E-BOOK OF EXTENDED ABSTRACT

THE 14TH INTERNATIONAL INVENTION, INNOVATION & DESIGN COMPETITION 2025

14TH INDES 2025

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DESIGN AND FABRICATION OF SPECIALIZED WRENCH FOR CONFINED SPACES APPLICATION

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ABSTRACT

Wrenches are essential tools in maintenance and assembly work, but conventional designs often prove ineffective in confined environments such as under sinks, where reach and flexibility are limited. This study aims to design and fabricate a specialised wrench that enhances usability in such restricted conditions. The research began with a user survey to identify key usability challenges experienced in real-life working environments. Design requirements were then derived using the Quality Function Deployment (QFD) method, which helped prioritise user needs and technical specifications. Conceptual designs were generated using the TRIZ methodology and a morphological chart to explore innovative solutions. Three conceptual wrench designs—A, B, and C—were developed and evaluated through a weighted decision matrix based on criteria such as grip, adjustability, manufacturability, and suitability for tight spaces. Among the three, Design A achieved the highest score and was selected for further development due to its potential to significantly improve grip, ease of adjustment, and accessibility in confined areas. The selected design was modeled using SolidWorks CAD software, prototyped using 3D printing, and then fabricated through the sandcasting method, utilising Aluminium 6063 due to its favorable strength and weight properties. Post-fabrication processes included surface finishing and visual inspection to assess porosity and ensure surface quality. Real-environment testing was conducted under a sink setup to evaluate the performance of the developed wrench compared to a conventional wrench. The results demonstrated that the newly developed wrench provided superior handling, better access, and increased efficiency. In conclusion, this study successfully developed a functional tool suitable for use in confined spaces.

Keyword: wrench, confined space tools, ergonomic design, sand casting

INTRODUCTION

The need for special tools in confined spaces is increasing due to the growing complexity of modern equipment and installations (Botti et al., 2022; Dimitropoulos et al., 2024; Wang et al., 2025). A wrench is a tool that is used to grip and turn things such as nuts and bolts. Existing wrench designs generally assume adequate workspace clearance, which is rarely the case in maintenance operations within domestic or industrial settings. Despite the availability of various wrench types, many fail to address the usability challenges in confined spaces. In such spaces, users face restricted movement, poor access angles, and fatigue due to awkward tool positions. These ergonomic constraints may lead to inefficient task completion and discomfort over time. This raises the question of how wrenches can be designed and fabricated to improve usability and ergonomic considerations in confined spaces such as under sinks when compared to conventional wrenches. This study aims: 1) to design and fabricate a user-

friendly specialised wrench suitable for confined spaces; 2) to validate the performance of the developed wrench by comparing it with a conventional wrench in real-use scenarios.

METHODOLOGY

This study began with a survey involving 33 respondents, including plumbers and technicians, to identify the issues encountered when using conventional wrenches in confined spaces. The data collected were used to establish design guidelines. Design requirements were acquired through the Quality Function Deployment (QFD) method. Three conceptual wrench designs were generated based on the Theory of Inventive Problem Solving (TRIZ) and a morphology chart. The designs were evaluated using a weighted decision matrix, and the selected design was modeled using SolidWorks software. A 3D-printed prototype was created and used as the pattern for the sand-casting process. Aluminium alloy 6063 was selected as the material for the product due to its favorable properties. Finally, the fabricated wrench was tested under a bathroom sink installation. Its usability and handling capability were compared with those of a conventional wrench.

FINDINGS

Three conceptual wrench designs (A, B and C) were developed to address the limitation of conventional tools used in the confined space as shown in Figure 1. Each design is considered with features such as grip comfort, reachability and flexibility in tight spaces.

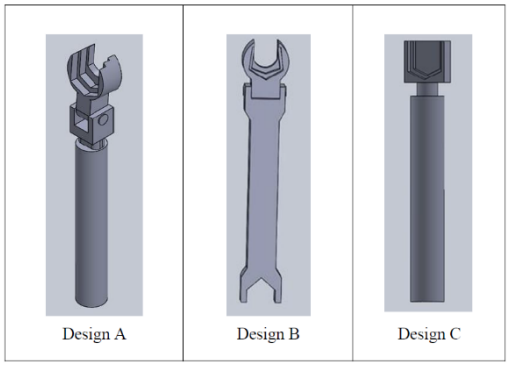

Figure 1 Three conceptual wrench designs (A, B and C)

A weighted decision matrix as shown in Table 1 shows the potential of each design to meet the six criteria set by the customer requirements obtained from surveys. Design A obtained the highest score of 4.18, especially in compatibility with tight spaces and rotatory head features. This supports the use of decision matrices in TRIZ-guided design selection, as demonstrated in prior research (Liu et al., 2016). Designs B and C, while showing moderate performance, lacked certain criteria such as adjustability and angular movement. Since design A has the highest overall score, the design is selected for fabrication to complete the project.

Table 1 Weighted decision matrix for design A, B and C

Criteria	Weightage	Design A		Design B		Design C	
		Score	Total	Score	Total	Score	Total
Anti-slip	0.2	4	0.8	3	0.6	4	0.8
Rotatory head	0.18	5	0.9	3	0.54	3	0.54
Various wrench size	0.14	4	0.56	4	0.56	4	0.56
Simple to use	0.1	4	0.4	3	0.3	3	0.3
Compatible in tight spaces	0.24	4	0.96	4	0.96	3	0.72

Adjustable	0.14	4	0.56	3	0.42	2	0.28
Total			4.18		3.38		3.20

The performance of the modified wrench was tested under a bathroom sink at one of the hostels in UiTM Penang. To ensure the objective of this project was achieved, the wrench was compared with a conventional wrench, as shown in Figure 2. The modified wrench demonstrated better accessibility and handling, allowing the user to reach and turn more quickly and comfortably within the tight area. In contrast, the conventional wrench required a more awkward arm position and offered limited angular movement. This could potentially lead to user fatigue or incomplete task execution. This side-by-side comparison highlights the advantages of the new design in terms of usability, particularly in terms of flexibility and ease of operation in confined spaces. Testing in a real under-sink setup showed improved usability, consistent with studies indicating that modified hand tools enhance comfort and operational access in confined areas (Meena et al., 2015).

Figure 2 Comparison of wrench used in confined space: (left) modified wrench; (right) conventional wrench.

CONCLUSION

This study successfully achieved its objectives by designing and fabricating a specialized wrench specifically intended for use in confined spaces. By applying methods such as Quality Function Deployment (QFD), TRIZ, and morphological charts, a functional concept (Design A) was developed, modeled in CAD, and fabricated using Aluminium 6063 via sand casting. Validation through comparative testing under actual sink conditions demonstrated that the developed wrench offered improved handling, accessibility, and task efficiency compared to a conventional wrench. The findings affirm that a user-focused design process, supported by practical fabrication techniques, can yield a tool that performs effectively in confined space applications.

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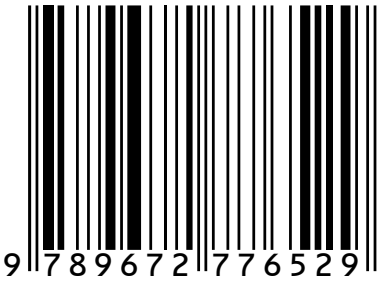

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