbaikan komponen, terutama untuk silinder boom, bucket, dan lengan, tantangan yang signifikan muncul karena tidak adanya alat yang sesuai untuk melepas dan memasang piston silinder hidraulik secara efisien. Ketergantungan saat ini pada alat generik seperti set kunci pas sekrup (L-keys) tidak optimal, sehingga menyebabkan inefisiensi, peningkatan risiko kecelakaan di tempat kerja akibat selipnya alat, dan waktu pemrosesan yang lebih lama. Studi ini membahas keterbatasan ini dengan menggunakan metode Seven Up++ untuk mengembangkan alat servis khusus yang dirancang khusus untuk perawatan piston silinder hidraulik. Metodologi ini mencakup tiga fase penting: Analisis, Solusi, dan Hasil, untuk memastikan pendekatan yang sistematis dan berfokus pada inovasi. Alat yang dikembangkan ditempatkan dengan aman pada silinder piston, memanfaatkan dua pin yang dimasukkan ke dalam lubang yang sudah ada pada permukaan piston. Hasilnya menunjukkan peningkatan yang signifikan: waktu proses perawatan berkurang hingga 70%, keselamatan operasional ditingkatkan karena pemasangan alat yang aman, dan kebutuhan tenaga kerja berkurang separuhnya, dengan tenaga kerja yang berkurang dari dua operator menjadi satu operator. Temuan ini menyoroti potensi alat ini untuk mengoptimalkan operasi pemeliharaan dan meningkatkan efisiensi keseluruhan dalam penggunaan excavator Komatsu PC210-10M0.

***Kata Kunci**: alat servis khusus; excavator hidraulik; efisiensi pemeliharaan; metode Seven Up++*

1. Introduction

Currently, coal dominates the primary energy mix as it is considered the most economical option, primarily due to its least-cost considerations, particularly for primary energy needs in power generation. Domestic coal utilization has grown significantly, with an annual increase of up to 12%, Fig 1 according to the National Energy Council (2020) [1].

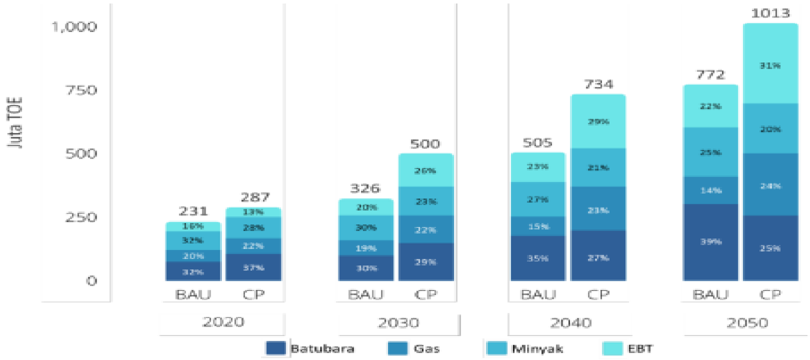

Figure 1. Primary energy
(Source: National Energy Council, 2020)

Fossil energy is projected to continue dominating Indonesia's primary energy supply until 2050, with an increase during the projection period of 407 million tons of oil equivalent (TOE) under the Business-as-Usual (BAU) scenario and 448 million TOE under the Current Policy (CP) scenario. Although the absolute value of fossil energy consumption increases, its share in the total primary energy supply is expected to decrease to 88% (BAU) and 69% (CP) [2,3]. The share of coal is projected to continue declining, although its role will remain significant until 2050 due to the high dependency on coal usage, particularly in the power generation sector. In the mining industry, hydraulic excavators are a common sight. Excavators play a crucial role in various heavy-duty tasks across the construction, mining, river rehabilitation, plantation, and other sectors. However, many factors can hinder the operation of excavator components, especially the cylinders, such as the bucket cylinder, arm cylinder, and boom cylinder [4,5].

Improper and unplanned repairs can cause further damage or cause existing damage to spread to other parts, potentially resulting in more severe or even catastrophic failures. Previous research used an 8-step troubleshooting method to analyze and address the problem. The findings of the study revealed that the cause of the service brake malfunction was the failure of the pressure switch, which prevented signals from being sent to the deceleration control monitor [6]. Similarly, research to identify the cause of oil leaks and determine appropriate remedial actions, using an 8-step troubleshooting approach [7]. In engine maintenance and repair, particularly in vehicles or heavy equipment, the use of specialized tools is often essential. These tools are specifically designed to facilitate the maintenance, repair and testing of specific components. The availability of specialized tools is closely related to the efficiency and safety of machine maintenance. By using the right tools, technicians or mechanics can perform their duties more effectively, thus speeding up the repair process [8].

There are several challenges associated with performing a general overhaul, specifically when removing and installing hydraulic cylinder pistons. The main issue is the large number of tools required for this process, which leads to wastage of time and effort, ultimately resulting in overall inefficiency. Research conducted by [9] designed a specialised tool to increase productivity and reduce costs. In their study, which focused on a Komatsu PC200-8MO unit, the approach taken was to design a tool that minimised time loss during track roller removal and installation as part of a general overhaul. Efficiency and productivity are critical in an industrial context, and developing effective work systems, tools and improving working conditions are fundamental to continuously improving overall performance [10,11].

Given the challenges identified, the objective of this research was to design and manufacture a specialised tool specifically for removing and installing hydraulic cylinder pistons on PC 210-10M0 excavators, with the aim of significantly reducing waiting times. This research sought to develop a more efficient and safer tool for the removal and installation of hydraulic cylinder pistons on PC 210-10M0 excavators. The proposed tool was designed to minimise time wastage and reduce the physical effort required, thereby significantly improving productivity and safety.

The importance of this research lies in its potential to advance maintenance practices within the construction and mining industries. By optimising the removal and installation process, the new tool will reduce downtime, lower operational costs and improve safety standards. These advancements are critical to maintaining machine performance and reliability in challenging industrial environments.

2. Methods

The Seven Up++ method, illustrated in Figure 2, serves as a structured framework for conducting innovation. This method ensures that the innovation process is systematically organized, easily monitored, and well-documented. By following this approach, the outcomes are not only optimized for current applications but also provide valuable insights for addressing similar challenges in the future. The methodology comprises three main stages: Analysis, Solution, and Result.

Overview of the Seven Up++ Method

Before initiating any repair or innovation project, a comprehensive analysis is conducted to establish the foundation for the subsequent solution stage, ultimately achieving the desired outcomes [12].

- Analysis Stage: This stage focuses on data collection and mapping, specifically for the overhaul of hydraulic pistons. It includes defining clear objectives, with a particular emphasis on designing specialized tools to address specific problems effectively.

- Solution Stage: This stage encompasses idea generation, detailed planning, and implementation. During this phase, solutions are developed and rigorously tested to ensure they align with the requirements of the overhaul process.

- Result Stage: This final stage involves evaluating the performance of the specialized tools, standardizing best practices, and concluding the project by implementing the tools for hydraulic piston cylinder overhauls [13].

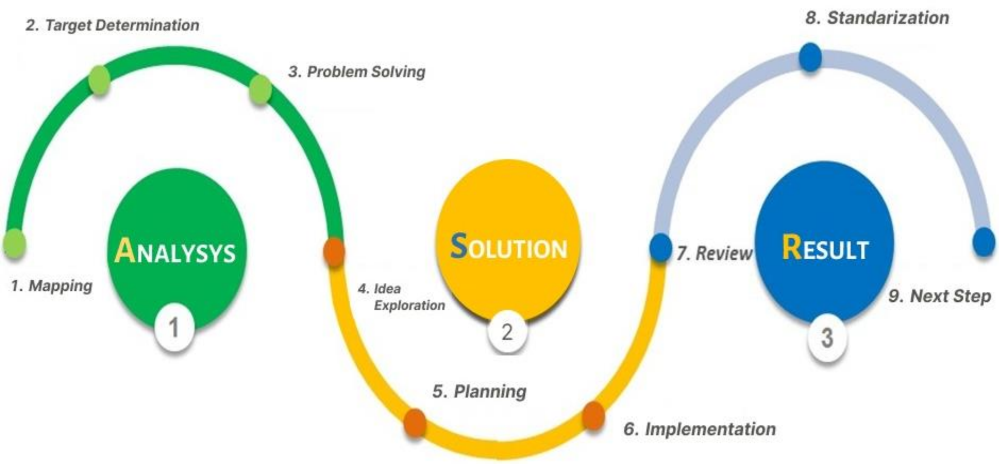

Figure 2. 7Up++ Method
(Source: Guide Book UT, 2022)

Application of the Seven Up++ Method in Hydraulic Piston Overhaul

To enhance the efficiency and effectiveness of the overhaul process, the Seven Up++ method is applied with a focus on three critical variables: manpower, safety, and time efficiency.

Manpower Optimization:

The variable Required Manpower evaluates the number of personnel needed to complete the overhaul process, comparing scenarios with and without the support of specialized tools. This analysis identifies potential human resource savings facilitated by the use of these tools, contributing to improved work efficiency and reduced operational costs.

Safety Enhancement:

Worker safety is assessed through the evaluation of incidents and near-misses mitigated by using specialized tools. These tools minimize risks associated with manual handling of large or heavy components, thereby reducing workplace accidents. The implementation of specialized tools directly supports the creation of a safer and more sustainable work environment [14,15].

Time Efficiency:

The variable Time Reduction measures the decrease in time required to complete the overhaul process when specialized tools are employed. Previous studies have demonstrated that these tools significantly accelerate task completion, improving overall productivity [16-18].

By addressing these variables—manpower optimization, safety enhancement, and time efficiency—the Seven Up++ method provides a comprehensive framework for evaluating and improving performance in engineering and heavy equipment maintenance industries. The insights gained from this method contribute to the development of more effective strategies for enhancing operational performance and sustainability [19-21].

3. Results and Discussion

Analysis

The analysis revealed several challenges related to the tools used for removing and installing hydraulic cylinder pistons on the PC 210-10M0 excavator unit. The predominant use of Allen wrenches (L-keys) was identified as a significant limitation. These tools often complicate operations, particularly in hard-to-reach areas, and pose safety risks for operators due to their tendency to slip during use, as depicted in Figure 3.

The ergonomic inefficiency of Allen wrenches leads to increased operator fatigue, higher risk of injury, and delays in task completion. These issues underscore the need for specialized tools tailored to the demands of hydraulic cylinder piston overhauls [22,23].

Figure 3. Limitations of Using Allen Wrench in Operations

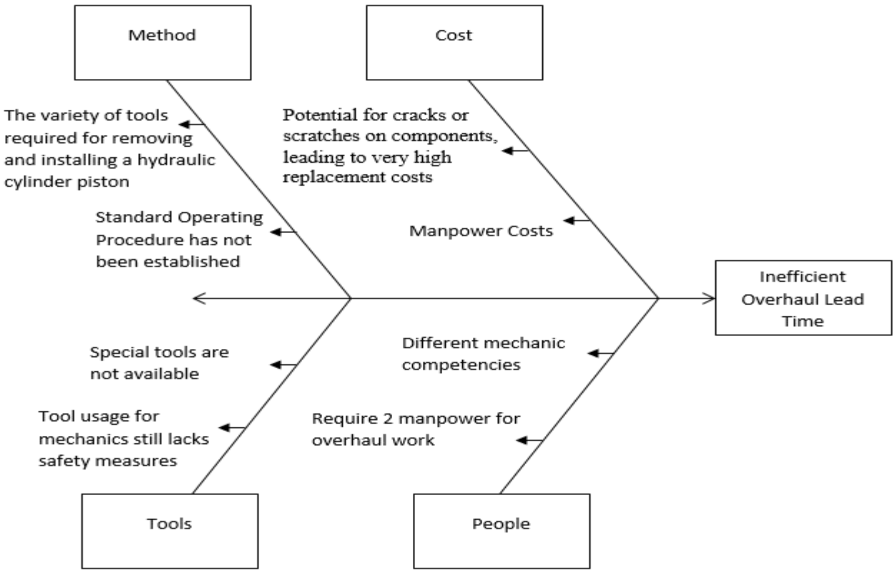

Figure 4. Fishbone Diagram

Further analysis using a fishbone diagram (Figure 4) identified four primary factors influencing the efficiency of the overhaul process: people, cost, methods, and tools. The excessive lead time for hydraulic cylinder overhauls was attributed to complex field procedures, inexperienced mechanics, and inadequate tools, highlighting the need for improvements in these areas [24,25].

Solution Development

Based on the analysis, solutions were developed to address the root causes, as summarized in Table 1.
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Table 1. Idea Exploration for Root Causes and Solutions

	Root Cause	Alternative Solution	Benefit	Final Solution
People	New mechanics (inexperienced)	Mentoring of new mechanics by senior experts	Quick skill improvement for inexperienced workers	Mentoring by senior (expert) mechanics during overhaul
Method	The work procedures differ	Developing Standard Operating Procedures (SOP)	Reduced lead time and increased efficiency	Implementation of SOPs
Cost	Risk of cracks or scratches on components, causing high replacement costs.	Investment in special tools	Prevents damage to parts and reduces manpower costs	Use of special tools
Tools	Special tools for the hydraulic cylinder piston on the PC 210-10M0 excavator are unavailable.	Designing specialized tools	Facilitates efficient removal and installation	Development of special service tools

In designing a special service tool for removing and installing hydraulic cylinder pistons, observations and literature reviews were conducted to define specifications based on field conditions and the shop manual. Key measurements include a pinhole diameter of 10 mm, tool thickness of 12 mm, and pin length of 32.50 mm. These dimensions informed the tool design, as shown in Figure 5.

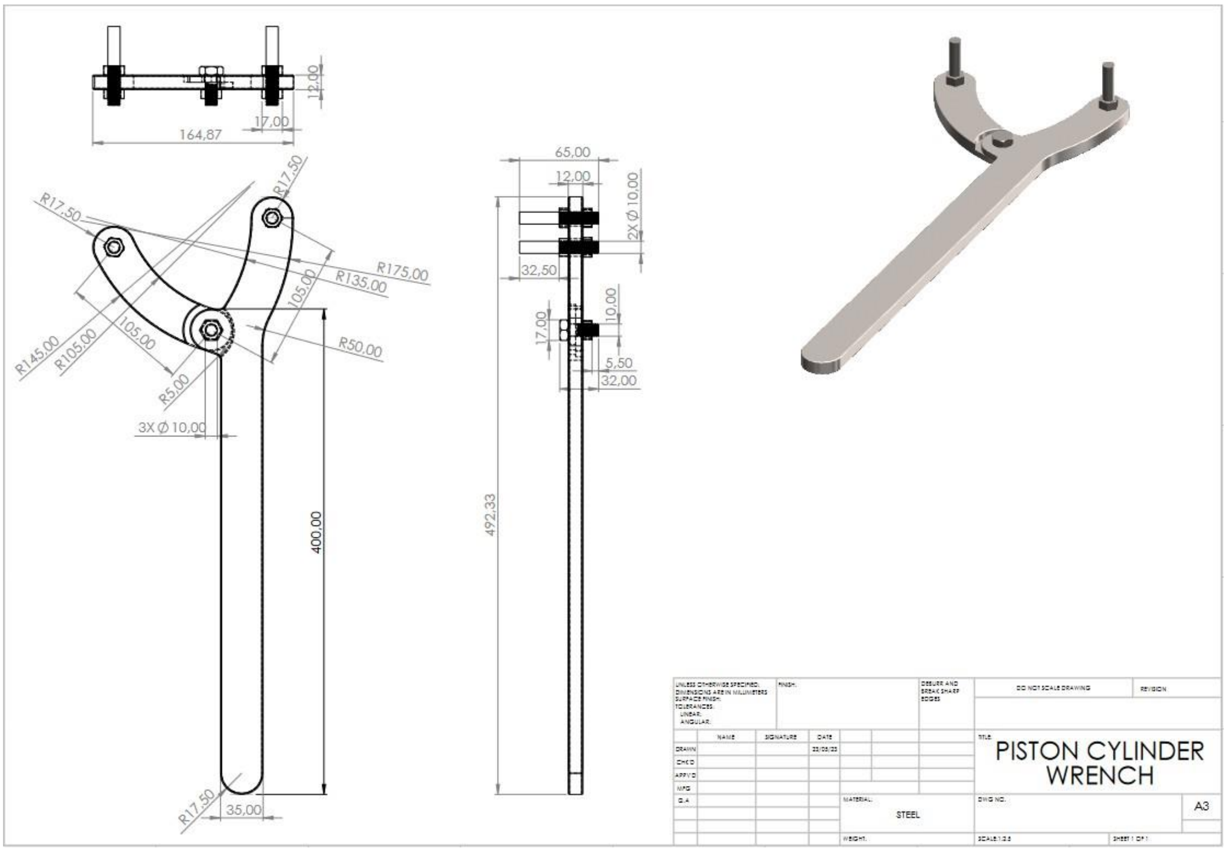

Figure 5. Design of Special Service Tools for Removing and Installing Hydraulic Cylinder Piston

Tool Development

The special tool was fabricated using a milling machine to ensure precision and efficiency in production, as depicted in Figure 6.

Figure 6. Development of Special Service Tools

Testing and Results

The developed tool was tested by securing it onto the hydraulic piston cylinder. The process involved inserting the tool's pins into the cylinder's access holes and tightening the tool securely. The tool was then operated by turning it upward to remove or install the piston, as shown in Figure 7.

Figure 7. Testing of Special Service Tools

The comparative results before and after using the special tool are summarized in Table 2.

Table 2. Comparative Results: Before and After Tool Implementation

Aspect	Before	After
Quality	Risk of component damage (e.g., scratches, deformation) due to improper tool use	Minimized risks with precise and secure tool design
Cost	Required two operators, costing approximately USD 650 per day	Reduced to one operator, cutting costs by 50%
Delivery	50 minutes per overhaul using Allen wrenches	15 minutes per overhaul with special tools, reducing time by 70%
Safety	Unsafe conditions due to inadequate tool precision, requiring additional support	Improved safety with secure pin-based tool mechanism

The implementation of the special service tool significantly improved the efficiency, safety, and cost-effectiveness of the hydraulic cylinder piston overhaul process. These results underscore the tool's potential for broader application in similar maintenance tasks across the industry.

4. Conclusion

The development and implementation of a specialized tool for removing and installing hydraulic cylinder pistons on the Komatsu PC210-10M0 excavator have significantly improved maintenance operations. The tool has reduced task duration by 70%, from 50 minutes to 15 minutes, enhancing productivity and optimizing manpower utilization.

The tool has also elevated safety standards by minimizing risks of slippage and mishandling, creating a safer work environment and reducing injury risks. Economically, it has reduced manpower requirements from two workers to one, cutting labor costs by 50% and achieving substantial operational savings.

These advancements highlight the tool's effectiveness in enhancing efficiency, safety, and cost-effectiveness in hydraulic excavator maintenance.

Future research should investigate the broader applicability of such tools across various heavy equipment maintenance tasks. Long-term studies on cost-effectiveness, tool durability, and maintenance needs are recommended. Additionally, integrating automation or smart technologies could further improve the efficiency, safety, and reliability of maintenance operations.

Acknowledgements

The authors express their gratitude to all contributors to the completion of this journal. Special appreciation is extended to the SINTEK JURNAL editorial team, research partners, and supporters for their invaluable contributions, which have enriched the journal's content. This collective effort has ensured the production of a high-quality work.

We hope this research will contribute positively to the advancement of science. Thank you for your dedication and collaboration.

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