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Design and Development of a Special Service Tool for Front Brake Caliper Sliding Extractor in Vehicles

Muhammad Dimas Riantama[1], Moch Solikin[1*]

[1]Department of Mechanical and Automotive Engineering, Faculty of Vocational, Universitas Negeri Yogyakarta, Kampus Wates, 55652, Indonesia

*Corresponding author: moch_solikin@uny.ac.id

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ABSTRACT

Special service tools are essential in maintenance and repair processes, aiming to facilitate work. One of the primary maintenance and repair areas in vehicles is the braking system, which requires specialized tools. This study designed and developed a tool to assist with the maintenance and repair of the vehicle brake system. The objectives of this study were to create a sliding calliper extractor for front brakes and to evaluate its performance. The second step involved creating an illustration of the new method and designing the tool. Load testing and design analysis were conducted before production. Design evaluation was necessary before entering the manufacturing stage, and finally, performance testing and evaluation data were collected to ensure conformity with the initial design. The steps resulted in a sliding calliper tool with dimensions of 120 mm x 65 mm x 35 mm, a weight of 0.742 kg, and tensile strength of up to 650 N/65 kg. Testing on the front brake calliper of a Suzuki vehicle demonstrated the tool’s effectiveness in removing calliper pins at a load limit of 650 N. Performance tests confirmed the tool’s functionality and alignment with the initial design. The extractor successfully removed pins with an average load of 500 N/50 kg. The tool was simple and user-friendly, with testing showing no deflection, and no scratches or damage were observed on components around the pin during pin extraction. This result was supported by simulation analysis, where the equivalent stress under a 489 N/49 kg limit load was 47.043 MPa.

1. Introduction

PT UMC Suzuki Surabaya is a company engaged in the automotive sector. The company is located at Jl. Ahmad Yani No. 40 Surabaya, East Java. This workshop is engaged in maintenance and repair as well as sales and spare parts. The services provided by this company to customers are very well considered. One of the most concerned services is vehicle maintenance and repair services. Good maintenance and repair must be in accordance with industry Standard Operating Procedures (SOP). In automobiles, especially those that help with work, maintenance is a mandatory and routine task to extend the life of the vehicle [1]. The maintenance process is carried out systematically and carefully so that the process is precise and does not endanger the technicians and drivers who drive the car. Maintenance and repairs are carried out to prevent the system from damage and restore it to its original condition after use. Maintenance is also carried out so that the vehicle can continue to operate properly. The maintenance procedures used are designed to keep the vehicle healthy [2].

The car periodic maintenance process is generally carried out by checking the condition of the engine, chassis and electrical and other systems related to driver safety. This is a benchmark for each workshop brand in the maintenance process. Periodic maintenance and service performed at Suzuki workshops are in accordance with vehicle mileage, so that the service or maintenance process does not spend a lot of capital. Vehicle mileage can be seen on the speedometer at the front of the car dashboard [3]. Mileage specifications have several classes of periodic service packages, namely; Periodic Service Package A, Periodic Service Package B, Periodic Service Package C, and Periodic Service Package D. Suzuki Ertiga, Karimun, and SX4 cars usually use periodic maintenance package type D with a comprehensive maintenance process including the brake system [4]. The brake system in a car has an important role, so it needs to be given periodic care and maintenance every year. Periodic maintenance on the brake system is carried out systematically to minimize errors during the repair process. Brake maintenance and repair procedures are quite easy, including checking the brake lining and calipers on the brakes. This check is not without reason, because the caliper work system on the brakes works to push the brake lining and crush the brake disc to stop the vehicle [5].

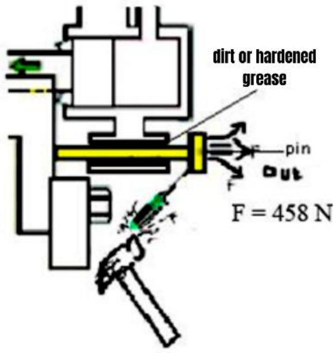

Figure 1. Conventional method of caliper pin maintenance

The process of repairing the brake system often experiences problems because there are no special tools to help repair work [6]. Based on the results of observations and interviews with a mechanic named Hendra at PT UMC Suzuki Surabaya, there were several problems found during the implementation of industrial practice. During the periodic maintenance process on the maintenance and repair of the front brake system of the car at the Suzuki workshop, they still use simple tools such as a hammer and screwdriver to pull the pin on the caliper out (see Fig. 1). The pin can be pulled out with bare hands, but in certain cases because it has not been given maintenance for a long time, the pin on the caliper is stuck [7]. This is very dangerous for other components if you are not careful during the removal process using a hammer. Some conditions where the car body and other brake components are hit causing damage to some brake system controls. This process is also dangerous if it hits the hand. Hand swelling due to slipping often occurs during the process of beating out the caliper pin. The license to use this old method was also not approved by the audit because it was very risky. Beating is also very risky to do because it can erode the housing on the lock pin so that it becomes worn. The function of the pin itself is more or less the same as a piston because it moves back and forth to press the piston during the brake process [8].

A solution to the issues that technicians often face while performing regular maintenance at the workshop was thought of based on the information provided above. A more effective, dependable, and ergonomic solution was required for these problems, which included things like the difficulty of disassembling front brake calipers and the length of time it took because of incorrect or improvised tools. All of these goals—a more efficient maintenance process, less physical strain on personnel, higher quality work overall, and faster service turnaround times—are part of the proposed approach. Research and development at PT UMC Suzuki Surabaya has thus focused on developing a specialized tool with improved functionality; this tool will be described in full under the heading Design of Special Tool: Sliding Car Front Brake Caliper Extractor. In order to streamline the process of caliper pin extraction, this specialist tool is designed to be both sturdy and easy to use. Engineers will be able to work more effectively with the final product since it is based on research into the form and arrangement of current parts and the application of ergonomic and material science concepts. Better tool longevity, less chance of component damage, and increased technician safety and comfort are long-term benefits, while a more simplified workflow provides an immediate gain. This invention is set to improve PT UMC Suzuki Surabaya's maintenance standards, which should lead to happier customers, more productive workshops, and overall operational excellence.

2. Methodology

This research adopts a Research and Development (R&D) methodology, which is oriented toward practical innovation through iterative design, testing, and refinement. The process is structured into several key stages to ensure a systematic and comprehensive approach such as 1) needs analysis, 2) functional approach and tool operation, 3) implementation and design realization and 4) testing, validation, and evaluation. During this initial phase, the focus is placed on a thorough understanding of the problem and the context in which it occurs. This involves examining the construction and operational characteristics of the car’s front brake caliper assembly. Special attention is given to identifying the weaknesses in the current method of removing and installing the caliper sliding pins, as well as recognizing any latent advantages that can be preserved or enhanced. Comparative assessments between the old method and the proposed new method are conducted, providing a clear baseline from which to measure future improvements.

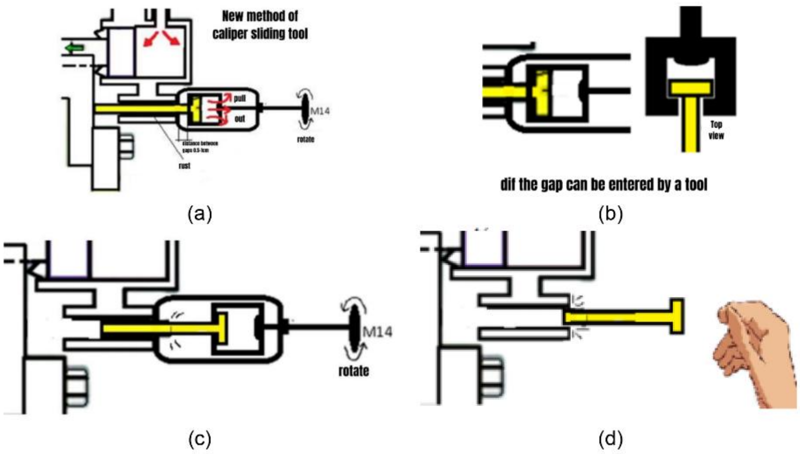

Figure 2. Car front brake caliper construction

The observation procedure before design involves understanding the car's front brake caliper construction (see Fig. 2). This requires evaluating the caliper assembly's layout, components, materials, working principles, and usual arrangement relative to the wheel hub, brake rotor, and suspension parts. Understanding where and how technicians struggle with basic maintenance, repairs, and part replacements is critical. It shows ways to improve accessibility, reduce disassembly time, and reduce caliper pin and component damage. Determine the primary workshop issues by thoroughly identifying caliper servicing pain areas and inefficiencies. We may observe how technicians remove and reinstall caliper sliding pins, note which tools they use, record the average time for each activity, and record any unintended damage or safety issues. Mechanical frustrations including tight workspaces, stubborn pins, and inadequate standard tools can be revealed through mechanic interviews and feedback. By identifying these obstacles, a design solution that solves the most important issues is established, guaranteeing that the special service tool meets end-user needs and improves maintenance.

The newly created sliding caliper tool's general conceptual design is shown in Fig. 3. Each of the four main parts of the assembly contributes to the overall efficiency and longevity of the whole. The mainframe is the sturdy and strong base of the tool, serving as its center body. Its high-strength construction guarantees uniform alignment and even force distribution throughout the extraction procedure. The precise engineering of its shape ensures a snug fit with the space surrounding the brake caliper assembly. The little box-like component known as the hook is responsible for immediately engaging the sliding pin of the caliper. At the very tip of the tool, where it will be used, the hook needs to be strong and accurate. It is designed to latch onto the pin securely without damaging the surface, thanks to its shape and proportions. This part takes the brunt of the force when it's applied, therefore it's important to choose a material that can withstand a lot of stress.

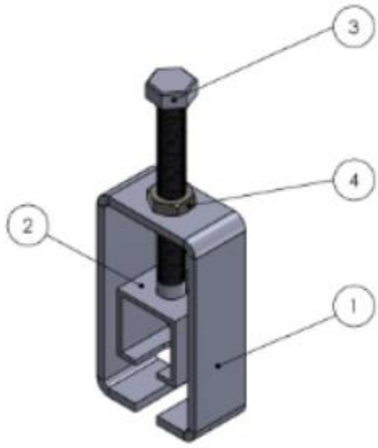

Figure 3. Special service tool design for front brake caliper

A threaded receptacle for the bolt is provided by the nut, which is built into the mainframe. The nut allows for gradual and controlled movement by turning against the threads of the bolt. The nut's threading quality and material hardness dictate the assembly's usability and lifespan. To make adjustments and transfer force, the bolt is the main component. It transfers axial force to the hook by means of the nut and mainframe when turned. By carefully applying pressure in a controlled manner, technicians can remove the caliper pin without causing any harm. This method of design takes cues from the shape and operation of standard piston press tools, tailoring their tried-and-true mechanics to the unique challenge of removing caliper pins. Making advantage of these basic mechanical principles, the design guarantees that the finished tool will be user-friendly, long-lasting in regular workshop use, and compatible with routine maintenance processes.

The durability, practical usefulness, and reliability of the special service tool are tested in two main stages. Comprehensive finite element analysis (FEA) simulations are run prior to tool manufacturing in order to forecast the design's response to operating stress [9]. In this phase, we model the tool in great detail on the computer and run it through a battery of tests meant to mimic actual use. Equivalent Stress (von Mises Stress), Total Deformation, and Safety Factor are three critical metrics that are assessed during the FEA process. Following successful completion of finite element analysis (FEA) simulations, the next step is to construct a tool prototype and test it in a controlled environment. During this step, mechanics and maintenance staff are watched closely while they use the tool on real caliper assemblies. Technicians are interviewed to get their honest opinions on the product's usability, comfort, potential for efficiency gains, and any small problems that may evolve while using it. Trial results, including metrics like pin extraction time and tool smoothness, help validate the instrument's efficacy in real-world settings and inform design decisions.

Interviews are a common way for qualitative researchers to get information, as stated in [9]. Through interviewing respondents in a range of settings, researchers can collect a wealth of data. It is clear from the preceding description that interviews are a great way to get knowledge and data that can serve as the foundation for research. There are a lot of different kinds of interviews and ways they can be administered, such as survey interviews, which are used for more sophisticated research, and interviews that do not involve surveys. In addition, a table confirming and surveying the success rate of tools in solving workshop difficulties is provided below.

3. Result and Discussion

3.1 Finite element analysis

The conceptual model is validated completely before to manufacture during the Finite Element Analysis (FEA) stage, which follows the initial design process. Engineers can test the suggested design under several loading scenarios and limits using sophisticated computational simulations, thereby simulating the tool's operating circumstances. Important performance indicators, such as stress distribution, total deformation, and the consequent safety factor, can be evaluated in this digital testing environment without actually making the tool. That is to say, FEA is a predictive tool that helps designers find possible flaws, maximize material utilization, and fine-tune geometric designs before they invest in expensive production processes. This is a critical step since it verifies that the tool design satisfies structural requirements and that it follows all workshop and industry safety rules. The FEA results assist in establishing a trustworthy safety margin and in guiding required design revisions by identifying regions of high stress or deformation. As a result, stakeholders may move forward with assurance when the design goes into production, knowing that the end result is strong and affordable. In the end, the FEA approach helps to simplify development, lessen the chances of mechanical failure, and create a tool that can endure real-world working circumstances right after it comes out of the factory.

Fig. 4a shows the results of a static structural analysis performed on the special service tool. The purpose of this analysis is to establish the distribution of equivalent (von Mises) stress under a specific load. From blue (low stress) to red (high stress), the color gradient shows the tool's stress levels. Localized areas of high stress are observed around certain geometrical elements, most notably close to the interface between the internal hook and the caliper pin, as well as the adjusting bolt and strain. Engineers can use these stress patterns to find possible weak spots and make sure the sized and material choices can handle the operational forces. In Fig. 4b, the tool's deformation under load is shown using a color scale to describe displacement. Locations tinted blue demonstrate very little movement, whilst areas shaded warmer (green, yellow, red) exhibit increasingly more deformation. The picture makes it very evident how the internal hook and the structures around it bend somewhat when force is applied. There will be some deformation, but overall there will be very little movement, so the tool will keep its shape and function within acceptable design limitations. The distribution of the safety factor across the instrument is shown in this image (Fig. 4c). The color coding moves from red for lower values to blue for greater ones, showing that the majority of the tool keeps a safe distance from the minimally needed threshold. Values over the specified norm indicate that the tool is robust enough to handle ordinary service circumstances without risk of structural failure; the safety factor effectively compares the tool's strength to the applied load [10]. You may rest assured that the design can handle real-world use circumstances with ease and lifetime of the tool, thanks to this figure.

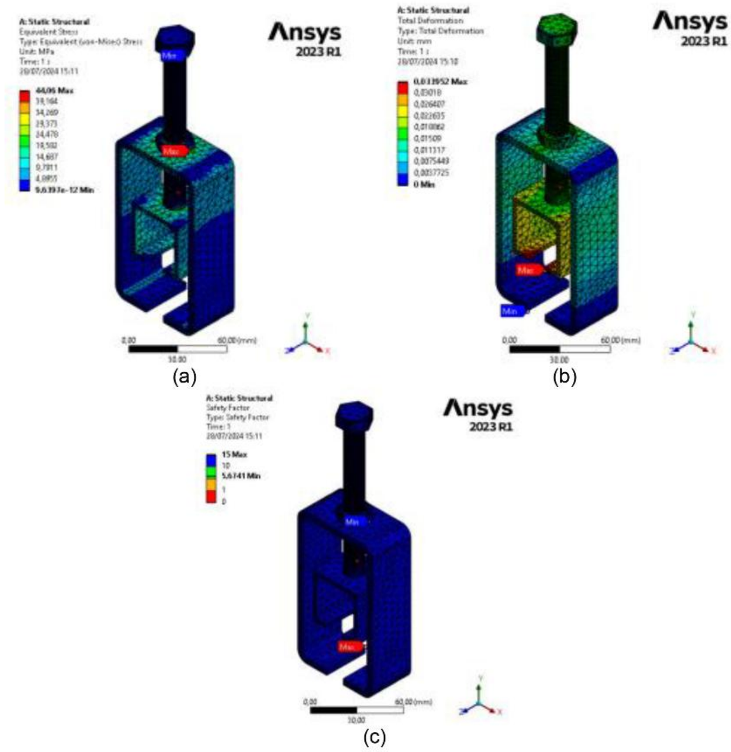

Figure 4. Finite element analysis on (a) stress, (b) total deformation and (c) safety factor

Fig. 5a shows a graph showing the stress that the tool's material undergoes as a function of increasing load (in Newtons). The stress levels (in MPa) are recorded on the vertical axis and different test loads (199 N, 244 N, 342 N, 458 N, 489 N) are applied along the horizontal axis. An increasing internal stress within the tool's structure is indicated by the line's consistent upward trend, which develops in relation to the applied force [11]. The maximum load threshold is depicted by the dashed red line. The stress level stays below the material's yield stress limit even as the tool approaches its greatest tested load, indicating that it can safely manage these loads without irreversible deformation. Under progressively increasing stresses, the tool's deformation (in millimeters) is shown in Fig. 5b. Amount of deformation is shown on the vertical axis, while the horizontal axis indicates the applied load in Newtons. As the weight increases, the tool gently bends or stretches somewhat more, as shown by the plotted line, which demonstrates a progressive climb. The maximum load that has been tested is again indicated by the dashed red line. Even though the deformation is getting slightly worse, the total deformation values are still tiny and perfectly acceptable [12]. This proves the tool is structurally sound and can be bent back into shape when the pressure is released.

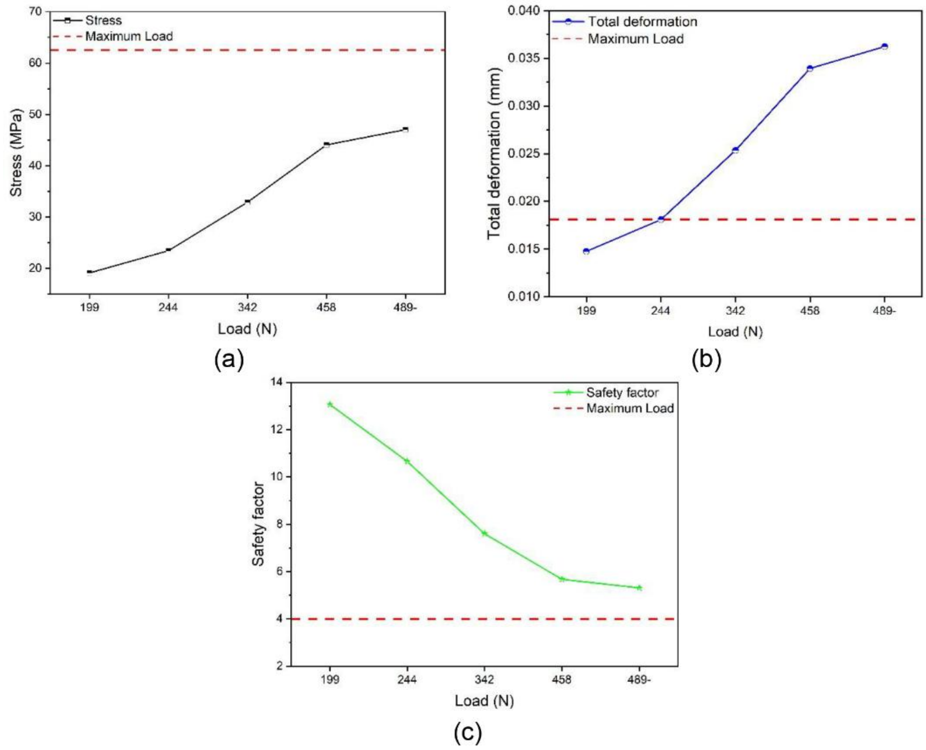

Figure 5. Results on all load variations of (a) stress, (b) total deformation and (c) safety factor

Fig. 5c shows the link between the tool's safety factor and the applied load. At each load level, the computed safety factor is displayed on the vertical axis, while the load levels are listed on the horizontal axis. The safety factor drops as the load goes up, according to the data, which shows a downward-sloping tendency. The safety factor is still more than the lowest allowed threshold, shown by the dashed red line, even when tested under the highest possible load. This verifies that the tool's strength and dependability remain adequate, guaranteeing that it can be used safely under typical working situations [13].

3.2 Special service tool function test

The whole mass of the sliding caliper tool is only 0.742 kg, which makes it both lightweight and sturdy enough for technicians to use without causing any discomfort. The size of its essential parts, as shown in the table below, were thoughtfully chosen to strike a balance between robustness, longevity, and user-friendliness. The instrument finds the best possible fit in the tight quarters that are typical of car repair jobs by continuously improving these measures through validation and iterative design methods. To view the sliding caliper tool specifications, refer to Table 1.

Table 1. The sliding caliper tool specifications

Component	Height	Length	Width	Additional specification
Mainframe	120 mm	70 mm	35 mm	-
Hook	40 mm	40 mm	40 mm	Side to center: 35 mm

The mainframe's height of 120 mm offers adequate vertical room to access the caliper pins without obstructing other brake components. The dimensions of 70 mm in length and 35 mm in breadth have been selected to ensure a compact profile while providing adequate structural stiffness. These dimensions also facilitate the tool's stability and solid positioning during operation, hence minimizing the possibility of slippage or misalignment. The hook's cubic dimensions of 40 mm x 40 mm x 40 mm facilitate its interaction with the caliper pin and adjacent assembly. The balanced dimensions, together with the 35 mm "side to center" size, facilitate an even distribution of force, allowing the hook to securely grasp and remove the pin with minimal chance of bending or damage. This precisely engineered geometry guarantees the hook's efficacy across various front brake caliper designs, enhancing the tool's adaptability in a professional workshop setting.

(a) (b)

Figure 6. Caliper sliding tool: (a) prototype and (b) functional test

The tool testing phase was conducted in the UMC Suzuki Surabaya workshop on Jl. Ahmad Yani, guaranteeing that the assessment transpired under genuine, real-world service conditions. Before executing the extraction, personnel conducted a typical preparatory disassembly of the pertinent brake assembly components. This involved meticulously detaching the brake lining, relevant mounting nuts, and any protective dust boots that could hinder the caliper housing. Through the methodical disassembly of these components, the service team obtained direct access to the caliper pin—the principal focus for the specialist tool. Fig. 6 demonstrates that upon opening the outer shell of the caliper, the caliper pin is easily observable. This unobstructed view is essential for verifying accurate tool alignment and engagement. The illustration serves as a visual guide, assisting technicians in verifying the accuracy of their positioning prior to exerting force. Examining the component in its installed condition enables the team to detect any indications of corrosion, dirt, or debris that may have led to the pin becoming immobilized. Equipped with this knowledge, technicians can implement suitable actions—such as cleaning or lubricating contact points—prior to utilizing the new sliding caliper tool. This preliminary phase is crucial for guaranteeing that the tool assessment appropriately represents daily usage contexts. Adhering to the workshop's standard operating procedures and best practices, the testing process verifies both the mechanical performance of the new tool and its compliance with current maintenance workflows. This methodical methodology facilitates a comprehensive and representative assessment, verifying that the instrument may improve operational efficiency and safety in routine brake system maintenance activities [14].

Table 2. The sliding caliper tool specifications

No	Testing	Name of examiner	Old method	Nes method
1	Test 1	Zainul Chabibi	Fast time frame but high risk	It takes a little longer but is safer
2	Test 2	Endra I.	Old method of damaging the rubber pin	New method minimizes damage to rubber pins
3	Test 3	Amir Mulyanto	Difficult to use, often touches hands and car body	More practical, safer and more comfortable for consumers to see
4	Test 4	Baskara	The old method damaged the screwdriver and components around the caliper.	Safer to use because it does not damage the caliper components.
5	Test 5	Hendri	Not effective for educating interns who are just learning	More effective and safe for intern education

A detailed workshop-based tool function test ensures that results reflect real-world situations rather than theoretical assumptions. This phase tests the novel sliding caliper tool on brake assemblies and compares it to earlier approaches. For meaningful, multi-dimensional feedback, experienced mechanics and automobile maintenance specialists are encouraged to participate in the assessment. Compared to the old technique, these experts provide key insights on ease of use, ergonomics, efficiency, safety, and efficacy. Table 2 summarizes structured interviews and hands-on observations as a significant evaluative component. When technicians finish maintenance using the old and new methods, they rate and remark on the procedure. Pin removal time, exertion, unintentional damage, and workshop safety norms are recorded. They include qualitative input like how pleasant the tool is to use and whether it simplifies extraction with quantitative indicators like average maintenance duration and error rates [15]. Testing the instrument with professional judgment and direct user experience ensures its technical compliance and real-world viability. These findings strengthen the tool's design, guide usage, and prove that the new way boosts workshop efficiency and safety.

4. Conclusion

The specialised front brake caliper sliding tool was designed through extensive study, load testing, and iterative design. Simple design streamlines manufacturing and makes normal maintenance easy. Final dimensions are divided into three components, each with a vital role in tool functioning. The mainframe is 12 cm x 6.5 cm x 3.5 cm, the hook frame is 4 cm x 4 cm x 3.5 cm, and the nut and adjuster assembly is 12 cm/M14. With a 2-millimeter dimensional variance, these measured values match the planned design criteria. The equipment is sturdy but lightweight at 0.742 kg, making it easy for technicians to use. Field application and prototype testing show that the new tool overcomes critical maintenance issues. This approach removes stuck caliper pins gently and effectively without using improvised or dangerous equipment. It avoids collateral damage to surrounding components, reducing operational downtime and replacement expenses. The instrument also passed workshop and quality assurance standards for official approval and audit compliance. Materials engineering-wise, the iron alloy's 250 MPa tensile yield strength and 3.99 minimum safety factor exceed the industry standard of 1.5. This large safety margin proves the tool can sustain regular workshop loads without compromising integrity or safety. Analysis, including FEA, has confirmed the tool's structural integrity and manufacturability. Performance testing in real life support these conclusions. The tool consistently extracts even the most tenacious caliper pins without lasting damage or bending, matching simulation model durability. The new tool's extraction procedure is 8 seconds slower than the old method, but the improved safety profile, reduced tool slippage risk, and audit and regulatory compliance make up for this. The old method may be faster, but it is unsafe and could harm caliper components, making it inappropriate for modern safety and quality standards.

Conflict of interest

The authors declare no conflict of interest.

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