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Development of Special Service Tools Tracker Kingpin Hino Series 300 to Increase Technician Work Efficiency

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ABSTRACT

This study focused on the design, development, and evaluation of a Special Service Tool (SST) created explicitly for maintaining kingpin components in Hino Series 300 trucks. The research focused on the challenges and safety issues encountered by technicians stemming from the lack of specialized tools for kingpin removal. This often led to extended service times, variable repair quality, and a heightened risk of damaging components. To address these challenges, the research employed the ADDIE development model, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation. In the design phase, 3D modeling was performed using SolidWorks, and Finite Element Analysis (FEA) was conducted to verify the tool's structural integrity under various load scenarios, reaching up to 19,613 N. The SST was made from ASTM A36 steel, recognized for its mechanical strength and ease of manufacturing. The simulation results demonstrated that the structure stayed within safe limits for both stress and deformation, achieving a minimum safety factor of 1.1. The implementation took place at PT. MPM Hino Yogyakarta, where field testing showed a significant enhancement in technician efficiency. The SST cut down kingpin maintenance time from 360 minutes to only 42.08 minutes, achieving an impressive 88.3% reduction in time spent. Testing for effectiveness, based on feedback from technicians and supervisors, revealed a high level of user satisfaction, particularly in terms of safety, usability, and ergonomic design. The SST tracker kingpin provides a dependable, effective, and secure option for maintaining commercial vehicles. The successful application of it at a Hino service center highlights its practical benefits and the potential for wider implementation throughout the automotive maintenance sector. Additional improvements could involve ergonomic adjustments and the ability to accommodate various truck models, thereby facilitating broader use.

1. Introduction

Transportation plays a vital role in supporting human life, especially in the industrial sector. In Indonesia, the demand for freight transportation continues to increase in line with population growth and economic development. Currently, people not only rely on private vehicles, such as motorcycles and cars, to support their daily activities, but also utilize public transportation, including buses and trucks, for freight transportation [1]. PT. Hino Motors Sales Indonesia (HMSI) and PT. Hino Motors Manufacturing Indonesia (HMMI) is a company that collaborates with Hino Motors to provide vehicles and after-sales services, particularly Hino trucks, which are known for their reliability in the logistics industry [2].

PT. Mitra Pratama Mobilindo Hino Yogyakarta, as part of PT. Sun Motor Group is responsible for distributing and maintaining Hino brand vehicles in the Yogyakarta region. Hino is renowned for the quality and reliability of its products. PT. MPM Hino Yogyakarta, as an official Hino dealer, sells high-quality trucks designed for durability, efficiency, and excellent performance. Hino trucks are engineered to withstand various road conditions and heavy workloads to create a better world through support for safe, economical, and environmentally friendly transportation [3]. Hino is committed to maintaining environmental sustainability by adhering to the principles of sustainable development, in line with the company's vision. Below is the Hino and MPM logo

One of the critical components in this vehicle is the kingpin, which plays a crucial role in safety and driving performance [4-6]. This component determines the vehicle's direction, and if it does not function properly, it can compromise the driver's safety, specifically the steering system. MPM Hino Yogyakarta currently lacks specialized tools or special service tools (SSTs) for handling the kingpin, resulting in slow repair processes that require significant effort and pose risks of damaging other components. This results in prolonged vehicle downtime, which impacts business operations and increases costs. Here is an image of the kingpin component in Fig. 1.

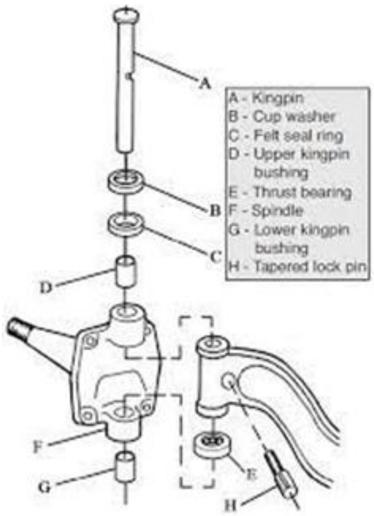

Figure 1. The kingpin component

This issue highlights the urgency of developing specialized SST to facilitate technicians in handling kingpin repairs. Additionally, the absence of kingpin trekker products in the Indonesian market presents a significant opportunity for innovation in this tool, which would not only benefit PT. MPM Hino Yogyakarta also drives changes across the Indonesian automotive industry as a whole. According to Nwanya et al. [7] , the efficient utilization of resources in the manufacturing industry is crucial for minimizing downtime and maximizing productivity. This aligns with PT. MPM Hino Yogyakarta needs to enhance the efficiency of the kingpin repair process. Downtime caused by difficult-to-repair kingpin issues results in operational losses that not only impact efficiency but can also reduce customer satisfaction, as outlined by Patel, Jigar K [8] regarding the importance of preventing equipment damage to reduce downtime.

Meanwhile, Dobromirov et al. [9] emphasize that effective vehicle maintenance is crucial for ensuring safety and optimal performance. The kingpin, as a critical component of the steering system, requires specialized maintenance because damage to this part can affect driving safety. Without adequate SST, technicians must resort to manual methods, such as hammers and chisels, which are not only dangerous but also inefficient, as highlighted by Titu et al. [10] in their emphasis on the importance of using specialized tools for quick and accurate repairs.

Alternative solutions to address this issue involve several approaches. One is to enhance technicians' skills through intensive training to optimize the use of existing tools [11]. However, this approach cannot fully address the issues of time and safety risks. Another alternative is to outsource difficult kingpin repair work to external welding shops, but this only increases costs and extends downtime.

The best solution proposed in this study is to design and develop a kingpin trekker as a specialized SST that can accelerate and secure the repair process. With this tool, technicians will be more efficient in handling repairs, reduce the risk of damaging other components, and shorten vehicle downtime. The development of this SST not only addresses the urgent needs of PT. MPM Hino Yogyakarta also offers innovations that can be applied across the broader automotive industry. This research is urgently needed to provide solutions that directly impact productivity improvements, cost savings, and workplace safety at PT. MPM Hino Yogyakarta, as well as its potential application in the commercial automotive industry in Indonesia.

2. Methodology

This study utilized the Research and Development (R&D) approach, emphasizing the systematic design, creation, and refinement of innovative tools or products aimed at addressing practical problems in real-world contexts. The study utilized the ADDIE development model to structure the development process effectively. This well-known instructional and engineering design framework consists of five interconnected phases: Analysis, Design, Development, Implementation, and Evaluation. Every phase has a distinct purpose to ensure that the tool is both technically sound and user-focused while also being functionally dependable. The ADDIE model was chosen for its iterative approach and capacity to adjust according to ongoing feedback, which makes it especially effective for creating mechanical tools utilized in industrial maintenance. During the Analysis phase, we evaluated the needs of the technicians and the limitations of the current tools. The Design phase included creating technical drawings and running simulations to verify the tool's mechanical integrity. The Development phase concentrated on creating prototypes by utilizing suitable materials and machining methods. During the Implementation phase, the prototype underwent testing in a genuine workshop setting to assess its performance in real-world operational conditions. Finally, the Evaluation phase involved both numerical and descriptive assessments like efficiency testing, user feedback, and structural integrity checks to assess the tool's overall effectiveness and identify areas for improvement.

2.1 Analysis Stage

The analysis phase focused on uncovering the real needs and challenges encountered by technicians in the kingpin maintenance process at PT. MPM Hino Yogyakarta. Observations made in the field, along with organized interviews with workshop personnel, including technicians, foremen, and service advisors, revealed various significant inefficiencies in the existing maintenance workflow. The workshop was particularly lacking a dedicated kingpin puller, leading technicians to use makeshift tools, such as hammers and chisels, instead. This not only prolonged the maintenance period often going beyond six hours but also posed a significant risk of collateral damage to nearby suspension and steering components. The manual removal process also created ergonomic and safety risks for the technicians, particularly during repetitive tasks. The lack of standardized tools resulted in varying maintenance outcomes and a decline in overall service quality. This phase also involved a thorough evaluation of the physical and technical needs of the proposed tool to tackle these issues. We identified key parameters, including operational force, working clearance, material strength, and compatibility with the existing workshop infrastructure. The team recorded the dimensions and limitations of the Hino Series 300 kingpin assembly to guide the design specifications. This groundwork established a crucial foundation for the subsequent design and development phases, ensuring that the final tool would be both effective and tailored to real-world conditions.

2.2 Design Stage

The design phase focused on conceptualizing and intricate modeling of the Special Service Tool (SST) using SolidWorks, a widely recognized 3D computer-aided design (CAD) software commonly employed in precision engineering tasks. This phase converted the initial design requirements identified during the analysis stage into a functional prototype model that considered dimensional accuracy, load-bearing capacity, technician ergonomics, and compatibility with the existing kingpin assembly of Hino Series 300 trucks. The modeling process included several iterations, with each design version undergoing careful review and modifications based on expected mechanical stresses, alignment tolerances, and ease of assembly. Finite Element Analysis (FEA) was performed on the 3D model to assess the structural performance of the tool under simulated real-world operational conditions. The tool underwent load tests varying from 500 kg to 2000 kg, reflecting the anticipated force needed to free a jammed kingpin. The simulations provided insights into Von Mises stress distribution, total deformation, and safety factors, which were crucial for pinpointing critical stress areas and confirming that the tool would withstand the load without failure.

The analysis demonstrated that the SST maintained its structural integrity when subjected to the maximum load, exhibiting acceptable deformation limits and a minimum safety factor of 1.1. The results gave assurance of the tool's mechanical strength. Simultaneously, the selection of materials was carried out with an emphasis on both mechanical strength and manufacturability. The tool components were primarily crafted from ASTM A36 mild steel, chosen for its excellent combination of strength (yield strength of 250 MPa), weldability, and affordability, making it ideal for medium-duty mechanical applications, such as vehicle service equipment. Additionally, design considerations included user ergonomics, focusing on hand placement, accessibility in tight spaces, and ease of alignment during operation, all aimed at reducing technician fatigue and minimizing the risk of injury. This stage resulted in a fully developed digital prototype that satisfied both structural and practical use-case requirements, making it ready to move on to the development and fabrication phase.

2.3 Development Stage

During the development phase, the prototype of the Special Service Tool (SST) was created using the finalized CAD model and the structural simulations that were completed in the design stage. The production activities took place at a local machining and fabrication workshop, Baja Karya, which had the necessary metalworking facilities appropriate for medium-scale tool manufacturing. This stage represented the shift from virtual modeling to actual production, making certain that every design specification could be converted into a real and functional product. The manufacturing process included a series of precise fabrication steps, beginning with the cutting of ASTM A36 steel profiles, plates, and hollow sections to match the component dimensions specified in the engineering drawings. The cut materials were subsequently machined and turned on lathes and milling machines to achieve precise geometries and surface finishes, particularly for critical components such as the housing mount, locking pin shafts, and hydraulic jack seat.

After machining, welding operations were carried out to connect the structural frame, adjuster supports, and reinforcement brackets using arc welding techniques. Attention was given to ensuring the integrity of the welds and proper alignment to uphold the overall strength of the tool and its dimensional accuracy. Next, drilling and tapping processes were performed to create threaded holes for bolt connections and alignment points. After the mechanical assembly was completed, the tool underwent a thorough surface finishing treatment to enhance its durability and visual appeal. This process involved grinding and sanding to remove surface burrs and welding spatter, followed by the application of automotive-grade putty to address minor imperfections. A coat of epoxy primer was applied to enhance corrosion resistance and improve the adhesion of the final paint layer. The finishing process wrapped up with spray painting in industrial yellow enamel paint, selected for its visual appeal and high visibility in workshop settings improving safety and aiding in tool identification.

2.4 Implementation Stage

The implementation phase included deploying and testing the developed Special Service Tool (SST) in a real operational environment at PT. MPM Hino Yogyakarta, utilizing a Hino Series 300 Dutro 110 SD truck that had been diagnosed with kingpin seizure. This phase acted as an essential validation step to evaluate the tool's performance in real service conditions. The testing scenario was designed to replicate the everyday challenges faced by workshop technicians, ensuring the results would apply to regular maintenance tasks. Two comparative procedures for kingpin replacement were conducted to evaluate the tool's effectiveness and efficiency. During the initial procedure, technicians carried out the disassembly using conventional manual tools, including hammers and chisels approaches typically employed when specialized equipment is unavailable. During the second procedure, the same technicians performed the replacement with the newly developed SST. This system featured a 2-ton hydraulic bottle jack that was integrated into a guided pulling mechanism, allowing for the safe extraction of the kingpin with minimal manual effort.

During the trials, technicians recorded the total time needed for each method by following standardized timing protocols. Furthermore, qualitative observations were made on several important aspects: (1) usability, which encompassed ease of operation, alignment precision, and ergonomic comfort; (2) safety, which emphasized the reduction of physical strain and the risk of component damage; and (3) time efficiency, measured by comparing the durations of both procedures. The test results showed a significant decrease in service time from about 360 minutes (6 hours) with traditional methods to just 42.08 minutes using the SST indicating an improvement in time efficiency of more than 88%. Additionally, utilizing the SST eliminated the need for continuous hammering, which reduced the risk of injury and prevented accidental damage to nearby components, such as bushings, axles, and suspension brackets.

2.5 Evaluation Stage

The evaluation phase aimed to thoroughly examine both the functional performance and user perception of the Special Service Tool (SST) created for kingpin removal on Hino Series 300 trucks. This phase was carefully divided into two primary components: efficiency testing and effectiveness testing, with each focused on validating distinct aspects of the tool's performance. For the efficiency assessment, we gathered quantitative data by comparing the total time taken to complete the kingpin replacement task using two different methods: (1) the traditional manual approach and (2) the SST-assisted approach. The results showed a significant reduction in task duration, with the traditional process taking around 360 minutes, while the SST-assisted procedure finished in only 42.08 minutes. The significant time difference of over 320 minutes, representing an 88% reduction, highlights the SST's ability to minimize downtime and significantly improve service throughput in workshop settings.

A structured questionnaire was created and sent out to three participants for the effectiveness assessment: two seasoned technicians and one foreman, all of whom played a direct role in the testing process. The questionnaire utilized Likert-scale and Guttman-scale tools to assess the level of agreement and binary performance evaluations across various key indicators. Factors considered included the availability of tools, user-friendliness, safety during operation, mechanical dependability, ergonomic design, and the perceived quality of construction. The Likert-scale results indicated an apparent inclination towards positive responses, as most indicators were rated as "Agree" or "Strongly Agree." This demonstrates a strong sense of user satisfaction, particularly regarding the tool's practical usability and intuitive handling in the field. In the meantime, the Guttman-scale analysis, which concentrated on Yes/No responses regarding technical performance and durability, achieved a flawless affirmative score of 100%. This result indicates a strong consensus among users that the tool met or exceeded all operational expectations.

Additionally, user feedback highlighted that the SST offered a more controlled, safer, and physically efficient option compared to the earlier manual method. Participants observed that the tool reduced the need for brute force, enhanced technician posture during use, and helped prevent possible damage to nearby components, such as axle housing and bushings. The results clearly showed that the SST enhanced both quantitative efficiency metrics and received positive qualitative feedback from the end users. Following a thorough dual evaluation, the tool was found to be technically effective and ready for field use, showing promise for broader integration into commercial vehicle maintenance processes.

3. Result and Discussion

3.1 Design of special service tools tracker kingpin

The unique kingpin tracking tool's design is depicted in Fig. 2. Aside from the main frame and top cover, there are seven more important parts: the frame adjuster, the hydraulic jack bottle, the seven-pin locking pin, the bottom cover, and the kingpin store. As you work to maintain the kingpin, each part is engineered to give you the assistance and functionality you need. In order to maintain stability and strength while it is in operation, the main frame serves as the principal structural support. To keep the kingpin housing in place and stable while the hydraulic jack applies pressure, the top cover is fastened. With the help of the frame adjuster, you can position and align the tool with pinpoint accuracy, making it easier to use and more precise. Aside from that, while the kingpin is being removed, it is securely housed in the kingpin storage. The tool is designed with a locking pin to prevent the kingpin from moving accidentally, a hydraulic jack bottle to provide the powerful mechanical force needed to remove it, and an M17 bolt to secure everything together, making it reliable and safe.

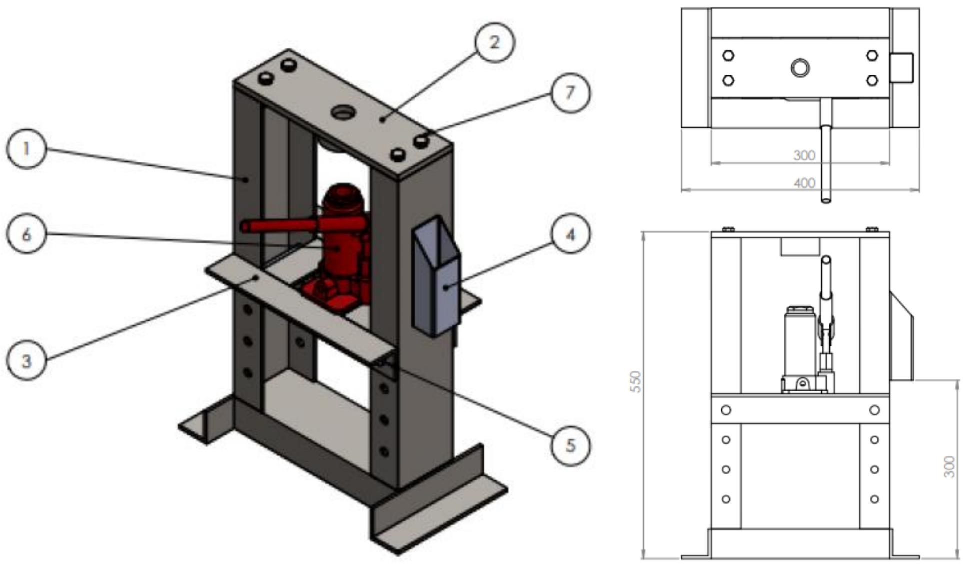

Figure 2. Design special service tools tracker kingpin

Table 1 shows the component name of the special service tools tracker kingpin. The main frame design of this tool serves as a support for the frame adjuster and jack. This main frame is made of 10mm thick UNP 100 iron and measures 200 x 400 x 550. The height of this main frame is 55 cm. The selection of UNP 100 material was made because it has high strength and durability, is capable of withstanding heavy loads, and is resistant to deformation and external pressure. With its sturdy structure, the main frame ensures the device's overall stability, enabling it to operate safely and efficiently under various working conditions.

The top cover functions as a kingpin retainer when the jack is in operation. This top cover is equipped with four 17 mm bolt holes to connect the top cover to the main frame. The Top Cover is made of a 1 mm thick steel plate with dimensions of 400 mm in length, 40 mm in height, and 100 mm in width. A 10 mm thick steel plate is chosen to ensure strength and stability during operation, thereby reducing the risk of deformation or damage when bearing loads. This design is also engineered to facilitate assembly and disassembly, thereby simplifying maintenance.

The frame adjuster is used to adjust and set the frame position to suit the needs and specifications of the tool being used. This ensures that the frame remains stable and precise during operation, thereby improving work efficiency and safety. With maintained precision, the frame adjuster also helps reduce the risk of errors in tool operation, provides comfort for technicians while working, and minimizes potential damage to other components. The frame adjuster is made from high-quality angle iron measuring 50 x 50 x 5 mm with a length of 400 mm, providing optimal strength and durability for long-term use.

Table 1. Component names special service tools tracker kingpin

No	Part name	Material	Dimension	Quantity
1	Main Frame	Standard	200 x 400 x 550	4
2	Top Cover	Iron Plate	40 x 100 x 300	1
3	Frame Adjuster	Angle Iron	50 x 202 x 300	1
4	Storage Kingpin	Hollow Iron	40 x 50 x150	1
5	Locker Pin	Solid Iron	Ø15 X 135mm	2
6	Jack Hydraulic Bottle 2 Ton	Standard	2 TON	1
7	Bolt M17	Standard	M17	4

This storage kingpin is designed as a special container for storing kingpins that are to be replaced or used kingpins that have been removed using special service tools. This storage kingpin is designed to ensure the safety and cleanliness of the kingpin during storage, thereby reducing the risk of contamination or damage to kingpins that will be reused. The tool is made from high-quality 5mm angle iron, providing the structure with strength and stability. The dimensions of the storage kingpin are as follows: a side width of 40 mm, a front width of 50 mm, and a height of 150 mm. This design provides sufficient space while remaining compact and easy to integrate into the work environment.

This locker pin serves as a lock for the frame adjuster, which is connected to the main frame. The locker pin is made of solid iron with a diameter of 15 mm at the head and 10 mm for the body. The locker pin measures 135 mm in length. The selection of solid iron as the primary material ensures high durability, capable of withstanding the pressure and forces that arise during operation without risk of failure [12, 13]. Its precise design also allows for quick installation and removal, facilitating adjustments or routine maintenance. This is crucial for maintaining the tool's overall performance and ensuring safety during use.

3.2 Simulation results of special service tools tracker kingpin

The results of design simulations with various load variations, namely 4903 N, 9806 N, 14709 N, and 19613 N. These simulations were conducted to analyze the structure's response to the applied loads, including stress values, deformation, and the resulting safety factors. The material used was ASTM A36.

This locker pin serves as a lock for the frame adjuster, which is connected to the main frame. The locker pin is made of solid iron with a diameter of 15 mm at the head and 10 mm for the body. The locker pin measures 135 mm in length. The selection of solid iron as the primary material ensures high durability, capable of withstanding the pressure and forces that arise during operation without risk of failure. Its precise design also allows for quick installation and removal, facilitating adjustments or routine maintenance. This is crucial for maintaining the tool's overall performance and ensuring safety during use.

Fig. 3a shows that the structure undergoes deformation of 566.277 mm and stress of 55.42 MPa under a load of 4903 N, as shown in the simulation results. The simulation yielded a safety factor of 4.5, as shown in Fig. 3b. These results demonstrate that the intended structure can reliably withstand operational loads without any structural damage. Although there is quantifiable deformation, it remains within the tolerated limit, indicating that the structure is stable under the projected operating conditions. In addition, the tool has a strong margin of strength, as indicated by its high safety factor, which means it can safely handle additional stresses above the tested load. That the specialized kingpin tracking gadget will last and work as intended when used in actual car repair procedures is reassuring.

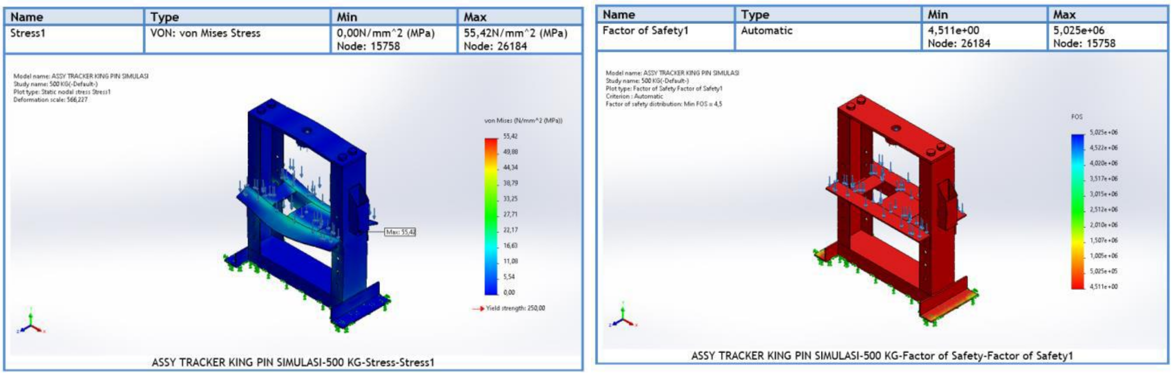

Figure 3. Simulation results at a load of 4903 N: a) Stress and b) Safety factor

The structure experiences a stress of 110.84 MPa and a deformation of 283.114 mm under a load of 9806 N, as shown in Fig. 4. This simulation yielded a safety factor of 2.3. This safety factor indicates that the tool's structural integrity remains adequate, even though there is less room for extra loading than in the lower load situation previously. There is a notable decrease in deformation at this higher load, indicating enhanced structural stiffness and efficient force distribution, even if the stress levels are significantly higher.

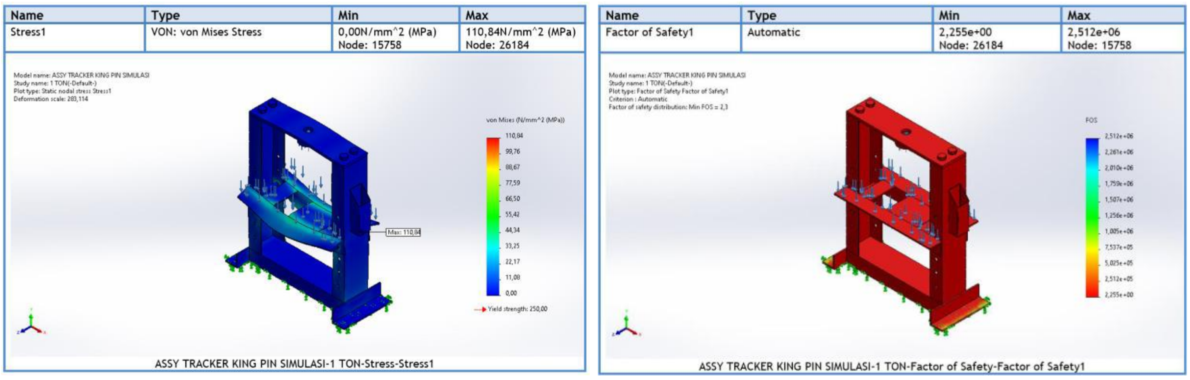

Figure 4. Simulation results at a load of 9806 N: a) Stress and b) Safety factor

Fig. 5 indicates that when the load is 14,709 N, the structure is under stress of 166.26 MPa and is deformed by 188.742 mm. The simulation gives us a safety factor of 1.5. This number shows that the structure can still handle the weight with a respectable level of safety. However, the margin is smaller than it would be with a lower load. The deformation observed is acceptable and does not impact the tool's performance or alignment when in use. However, the fact that the safety factor decreases as the load increases indicates that using something near this load threshold for an extended period or repeatedly should be done with caution.

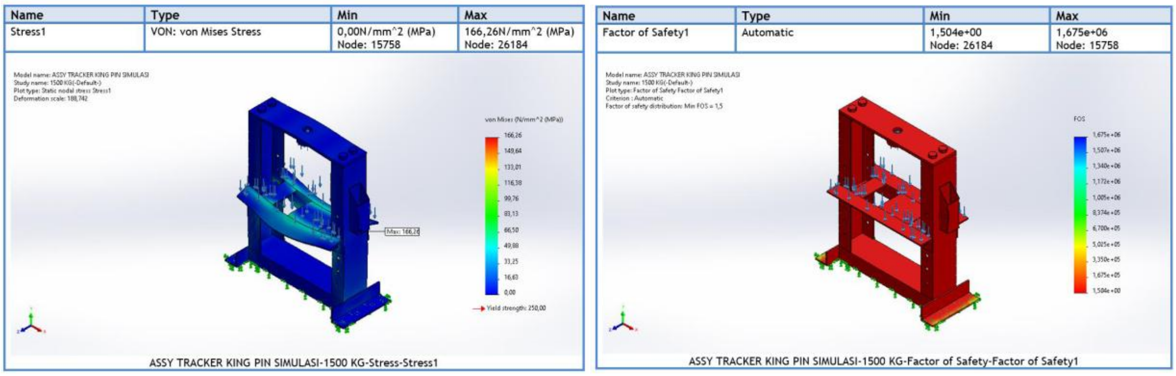

Figure 5. Simulation results at a load of 14709 N: a) Stress and b) Safety factor

The simulation results reveal that the structure undergoes a stress of 221.68 MPa and a deformation of 141.557 mm under a load of 19,613 N, as shown in Fig. 6. Fig. 6b shows the safety factor that was achieved from this simulation, which is 1.1. This number indicates that the structure is likely to be unable to withstand much more stress before it breaks. Although the distortion is still below permissible limits, structural collapse or permanent deformation could occur with any additional increase in load due to the low safety factor.

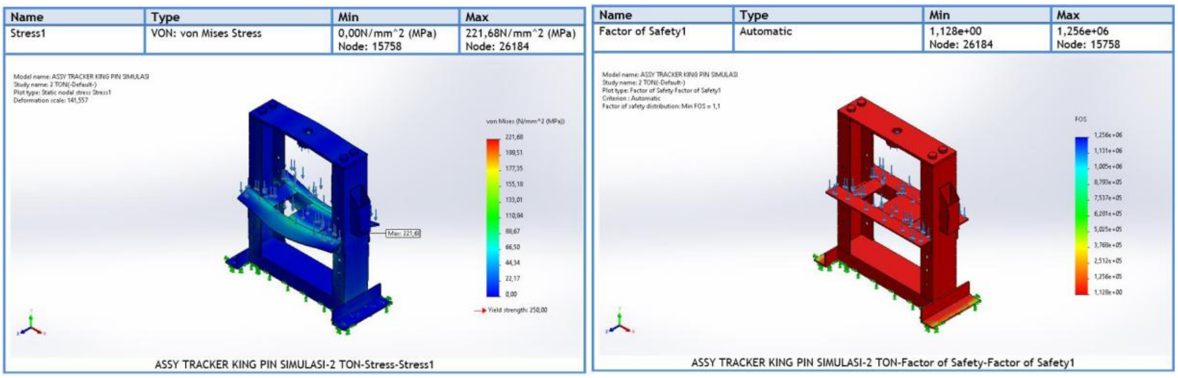

Figure 6. Simulation results at a load of 19613 N: a) Stress and b) Safety factor

The kingpin of the special service tool tracker prototype is shown in Fig. 7a. Pressing down on the jack lever causes resistance, which is used to detect the kingpin application of the testing tool (Fig. 7b). Fig. 7c shows the results of the successful testing of the special tracker kingpin tool, which proved to help handle stuck kingpin components. This demonstrates that the hydraulic jack mechanism can generate sufficient force to disassemble components that are often difficult to remove by hand. Moreover, the tool's structural integrity remained unaltered throughout the procedure, demonstrating its reliability and endurance under operational stress. The test's positive results demonstrate that the SST can reduce time, effort, and risk during kingpin removal operations, thereby significantly improving maintenance procedures.

(a)

(b)

(c)

Figure 7. Special service tools tracker kingpin: a) prototype, b) and c) prototype testing

The simulation results from the special service tools tracker kingpin offer important insights into how the tool behaves structurally and its mechanical limits when subjected to different load conditions. The structure was evaluated through Finite Element Analysis (FEA) under loads of 4903 N, 9806 N, 14,709 N, and 19,613 N, reflecting a variety of realistic operational stresses faced during kingpin maintenance. With a minimum load of 4903 N, the observed stress was 55.42 MPa, resulting in a deformation of 566.277 mm and a safety factor of 4.5. The impressive safety factor highlights the tool's strong structural redundancy and durability during light to moderate use, ensuring it can handle occasional overloading without issue.

With the increase in load, a clear pattern emerged: stress and deformation escalated, whereas the safety factor diminished. At 9806 N, the tool underwent a stress of 110.84 MPa and a deformation of 283.114 mm, resulting in a safety factor of 2.3, which remains within acceptable limits for mechanical operations. At 14,709 N, the stress rose to 166.26 MPa, the deformation fell to 188.742 mm, and the safety factor decreased to 1.5. Even though the structure continued to function, this decreasing safety margin indicates a point at which ongoing use might jeopardize its long-term dependability. Under the highest load tested at 19,613 N, the stress reached a maximum of 221.68 MPa, accompanied by a deformation of 141.557 mm, leading to a safety factor of only 1.1. This value, although still above the critical limit, suggests that the tool is nearing its yield point and should not be regularly employed in such extreme conditions.

The results of these simulations indicate that the SST design is mechanically robust under standard operating loads and possesses adequate durability for practical use. They emphasize the need to establish a safe working load limit for regular use to prevent fatigue or structural failure in the long run. The decreasing safety factor at increased loads highlights the importance of establishing appropriate usage guidelines and regular inspection routines. In summary, the simulation confirms that the SST tracker kingpin is a dependable, high-strength tool designed for medium-duty service tasks, ensuring both operational safety and performance efficiency.

3.3 Efficiency of special service tools tracker kingpin

Efficiency testing was carried out to measure the improvement in work efficiency gained by using Special Service Tools (SST) for kingpin trekkers in comparison to traditional manual methods. The testing was conducted at PT. Mitra Pratama Mobilindo Hino Yogyakarta, utilizing a Hino Series 300 Dutro 110 SD unit that had been identified with kingpin problems. Two distinct methods were employed for the kingpin replacement task: the first involved traditional tools and techniques, such as hammers and chisels. At the same time, the second made use of the specially developed SST tracker kingpin.

The findings showed a significant variation in performance between the two methods. The conventional approach took approximately 360 minutes (6 hours) to complete the kingpin replacement, underscoring its lengthy and labor-intensive nature. On the other hand, utilizing the SST allowed the same procedure to be completed in just 42.08 minutes. This represented a significant decrease of 320 minutes, translating to an 88.3% enhancement in time efficiency. This significant reduction enhances productivity in the workshop while also reducing vehicle downtime, enabling commercial units to return to work more quickly and improving service delivery to customers.

Additionally, utilizing the SST greatly reduces the physical strain on technicians by eliminating repetitive, labor-intensive tasks, such as hammering. This enhances occupational health and safety, reducing the likelihood of work-related injuries and technician fatigue. In addition to the numerical assessment of efficiency, it was crucial to confirm the tool's performance in real-world scenarios. As a result, effectiveness testing was carried out by distributing structured questionnaires to the technicians and supervisors participating in the trial. The assessment centered on three main areas: the tool's availability when required, its operational performance during kingpin removal, and the overall quality of construction and ergonomics. The gathered feedback provided important insights into user satisfaction and validated the tool's reliability and usefulness in the field.

4. Conclusion

The kingpin components of Hino Series 300 trucks were the focus of this study's successful development of a Special Service Tool (SST). A systematic approach was ensured throughout the development process, from analysis to assessment, by following the ADDIE methodology. Using SolidWorks for initial design and modeling, the instrument was then structurally validated through Finite Element Analysis (FEA) to assess its mechanical performance under various loading conditions. The material that was chosen, ASTM A36 steel, is ideal for medium-duty automotive maintenance applications due to its cost-effectiveness, machinability, and attractive strength-to-cost ratio. With stress and deformation values kept within acceptable ranges, the tool was found to be capable of securely withstanding operational loads up to 19,613 N, according to the simulation results. The tool's structural integrity and appropriateness for actual field use in high-stress settings were confirmed by the minimum recorded safety factor of 1.1 under maximum load conditions. A Hino Series 300 Dutro 110 SD unit was used for field testing at PT. MPM Hino Yogyakarta to assess the tool's performance in real-world conditions. A remarkable time savings of around 88.3% was achieved by the SST, which reduced the kingpin replacement time from 360 minutes to just 42.08 minutes, demonstrating a significant improvement in technician labor efficiency. By eliminating potentially harmful manual procedures, such as hammering, the instrument enhanced technician safety and reduced the risk of damage to nearby components, including axle housings and bushings. The tool's practical efficacy in a workshop setting is further supported by the significant favorable reactions to its usability, operational safety, ergonomic design, and durability, as indicated in the user feedback obtained through structured questionnaires. Ultimately, the developed SST tracker kingpin is an efficient, safe, and sturdy solution that addresses critical issues in commercial truck maintenance. It enhances uniformity in repair results, increases job safety, and reduces labor time without compromising service quality. Thanks to its effective deployment at PT. MPM Hino Yogyakarta, this product is already useful for Hino's service networks. The design may not be perfect, but it is adaptable and efficient, offering hope for its widespread adoption in the truck repair sector. Improving the tool's adaptability to different vehicle types, making it more ergonomic to lessen technician weariness, and investigating scalable manufacturing methods for nationwide distribution and mass production should be the priorities of future development.

Conflict of interest

The authors declare no conflict of interest.

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