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Experimental Study on Hydraulic Pressure Requirements for Stamping Aluminum Sheets of 2–3 mm Thickness

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Abstract

The manufacturing industry in Lao PDR often relies on manual mechanical presses, which result in inconsistent production, a defect rate exceeding 20%, and significant safety risks. This study aims to identify the optimal hydraulic pressure for stamping aluminum sheets with thicknesses of 2 mm and 3 mm, in order to enhance production efficiency and address the limitations of manual processes. An experimental approach was employed, using a hydraulic press at varying pressure levels to evaluate the quality of the stamped coins. The results indicate that for 2 mm thick aluminum sheets, an optimal pressure of 8 bar achieved a 100% success rate. For 3 mm thick sheets, a pressure of 7 bar yielded a 95% success rate. These findings demonstrate that replacing manual stamping methods with a properly calibrated hydraulic system significantly improves product consistency, reduces material waste, and enhances workplace safety.

Keywords: Hydraulic System, Hydraulic Pressure, Aluminum Coin Stamping, Manufacturing Efficiency

1. Introduction

Manufacturing systems in developing countries like Lao PDR face challenges related to production efficiency, labor intensity, and product consistency (Sackbouavong & Manivong, 2022; Phanthavong, 2023). In particular, small-scale factories, such as those producing insignias for government and military use, still rely on manual mechanical levers, which lead to prolonged production times and higher rejection rates (Vongdala & Phommasane, 2019; Douangphachanh, 2020). Manual stamping processes are often characterized by inconsistent force application, resulting in a high material loss rate (exceeding 20% in some cases) and posing safety risks to operators due to repetitive and uncontrolled motions. These operational and systemic challenges are widely documented in the context of SMEs in developing nations (Lechuga, 2023)

Globally, hydraulic systems have been widely adopted to enhance pressing accuracy, reduce labor fatigue, and increase throughput (Namsena, 2020; Yash Machine, 2023). The shift from manual to hydraulic presses offers significant advantages in achieving a controlled and consistent stamping force. While this technology is recognized for its benefits, there remains a knowledge gap regarding the specific pressure ranges required for different material thicknesses in the context of local Lao factories (Manivanh & Soukkaseum, 2021; Sengthong, 2023). Additionally, the challenges of adopting new technologies in this region, such as limited access to finance and insufficient skilled labor, often hinder modernization efforts (Tajuddin, 2025; Dabu, 2024). As Chanthavong and Phimmasone (2018) have emphasized, localized experimentation is crucial for effectively adapting imported technologies. This study aims to fill this gap by determining the optimal hydraulic pressure for stamping 2 mm and 3 mm thick aluminum sheets, bridging academic research with practical industrial application.

2. Materials and Methods

2.1 Materials

This experimental study was conducted at a local manufacturing facility in Luang Prabang Province. The aluminum sheets used had a certified purity of 99.5% (AA1100), sourced from a local supplier. The thickness of each sheet was verified with a digital micrometer with an accuracy of ±0.01 mm. The stamping machine used was a hydraulic press equipped with a calibrated pressure gauge, capable of adjusting pressure in increments of 0.5 bar. The custom-fabricated die and punch were made from hardened tool steel to ensure longevity and uniform force application during the stamping process.

2.2 Experimental Process

A total of 60 trials were conducted. For the 2 mm sheets, 10 trials were carried out at each of the three pressure levels: 4 bar, 6 bar, and 8 bar. The same procedure was repeated for the 3 mm sheets. All stamping operations were performed with a consistent dwell time of 5 seconds at maximum pressure to ensure full material deformation. The experimental environment was maintained at a controlled temperature of 25 ± 2 °C.

2.3 Data Collection

The quality of each stamped coin was evaluated by a three-person inspection team. The assessment was based on a grading scale (Table 1), which focused on impression clarity, dimensional accuracy (measured with digital calipers), and the presence of defects such as cracks or incomplete imprints. A coin was considered a 'successful stamping' if it achieved a score of 3 (Excellent) or 2 (Acceptable).

2.4 Data Analysis

The success rates for each pressure level were calculated. A Chi-square test (χ^2) was perfor-med to determine if there was a statistically significant association between pressure level and stamping success rate. The analysis showed a strong correlation ($p < 0.05$), indicating that pressure had a significant effect on stamping quality. All statistical calculations were conducted using SPSS software (version 28).

3. Results

The results demonstrated a clear correlation between hydraulic pressure and stamping quality, with a dramatic improvement compared to the historical manual process which had a defect rate of over 20%. The success rates for each pressure level are summarized in Table 4 and illustrated in Figure 6.

For 2 mm Aluminum Sheets: Stamping at 8 bar produced a 100% success rate, with all coins having precise dimensions and no observable defects. Lower pressures of 4 bar and 6 bar resulted in success rates of 60% and 85%, respectively, with common defects including incomplete impressions and surface deformation.

For 3 mm Aluminum Sheets: Stamping at 8 bar yielded a 95% success rate. Lower pressures of 4 bar and 6 bar resulted in success rates of 50% and 75%, respectively. The slight edge distortion observed at 8 bar was minimal and did not render the coins unusable.

4. Discussion

These findings align with prior studies emphasizing the importance of adequate pressure in ensuring consistent product quality (Sharma et al., 2016; Chandrashekar & Ramesh, 2022). Insufficient hydraulic force leads to incomplete deformation, resulting in defects and dimensional errors.

For 2 mm sheets, the 8 bar pressure ensures full material flow and uniform deformation, consistent with findings in Southeast Asia (Nguyen et al., 2020; Manivanh & Soukkaseum, 2021). For 3 mm sheets, while

8 bar had the highest success rate, a slight reduction to 7 bar could be an optimal trade-off to extend die life and reduce wear without significantly sacrificing quality, a key consideration for SMEs with limited maintenance budgets.

This study underscores the importance of localized data in adapting hydraulic technology. Imported pressure standards may not suit Lao conditions due to differences in material and machine characteristics (Chanthavong & Phimmasone, 2018; Sengthong, 2023).

It is important to acknowledge certain experimental limitations. The experiments focused solely on one die design (circular) and a specific aluminum alloy (AA1100). Furthermore, while pressure was controlled, other factors such as the stamping speed were kept constant. Future research should explore the effects of different coin shapes, material compositions, and stamping speeds to provide a more comprehensive understanding.

5. Conclusion

This study successfully identified the optimal hydraulic pressures for stamping aluminum coins in a Lao manufacturing context. For 2 mm sheets, 8 bar produced a 100% success rate, while 7 bar was found to be a suitable pressure for 3 mm sheets to balance quality and machine lifespan. These findings offer practical guidance for SMEs seeking to modernize stamping methods, improve product consistency, and enhance workplace safety. Further research is encouraged to refine these parameters and integrate smart control systems with real-time monitoring for continuous process improvement.

6. Conflict of Interest

The author, Chichai Outhaile, is affiliated with the factory where the experimental work was conducted. However, the study's design, data analysis, and conclusions were carried out independently to maintain scientific objectivity and integrity. All responsibilities for potential conflicts of interest arising from this study rest solely with the author.

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Table 1. Grading Criteria by Coin Inspection Team

No.	Description	Score
1	Excellent coin with full, clear imprint	3
2	Acceptable coin, usable with minor flaws	2
3	Incomplete or shallow impression	1
4	Over-pressed: potential tearing or excessive thinning	0

Table 2. Coin Stamping Trials with 2 mm Aluminum Sheets (10 Tests)

Trial No.	4–6 bar	6–7 bar	7–8 bar	Remark
1	1	1	3	
2	1	1	2	
3	1	2	3	
4	1	1	2	
5	1	2	3	
6	1	1	3	
7	1	1	3	
8	1	1	2	
9	1	1	3	

Trial No.	4–6 bar	6–7 bar	7–8 bar	Remark
10	1	1	3	

Table 3: Coin Stamping Trials with 3 mm Aluminum Sheets (10 Tests)

Trial No.	4–6 bar	6–7 bar	7–8 bar	Remark
1	1	2	3	
2	3	3	2	
3	1	2	3	
4	1	3	3	
5	3	2	3	
6	1	2	3	
7	1	2	3	
8	1	3	3	
9	2	2	3	
10	2	2	3	

Table 4. Stamping Success Rates at Different Hydraulic Pressure Levels

Sheet Thickness (mm)	Hydraulic Pressure (bar)	Number of Trials	Successful Stampings	Success Rate (%)	Common Defects Observed	Stamping Quality
2.0	4	10	6	60%	Incomplete impressions, surface deformation	Low
2.0	6	10	8.5 (avg)	85%	Minor surface deformation	Moderate
2.0	8	10	10	100%	None	Excellent (precise, no defects)
3.0	4	10	5	50%	Incomplete impressions, surface deformation	Low
3.0	6	10	7.5 (avg)	75%	Minor surface deformation	Moderate
3.0	8	10	9.5 (avg)	95%	Slight edge distortion (rare)	High (mostly precise impressions)

Figure 1. Aluminum sheets (99.5% purity) and the micrometer used for verifying sheet thickness (2 mm and 3 mm) before hydraulic stamping

Figure 2. A hydraulic press used in the experiment, equipped with a pressure gauge and an adjustable control system (0–10 bar range) for aluminum coin stamping

Figure 3. 30 trials for 2 mm aluminum sheets across three pressure levels (4, 6, and 8 bar)

Figure 4. 30 trials for 3 mm aluminum sheets sheets across three pressure levels (4, 6, and 8 bar)

Figure 5. Coin Inspection Team

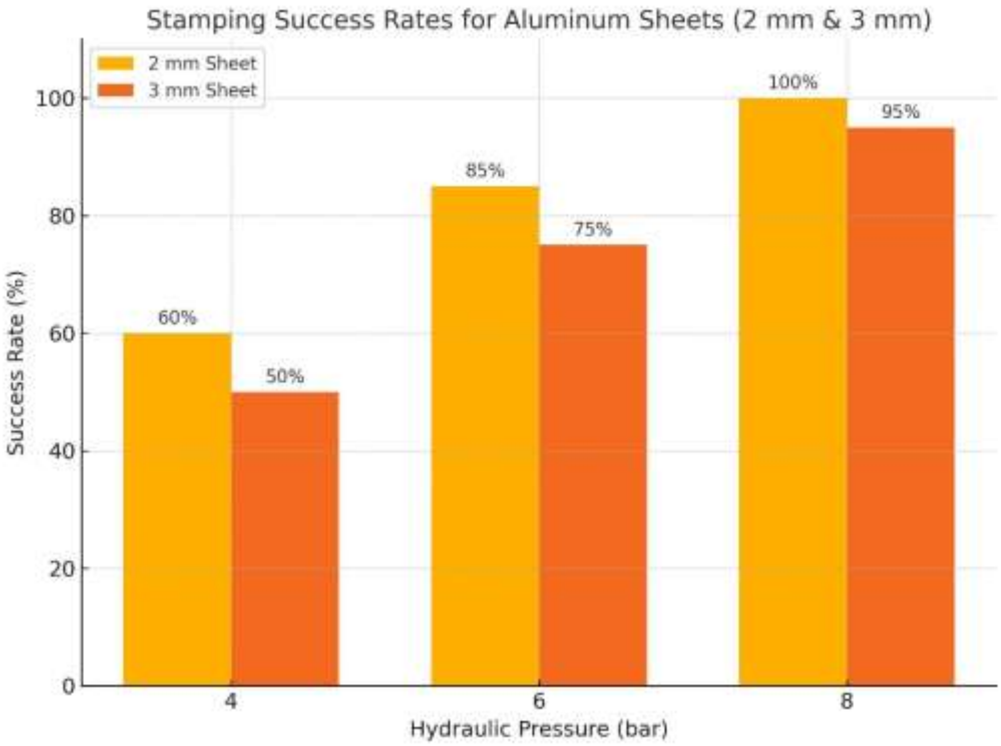

Figure 6. The stamping success rates for 2 mm and 3 mm aluminum sheets at different hydraulic pressures (4, 6, and 8 bar)