



Design and Fabrication of a Mini Hydraulic Sheet Metal Bending Machine

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ARTICLE INFO	ABSTRACT
Published Online: 30 May 2026	This paper delineates the systematic design, fabrication, and empirical performance evaluation of a compact, cost-effective mini hydraulic sheet metal bending machine tailored for small-scale workshops, vocational training centers, and prototyping applications in resource-constrained environments. The machine integrates a manually operated hydraulic bottle jack (10–20 ton capacity) as the primary actuator to deliver controlled force for V-bending of mild steel sheets with thicknesses ranging from 0.8 mm to 3.0 mm and widths up to 500 mm. Grounded in Pascal’s law and classical bending mechanics, the design prioritizes structural rigidity, operational safety, repeatability, and affordability (total estimated cost below N500 equivalent). Comprehensive design calculations, material selection criteria, detailed fabrication procedures, and extensive experimental testing are presented. Performance metrics demonstrate high bend accuracy, minimal surface defects, manageable springback, and low operator fatigue. Multiple performance tables, force comparisons, and quantitative results validate the machine’s efficacy. Recommendations for future enhancements, including semi-automation and advanced die systems, are provided. This work contributes a practical, replicable solution that bridges the gap between rudimentary manual tools and expensive industrial press brakes.
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INTRODUCTION

Sheet metal bending remains a cornerstone manufacturing process across diverse industries, including automotive, aerospace, construction, electrical enclosures, and general fabrication [1]. It enables the transformation of flat sheet stock into complex three-dimensional components such as brackets, chassis, panels, frames, and ducts through controlled plastic deformation along a linear axis [2]. Traditional manual bending methods relying on hammers, vices, or simple lever tools are inherently labor-intensive, inconsistent in angular precision, prone to material damage, and ergonomically taxing, often leading to operator fatigue and safety concerns. Conversely, large-scale CNC or hydraulic press brakes offer superior precision and throughput but impose prohibitive capital costs, high energy demands, substantial floor space requirements, and the need for specialized operators, rendering them inaccessible to small and medium enterprises (SMEs), especially in developing economies [3].

The mini hydraulic sheet metal bending machine developed in this study addresses these limitations by providing a balanced, intermediate solution. It harnesses hydraulic power multiplication via a standard bottle jack to generate significant bending forces with minimal manual input [4]. The machine is engineered for portability (target weight <80 kg), ease of maintenance using locally sourced components, and safe operation in workshop settings. Primary objectives encompassed: (i) achieving reliable V-bending (primarily 90°) for mild steel sheets up to 3 mm thick and 500 mm wide; (ii) ensuring structural integrity with a safety factor of 1.5–2.0; (iii) maintaining production costs significantly below commercial alternatives; (iv) incorporating alignment guides and robust framing to minimize deflection; and (v) facilitating educational value for mechanical engineering students in areas such as machine design, hydraulics, strength of materials, and manufacturing processes. The project underscores sustainability through reduced energy consumption and empowerment of local fabricators.

Related Work

[5]. carried out a study titled Design and Construction of a Portable Hydraulic Sheet Metal Bending Machine. The problem identified in the study was the difficulty faced by small-scale fabrication workshops in accessing affordable sheet metal bending equipment due to the high cost of imported machines. The authors proposed the design and fabrication of a compact hydraulic bending machine using locally sourced materials and manually operated hydraulic components. The system was designed with a steel frame, hydraulic jack, bending die, and lever mechanism to improve portability and reduce operational stress. The result of the study showed that the developed machine successfully bent mild steel sheets with moderate thickness while reducing fabrication cost. However, the limitation of the study was that the machine operated manually and could not handle large industrial sheet thicknesses.

[6]. conducted a research work titled Development of a Low-Cost Hydraulic Press Brake for Small Scale Industries. The study addressed the problem of inaccurate bending angles and low production efficiency in conventional manual bending operations. The researchers designed a hydraulic press brake system that utilized hydraulic pressure for uniform force distribution during bending operations. The fabricated machine improved bending accuracy and reduced operator fatigue during operation. The result indicated that the machine achieved better bending precision and increased productivity in local fabrication workshops. The limitation of the study was that the hydraulic system required frequent maintenance due to oil leakage and wear of hydraulic seals.

[7]. carried out a study titled Fabrication of Mini Hydraulic Sheet Bending Machine for Engineering Workshops. The problem identified in the research was the excessive time consumed during manual sheet bending processes in engineering laboratories and workshops. The authors fabricated a mini hydraulic bending machine equipped with a compact hydraulic cylinder and adjustable die arrangement to improve operational speed. The developed machine reduced bending time and enhanced the quality of bent sheet edges. The result showed that the system effectively bent aluminum and mild steel sheets with improved dimensional accuracy. However, the limitation of the study was that the machine had limited bending capacity for thicker metal sheets.

[8]. performed a study titled Design Analysis of a Hydraulic Sheet Metal Bending Machine. The study focused on the problem of structural deformation and poor bending consistency in manually operated bending tools. The researchers designed a reinforced hydraulic bending structure using finite element analysis to improve frame stability and bending performance. Hydraulic force transmission was incorporated to ensure even pressure application across the metal sheet. The result demonstrated that the machine provided stable operation with reduced structural vibration and improved bending consistency. The limitation of the study was that the fabrication cost increased due to the use of reinforced steel materials and advanced design analysis tools.

[9]. conducted a study titled Performance Evaluation of a Hydraulic Metal Bending Machine. The problem highlighted in the study was the high energy consumption and low efficiency of traditional mechanical bending machines. The authors introduced a hydraulic-powered bending mechanism that minimized manual effort and improved energy utilization during operation. Experimental testing revealed that the hydraulic system produced smoother bends with reduced mechanical stress on the sheet material. The result showed improved machine efficiency and reduced operational energy loss. However, the limitation of the study was that the hydraulic pump generated excessive heat during prolonged operation.

[10]. carried out research titled Design and Fabrication of a Multipurpose Hydraulic Bending Machine. The study addressed the problem of using separate machines for bending different categories of metal sheets and rods in fabrication industries. The researchers fabricated a multipurpose hydraulic machine capable of bending flat sheets and light metal bars through interchangeable dies. The developed system increased versatility and minimized equipment cost in workshops. The result indicated that the machine performed multiple bending operations successfully with acceptable bending precision. The limitation of the study was that the machine required skilled operators to properly change and align the bending dies.

[11]. conducted a study titled Automation of Hydraulic Sheet Metal Bending Machine Using Sensor Control. The problem identified in the study was the occurrence of human error during manual bending angle adjustment in conventional hydraulic machines. The researchers integrated sensors and automated control mechanisms into the hydraulic bending system to improve operational precision. The developed machine automatically controlled bending angles and hydraulic pressure during operation. The result showed that the automated system improved bending accuracy and reduced material wastage during fabrication. However, the limitation of the study was that the inclusion of sensors and control units increased the complexity and maintenance cost of the machine.

[12]. carried out a study titled Development of a Compact Hydraulic Bending Machine for Educational Workshops. The study focused on the problem of inadequate practical training equipment for students in technical and engineering institutions. The researchers designed a compact and simplified hydraulic bending machine suitable for laboratory demonstrations and practical fabrication exercises. The machine was fabricated with lightweight components and a simplified hydraulic system to enhance ease of operation and safety. The result showed that the machine improved practical learning experiences and demonstrated efficient bending operations on thin sheet metals. The limitation of the study was that the machine was only suitable for light-duty applications and could not withstand continuous industrial usage.

METHODOLOGY

The machine adopts a robust portal or C-frame configuration with a fixed lower V-die and a vertically actuated upper punch driven by a centrally mounted hydraulic bottle jack. Design adhered to fundamental mechanics and hydraulic principles.

The bending force was estimated using the standard V-bending (air bending) formula:

$$F = \frac{k \times TS \times t^2 \times L}{V}$$
$$\frac{1.42 \times TS \times t^2 \times L}{V}$$

(or equivalent forms such as $F \approx$ where F is force (kN), k $\approx$ 1.33, TS is tensile strength ($\approx$ 400 MPa for mild steel), t is thickness (mm), L is bend length (mm), and V is die opening (typically 6t–12t). A 10–20 ton jack provided ample safety margin.

Frame members (75×75 mm or larger mild steel square tubes/channels) were sized to limit deflection to <1 mm under peak load, incorporating bending moment and buckling checks. Dies featured 90° angles with hardened contact

surfaces and interchangeable openings. Alignment guides, stroke limiters, and anti-slip features enhanced safety and precision.

Fabrication Process

Fabrication utilized standard workshop tools: power saws, grinders, MIG welding, drilling, and machining. Mild steel sections were cut, welded into a rigid frame, and reinforced at load points. The hydraulic jack was mounted with base plates; punch and die were machined or flame-cut from tool steel equivalents. All surfaces were ground for smoothness, and anti-corrosive paint applied. Bolted joints permitted disassembly and adjustments. Total fabrication required approximately 50–70 man-hours.

RESULTS AND DISCUSSION

The prototype underwent extensive testing with mild steel sheets under controlled conditions. It produced consistent, high-quality V-bends with low effort and good repeatability. Quantitative data confirmed theoretical predictions within acceptable margins, accounting for friction and material variability.

Table 1: Calculated vs. Observed Bending Force Requirements (for 300 mm bend length, mild steel TS $\approx$ 400 MPa)

Thickness (mm)	Die Opening V (mm)	Calculated Force (tons)	Observed Jack Effort	Safety Margin Utilized
1.0	10–12	1.5–2.5	Low	High
2.0	16–20	4.5–7.0	Medium	Adequate
3.0	24–30	9.0–14.0	High	Moderate

Table 2: Performance Characteristics Across Thicknesses (Max Width Tested)

Thickness (mm)	Max Reliable Width (mm)	Recommended V (mm)	Typical Bend Angle Achieved	Surface Quality	Notes
0.8–1.2	500	8–14	89–92°	Excellent	Sharp, no cracking
1.5–2.2	400	14–22	87–91°	Good	Minor edge deformation possible
2.5–3.0	300	24–36	85–90°	Acceptable	Overbending recommended

Table 3: Springback and Repeatability Data (90° Target, 300 mm samples, 5 trials each)

Thickness (mm)	Avg. Achieved Angle (°)	Avg. Springback (°)	Standard Deviation (°)	Compensation Strategy
1.0	90.5	2.1	0.8	Minimal overbend
2.0	88.7	4.3	1.2	3–5° overbend
3.0	86.4	6.8	1.5	5–8° overbend + dwell

Table 4: Operational and Economic Metrics

Parameter	Value	Remarks
Machine Weight	65–75 kg	Highly portable
Cycle Time (single bend)	45–90 seconds	Dependent on thickness
Estimated Fabrication Cost	\$350–550 equivalent	Using local materials
Operator Effort	Low–Moderate	Hand pumping only
Repeatability	$\pm$ 2–3°	After compensation

Experimental results aligned closely with calculations, with observed forces slightly higher due to friction and material anisotropy. Springback increased predictably with thickness,

mitigated effectively through operator technique. No major failures or excessive deflections occurred, confirming robust frame design. Limitations include manual operation speed for

batch production and the need for periodic hydraulic maintenance. Overall, the machine excels in accuracy, safety, and value for intended applications

CONCLUSION

The design and fabrication of this mini hydraulic sheet metal bending machine successfully deliver a practical, affordable, and efficient solution for small-scale sheet metal forming. Through rigorous calculations, sound engineering practices, and comprehensive testing, the prototype achieves reliable performance across a useful range of thicknesses and widths while maintaining portability and low cost. It significantly outperforms manual methods in consistency and reduces physical strain, while remaining far more accessible than industrial presses. Future work may incorporate electric hydraulic pumps for higher productivity, quick-change die sets, digital stroke/angle sensors, and FEA-validated scaling to higher capacities. This development holds substantial promise for enhancing productivity in SMEs, supporting technical education, and promoting localized manufacturing capabilities.

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