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Design and Development of Multi-Purpose Joystick Operated Multi-axis Machining Table

Harsh S. Avhad ¹, Siddharth R. Shejpure ², Shubham S. Bilwal ³, Prasad S. Gavhane ⁴,

Pratik A. Gosavi ⁵, V. J. Suryawanshi ⁶

Department of Mechanical Engineering, Sanjivani College of Engineering, Kopergaon, MH, India¹⁻⁶

ABSTRACT: This research proposes the design and development of a multi-purpose joystick operated, multi-axis machining table for welding, drilling, grinding, and other related operations with a view to reduce operator fatigue, enhancing process efficiency, and offering operator ergonomic working conditions. The system incorporates lead screw mechanisms for X-Y axis movement, which ensures precise workpiece positioning. A servo motor facilitates rotational movement, which makes the work activities more accessible, and a hydraulic jack is employed in height adjustment. Joystick control based on Arduino facilitates controlled, automatic movement and minimizes manual efforts and operator fatigue. Lockable wheels for movement and a tools storage utility space are part of the design in order to enhance the productivity and workflow. This research shows that a well-designed mechanical system can improve the efficiency of machining processes while being simple and reliable.

KEYWORDS: Joystick operated, Multi-axis, Storage utility space, Reduce operator fatigue, Increases process efficiency, Ergonomic working conditions.

I. INTRODUCTION

In today's modern manufacturing and fabrication industries, there is a strong demand for machines capable of performing more than one operation, while also enhancing operator comfort and productivity. Conventional machining tables tend to be inflexible, need to be adjusted manually very often, and are not ergonomically designed, leading to fatigue and decreased productivity during extended working hours.

To overcome these limitations, this study emphasizes the design and development of a multi-purpose, joystick-controlled, and multi-axis machining table. This table is specifically designed to accommodate typical machining operations, such as welding, drilling, and grinding, in one compact unit. It features lead screw mechanisms for smooth X- and Y-axis travel, enabling the precise positioning of the workpiece. A servo motor offers controlled rotational adjustment and a hydraulic jack facilitates easy height adjustment to accommodate the posture of the operator. These features are combined to provide a more ergonomic and user-friendly working experience. An Arduino-driven joystick system enables operators to manipulate the motion of a table with precision and ease, minimizing manual effort. Features such as lockable wheels for mobility and built-in tool storage compartments enhance the workflow and convenience. The goal of this project was to illustrate how automation and smart design can improve productivity, safety, and operator satisfaction in machining operations.

II. LITERATURE REVIEW

Scientists have searched for many ways of making welding tables more efficient, flexible, and safe. Most conventional welding tables are rigid and ergonomic, particularly in lengthy operations. Research on a 360-degree rotary welding table emphasizes the benefit of full rotation, which assists the worker in achieving difficult angles without relocating the workpiece. Another article specializes in an adjustable welding table which allows users to modify the tilt and height of the surface to avoid worker fatigue and enhance weld quality. Others incorporate foot controls or joystick-type control systems allowing movement of tables without the hands being occupied.

Precision movement and positioning have become feasible using circular guide rails, worm gears, and electric motors. Throughout the papers, the intention is the same: to enhance productivity, precision, and ergonomics while welding and in other machining operations. Multi-functionality and automation are major trends. These characteristics not only eliminate human error but also conserve time. Collectively, these works of research imply that a blend of height adjustment, rotary movement, and simplicity of controls makes welding tables more effective for industrial and educational applications.

Table. 1 Comparative Summary Table of Research Papers on Welding Tables

Author(s)	Title	Year	Focus Area	Key Findings
IRJET - Anonymous	360° Welding and Cutting Rotary Turn Table	2020	Automation in welding platforms	Used Arduino-controlled system for rotating and positioning workpiece; improved safety and precision.
Dinesh A., et al.	Adjustable Welding Table	2021	Height adjustable welding table	Improved ergonomics and reduced worker fatigue with adjustable height and clamping fixtures.
R. Sivakumar, R. Kannan	Design and Fabrication of Multipurpose Welding Table	2022	Multi-functional welding table	Integrated grinding and clamping functionality to increase productivity.
IRJET - P. Adithya, et al.	360 Degree Rotatable Welding Table	2021	360° rotatable table for welding	Enhanced maneuverability of the workpiece using servo motors and rotating base.

III. PROBLEM STATEMENT

In small-scale fabrication units and workshops, machining operations, such as grinding, drilling, and welding, are typically performed on fixed or manually adjustable tables. Such arrangements are typically simple, nonautomated, nonadjustable, and nonergonomic. Operators typically bend, stretch, or move themselves to access various angles and heights while performing machining operations. Over time, this results in fatigue, poor posture, decreased efficiency, and uneven results. Similarly, conventional tables do not facilitate the accurate control of workpiece travel on more than one axis, thus restricting their application in sophisticated or multi-stage operations. Furthermore, most conventional tables are immobile and do not offer onboard storage for critical tools and accessories, which further interrupts the workflow and lowers productivity. Although computers exist to enable automated tables in the form of CNC-based or electronically controlled systems, they remain costly and overly complex to sustain; hence, they are too expensive for small workshops or frugal workshops. Thus, an obvious requirement exists for an adaptable, economical, and half-automatic alternative intermediate between simple hand tables and expensive CNC setups.

This project seeks to address these problems by developing a multi-axis machine table with X, Y, and rotational movements controlled by joysticks, height adjustment, and storage on board. Employing mechanical systems, such as lead screws and servo motors driven by Arduino, the system guarantees precise positioning and convenience. With features such as lockable wheels and ergonomic design, this table should decrease operator fatigue, increase productivity, and provide a versatile solution for workshops requiring welding, drilling, or grinding functions in all one portable unit.

IV. OBJECTIVES AND GOALS

The primary objective of this project is to design and construct a joystick-operated, multi-axis machine table that improves the efficiency, safety, and convenience of operations like welding, drilling, and grinding, particularly in small workshops and fabrication shops. The goal is to offer an economical, ergonomic, and automated solution that bridges the gap between low-cost manual tables and high-cost CNC machines.

Objectives:

1. To develop a table with lead screw drives for X and Y movements to achieve accurate and convenient placement of the workpiece.
2. To integrate servomotor-driven rotational motion to enhance accessibility during complex operations.
3. Add an adjustable height system with a hydraulic jack to ensure ergonomic working conditions for different users.
4. Automate the table's motion using Arduino to reduce manual effort and operator fatigue.
5. To provide a portable table due to the integration of lock castors, allowing simple repositioning with continuous operational stability.
6. To provide a built-in tool and accessory storage utility space to reduce downtime and increase workflow.

Goals:

1. Install and design an easy joystick-based user interface for controlling table movement along different axes.
2. Implement structural and mechanical evaluations to determine the endurance and strength of the parts and frame under operational conditions.
3. Come up with a complete functional prototype that combines every aspect including automation, mobility, and storage space for tools.
4. The system was evaluated in its precision, steadiness, and usability for the different machining applications.
5. Make the design inexpensive, simple to upkeep, and viable for workshops not equipped with heavy machinery.

V. METHODOLOGY

The design of a joystick-controlled multipurpose machining table is a disciplined and pragmatic approach to engineering. The initial process involved selecting universal problem areas in the welding, drilling, and grinding operations. These include operator weariness, slow manual positioning, and nonergonomic workplaces. Once aware of this issue, we formalized the requirements of the system: height adjustable, X-Y axis travel, table rotation, and ease of use.

In the second stage, we brainstormed and created various design concepts. We established a concept that employs lead-screw mechanisms for the X- and Y-axes, a hydraulic jack for controlling height, a servo motor for rotation, and joystick control through an Arduino system for automation.

Next, detailed 3D designs of the components were modeled using the CAD software. For the material selection phase, we used materials that were durable, strong, and cost-effective. The primary structure used was mild steel, and parts with recurrent motion employed wear-resistant and low-friction materials.

After the design was completed, fabrication was started by cutting every part to a defined size. All parts were assembled with caution: hand wheels were added to lead screws, lift was added by integrating the hydraulic jack, and rotation was provided by the installation of servo motors. The joystick and Arduino units were connected afterwards to enable the movement of the table.

During the test phase, we assessed how precisely the table could place workpieces, how simple it was to use, and how well it minimized the operator effort. We quantified aspects such as the X-Y travel accuracy, lift range, ease of control, and overall functionality during welding and drilling.

A cost breakdown was also conducted to ensure that the table was within the budget compared to other systems. Finally, minor changes were made depending on the test outcomes to enhance reliability and performance.

A. Components

Table 2. Components and functions

Sr. No.	Component	Function
1	Lead Screw Mechanism	Provides precise linear motion along X and Y axes for accurate workpiece positioning.
2	Hydraulic Jack	Allows vertical movement for height adjustment, ensuring ergonomic working conditions.
3	Servo Motor	Enables controlled rotational motion to improve accessibility during operations.
4	Joystick Controller	Allows the operator to easily control multi-axis movement via Arduino system.
5	Arduino Board	Processes joystick inputs and controls motor outputs for semi-automation.
6	Wheels with Brake Lock	Enable table mobility and provide stability during operations when locked.
7	Accessory Storage Area	Holds tools and components to improve workflow efficiency.
8	Table Frame Structure	Provides structural support and rigidity for all components during operation.

A. 3D CAD Model

Onshape software was employed to design the 3D CAD model for a multifunctional joystick-controlled machining table.

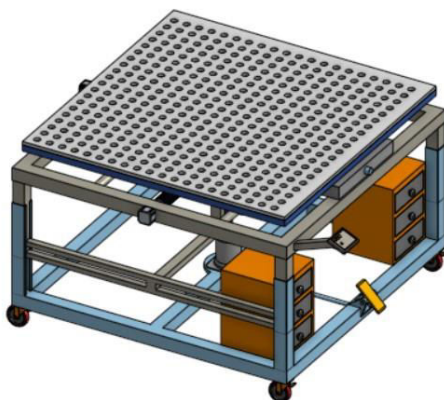


Fig 1. Isometric View

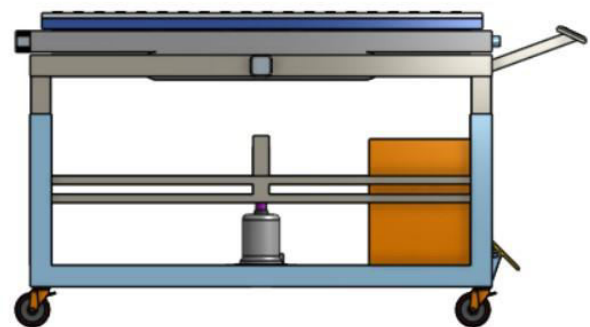


Fig 2. Front View

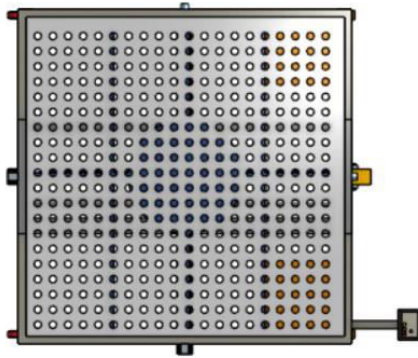


Fig 3. Top View

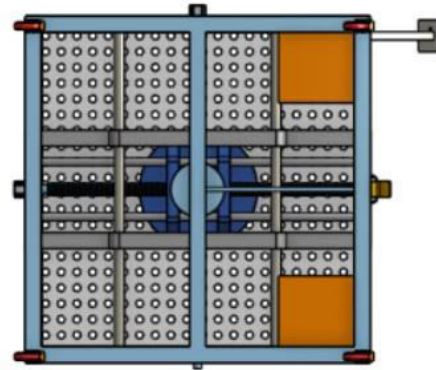


Fig 4. Bottom View

VI. ADVANTAGES

1. **Joystick Control:** Minimizes manual labor and maximizes accuracy in machining processes.
2. **Multi-Axis Movement:** X, Y, and rotational axis control provides precise positioning of the workpiece.
3. **Height Adjustability:** Facilitates ergonomic working conditions and minimizes operator fatigue.
4. **Mobility:** Fitted with wheels and brake locks, making it convenient to move and stable when in operation.
5. **Integrated Storage:** In-built utility space keeps tools within reach, enhancing workflow efficiency.
6. **Less Fatigue:** Operator is able to make all movements from a single position, reducing physical fatigue.
7. **Increased Safety:** Controlled motion and stable design minimize the risk of accidents while operating.
8. **Increased Productivity:** Quick and precise adjustments enable jobs to be finished faster.
9. **Multi-Use:** Applicable for welding, drilling, grinding, and more-minimizing the number of setups.

VII. APPLICATIONS

1. **Fabrication Workshops:** Convenient for welding and metal fabrication operations with fine control.
2. **Automotive Garages:** Facilitates part assembly, drilling, and grinding during repair or customization.
3. **Training Institutes:** Suitable for educating students on sound and efficient machining practices.
4. **Maintenance departments:** Facilitate in-house repair and maintenance operations with maximum flexibility.
5. **Tool Rooms:** Serves as a positioning and support unit for the development of components.
6. **Prototyping Labs:** Facilitates the construction of small parts and prototypes for testing.
7. **Educational Labs:** Facilitate demonstrations of mechanical control and automation systems.
8. **DIY Workshops:** Convenient Solo Creators with Metal-based Projects.
9. **Small manufacturing units:** Facilitate multipurpose operations without the requirement of multiple machines.

VIII. RESULTS AND DISCUSSION

After the successful production and assembly of the prototype of the Multi-Adjustable Joystick Operated Multi-Operational Machining Table, a series of performance tests and user-based testing were carried out. The goal was to ensure the mechanical dependability of the table, multifunctionality, comfort for users, efficiency in operation, and applicability for small-to medium-scale industrial uses.

1. Operational Performance

The machining table was subjected to different working conditions such as drilling, grinding, and welding operations. The joystick-operated mechanism permitted operators to move the table position smoothly in both vertical and horizontal directions. The adjustable height option helped users set the working platform to their comfort level, easing the strain during prolonged operations. The movement via joystick control was smooth and accurate, proving the efficiency of the mechanical linkage and base wheel supports.

Table 3. Performance Evaluation Table

Parameter	Observed Value
Vertical Lift Range	0–400 mm
Table Rotation	0–360° (with lock)
Load Capacity	80–100 kg
Tool Switching Time	Less than 2 minutes
Height Adjustment Time	Less than 15 seconds

2. Functional Flexibility

The machine exhibited versatility in changing tools for drilling, welding, and grinding. The tool-holding interface is robust, and the storage utility provides convenient access to frequently used accessories. In the tests, the operators were able to alternate tools with little downtime. The multifunctionality of the setup makes it perfect for workshops or learning labs with tight space and resources.

3. Welding and Drilling Results

The table was employed for intermittent and continuous welding of the mild steel specimens. Adjustable height facilitates an easy working angle, thus improving weld accuracy and minimizing operator fatigue. During drilling, a common bench drill was fitted, and holes of different diameters were successfully drilled into 4 mm and 6 mm thick mild steel sheets. No slippage or vibration was encountered while using the tools, attesting to the table's rigid structure and balanced support system.

4. User Ergonomics and Ease of Use

Operators found joystick control helpful, which minimized the use of manual adjustment knobs. Without much training, users can easily control the table. The adjustable components were smooth to use because of the precision of the machined parts and the uncomplicated mechanical linkages.

5. Cost-Effectiveness

Compared with commercial automated positioning tables, the prototype is considerably cheaper. The utilization of locally available materials and basic mechanical structures reduces fabrication costs. The system did not require any electricity for adjustments, making it an ideal choice for places with a low power supply.

6. Mechanical Efficiency and Durability

The design underwent a simple structural analysis, and the simulations showed that all the parts were within the safe stress limit. No permanent deformation or misalignment was observed during the loading tests. This demonstrates the durability of the prototype for daily workshop use.

7. Safety and Stability

The machine has locking mechanisms to avoid accidental movements during operation. The joystick returned to a neutral position when released, thereby improving safety. The base support frame provided stability even after a full height adjustment.

8. Socio-Technical Impact

This machine is of great importance in technical education, small-scale fabrication, and rural or semi-urban workshops. It facilitates skill development, minimizes tool change times, and offers a low-cost solution for multioperation jobs.

IX. CONCLUSION

The creation of a multi-adjustable joystick-operated multi-operational machining table effectively overcomes the significant issues encountered in traditional welding, grinding, and drilling workstations. Conventional setups tend to be inflexible, leading to operator fatigue, and present ergonomic concerns during extended usage.

This project provides an excellent engineered solution that maximizes ease of use, safety, and productivity. The adjustable height, rotatable surface, and joystick control of the table allow for the accurate positioning of the

workpieces and tools by users, minimizing errors and physical stress. Through the combination of mechanical adjustability and simple automation using a joystick, the system balances the cost and performance. Multiple operations can be performed in a single setup without requiring individual setups, thereby saving time and space. Its performance was proven through testing in real-world operations using components that acted reliably within a range of loading conditions.

In addition, the modularity of the design makes it simple to customize and scale according to particular industrial or workshop requirements. The solution is particularly applicable to small- and medium-scale workshops, where resource optimization is a priority. Overall, the project helps enhance worker comfort, minimize setup time, and increase the overall quality of machining operations. It also has the potential to contribute to wider objectives of sustainable and inclusive industrial development.

X. FUTURE SCOPE

- The multi-adjustable joystick-operated machining table provides a sound basis for enhancing productivity, comfort, and safety within workshop settings. However, future development of this system can make it more versatile and efficient.
- One area where improvements can be made in the future is the inclusion of semi-automated features, including powered actuators or servo systems, to minimize manual adjustments and improve accuracy.
- In addition, adding a digital screen or sensor-based feedback system can assist in monitoring the table positions, angle settings, and loads for more precise operation. Enlarging the compatibility of the table to support CNC machines or robotic arms can be turned into a smart workstation for modern manufacturing facilities.
- Flexible tooling fixtures and universal clamps can also be included to accommodate a greater variety of machining operations such as plasma cutting or sheet metal work. Modular table surface or control unit extensions can enable users to tailor the system to specific tasks or workspace constraints.
- Finally, wider field testing and user input can provide insights into optimizing ergonomics, user interfaces, and safety features. With these improvements, the system has the potential to cater not only to small workshops, but also to vocational training schools, fabrication shops, and educational institutions.

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