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# DEVELOPMENT AND PERFORMANCE EVALUATION OF AN INNOVATIVE MECHANIZED SHEET PUNCHING DEVICE

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## ABSTRACT

This study presents an innovative mechanized sheet punching device, using locally sourced materials. The device aims to significantly reduce labor costs, time, and effort associated with sheet metal punching. Comparative analysis of performance showed that the mechanized punching device has resulted in a reduction of time by as much as 83% compared to the manual process. Moreover, visual inspection of the cuts revealed good quality in terms of precision and accuracy. This innovative device is well-suited for mass production applications, leading to improved productivity for small-scale metalworking shops and laboratories.

**Keywords:** sheet metal, sheet punching device, tool steel, cold-rolled steel, punch and die, metalworking industry.

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## INTRODUCTION

Sheet metal is a fundamental material in metalworking, characterized by its thin, flat form, which can be easily cut, bent, and shaped into a wide variety of objects and products (Dobos, 2024). Its versatility stems from the ability to form it into diverse shapes (Dobos, 2024). Its malleability makes it a popular choice for numerous industrial and commercial applications, ranging from everyday items to the production of car bodies, outer panels of electric products and appliances, metal furniture, and structural panels (Grimberg, 2024; Namoco, 2010), with thicknesses that vary significantly. The automotive industry drives constant developments and innovation in sheet metal forming processes due to the need for lightweight manufacturing(Iizuka *et al.*, 2006) (Namoco, 2013; Namoco et al., 2007) (Wadas & Tisza, 2020). Sheet metal is also used in HVAC systems, enclosures for electronics (Grimberg, 2024), and various other applications (Pratihar, 2020).

Traditional methods for creating holes in sheet metal often involve manual punching devices, which typically consist of a movable cover that houses punches aligned with holes, and a lower section that supports the material being processed. These devices often use a counteracting spring mechanism to facilitate operation. However, these manual methods can be labor-intensive and time-consuming, necessitating a more efficient solution (Ajay *et al*., 2019). Furthermore, achieving precise hole placement and consistent quality can be challenging with manual methods (Presling, 2022). In response to these challenges, there is a growing need for more efficient and automated methods (Pratihar, 2020).

This study aims to design and develop a mechanized punching device for sheet metal, incorporating essential components such as a punch (male tool), guide, die (female tool), springs, and a lock pin. This addresses the limitations of manual methods, which can be labor-intensive and lack precision (Pratihar, 2020). The said punching device is suitable for fabricating circular shapes in sheet metal. Its design considered the device's capacity in terms of material thickness, making it applicable for both mass production and laboratory use.

## MATERIALS AND METHODS

This research was conducted through extensive observation and testing to develop an innovative mechanized punching device. Each component of the device was designed with a specific function and evaluated for its performance during operation. The primary materials used for construction include carbon steel and cold-rolled steel (CRS), which are essential for the assembly of critical parts such as the pin, guide, and base. The device operates using a hydraulic press mechanism to apply force effectively.

## DESIGN CONSIDERATIONS

### Safety

Safety is a paramount consideration for the operator of the device. To enhance safety, the design incorporates a punch and die connected by four pins secured with lock screws, along with springs to prevent slippage during operation. Additionally, the device is designed without cutting or turning tools attached, ensuring adequate distance between the device and the user during operation.

### Structural Integrity

The integrity of the structure focuses on the materials used in the punch and die. Tool steel is utilized for the male and female components due to its resistance to heat and thermal expansion, which helps prevent damage during operation. Cold-rolled steel (CRS) serves as a supportive mechanism, providing a cost-effective

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solution. The die features a conical hole with a 15-degree angle to facilitate the easy removal of finished products. A guide pin and set screw are incorporated to secure the die's position, while a spring between the punch (male) and die (female) ensures smooth operation.

**Components of the Device**

Figure-1 presents the exploded view of the device, highlighting the dimensions and labels of each component. The assembly includes two plates with the guide pin (B) to connect the punch and die via lock screws (A). The push pin, attached to the first plate, operates the hydraulic press, moving through to the second plate where the male cutter is secured. The guide (A) ensures proper alignment of the spring, preventing slippage, while the spring assists in returning the punch after operation.

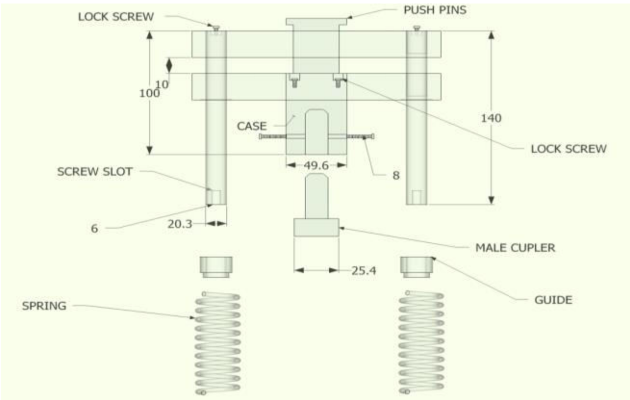


**Figure-1.** Exploded view of the punch (Male).

Figures 2 and 3 depict additional views of the device, illustrating the sectional and top views with all components labeled. The hydraulic press setup, shown in Figure-4, includes a channel bar frame that supports the hydraulic jack, which drives the push pin to punch holes in sheet metal, allowing for the removal of scrap slugs that may be recycled or discarded.

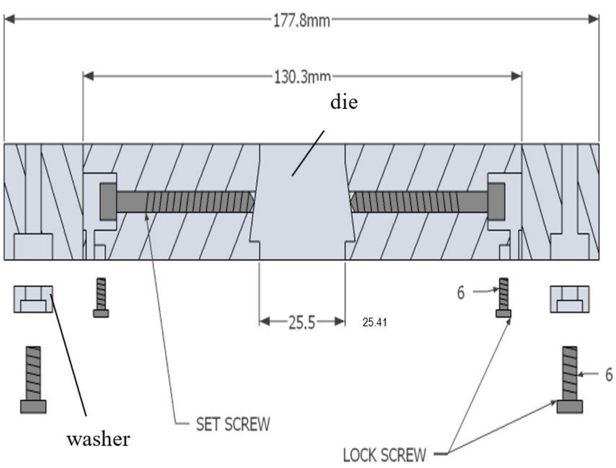


**Figure-2.** Section view of the die (Female).

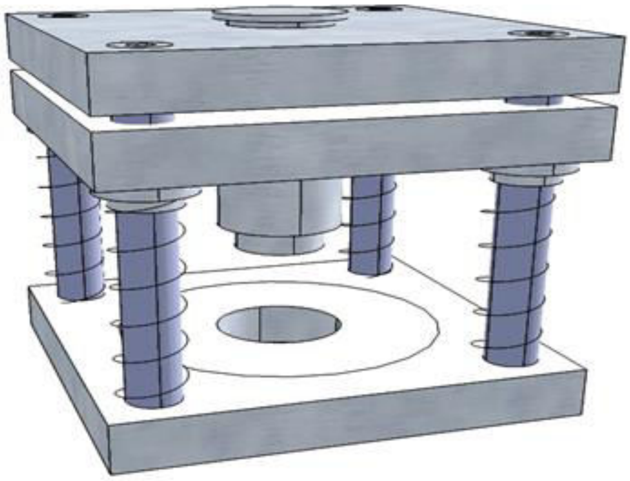

**Figure-3.** Isometric view of the device.

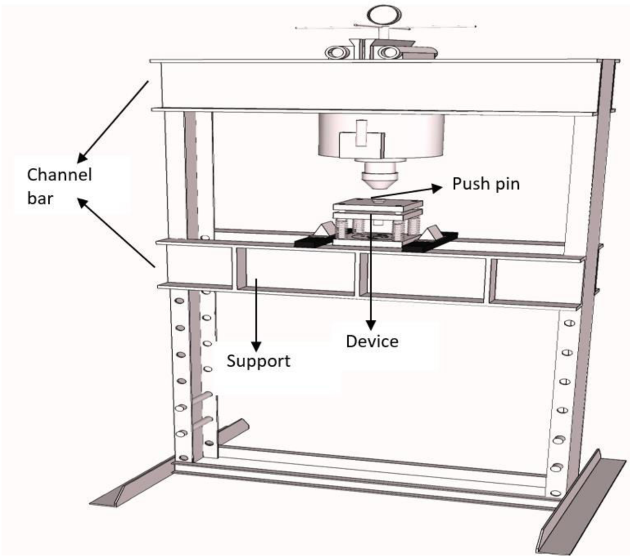


**Figure-4.** Device attached to the hydraulic press.

**Prototype Development**

The prototype was fabricated in a Machine Shop Laboratory. This process included machining the parts and the final assembly of the device, ensuring all elements functioned together effectively.

**Testing and Fine Tuning**

Initial testing was conducted at the laboratory, with any operational errors documented for analysis. These errors informed the fine-tuning process, enabling iterative adjustments to enhance performance. Subsequent tests confirmed successful operation after addressing initial issues.

**Evaluation of Device Performance**

The performance of the device was evaluated based on a comparative analysis with traditional manual methods. Key evaluation criteria included: (1) the time taken to punch ten pieces of varying thicknesses, and (2)

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the quality of cuts, assessed through visual inspection, in terms of precision and finish.

## RESULTS AND DISCUSSIONS

### Development of the Mechanized Sheet Punching Device

Figure 5 through 8 provide visual documentation of the mechanized sheet punching device and its components. Figure-5(a) illustrates the punch (male) component, which incorporates four pins for spring attachment, with the cutting tool positioned centrally and secured by a set screw. Figure-5(b) depicts the die (female) component, featuring four holes for pin insertion, along with springs, washers, and a set screw. The central hole serves as the exit for materials post-punching. Figure-6 displays the key components of the device. The spring is crucial for returning the punch to its initial position, facilitating efficient operation. Washers are employed to secure the springs and lock screws. Figure-7 presents the fully assembled device, highlighting the integration of the punch, die, and spring components, all secured with pins and washers. Figure-8 shows the device in action, attached to the hydraulic press, which provides the necessary force for punching.

(a) Punch or the male part of the device

(b) Die the female part of the device

**Figure-5.** Actual photos of the device and its parts and components.

**Figure-6.** Components of the device.

**Figure-7.** Assembly of the device.

**Figure-8.** Actual photo of the utilization of the device.

### Performance of the Device

The performance of the mechanized punching device was evaluated by measuring the time consumed to punch ten (10) pieces of sheet metal of various thicknesses and comparing it with that of the manual process (using Tinner Snips), as presented in Table-1. As shown in the table, utilizing the mechanized punching device resulted in a reduction of time by as much as 83% compared to the manual process. All the sheets tested at various thicknesses have time reductions of more than 55%, indicating an increase in efficiency and productivity. As the sheet thickness increases, an increase in time consumed is observed in punching with the mechanized device. In Table-2, the quality of cuts produced by the mechanized punching device and manual process, evaluated by visual inspection in terms of precision and finish, was compared. Almost all sheet metals tested with a mechanized punching device yielded good quality. On the other hand, using traditional tin snips in cutting sheets into a circular shape yielded poor quality in terms of precision and finish.

Overall, the mechanized punching device demonstrated superior performance compared to the manual process using tin snips. It provided higher-quality cuts in significantly less time across various thicknesses, underscoring its efficacy as an innovative solution for sheet metal punching.

**Table-1.** Comparative evaluation of time consumed to punch 10 pieces of sheet metal.

| Sheet Metal Thickness | Time (min) | | % Difference [(b-a)/b] x 100 |
|---|---|---|---|
| | Mechanized Punching Device (a) | Manual Process (Tinner Snips) (b) | |
| Gauge 32 | 1.40 | 8.23 | 83.0% |
| Gauge 20 | 2.30 | 7.29 | 68.4% |
| Gauge 13 | 3.30 | 8.17 | 59.6% |
| Gauge 12 | 3.30 | 7.30 | 54.8% |
| Gauge 10 | 3.40 | 8.50 | 60.0% |
| Gauge 9 | 4.17 | 12.0 | 65.3% |

**Table-2.** Quality of cuts produced by mechanized punching device and manual process.

| Sheet Metal Thickness | Quality of Cuts (Visual Inspection) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mechanized Punching Device | | | | | Manual Process (Tinner Snips) | | | | |
| | Trial no. | | | | | Trial no. | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Gauge 32 | X | X | X | X | X | X | X | X | X | X |
| Gauge 20 | O | O | O | O | O | X | X | X | X | X |
| Gauge 13 | O | O | O | O | O | X | X | X | X | X |
| Gauge 12 | O | O | O | O | O | X | X | X | X | X |
| Gauge 10 | O | O | O | O | O | X | X | X | X | X |
| Gauge 9 | O | O | O | O | O | X | X | X | X | X |
| Plate 3mm | O | O | O | O | O | X | X | X | X | X |
| Plate 3.5 mm | Uncut | Uncut | Uncut | Uncut | Uncut | X | X | X | X | X |

Legend:
O - Acceptable
X - Not Acceptable

## CONCLUSIONS

The study has presented an innovative mechanized sheet punching device for small-scale metalworking shops and laboratories. Performance evaluation has demonstrated its functionality and efficiency in terms of time consumed in punching sheet metals, as well as in the quality of cuts in terms of precision and accuracy. This innovative device is well-suited for mass production applications, providing a significant improvement over traditional manual methods.

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