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Perancangan Workbench Universal Dengan Mekanisme Scissor Lift Manual

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ABSTRACT

The study purpose was to design and preliminarily validate a universal adjustable workbench that supports seated and standing bench-work activities in educational workshops, overcoming ergonomic limitations of fixed-height benches.
Materials and methods. An engineering design–fabrication–testing approach was applied. The prototype was modeled in Autodesk Inventor and built using a manual scissor-lift mechanism actuated by an M10 grade 4.6 threaded bar. The work surface measured 1200 × 700 mm with an adjustable height range of ~75–110 cm. The frame used hollow steel sections (40×40×2.3 mm and 30×30×2 mm; mild steel, $\sigma y \approx 240$ MPa) and a double-layer 10 mm plywood tabletop. Actuator capacity was analytically verified using an effective stress area of 58 mm², yield strength 240 MPa, and a safety factor (SF) of 2. Performance evaluation included incremental static loading (100–280 kg), repeated height adjustment (≥50 cycles), and eccentric-load stability testing.
Results. The threaded-bar analysis estimated a yield-limit capacity of ~6,276 N (≈640 kg), corresponding to a recommended safe working load of ~320 kg (SF=2). Physical tests up to 280 kg showed stable lifting and height holding with no permanent deformation of the screw or frame; cycle and eccentric-load tests indicated reliable operation under repeated and uneven loading within the tested range.
Conclusions. The manual scissor-lift adjustable workbench achieved functional adjustability and demonstrated promising structural stability for workshop/laboratory use. Further work should extend load testing to the recommended safe limit and add quantitative ergonomic posture assessment to substantiate ergonomic benefits.

Keywords: adjustable workbench, scissor lift, threaded bar, structural verification, load testing

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INTRODUCTION

A workbench is a key facility in bench-work activities in workshops and engineering laboratories because it serves as the central station for a wide range of manual tasks such as measuring, marking, cutting, filing, and assembly. However, many workbenches used in educational settings and training workshops still adopt a fixed height, which fails to accommodate variations in users' anthropometry and posture preferences. A mismatch between workstation dimensions and users' body characteristics directly affects working posture quality, comfort, and biomechanical loading on the musculoskeletal system, particularly when tasks are performed repeatedly or over extended durations (Kroemer & Grandjean, 1997; Tarwaka et al., 2004).

In manual work ergonomics, non-neutral postures—such as neck and trunk flexion, shoulder elevation, and wrist deviation—are known to increase the risk of musculoskeletal complaints in the back, neck, shoulders, and upper extremities. Ergonomic evaluation using the Rapid Upper Limb Assessment (RULA) method is frequently applied to map upper-body risk levels and to identify the need for workstation design interventions. A study on bench-work practice in vocational high schools reported that using a workbench with an inappropriate height can yield RULA scores in the moderate-to-high risk categories, indicating the need to improve workstation dimensions, particularly bench height and the placement of supporting tools such as vises, to achieve safer postures (Setiawan, 2018).

A number of anthropometry-based workstation design studies have shown that ergonomic workbenches can improve comfort and reduce muscle complaints, including in technical education contexts. For example, anthropometry-based ergonomic workbench design has been reported to produce dimensions that better match local user characteristics (Pratama et al., 2024), while an anthropometry-based redesign of a welding workbench also demonstrated improved comfort and reduced complaints in the neck and back regions (Dwijayanto et al., 2022). Similar findings were reported in the design of an ergonomic work desk for practicum activities that resulted in low RULA scores (indicating relatively safe posture), reinforcing that adjusting workstation dimensions is a critical factor in reducing ergonomic risk (Artika et al., 2019).

Nevertheless, many ergonomic workbench designs in practice remain limited to static dimension approaches (a single fixed design height) or require electric systems that increase cost and maintenance complexity. At the same time, educational workshops typically demand solutions that are strong, stable, easy to fabricate, and economical, while still enabling height adjustment for different types of activities (precision tasks, general work, and forceful tasks). Therefore, an adjustable workbench using a mechanical mechanism becomes a rational alternative, particularly if it can be operated manually using readily available components.

In this context, the present design focuses on developing a universal adjustable workbench using a manual scissor-lift mechanism as a relatively stable and efficient lifting system. Scissor-lift mechanisms have been used in various lifting applications to improve operator work flexibility (Siska & Saputra, 2014), making them relevant for adaptation to workbenches that require height adjustment according to user anthropometry. By integrating ergonomic principles, anthropometric considerations, and structural strength analysis, this design is expected to provide a workbench that is more adaptive to user and task variability while simultaneously reducing the risk of non-ergonomic working postures in workshops and engineering laboratories.

METHOD

Research Design

This study employed an engineering research approach oriented toward the design–fabrication–testing of a product, namely an adjustable bench worktable using a scissor-lift mechanism and a manual actuator in the form of a threaded bar. The study aimed to produce a robust, practical workbench that supports ergonomic working postures. (ISO, 1998; Setiawan, 2018).

Research Procedure

The development procedure followed a prototype workflow consisting of **(1) design, (2) selection of tools and materials, (3) fabrication, (4) trial testing, (5) functional verification—if results were not satisfactory, the design was revised, and (6) report writing**. The research activities were scheduled for **May–July 2025**, including data collection, drafting and material selection, tool fabrication, testing, as-built drawing preparation, and report completion.

Tools and Software

The main tools and resources included paper and pencils (initial sketches), a computer (design references), and Autodesk Inventor for final 3D modeling and technical drawings (Ningtyas et al., 2021).

Product Design and Technical Specifications

The design began with identifying user needs (students, technicians, and workshop users) and defining ergonomic specifications. The workbench height was designed to be adjustable within approximately 75–110 cm (the document also notes a 70–110 cm range) to support both seated and standing work positions (Tarwaka & Lulik, 2004; Kroemer & Grandjean, 1997). The work surface dimensions were set at 1200 mm × 700 mm, and the table was equipped with casters to enhance mobility and stability.

Key components and materials included:

- Frame: hollow steel sections for top and bottom frames (40×40×2.3 mm and 30×30×2 mm)
- Work surface: double-layer 10 mm plywood (triplex)
- Lifting system: scissor lift + M10 grade 4.6 threaded bar
- Bearings: 6304 (wheels), 51101 (axial), and 6200 (screw rotation)

Strength Analysis (Threaded Bar Calculation)

The actuator strength was calculated using an M10 grade 4.6 threaded bar. The parameters included a nominal diameter of 10 mm, a pitch of 1.5 mm, an effective cross-sectional area of 58 mm^2, and a yield strength of 240 MPa, referring to the ISO metric thread profile standard and machine-element literature (ISO, 1998; Budiono, 2018). Using a safety factor (SF) of 2 (Ashby, 2011; Saputra & Romahadi, 2023), the maximum load capacity was estimated at approximately 6,276 N (≈ 640 kg). Therefore, the recommended safe working load was approximately 320 kg.

Testing and Success Criteria

Evaluation was conducted through functional testing and stability verification:

- Static load testing in increments from 100 kg to 280 kg to assess stability and mechanism strength.
- Height adjustment testing: repeated raising–lowering operation for ≥ 50 cycles to evaluate screw smoothness and mechanical joint reliability.
- Stability testing under eccentric loading to examine resistance to torsional moments and wobbling.

Success was defined by stable lifting operation without permanent deformation and the ability to maintain a selected height under the recommended safe working load.

FINDING AND DISCUSSION

The primary challenge in designing an adjustable workbench is ensuring that the structure can safely support working loads while remaining stable and ergonomically suitable for users, including students, technicians, and workshop workers. Accordingly, from the early stage of development, a height-adjustment system based on a scissor-lift mechanism with a manual drive using an M10 grade 4.6 threaded bar was defined as the key component, as it directly functions to lift and sustain the workbench load. The design criteria included structural strength, operational stability, ease of assembly and maintenance, user comfort based on ergonomic principles, and the market availability of components to ensure the design is practical and cost-effective. Material selection and safety factor determination referred to relevant engineering catalogs and applicable standards (SNI) to ensure the structure can withstand variations in working loads associated with user activities.

The design outcomes were realized as a prototype of an adjustable bench worktable that can be used in both seated and standing positions. Height adjustment is performed manually through a scissor-lift mechanism, with the threaded bar serving as the mechanical actuator.

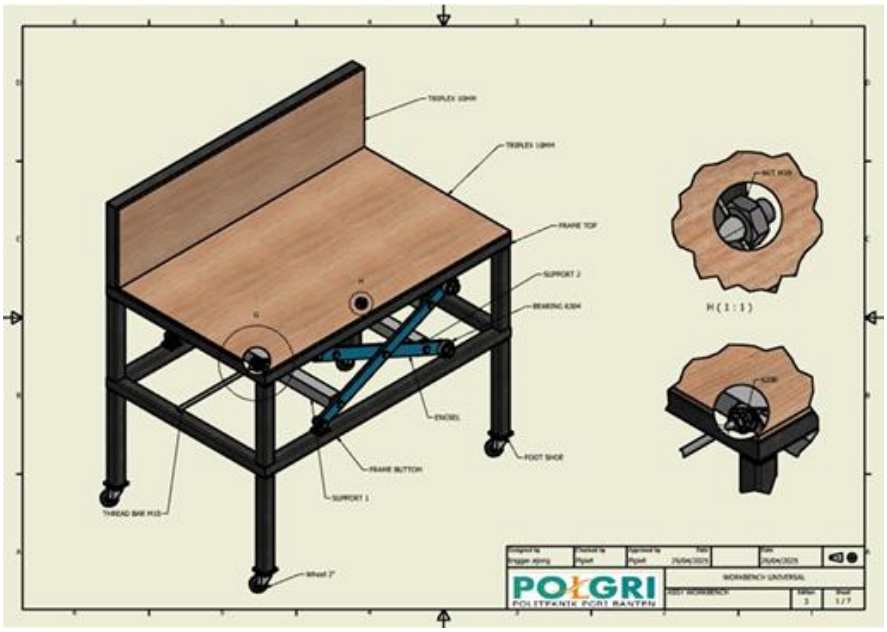


Figure 1. *Image of the Tool*

Figure 1 presents the overall appearance of the realized prototype, including the main frame, lifting mechanism, wheel system, and tabletop surface, thereby providing a visual overview of how the key components are integrated to support height adjustability and structural stability. The prototype has a tabletop dimension of 1200 mm × 700 mm and a working height range of approximately ±75 cm to ±110 cm. The frame was constructed from hollow steel sections of 40×40×2 mm and 30×30×2 mm made of mild steel ($\sigma y \approx 240$ MPa), while the tabletop used 10 mm double-layer plywood (triplex). Mobility is provided by caster wheels equipped with brakes, and the lifting mechanism utilizes an M10 grade 4.6 threaded bar.

In addition to these main components, the prototype was equipped with 6304 bearings on the wheels, a 51101 axial bearing to resist compressive forces, and a 6200 bearing to support screw rotation. Hinges at the scissor joints enable more flexible up–down movement, while additional supports were installed to improve frame stability. The ±75–110 cm height range was selected to accommodate both seated and standing working postures, making the workbench more adaptive to differences in user anthropometry and bench-work task types. This approach aligns with ergonomic principles suggesting that work facilities should be adjustable to improve comfort and reduce muscle fatigue (Tarwaka & Lulik, 2004; Kroemer & Grandjean, 1997).

Actuator strength was verified through an analytical calculation of the M10 grade 4.6 threaded bar using the following parameters: nominal diameter 10 mm, pitch 1.5 mm, effective cross-sectional area 58 mm², ultimate tensile strength 400 MPa, and yield strength 240 MPa. Based on these values, the maximum load at the yield limit was estimated at approximately ±6,276 N, equivalent to ±640 kg. With a safety factor of 2, the recommended safe working load is ±320 kg. This result highlights the importance of distinguishing between the maximum theoretical capacity and the safe working limit, ensuring that capacity claims do not exceed the available calculation and verification evidence.

Initial prototype testing was conducted through incremental static loading from 100 kg to 280 kg, repeated height-adjustment operation for ≥50 cycles, and stability testing under eccentric loading. The test results indicated that the lifting system operated stably, no permanent deformation occurred in either the threaded bar or the frame, and the workbench was able to maintain its set position within the tested load range. Static loading up to 280 kg provides initial empirical evidence that the prototype performs effectively within this range, while the cycle and eccentric-load tests suggest that the mechanism is sufficiently reliable for repeated use and uneven loading conditions commonly encountered in workshop environments.

Overall, the design and realization of the prototype demonstrate that this manually operated scissor-lift adjustable workbench meets the intended design objectives by providing a flexible and ergonomic workstation while maintaining structural strength and stability. These findings indicate advantages over conventional fixed-height workbenches, particularly in accommodating variations in

user working posture. Nevertheless, this study has limitations, notably that the reported static load test was only conducted up to 280 kg and the ergonomic evaluation remains conceptual without quantitative posture measurement. Therefore, future work is recommended to extend load testing up to the recommended safe working limit and to complement the ergonomic analysis with measurable assessment methods. Further improvements should also aim to increase tabletop rigidity and enhance wheel stability to achieve more optimal performance.

CONCLUSIONS

This study successfully designed and realized a prototype of an adjustable bench worktable based on a manually operated scissor-lift mechanism with an M10 grade 4.6 threaded bar actuator, featuring a 1200 mm × 700 mm work surface and an adjustable working height range of approximately ±75–110 cm, thereby enabling both seated and standing use and offering greater adaptability than conventional fixed-height benches. Analytical verification indicated that the threaded bar capacity at the yield limit was approximately ±6,276 N (≈±640 kg) and, with a safety factor of 2, yielded a recommended safe working load of ±320 kg, while initial testing—comprising incremental static loading from 100–280 kg, repeated up–down height adjustment for ≥50 cycles, and stability testing under eccentric loading—showed stable lifting operation, reliable height holding, and no permanent deformation of either the screw or the frame within the tested load range. These findings confirm that the design met the primary objective of providing a flexible, stable, and practically applicable workbench for educational workshop/laboratory settings; however, the study remains limited because the reported static load testing reached only 280 kg and the ergonomic evaluation was not quantified, thus future work is recommended to extend load testing up to the recommended safe working limit, incorporate measurable ergonomic assessment methods, and improve tabletop rigidity and wheel-system stability (e.g., thicker plywood and a foldable wheel mechanism) to achieve more optimal performance.

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