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A Report on Metal Forming Technology Transfer from Expert to Industry for Improving Production Efficiency

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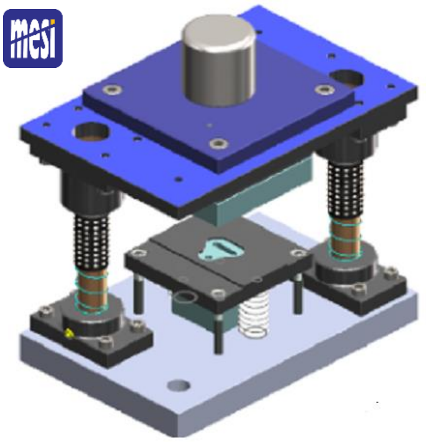

Highlights:

- Metal forming is a crucial production technology that involves drawing, forging, rolling, and bending
- Participatory Action Research (PAR) is a qualitative research method that requires more knowledge and consideration
- A motorcycle helmet is a type of helmet worn by motorcycle riders to keep them safe in the case of an accident by protecting the rider's head
- Blanking and piercing are shearing processes that make products from coil or sheet stock using a punch and die

Abstract

This article reports on technological mastery assistance in three small metal forming industries in Indonesia. Problems in the blangking and piercing separately process caused increased production time which resulted in inefficiency cost. Therefore, the expert team aided in metal forming technology through participatory action research (PAR) methods and experimental methods through reverse engineering for several products. The PAR method involves optimal contribution and participation from the industry. Assistance in mastering technology in small metal-forming industries reduces the manufacturing process from seven to three stages, increasing efficiency. The press machine's tonnage capacity must balance with the force blanking/piercing requirement. The minimum press machine requirement is 6.7 tons, and based on the availability of existing press machines, the expert team recommends a 20-ton capacity press machine. Total efficiency can be further increased by implementing full progressive die technology by combining piercing, blanking, and bending processes.

Keywords: Blanking and piercing, Metal forming, Progressives die, Reverse engineering, Technology dissemination

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1. Introduction

Many SMEs are active in metal processing in Bekasi Regency, Indonesia and they are expected to supply steel processing components to industrial areas in Jakarta, Bekasi regency, and Bekasi city. The strategic geography with the industrial field and supported by adequate material resources are expected to increase the efficiency and effectiveness of the manufacturing process. The development of metal processing for SMEs has excellent potential to improve the efficiency and quality of metal processing products, especially in metal forming.

This dissemination of metal forming technology is an advanced project previously completed for clamping helmet motorcycle components. A motorcycle helmet is a type of helmet worn by motorcycle riders that helps to keep them safe by shielding the rider's head in the case of an accident. As we know that, the university/college is expected to support the development of small and medium scale metal processing industry towards a more efficient process. The presence of universities/colleges in supporting the improvement of process efficiency and quality for small industries is tangible proof of implementing one of the implementations of three pillars of higher education, especially for community service [1]. The Mechanical Engineering Study Program of Buana Perjuangan Bekasi University and Wastukancana College of Technology was initiated by disseminating metal-forming technology collaborating with PT Isaka Alindo Nusantara's partner. This metal forming technology dissemination activity also involves researchers from Universiti Kuala Lumpur Malaysia France Insitute (Unikl MFI). The dissemination of this technology was conducted and followed by several participants from SMEs. They are involved in metal processing and small industries in the field of the stamping process. Among them are from Isalindo Jaya Tehnik, CV Anugrah, and participants from PT Isaka Alindo Nusantara. Due to limited time and resources, the dissemination of metal forming technology implementation agreed on one of the automotive components produced by the workshop of Isalindo Jaya Tehnik. **Figure 1** shows a power press machine in the Isalindo and a picture of a clamping helmet component.

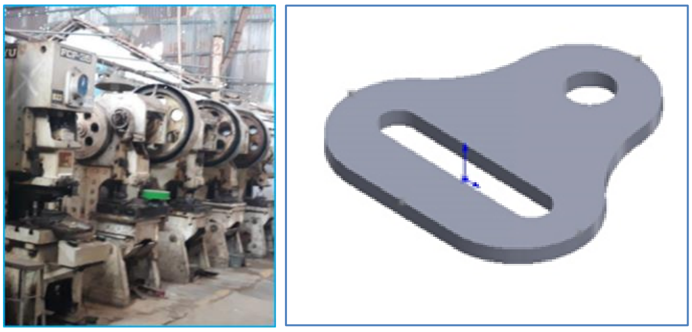

Figure 1. Power press machine and clamping helmet geometry in the selected industry partners

Sheet metal processing technology is one of the earliest manufacturing technologies developed in the manufacturing industry [2][3]. Metal forming technology has developed rapidly [4]. In general, the partner's production process can be identified by the blanking process, piercing process, bending process, and trimming process. The blanking and piercing process is a cutting technique in which the die and punches produce coil or sheet plate parts [5]. The two processes differ significantly in that the blanking process produces external features of the component, whereas the piercing process produces holes or internal shapes [6]. Waste produced by pushing interior features is also regarded as scrap [5][7]. In contrast to the cutting/blanking and piercing processes that work on the fracture area [8][9], while the bending process works on the plastic area [10]. The results of the evaluation of the metal forming process and situation analysis in the partner, then the problem formulation can be identified as follows: (1) The blanking process is done separately from the piercing process, namely with the stages of blanking process, piercing-1 and piercing-2 (2) piercing process 1 and 2 performed with a single process that requires several die; (3) both process problems above, trigger the inefficiency of the production process because each process requires a longer setting time and production process.

Unlike some other dissemination programmes, this one combined the PAR with an experimental methodology. The PAR methodology increases partner participation, whereas the experimental method is used to redesign the die and punch. According to the problem identification in the preceding paragraph, the inefficiency of clamping helmet manufacturing processes in design is a significant issue in the partner. Shearing, blanking, piercing-1, and piercing-2 are the four significant steps in clamping helmet manufacturing. The aim of disseminating metal forming technology to the community is to assist SMEs as partners in increasing the efficiency of clamping helmet production. It can be made more efficient by improving the clamping helmet's die design and reducing its production processes by redesigning the die and punch.

2. Method

The leading partner in the dissemination of metal forming technology is PT. Isaka Alindo Nusantara, Isalindo Workshop and CV Anugrah in Karangsentosa village, Karangrahayu subdistrict, Bekasi regency. They are small and medium enterprises involved in sheet steel processing. This activity starts on January 4, 2021, until June 30, 2021. Due to the covid-19 pandemic, all public service activities conducted offline must adhere to health protocols. They maintain a minimum distance of 1 meter, always wear a mask, wash hands as often as possible, and other matters that are mandatory/regulated in regulations/legislation [11]. During offline activities, it is possible to remove the mask when taking photos for documentation.

This community service activity uses a participatory action research (PAR) approach. PAR is a method of research approach in the community with an emphasis on community participation and action, so it must be done collaboratively and simultaneously between the facilitator as an agent of social change with the community [12]. Collaboration with responsible partners is sought to enhance partner capabilities. The application of this method is made to evaluate and understand the problem by trying to change it collaboratively with all the partners involved. The emphasis of the PAR method is on two essential aspects. They are the collaborative research and experimentation based on experience and social history; emphasis on investigation and partner actions developed to answer questions and significant problems faced by partners to actively participate as research partners [13][14]. The stages of the PAR method in the implementation of community service is presented in **Figure 2**.

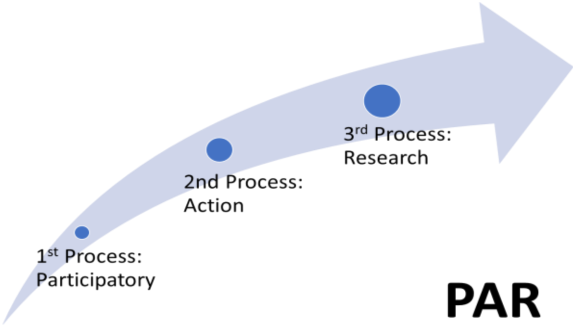

Figure 2. Stages of PAR Method in dissemination in metal forming technology

The stages of implementation of the PAR method in community service with the entitled "Disseminations of Metal Forming Technology for Automotive Part in Small and Medium Enterprises Community" are presented in **Table 1**.

Table 1. Stages of metal forming technology dissemination activities

No	PAR implementation stage	Period 2021							PAR Method
		Jan	Feb	Mar	Apr	Mei	Jun	Jul	
1	Identification of the process of making a clamping helmet								PROCESS I PARTICIPATION
2	Identification of materials and equipment.								
3	Introduction and socialization of metal forming technology.								PROCESS II ACTION
4	Training and practice of combining piercing and blanking processes								
5	Partner mentoring and evaluation								PROCESS III RESEARCH
7	Research publications								

2.1. Identification of the process of making a clamping helmet

The identification of metal forming processes forms a participatory process that is an integral part of the PAR method. The formation of the forming metal present in the leading partner is shaving, emptying, piercing, and bending. While the manufacture of clamping helmets only consists of three sequential processes: the blanking process, piercing I, and piercing II. At this stage, the welding process for some components proposed by the partner is known. The goal at this stage is to identify the obstacles faced so far and evaluate the processes that can be improved to increase productivity and tie the efficiency of production processes and improve the quality of the final product. This stage is done by actively working through discussion and direct observation.

2.2. Identification of materials and equipment

This stage is part of the participation stage of the PAR method. The material and equipment identification stage is conducted by evaluating the material specifications requested by the customer. At this stage, the partner prepares component drawings and other supporting documents to know what materials are currently being used. Identifying the material used by the partner will be made a table of mechanical properties and chemical composition that refers to national or international standards. A table of mechanical properties is made to determine the accuracy of the power press machine used. The mechanical properties also serve as design inputs in designing die and punches, which are the basis of the calculation of the metal forming process.

2.3. Introduction and Socialization of metal forming technology

The introduction and socialization of metal forming technology is an active process that is the second process of implementing the PAR method. This stage socializes the technique of merging several metals forming processes into a shorter process and introduces the basics of progressive die design in the metal forming process. The purpose of the socialization stage of metal forming technology is to obtain process efficiency that can be applied in the future. The combining piercing and blanking process is made by taking some examples of die and punch design. Progressive die are an application of metal forming technology that can combine several materials forming processes such as shearing, blanking, piercing, and so forth into one work step [15]. Training and design making of the incorporation of piercing and blanking processes. The training is conducted regularly involving the active participation of partners and is conducted in the framework of the reverse engineering process by combining piercing and blanking processes. The calculation of force blanking and piercing is presented in Eq. (1) [7]:

$$F = 2(a + b)\, T\, 0.8\, (UTS) \tag{1}$$

Where F n is the blanking force in N units, a is the length of the material in mm, b is the width of the material in mm, T is the thickness of the material in mm), and UTS is the ultimate tensile strength in N/mm^2. Since a and b are length and breadth, respectively, then 2(a+b) is the circumference of the workpiece, so Eq. (1) becomes Eq. (2):

$$F = Cr.T\ 0{,}8\ (UTS) \tag{2}$$

Where Cr is the circumference of the workpiece in mm. Equations (1) and (2) are used to calculate the capacity of the power press machine to match the availability of the existing machine in the partner. The tonnage requirements of the power press machine can be converted using the Eq. (3).

$$m = \frac{F}{gx1000} \tag{3}$$

Where m, and g are successively the power press machine tonnage requirement in Tons and the gravitational acceleration constant whose value is 9.82 m/s^2.

2.4. Training and practice of combining piercing and blanking processes

The direction and practice of combining piercing and blanking processes in the production of clamping helmets are part of the implementation phase PAR method, namely the action stage. At this stage, the calculation of the tonnage capacity requirements of the power press machine was discussed concerning the mechanical characteristics of the material used training and practice of dissemination the metal forming conducted in the workshop at Wastukancana College of Technology. It was attended by employees of the partners in the metal forming manufacturing.

2.5. Mentoring and improvement evaluation

Mentoring and evaluating partner improvement is carried out as an effort to implement the PAR method, which is part of the research process. At this stage, an evaluation is carried out to improve the ability to implement the metal forming technology to incorporate piercing and blanking processes for the clamping helmet production process. The purpose of the mentoring is to ensure that partner has sufficient knowledge to design die and punches in the metal forming process so that the output meets the requirements of the input design.

3. Result and Discussion

3.1. Evaluation of the process of making clamping helmets

Identifying the metal forming process used in the production of clamping helmets revealed the possibility of improving the process by combining several processes into a single die. The primary manufacturing process of clamping helmets in partners are shearing, blanking, piercing 1, and piercing 2. The first stage of clamping helmet manufacturing was successfully identified also on the field (**Figure 3a**). **Table 2** presents the data of this stage's identification. The result of the discussion with partners was that the best solution was to merge the blanking, piercing-1, and piercing-2 processes into one process (**Figure 3b**).

Figure 3. Implementation of PAR methodology (a) Identification of the clamping helmet processes, and (b) optimum discussions to identified of the clamping helmet production process

Table 2. Identification of metal forming process for clamping helmet

No	*Metal forming processes*	Symbol	Manufacturing of helm clamping	
			Existing	After dissemination
1	Shearing	S	✓	✓
2	Setting main die *	N_1	✓	✓
2	Blanking	B	✓	✓
3	Setting die P_1*	N_2	✓	x
4	Piercing 1	P_1	✓	x
5	Setting die P_2*	N_3	✓	x
6	Piercing 2	P_2	✓	x
7	Number of processes	-	7 processes ($S-N_1-B-N_2-P_1-N_3-P_2$)	3 processes ($S-N_1-B$)
8	Manufacturing process	-	Blanking → piercing 1 → piercing 2	Piercing 1 and 2- → blanking
7	Number of die & punch	-	3 units	1 unit

Note: the mark ☑, ☒, and "*" indicates that the process is still available/needed, the merging process with the blanking process, and the non-added value process, respectively.

3.2. Mechanical properties of material

According to the material identification results, the partner uses and processes SPCC-SD material, SPHC, galvanised material, and SUS 304. Because mechanical properties are the input design for die-making, it is critical to know them during the material formation process. Table 3 shows the mechanical properties of the materials [16-18].

Table 3. Mechanical properties of materials

Reference	Material	UTS (N/mm^2)	YP (N/mm^2)	EL (%)
JIS G 3141, [19]	SPCC SD	≥ 270	≤ 240	≥ 37
JIS G 3131, [20]	SPHC	≥ 270	≤ 240	≥ 45.2
ASTAM A-240 [19]	SUS 304	≥ 515	≥ 250	≥ 40
JIS G 3313 [20]	El. Galvanized (JIS 3313)	≤ 370	≤ 240	≥ 30
JIS G 3302, [21]	SGCC	≤ 270	≥ 240	-

3.3. Socialization of metal forming technology

Three partners attended an offline discussion on the communication and consultation activities of metal-forming technology. Three participants are from the primary partners (PT Isaka Alindo Nusantara) and secondary partners (workshop Isalindo and CV Anugrah) in Karangsentosa Village, Karangbahagia subdistrict, Bekasi Regency, West Java. The blanking force should be accurately calculated in this work using Eq. (2). The PAR method includes communication. It began with an opening speech from the Head of Mechanical Engineering Study Program at Wastukancana College of Technology (Figure 4). The following activities were also given the metal-forming technology materials and their application from team teaching, open discussions, and questions. The socialising activities and extension of metal forming technology were conducted in the second week of March 2021.

Figure 4. An offline of socialization activities and extension of metal forming technology

The FEM (finite element method) was used to simplify the calculation of the workpiece's circumference. The FEM analysis used the software engineering design and discovered that the clamping helmet's circumference is approximately 95.67 mm. The SPCC-SD steel sheet bought is 1.6 mm thick, with ultimate tensile strength (UTS) generally ranging from 290 to 320 N/mm^2. The maximum UTS will be used to calculate the capacity of the power press machine. Before combining the blanking and piercing processes, Eq. (2) was calculated entirely for the power press machine's needs.

$$F = Cr.T\ 0{,}8\ (UTS)$$
$$F = (95.67\ mm)\ (1.6\ mm)(0.8)\ (320\ N/mm^2)$$
$$F = 39553.81\ N = 39.6\ \text{kN}$$

The power press machine requirement can be calculated after the blanking and piercing merging processes by combining the circumference of the workpiece plus the circumference of two holes in the piercing process by using Eq. (2). After the merging process, the total circumference is 15.71 mm + 46.57 mm) + 95.67 mm) = 157.95 mm, allowing the blanking force to be calculated using Eq. (2).

$$F = Cr.T\ 0{,}8\ (UTS)$$
$$F = (157.95\ mm)\ (1{,}6\ mm)(0{,}8)\ (320\ N/mm^2)$$
$$F = 66119.76\ N = 66.12\ \text{kN}$$

The tonnage requirement of a power press machine can be calculated by using Eq. (3) with the following calculation results:

$$m = \frac{F}{gx1000}$$
$$m = \frac{66119.76}{9.82\frac{m}{s2}x1000} = 6.7\ Ton$$

The above calculation indicates that a power press machine is required after combining blanking and piercing. A power press of 20 tonnes was used based on the partner's minimum availability of tonnage of the power press machine. The new dies still utilise a power press machine with the same tonnage capacity and the same calculation method. It demonstrates the program's success in disseminating metal forming technology. The clamping helmet process was accelerated through the dissemination program by eliminating two major processes [6]. The complexity of the part and the material used influenced the optimal design of the die and punch. As a result, the calculation's output cannot be directly compared.

3.4. Manufacture of clamping helmet design

Training activities and practices to make a combination of piercing and bending processes are done in several stages, namely:

a. Metal forming technology was discussed, including stamping industry merging processes, and identification material properties;
b. An examination of the clamping helmet CAD-CAM practises (**Figure 5a**);
c. Preparation of required materials, such as SKD-11 and S45C materials;
d. Machining process, EDM wire cutting, and hardening;
e. Assembling and setting dies and punches, as well as testing die-blanking and piercing processes (**Figure 5b**).

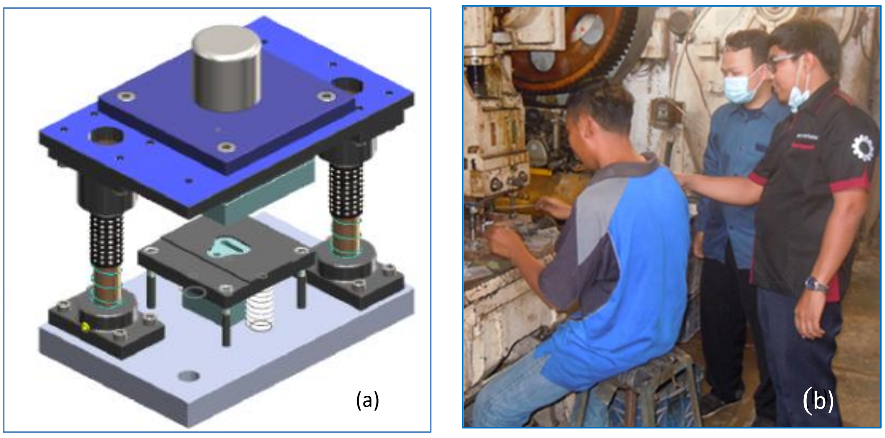

Figure 5. Result of reverse engineering die and punch: CAD-CAM design of clamping helmet (a), setting die and punch (b)

3.5. Mentoring and improvement result

In this process, the ability of the power press machine is verified on the results of reverse engineering die and punch. The trial process showed that the results of the calculation of the blanking force (blanking force) on the combination of blanking and piercing processes still meet the availability of power press machines in the partner. The result of the calculation of the tonnage requirement of the press machine is a minimum of 6.7 tons. The minimum availability of the tonnage of the power press machine owned by the partner is 20 tons. For process efficiency and to see the minimum capacity of the power press machine, the die can be developed using three cavities.

4. Conclusion

The metal forming technology dissemination programme has successfully assisted SMEs partners in performing the metal forming process efficiently. Technology dissemination to improve the efficiency of the manufacturing process, particularly for clamping helmet components. It is possible to conclude that this programme successfully combines the metal forming process from seven processes into three. This dissemination has reduced the number of dies from three to one die in terms of die issues. The efficiency was achieved by eliminating four processes: two times the die setting and punch and two piercing processes. The following metal forming technology dissemination programme will be implemented with the central theme "Dissemination of die-progressive and metal forming technology to increase SMEs' productivity." The following metal forming dissemination, which is then included, will focus on deep drawing or other complicated processes.

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Authors' Declaration

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