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A Comprehensive Study on Production Efficiency Enhancement Using Optimal Power Press Tonnage in Stamping

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ABSTRACT

The use of press machines in stamping is an important aspect of the manufacturing industry, especially in producing efficient and quality components. This article aims to analyze the cost of the stamping process using mild steel SPCC-SD material measuring 200 mm x 25 mm x 0.8 mm, using two types of press machines, namely 80 tons and 40 tons. Through the cost analysis method, the total cost of the stamping process for the 80-ton press machine is Rp 16,417.4 per 10 pcs, while for the 40-ton press machine, it is Rp 15,028.5, indicating the cost efficiency of the 40-ton press machine is around 8.5%. The tonnage calculation shows that the 40-ton press machine is adequate for the blanking process, with a tonnage requirement of 4 tons, far below the available capacity. These results provide recommendations for the use of 40-ton press machines in the production of steel components on a small to medium scale, considering cost efficiency and optimal performance. This work is expected to increase productivity and cost efficiency in the manufacturing industry, especially at PT GA.

Keywords: Blanking Process, Press machine, Manufacturing industry, Stamping process. Cost Analysis.

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1. Introduction

In response to high consumer demand and rapid technological advancements, the manufacturing sector is continuously seeking methods to enhance production efficiency and reduce operational costs to maintain global competitiveness [1]. Metal stamping, especially the blanking process, is a critical technology that is widely utilized in automotive and electronics manufacturing for mass production. It is notable for its capacity to produce components with consistent quality, reduced cycle times, and minimal waste [2]. The selection of an appropriate power press machine (PPM) is crucial to the efficiency and efficacy of stamping processes and directly influences production speed, precision, energy efficiency, and output quality [3]. A judiciously selected press can optimize workflows, increase productivity, and substantially reduce long-term costs. Conversely, an unsuitable power press may lead to frequent downtime, increased maintenance expenditures, and compromised product quality, ultimately diminishing the manufacturer's market position.

The PPM selection process must also consider long-term strategic objectives including scalability, workforce expertise, safety measures, and environmental sustainability [4]. Power presses have the potential

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to enhance workplace safety, reduce energy consumption, and contribute to sustainability objectives, which are increasingly important in the contemporary manufacturing sector [5, 6]. Despite its importance, the systematic evaluation of power press tonnage in industrial settings remains understudied, with many manufacturers relying on general guidelines or empirical methods. Power press tonnage determines a machine's capacity to form components effectively and influences the production efficiency, tool longevity, and energy consumption [7, 8].

The metal stamping process is an important manufacturing method in industry, particularly for mass-producing metal components with high precision and low cost [9]. The optimization of stamping process parameters is a significant concern in research to improve production efficiency and product quality. Badgujar and Wani [10] utilized a multiple regression analysis approach to identify and optimize key process parameters, such as pressure and speed, that significantly affect output quality. They showed that the optimal combination of parameters can simultaneously reduce the cycle time and energy consumption. Gantar and Kuzman [11] focused on the process stability and revealed that increasing the tool stiffness and appropriate pressure force setting can reduce product variability and improve the efficiency of the stamping process. In another study, Liang *et al.* [12] adopted a biomimetic design using a steel-aluminum sandwich structure to develop a lighter and more energy-efficient slider press. Their results showed that this approach could reduce energy consumption by up to 20% without sacrificing structural strength, thereby providing new energy-saving opportunities in the manufacturing sector. These studies offer a solid foundation for developing more efficient and sustainable stamping technologies by integrating optimization methods and innovative designs. Cooper *et al.* [13] conducted an environmental and cost analysis of the sheet metal stamping process, utilizing a life cycle analysis (LCA) approach to evaluate environmental impacts and a cost analysis to assess total production costs. Their findings indicated that, although stamping can reduce environmental impacts, design optimization and appropriate material selection are crucial for improving energy efficiency and reducing waste. Tang *et al.* [14] conducted quantitative and qualitative cost analyses for stamping processes, identifying various cost-influencing factors such as design complexity and material choice. They stressed the importance of thoroughly understanding cost components to enhance stamping process efficiency and optimize production expenses. Additionally, Klingenberg and Singh [15] employed a finite element simulation (FEM) to examine the punching and blanking processes of mild steel SPCC-SD, concentrating on the material behavior during operation. Their research demonstrated that FEM simulations can accurately predict material deformation and final product quality, allowing further optimization of the manufacturing process. Together, these studies offer valuable insights into improving efficiency, reducing costs, and minimizing the environmental impact of sheet metal manufacturing.

Blanking is a cutting technique widely used in manufacturing to produce metal components from sheet metals. This involves the use of a mold to cut the material into the desired shape and dimensions [15]. The blanking process is one of the main techniques used in metal forming to cut certain parts of sheet metal with high precision. This technique works on the cutting area of the material through the interaction between the punch and the die, producing a blank that matches the desired design. By utilizing the shear zone, this process combines elastic, plastic, and fracture deformations to separate the material efficiently. Blanking is widely used in the manufacturing industry because it can increase productivity, reduce material waste, and ensure dimensional consistency of the final product. Optimizing process parameters, such as clearance and tool material, is key to improving product quality and production efficiency and is frequently utilized in this process because of its favorable mechanical properties, suitable ductility and strength, and relatively low cost [16].

Blanking is a widely used cutting technique in manufacturing to produce metal components from sheet materials, where a mold is used to cut the material into specific shapes and dimensions [14]. As a primary metal forming process, blanking achieves high precision by cutting parts through the interaction of a punch and die. This process leverages the shear zone of the material by combining elastic, plastic, and fracture deformations to separate the material efficiently [17]. This technique enhances productivity, minimizes material waste, and ensures dimensional consistency in the final products. The optimization of parameters,

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such as clearance and tool material, plays a critical role in improving product quality and production efficiency. Mild steel SPCC-SD is commonly employed owing to its favorable ductility, strength, and cost-effectiveness [18-20].

Tonnage selection is crucial for optimizing stamping operations; however, systematic evaluations and empirical data are limited. Existing guidelines rely on general rules or empirical methods, potentially causing inefficiencies and incurring higher costs. While metal stamping offers high precision, reduced cycle time, and minimized waste, the role of power press tonnage in production efficiency lacks a systematic evaluation. Studies have focused on material behavior, process stability, and energy efficiency in stamping [10-15], but the impact of tonnage selection on cycle time, tool life, energy consumption, and production cost has not been explored. This study aims to enhance SMEs' production efficiency by analyzing press cost and performance, addressing the knowledge gap on the effect of tonnage selection on efficiency. Using case studies, we examine the stamping process and the impact of appropriate tonnage on cycle time, cost, and quality, exploring the technical and financial implications of suboptimal selection, such as machine overload, tool failure, and increased costs. By proposing a systematic framework for tonnage selection, this study aims to guide manufacturers in improving the stamping efficiency. The results will contribute to manufacturing optimization and aid practitioners and researchers in mechanical engineering and production management. Inappropriate tonnage selection can increase downtime and maintenance costs and reduce product quality, thereby undermining manufacturing competitiveness. This study investigates the effect of optimal press power tonnage selection on stamping efficiency, offering practical insights for SMEs to improve production and reduce costs.

2. Methods

2.1. Press machine selection

The determination machine aimed to assess the cost-effectiveness and performance of 80-ton and 40-ton press machines in stamping mild steel SPCC-SD components measuring 200 mm × 25 mm x 0.8 mm for tensile test coupons as per ASTM E8 [21]. The investigation commenced by selecting appropriate press machines and preparing the specified mild steel SPCC-SD test material. The stamping operation employed a customized die design and punch force to achieve optimal outcomes. Figure 1 illustrates the punch and die design. Several key parameters were monitored throughout the experiment, including stamping cycle duration, quality of the produced items, dimensional accuracy, and surface finish of the resulting components. This method extends beyond the initial setup and operation of the press machines. This involves a comprehensive analysis of the entire stamping process, including preparing mild steel SPCC-SD components, designing and implementing a customized die, carefully monitoring various performance indicators, and conducting multiple trials for each press machine to ensure the statistical significance of their results.

Furthermore, the cost-effectiveness of this study necessitates detailed economic analysis. This includes factors such as preparation, material, maintenance requirements, and labor costs associated with the operation of each press machine. Analysts will also consider the long-term durability of the equipment and its impact on overall production efficiency. By comparing these factors between 80-ton and 40-ton press machines, this study aims to provide valuable insights into the optimal choice of equipment for manufacturing mild steel SPCC-SD (JIS G3141) components with specified dimensions [22], potentially influencing future investment decisions in the industry.

2.2. Materials

The specimen for this experiment was chosen as the tensile test coupon, which is commonly used in testing processes according to the ASTM E8 standard [21]. The material used in this study was mild steel SPCC-SD with dimensions of 200 mm × 25 mm × 0.8 mm. Mild steel SPCC-SD, specifically JIS G 3141 grade [22], was selected for its sufficient strength, resistance to deformation, and suitability for the cutting and forming processes.

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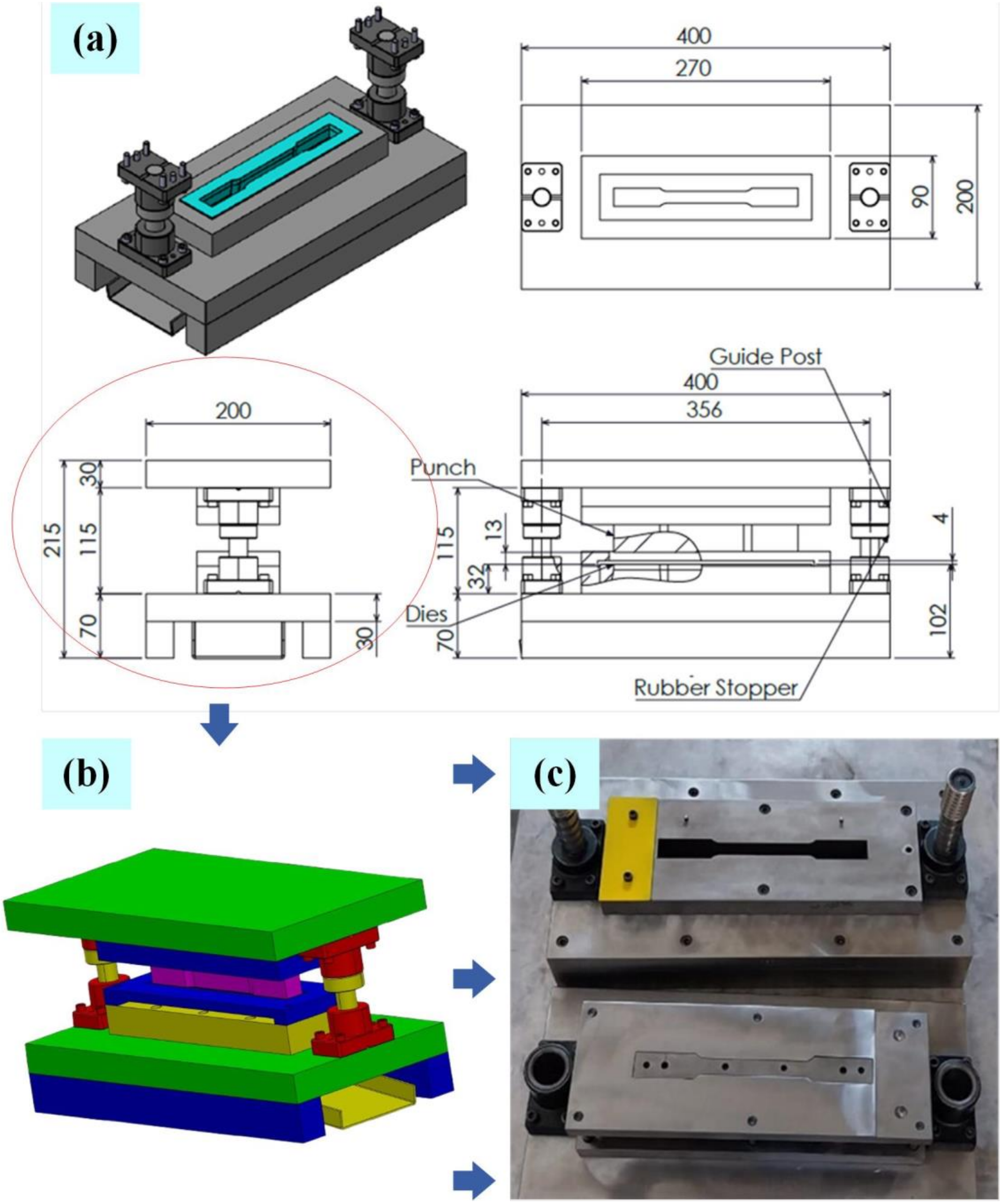

Figure 1. Punch and die for tensile strength coupon: (a) detailed dies and punch, (b) 3-D dies and punch, and (c) Dies dan punch.

Additionally, its widespread use in the manufacturing industry, particularly for components that require high precision, renders it ideal for this experiment. The tensile test coupon adhered to the ASTM E8 standard, which is widely recognized for its reliability in assessing the mechanical properties of metallic materials. This standard provides comprehensive guidelines for specimen preparation, testing procedures, and data analysis, ensuring consistency and comparability of results across various laboratories. The dimensions of the specimen (200 mm × 25 mm × 0.8 mm) were carefully selected to meet the standard requirements while also considering practical aspects, such as material availability, as illustrated in **Figure 2**.

JIS G 3141 mild steel SPCC-SD was selected for this study owing to its desirable properties and industrial relevance. This steel grade provides a balance between the strength and ductility, making it suitable for a wide range of manufacturing applications. Its resistance to deformation ensures that the specimen maintains its shape during testing, allowing for accurate measurement of the mechanical properties. Furthermore, the amenability of the material to the cutting and forming processes facilitated the preparation

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of precise test specimens [18]. The widespread use of JIS G 3141 mild steel SPCC-SD in industrial applications, particularly in components requiring high precision, enhances the significance of this study's findings, as it can be directly applied to real-world manufacturing scenarios [23].

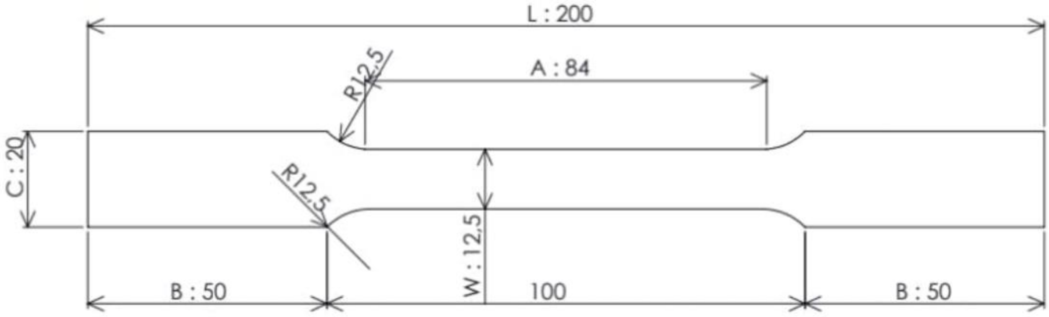

Figure 2. Detail of the tensile strength coupon according to ASTM E8, with all dimensions in millimeters

2.3. Power press calculation

Determining the required tonnage (*T*) of a press machine is crucial to ensure that it can exert a sufficient force for the material-shaping operation [24]. Determining the tonnage *T* of a press machine is essential for the design and operation of processes involving shaping materials. This calculation determines the magnitude of the force required to successfully shape, cut, or form materials into desired configurations. Precise tonnage calculations play a crucial role in choosing the correct press machine, enhancing the production efficiency, and maintaining the well-being of workers and machinery. These calculations are vital to ensure operational success and workplace safety. Several factors influence the required tonnage, including material properties (yield strength and thickness), specific forming operations (e.g., bending, stamping, or punching), and geometry of the workpiece and tooling [25].

Additionally, proper tonnage calculations help prevent machine overloading, which can lead to premature wear, reduced precision, and potential safety hazards. Manufacturers can optimize their production processes, minimize energy consumption, and ensure consistent product quality by accurately determining the required press machine tonnage. For a material such as mild steel SPCC-SD with dimensions of 200 × 25 mm × 0.8 mm, the required force can be calculated using the following formula [26]:

$$T = Cs \times t \times \tau \tag{1}$$

Where *Cs* is the circumference (mm), *t* is the thickness of the test sample (mm) and τ is the shear stress (N/mm^2). This formula provides the tonnage required for a press machine by considering the dimensions of the material, its mechanical properties, and the specific operation performed. For Mild steel SPCC-SD, the shear stress typically ranges from 250 to 320 MPa, according to the JIS G3141 standard.

Once the required force is determined, it is crucial to select a press machine with a tonnage capacity that exceeds the calculated value. This ensures a safety margin to accommodate variations in material properties, tooling wear, and other factors that may impact the forming process. In addition, the stroke length, bed size, and speed capabilities of the press machine should be considered to ensure compatibility with the forming operation and production requirements. Proper sizing of the press machine ensures not only successful material formation but also extends the longevity of the equipment and enhances the quality of the finished products.

During the blanking operation, the circumference of the tensile test specimen was precisely calculated, as illustrated in Figure 2.The blanking process involves cutting the material into the desired shape using a punch and die. To determine the necessary force, the circumference of the sample must be calculated by considering both the straight and curved edges shown in Figure 2, as expressed in Equation 2. The total required blanking force was estimated by multiplying the circumference by material thickness and shear strength. This calculation ensures the proper selection of equipment, optimizes the blanking process, and ensures the efficient and precise manufacturing of the test samples.

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$$Cs = (A + 2B + 2R12.5 + C) \times 2 \quad (2)$$

3. Results and Discussion

An analysis of the cost components in the stamping process utilizing mild steel SPCC-SD with dimensions of 200 mm × 25 mm × 0.8 mm was conducted, encompassing preparation, press machine, labor, mold, and material costs for the production of 10 components, as shown in **Figure 3**. The results elucidate the cost differentials between employing an 80-ton press machine and a 40-ton press machine. The detailed calculations of the manufacturing costs are listed in **Table 1**.

Figure 3. Illustrates the product photos obtained through the stamping process, demonstrating high dimensional consistency and visual stability, indicating superior production quality compared with alternative methods.

3.1. Preparation cost

The preparation cost, which incorporated the cutting process for the 10 components, was Rp 1,282. This cost remains constant for both 80-ton and 40-ton machines because the shearing process is unaffected by the press machine capacity. The cycle time for processing the 10 components was 50 s, with a total processing time of 0.0139 h. A significant disparity exists between the two machines in terms of their operating costs of the press machine. This stark contrast in operating costs underscores the importance of carefully selecting an appropriate press machine capacity to achieve optimal production efficiency and cost-effectiveness. The operating cost for the 80-ton press machine was Rp 3,472, whereas the operating cost for the 40-ton press machine was Rp 2,083. This discrepancy reflects the difference in their hourly machine operating costs: the 80-ton machine costs Rp 250,000 per hour, whereas the 40-ton machine costs Rp 150,000 per hour.

3.2. Labor and materials cost

Labor costs were identical for both machines based on equivalent delivery times and amounted to Rp 694 for the 10 tensile test coupons. For the mold cost component, assuming that the mold has a service life of 50,000 components, the cost per component is Rp 458.82, and the total mold cost for 10 components is Rp 4,588.2. The material cost is calculated based on the weight of the steel material used. The total material cost for the ten components was Rp 6,380.48, which was derived from a steel price of Rp 16,000 per kilogram and an adjusted nesting correction factor of 127%.

3.3. Total manufacturing cost

The total cost of producing 10 components using the 80-ton press machine was Rp16,417.4, whereas the 40-ton press machine reduced the total cost to Rp15,028.5. This translates to a per-component cost of Rp 1,641.74, for the 80-ton machine, and Rp 1,502.85, for the 40-ton machine. The primary cost difference arises from the lower operating costs of the 40-ton press machine. The results indicate a cost-saving

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advantage of approximately 8.5%, mainly owing to reduced operating costs. This comparison highlights the importance of evaluating the machine capacity and operational efficiency in production decisions. The cost reduction equals 1.2% of the material expenses, specifically in terms of 2.2% material cost units.

Table 1. A detailed breakdown of the manufacturing costs associated with the production of tensile strength coupons highlights the individual cost components and their contributions to the overall expenditure.

No.	Cost Components and Details	CODE	Unit	80-ton	40-ton	Description
A	Preparation Cost					
	Nesting - optimum shearing process (1219 x 2438 mm)	A1	pcs/sheet	468	468	
	Number of shearing processes	A2	Shearing/sheet	12	12	
	Shearing process cost per sheet	A3	Rp/shearing	5000	5000	
	Total shearing process cost per sheet	A4	Rp/sheet	60000	60000	A4 = (A3 x A2)
	Shearing process cost per pcs	A5	Rp/pcs	128	128	A5 = (A4 / A1)
	Shearing process cost for 10 pcs	A	Rp	1282	1282	A = A5 x 10
B	Stamping process time					
	Cycle time per pcs	B1	sec/pcs	5	5	
	Cycle time for 10 pcs	B2	sec	50	50	B2 = B1 x 10
	Total processing time	B	hours	0.0139	0.0139	
C	Press machine cost					
	Press machine operating cost per hour	C1	Rp/hour	250000	150000	
	Total processing time	C2	hours	0.0139	0.0139	
	Total press machine cost	C	Rp	3472	2083	C = C2 x C1
D	Labor Cost					
	Operator hourly wage	D1	Rp/hour	50000	50000	
	Total processing time	D2	hours	0.0139	0.0139	
	Total labor cost	D	Rp	694	694	D = D1 x D2
E	Mold cost					
	Mold lifetime (usable for 50,000 pcs)	E1	pcs	50,000	50,000	
	Mold cost	E2	Rp	22,941,000	22,941,000	
	Mold cost per component	E3	Rp/pcs	458.82	458.82	E3 = E2 / E1
	Total mold cost for 10 pcs	E	Rp	4588.2	4588.2	E = E3 x 10
F	Material cost (for 10 pcs)					
	Material price per kg	F1	Rp/kg	16000	16000	
	Material volume (per pcs)	F2	m^3 pcs	0.000004	0.000004	
	Steel density = 7,850 kg/m^3	F3	kg/m^3	7850	7850	
	Material mass (per pcs)	F4	Kg/pcs	0.0314	0.0314	F4 = F3 / F2
	Nesting mass correction for 4 x 8 F	F5	%	127	127	F5 = F4 x 127%
	Material mass (for 10 pcs)	F6	kg	0.3988	0.3988	F6 = F4 x F5%
	Total material cost	F	Rp	6,380.48	6,380.48	F = F6 x F1
G	Total cost for 10 pcs	G	Rp	16,417	15,029	G = A + C + D + F
H	**Unit cost**	**H**	**Rp/pcs**	**1,641.74**	**1,502.85**	**H = G / 10**

In contrast to the findings reported by [9], which indicated an efficiency gain of approximately 2.7%, converted from an average yield increase from 85% to 87.7%, or a 0.9% improvement in processing losses using an alternative approach, specifically scrap, carbon, and cost savings, from the adoption of flexible nested blanking.

However, further analysis is required to assess the impact of utilizing smaller-capacity press on overall production efficiency and product quality. This optimization process is crucial for determining the most efficient and cost-effective production setup and for balancing immediate cost savings with long-term production goals and quality standards.

4. Conclusions

This study aims to enhance the production efficiency in the MSME sector by analyzing the costs and performance of 40-ton and 80-ton press machines for stamping mild steel SPCC-SD components. Using a case study approach, this study investigates the influence of power press tonnage selection on critical production metrics, including cycle time, operational costs, and product quality. The findings can be summarized as follows:

- The results indicate that the 40-ton press demonstrates superior energy efficiency and cost-effectiveness for small-to medium-scale production, whereas the 80-ton press is more suitable for large-scale operations and thicker materials.
- Based on the production cost analysis, the 40-ton press machine exhibited approximately 6.31% higher efficiency than the 80-ton machine, primarily because of its lower hourly operating cost. For instance, producing 10 components costs Rp15,028.5 (Rp1,502.85 per pcs) with the 40-ton machine, compared to Rp 16,417.4 (Rp1,641.74 per pcs) with the 80-ton machine.
- Other costs, such as preparation, labor, materials, and molds, remain relatively constant across both machines. However, the lower operating cost of the 40-ton press renders it a more economical choice for small-to medium-scale production, without compromising product quality.

This study underscores the significance of selecting an appropriate power press to improve productivity, reduce costs, and enhance market competitiveness in the MSME sector. It contributes to the mechanical engineering literature, particularly in the field of stamping process optimization, offering actionable insights for manufacturers and researchers. These findings provide practical guidance for MSMEs to optimize their production processes while maintaining sustainability and efficiency.

Author's Declaration

Authors' contributions and responsibilities

The authors played a significant role in the conception and design of this study. The authors also took responsibility for the data analysis, interpretation, and discussion of the results. All authors have reviewed and approved the final manuscript.

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Availability of data and materials

All data are available from the corresponding authors.

Competing interests

The authors declare that they have no conflicts of interest.

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