Type of contribution:
Editorial
Research Paper
Case Study
Review Paper
Scientific Data
▶ Report of Tech. Application

Mechanical Engineering for Society and Industry
e-issn. 2798-5245
Vol. 4, No. 1 (2023) pp 38-49
https://doi.org/10.31603/mesi.10298

The Square cup deep drawing: Technology transfer from experts to increase production in small and medium enterprise (SME) groups

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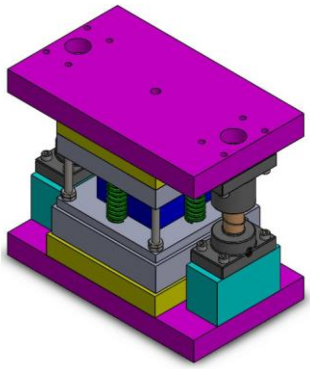
This article contributes to:

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
SUSTAINABLE DEVELOPMENT GOALS



Highlights:

- The non-added value (NAV) of R-ornament #3D40x40 production has been identified and eliminated by blank dimension optimization.
- Optimization of blank dimensions successfully eliminates both the trimming process and sets up the dies.
- Eliminating the trimming process in R-ornament #3D40x40 production has an investment efficiency of about IDR 15,000,000.

Abstract

The deep drawing is a complex steel forming method involving blank dimensions, dimension/height ratio (D/H ratio), and clearance between die and punch (D/P allowance). Failure to identify proper blank dimensions and D/H ratio can lead to production defects such as tears, while failure to recognize the correct clearance can cause wrinkles. This article discusses technology dissemination to Small and medium-sized enterprises (SMEs) for the deep drawing process in producing R-ornament components #3D40x40, considering these crucial parameters. R-ornament #3D40x40 was manufactured using SPCC-SD material with a thickness of 0.65 mm. The Participatory Action Research (PAR) method was employed to collaboratively optimize blank dimensions, D/H ratio, and dies/punch (D/P) allowance with partners. The optimization of blank dimensions successfully eliminated the need for the trimming process, resulting in reduced investment costs in dies and die setup by IDR 15 million and 2.16 million, respectively. Identifying a D/H ratio of 1.32 successfully eliminated tear defects and determining a D/P allowance of 0.87 mm on each side eradicated wrinkle defects in the product. This article contributes to Goal 9 of the Sustainable Development Goals (SDGs), specifically focusing on the Small and Medium-sized Enterprises (SMEs) sector.

Keywords: Blank dimensions; D/H ratio; Dies/punch allowance; Square cup deep drawing; Participatory action research

Article info
Submitted: 2023-10-01
Revised: 2024-02-03
Accepted: 2024-03-17

Publisher
Universitas Muhammadiyah Magelang

1. Introduction

Metal forming and processing technology has developed for various purposes [1]–[7]. On an industrial scale, failures and potential losses can be reduced through strict quality control. However, in the Small and medium-sized enterprises (SMEs) scale metal industry, the potential for failure and loss is greater due to machine and labor factors, as well as less strict quality control.

Isalindo Jaya Teknik Workshop (IJT Workshop) is a mechanical workshop that manufactures various steel components through shearing, blanking, bending, piercing, and trimming processes. IJT Workshop is a family business that comprises small and medium enterprises, currently employing approximately four workers. Most employees originate from the surrounding community and have attended only elementary and junior high school. The production process at IJT Workshop utilizes multiple power press machines with mechanical drives. Consequently, they often encounter challenges when components necessitating deep drawing processes arise. Typically, deep drawing processes are performed using hydraulic power press machines; thus, executing this procedure with a mechanical drive presents an inherent challenge. **Figure 1** displays the location of service activities and the steel forming process utilizing a machine power press machine in their workshop.

The deep drawing process constitutes a metal-forming technique wherein force and pressure shape the material into a predetermined form. Deep drawing entails the mechanical pulling of sheet metal into a dies/punch, thereby inducing a transformation in the material's shape through a series of dies/punch. During the deep drawing process, the flange area experiences radial tensile and tangential compressive stress, potentially resulting in wrinkles due to circular pressure [8]. The utilization of blank holders can mitigate wrinkling by facilitating controlled material flow into the die radius [9].

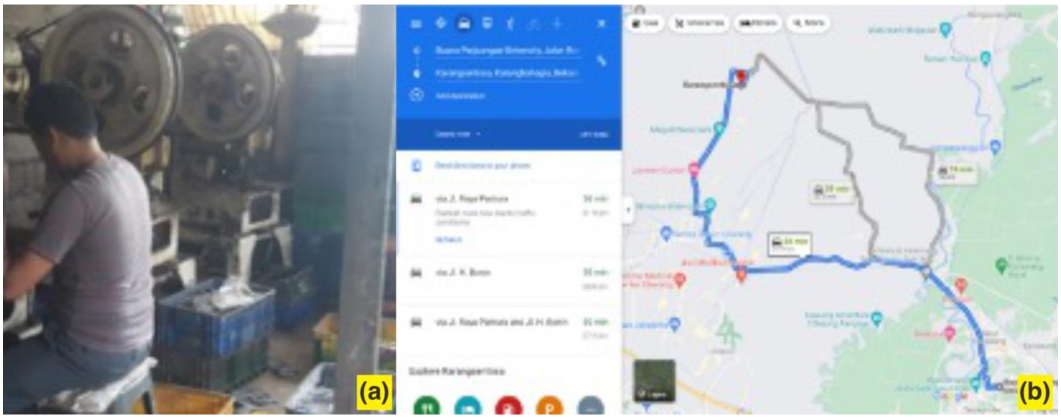


Figure 1. Partner locations: (a) A power press machine at the partner's site; (b) UBP Karawang university map of partner locations

A recurring issue encountered during the deep drawing process when utilizing a stamping machine (power press) is the material's emergence of cracks and wrinkles [10]. **Figure 2** presents an instance of a crack mode failure that transpired during the component manufacturing process through deep drawing with one of our partners. This issue is understandable since our partners often need more knowledge about the deep drawing process. Another impediment is that the speed of the deep drawing operation cannot be regulated in the press machine process. This limitation arises from the fact that the drive mechanism in the press machine operates mechanically using a flywheel [11]. Tearing and wrinkling are the two primary failure modes encountered during the deep drawing of sheet metal [12], [13]. The utilization of thin, high-strength metal sheets has become increasingly prevalent in recent years, leading to a rise in these two failure modes in stamping various automotive and non-automotive components [14]. Hence, our primary concern centers on predicting and preventing tearing and wrinkling, particularly at the end of the sheet metal [15].

Figure 2. Instances of tear defects observed during the execution of square cup deep drawing

The utilization of square (cup drawing) metal forming technology in the Small and Medium-sized Enterprises (SMEs) sector is a crucial aspect of our development report for the Community Service project, which has received support and funding from the Directorate of Higher Education (DIKTI). The dissemination of this technology is aimed at producing trellis (fence) components that serve as accessories for fence pillars, a project undertaken in collaboration with our partners.

Universities play a critical role in fostering the growth of small to medium-sized businesses and enterprises and improving quality and process efficiency. The active involvement of universities in assisting small industries with process efficiency and quality improvement serves as tangible evidence of one of the three primary pillars of higher education, particularly in the context of community service [16].

Within the scope of this community service initiative, we focused on the production of the R-ornament #3D40x40 product. The R-ornament #3D40x40 is a three-dimensional rectangular fence decoration crafted from 40x40 mm hollow material. The intricate three-dimensional shape of this component necessitates a deep drawing process during production. We opted for SPCC SD steel, which complies with JIS G3131 standards and possesses a thickness of 0.65 mm as the chosen material. The primary objective of this community service project is to assist in the development of dies that can eliminate the need for the trimming process. It is achieved by optimizing blank dimensions and deep drawing ratios, reducing the manufacturing process and investment costs associated with dies and materials. The project was executed at two locations: Buana Perjuangan University, Karawang, and the IJT Workshop, where our partners actively participated in the project's implementation.

2. Method

2.1. Participatory Action Research Approach

This community service initiative adopts a Participatory Action Research (PAR) approach. PAR is a research methodology that strongly emphasizes the active involvement of the community being studied in the research process. It prioritizes participation, action, and research from the community itself [17]. The PAR method highlights two key aspects: collaborative research and experiments that stem from practical experience. Consequently, implementation must occur collaboratively and concurrently, involving facilitators as agents of social change and the community [18].

Collaboration with partners who bear specific responsibilities is pursued to enhance their capacity. The application of this methodology is intended to assess and comprehend issues by jointly attempting to address them with the active involvement of all stakeholders [14]. The stages of implementing the PAR method in the execution of community service are outlined in **Figure 3**.

The stages of implementing the PAR method in community service, with the theme "Enhancing Technical Skills in the Metal Forming Process through a Mentorship Program for Small Business Groups in Karangsentosa Village, Bekasi District, West Java," are outlined in **Table 1**. This table provides a comprehensive overview of the steps involved in executing the Participatory Action Research (PAR) approach in community service, with a specific focus on the dissemination of square cup deep drawing technology for trellis component production (fences) to Small and Medium-sized Enterprises (SME's).

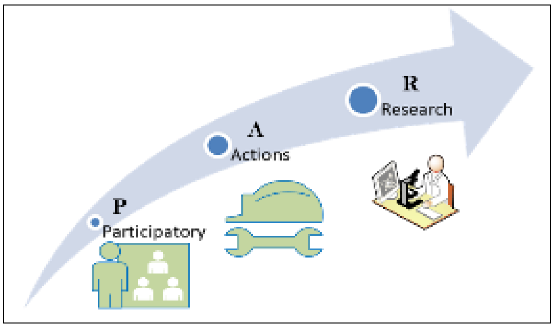


Figure 3. An overview of the PAR methodology: General description and implementation stages

2.2. Identification and Process of Making R-ornament #3D40x40

The implementation stage commences with identifying and understanding the square cup drawing process for producing the R-ornament #3D40x40 product . This identification process involves active participation from our partners and PAR facilitators, who collaborate in pinpointing the challenges and requirements associated with metal forming for trellis (fence) components. Extensive discussions were conducted to gain insights into the technical and quality-related hurdles our partners encountered during the square deep drawing process.

Table 1. Stages of applying the PAR methodology to Cceate R-ornament #3D40x40 using the square cup drawing process

No	Implementation Stages	Month-stage implementation												PAR Identification*
		1	2	3	4	5	6	7	8	9	10	11	12	
1	Identification and Process of Making R-ornament #3D40x40													P
2	Collaborative Planning and Material Identification													P
3	Introduction, Training, and Workshop on the Square Cup Drawing Process													A
4	Assistance in Producing R-ornament #3D40x40													A
5	Reflection and Process Refinement													A
6	Publication of Research Results and Experiences													R

Inaccuracies in calculating the deep drawing ratio and determining the blank dimensions were the main sources of our partners' problems, which led to flaws and tears in the R-ornament #3D40x40 product. It necessitated a thorough examination of the existing production processes. The production process for the R-ornament #3D40x40, as currently identified, encompasses several key stages, including shearing, setting up dies for blanking, blanking, setting up dies for deep drawing, deep drawing, setting up dies for trimming, trimming, 40x40 mm piercing, finishing (sharp edge removal), and galvanization. The outcomes of the blanking, deep drawing, trimming, and piercing processes are visually represented in Figure 4, providing a comprehensive understanding of the production steps and the components produced at each stage.

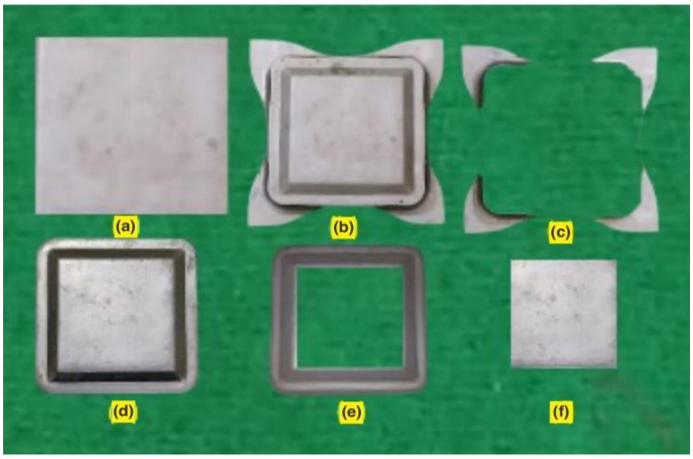


Figure 4. Stages of the process for making R-ornament #3D40x40: (a) blanking, (b) deep drawing, (c) Trimming-scrap, (d) trimming-product, (e) Piercing-scrap, (f) Piercing-scrap

2.3. Collaborative Planning and Material Identification

The subsequent stage involves collaborative planning and material identification. An action plan is formulated to delineate training objectives, implementation methodologies, and the necessary resources. In producing the R-ornament #3D40x40, SPCC-SD steel (JIS G3131) with a thickness of 0.65 mm will be employed as the primary material. SKD 11 material will be utilized for crafting dies and punches. Additionally, SPHC material has been selected to develop auxiliary components, including top/bottom shoes, strippers, and holder materials.

2.4. Introduction, Training, and Workshop on the Square Cup Drawing Process

The third stage focuses on the introduction, training, and workshop sessions for the square cup drawing process. Partners undergo rigorous training in square cup deep drawing techniques, encompassing the calculation of blank dimensions and deep drawing ratios. Throughout the training sessions, partners actively engage in practical, hands-on exercises utilizing this technology to manufacture R-ornament components #3D40x40. Blank dimensions refer to the initial sheet metal dimensions before the commencement of the deep drawing process.

2.4.1. Calculating Blank Dimensions

Blank dimensions wield significant influence over the deep drawing process and profoundly affect the results achieved. When determining blank dimensions, it is imperative to consider the material's propensity to shrink during the forming process. Metallic materials tend to undergo shrinkage as they are shaped, necessitating meticulous consideration of these factors when establishing blank dimensions to attain the desired final dimensions.

Selecting the correct blank dimensions is pivotal in the deep drawing process [18]. The precise measurements are instrumental in ensuring the smooth execution of the metal forming process, resulting in a final product that aligns with design specifications and attains the desired level of quality [19]. This optimization procedure unfolds in two stages: firstly, the calculation of the optimal length and width of the requisite steel, followed by the process of shaping a blank dimensional profile, as illustrated in **Figure 5**.

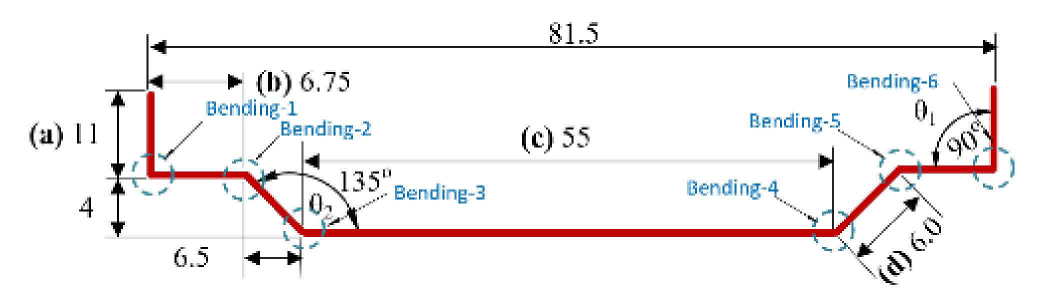


Figure 5. Blank dimension profile of R-ornament #3D40x40 product (all linear dimensions in mm)

For the shearing process, calculating the ideal length and width dimensions is crucial, whereas figuring out the ideal blank profile dimensions is essential for getting the best results from profound drawing. The die radius (*r*), material thickness (*s*), and bending angle (θ) are three important variables that must be taken into account in these calculations. In this instance, the material thickness and die radius are 0.65 mm and 1.0 mm, respectively. Eq. (1) illustrates the calculation for determining the ideal length and width dimensions given various 0-165 degrees values [10].

$$l = 2(v_1 + a + b) + \left(2(v_2 + d + (\frac{c}{2})\right) \tag{1}$$

The lengths of the bending arms are represented by "a," "b," "c," and "d" in the equation, as shown in **Figure 5**. The millimeter (mm) value of the variable "l" represents the length of the component's blank dimensions. It is crucial to remember that the blank's length and width are the same when manufacturing components. Meanwhile, a millimeter-based compensation factor known as "v" is also introduced [20]. This factor serves as a correction for the bending angle θ, and its specific value is determined based on the information provided in **Table 2** [10].

Table 2. Bend allowance constant (v)

Angle θ	Constant (v), mm	Angle θ	Constant (v), mm
10 minutes	0.0029	35°	0.6109
30 minutes	0.0087	40°	0.6981
1°	0.0175	45°	0.7854
2°	0.0349	50°	0.6573
3°	0.0524	55°	0.9599
4°	0.0698	60°	1.0742
5°	0.0873	65°	1.1345
10°	0.1745	70°	1.2217
15°	0.2618	75°	1.3090
20°	0.3491	80°	1.3963
25°	0.4363	85°	1.4835
30°	0.5236	90°	1.5708

2.4.2. Calculating Blank Dimensions to Blank Height (D/H ratio)

The ratio of blank dimensions to blank height, commonly referred to as the D/H Ratio, holds significant importance in determining the number of deep drawing processes required [21]. This ratio plays a critical role in shaping the distribution of force and pressure during the deep drawing process. It exerts a substantial impact on the ultimate wall thickness and deformation in specific regions of the formed component. The calculation of the D/H ratio is elucidated by Eq. (2) [22], [23].

$$D/H\ ratio = \frac{D_{max}}{D_{punch}} \tag{2}$$

where $D_{max} = \frac{D_i + D_o}{2}$, as explained in detail in **Figure 6** [22].

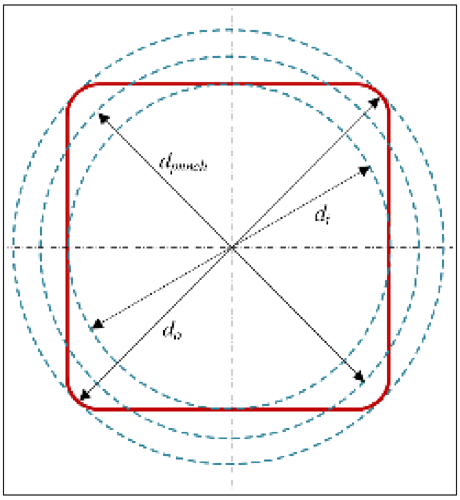


Figure 6. Determination of the average punch diameter for square cup deep drawing process

The distance between the punch wall and the die is crucial in deep drawing operations [24]. In drawing operations, without reducing the thickness of the workpiece, the material clearance must be greater than the thickness of the material itself. The punch may puncture or cut the blank if the gap is too small. This clearance can be measured as a percentage of the material thickness or calculated using the empirical formula in Eq. (3) [25]. In this equation, c represents the clearance or gap, which is the distance between the punch wall and the dies denotes the material thickness in millimeters (mm), and k is a coefficient with different values depending on the type of material used, specifically 0.07 for carbon steel, 0.02 for aluminum, and 0.04 for other materials [26].

$$c = s + k\sqrt{10} \tag{3}$$

2.5. Assistance in Producing R-ornament #3D40x40

The fourth stage involves assisting in producing R-ornament #3D40x40, commencing with the design phase, die manufacturing, trial runs, and, ultimately, the production process itself. All these phases are subject to joint monitoring and evaluation, a critical step to ensure the program's effective implementation. During this stage, PAR partners and facilitators collaboratively oversee the technology's execution and conduct periodic assessments of production outcomes, efficiency, and the quality of the manufactured products. This comprehensive monitoring and evaluation process aims to guarantee the successful implementation of the program.

2.6. Reflection and Process Refinement

The fifth stage involves reflection and refinement of the process, conducted to evaluate the success of the technology in optimizing the manufacturing process of R-ornament #3D40x40. During this stage, challenges encountered in implementing the deep drawing process for producing R-ornament #3D40x40 are identified. It includes pinpointing obstacles and constraints and formulating corrective measures to enhance the metal-forming process.

2.7. Publication of Research Results and Experiences

The final stage encompasses disseminating the outcomes resulting from implementing the deep drawing technique for the R-ornament #3D40x40 product. The dissemination of these results contains technical guides, training reports, and evidence of the accomplishments achieved by utilizing square cup deep drawing technology. These valuable insights and achievements are shared with the broader community through workshops or publications, contributing to this technology's more comprehensive knowledge and understanding.

3. Result and Discussions

3.1. Evaluating the R-ornament #3D40x40 Manufacturing Process

The identification and process of square cup drawings for producing R-ornament #3D40x40 products have been significantly enhanced by optimizing blank dimensions. This optimization has successfully eliminated the need for the trimming process. As a result, eliminating this process has led to cost savings, including avoiding die-trimming investment expenses and removing the die-trimming setup process. These cost savings are estimated at approximately IDR 15 million and IDR 2.16 million, respectively. **Table 3** comprehensively compares the strategies before and after improving the square cup drawing process for the production of R-ornament #3D40x40 product .

3.2. Mechanical Properties of Material

In accordance with the identification results presented in section 2.3, the production of R-ornament #3D40x40 entails the use of SPCC-SD steel (JIS G3131) with a thickness of 0.65 mm as the primary material. The main processes involved, as detailed in **Table 2**, encompass shearing, blanking, deep drawing, and piercing operations. It's important to note that the shearing, blanking, and piercing processes primarily function in fracture areas, while the deep drawing process operates within plastic deformation zones.

Given the requirements of these processes, it is imperative to utilize a tough and ductile material for the production of R-ornament #3D40x40. Consequently, SKD 11 material has been selected for crafting dies and punches. Additionally, SPHC material has been chosen to fabricate supporting components, including top/bottom shoes, strippers, and holder materials. The mechanical properties of the primary materials required for these processes are outlined in **Table 4**.

Table 3. Non-added value identification and comparison before and after the improvement process for producing R-ornament #3D40x40.

No	Process	AV/NAV	Existing process	Process of After improvement	Remarks
1	Shearing	AV	✓	✓	
2	Set-up Dies Blanking	AV	✓	✓	
3	Blanking	AV	✓	✓	
4	Set-up dies deep drawing	AV	✓	✓	
5	Deep-drawing	AV	✓	✓	
6	Se-tup dies trimming**	NAV	✓	×	IDR 2.160.000
7	Trimming*	NAV	✓	×	IDR 15.000.000
8	Piercing 40x40 mm	AV	✓	✓	
9	Finishing-sharp edge off	NAV	✓	✓	

Note: AV= added value, NAV= non-added value, * Estimated dies investment, **) Set-up dies/punch estimated at 2 hours, which is equivalent to 1200 products assuming a product cycle time of 10 pcs per minute and a product price of IDR 1800

Table 4. Mechanical properties of material

Materials	UTS (N/m^2)	YS (N/m^2)	EL (%)	Hardness (HRC)	References
SPCC-SD	Min. 270	Max 240	Min. 37	-	JIS G 3141 [8]
SPHC	Min. 270	Max 240	Min. 45.2	-	JIS G 3131 [27]
Alloy steel SKD-11*	-	-	-	55	JIS G 4404 [28]

Note: UTS=Ultimate tensile strength, YS= yield strength, EL= Looseness, *SKD 11 alloy steel (JIS G4404) equivalent to T30402-D2 (ASTM A 681-8)

The initial hardness value of the SKD 11 material before the heat treatment process is approximately 163 HV (Vickers hardness) [28]. Through the heat treatment process, the hardness of the SKD 11 material can be significantly increased to nearly 55 HRC (Rockwell hardness). This heat treatment procedure is conducted within the UBP Karawang Manufacturing Laboratory, where a furnace is utilized, with a temperature range set at around 950°C and a holding time of approximately 30-45 minutes. As a result of this heat treatment, the material's hardness is elevated to 52.1 HRC or 549 HV, as depicted in **Figure 7**.

Figure 7. Alloy steel SKD 11: (a) No hardening process, (b) After-hardening process

3.3. Sharing Information about the Square Cup Drawing Process

Comprehensive training sessions were conducted for our partners, focusing on square cup deep drawing techniques, particularly emphasizing the R-ornament #3D40x40 production process.

These training and workshops encompassed various aspects, including CAD/CAM, calculations of blank dimensions, and deep drawing ratios. The training sessions and workshops were hosted at the IJT Workshop and were collaboratively led by the instructional team from UBP Karawang from August to September 2023.

The training and workshop stages were carried out informally, which involved delivering course materials, open discussions, question and answer sessions, hands-on process implementation, and consultation opportunities. Additionally, occupational safety (K3) measures were introduced during this stage, particularly about the safe usage of power press machines. This holistic approach aimed to equip our partners with the necessary knowledge and skills to excel in the square cup deep drawing process for producing R-ornament #3D40x40 product. **Figure 8** depicts the CAD/CAM introduction session conducted by the PAR Team at the IJT workshop.

Figure 8. Introducing the use of CAD/CAM by the UBP Karawang lecturer team

3.3.1. Analysis of Blank Dimension Calculations

The necessary blank material dimensions, as referenced in **Figure 5**, are calculated employing Eq. (1). Here, the values of v_1 and v_2 are crucial in these calculations. For the bending-1 process with a bending angle ϑ_1 of 90 degrees, based on the information from **Table 2**, the value of v_1 is 1.5708 mm. In contrast, for the bending-2 and bending-3 processes, each with a bending angle θ2 of 45 degrees (135 degrees - 90 degrees), the value of v_2, according to **Table 2**, is 0.7854 mm. These values of v_1 and v_2 will be used in Eq. (1) to compute the length and width of the blank dimensions [10].

$$
\begin{aligned}
l &= 2(v_1 + a + b) + \left(2(v_2 + d + (\frac{c}{2})\right) \\
&= 2(0.7854 + 11 + 6.75) + (2(1.5708 + 6.0 + (\frac{55}{2})) \\
&= 2(0.7854 + 11 + 6.75) + (2(1.5708 + 6.0 + (\frac{55}{2})) \\
&= 37.0718 + 70.1416 = 107.2832 \approx 107.3\ mm
\end{aligned}
$$

3.3.2. Analysis of Blank Dimensions to Blank Height (D/H ratio)

The material used to make R-ornament #3D40x40 is SPCC-SD with a thickness of 6.5 mm. Referring to **Figure 5** and Eq. 2, the distance between dies/punches can be calculated as follows.

$$c = s + k\sqrt{10} = 6.5 + 0.07\sqrt{10} = 0.65 + 0.22 = 0.657 \text{ mm.}$$

Based on the above calculations, the gap between the dies and the punch is 0.657 mm on each side. Subsequently, calculations are performed to determine the required punch dimensions. This calculation is based on the dimensions of the dies, which are determined according to the outer dimensions of R-ornament #3D40x40, namely 81.5 x 81.5 (**Figure 5**). Thus, the dimensions of the punch, d_{punch} can be calculated as follows:

$$d_{punch} = d_i - 2c = 81.5 - 2.(0.657) = 81.5 - 1.74 = 79.76\ mm$$

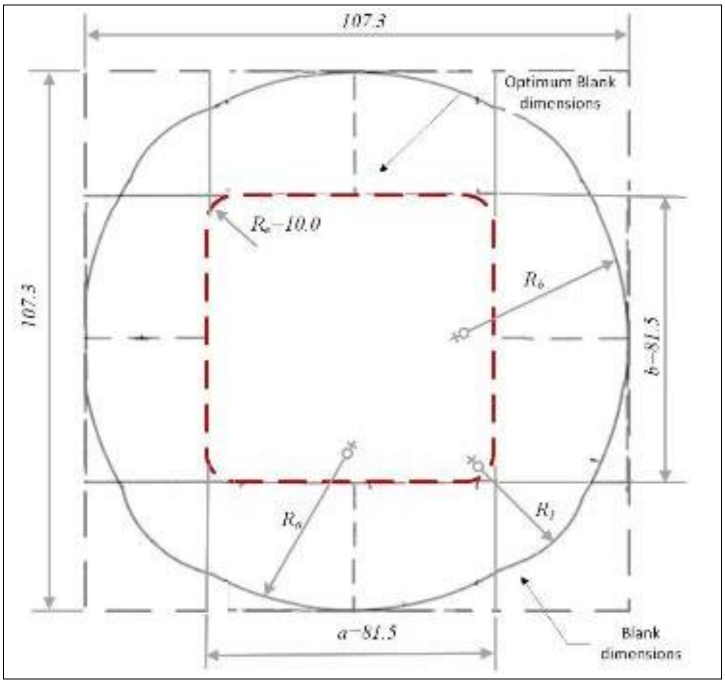


Figure 9. Optimum blank dimensions (all dimensions provided in mm)

Referring to **Figure 9**, the value of R_1=xR, where the values of x and R are calculated using the following equation [26].

$$R = \sqrt{Re^2 + 2R_e c} = \sqrt{10^2 + (2x10x14)} = 19.5\ mm$$
$$x = 0.0185\left(\frac{R}{R_e}\right)^2 + 0.982 = 0.0185\left(\frac{19.5}{10}\right)^2 + 0.982 = 1.05\ mm$$

Hence, the value of $R1$=1.05×19.5=20.52 mm. The subsequent step involves calculating the D/H ratio, which is determined using Eq. (2) [22], [29].

$$D/H\ ratio = \frac{107.3\ mm}{81.5\ mm} = 1.32$$

The calculated D/H ratio is 1.32, which is less than 1.8. Therefore, it is possible to proceed with the deep drawing process [27].

3.4. Manufacturing Process for R-ornament #3D40x40 products.

Accompanying the manufacturing process of #3D40x40 R-ornaments is a crucial stage aimed at ensuring the success of training activities to enhance the competency of our partners in applying deep drawing technology. The primary goal of this project is to assist our partners in producing R-ornament #3D40x40 using more effective and efficient metal forming technology, both in terms of the production process and die investment. The collaborative effort between PAR team and partners has resulted in substantial improvements in the efficiency and effectiveness of the R-ornament #3D40x40 manufacturing process by eliminating the trimming stage. The trimming process is eliminated by optimizing blank dimensions, thereby minimizing the finishing process. The various stages of the R-ornament #3D40x40 production process are detailed below:

a. Discussion on the Application of Steel Forming Technology: This stage involves comprehensive discussions on steel forming technology, mainly through deep drawing. It covers topics such as material identification and the elimination of the trimming process.
b. Introduction to Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM): Partners are introduced to CAD and CAM techniques for deep drawing.
c. Optimization of Blank Dimensions and D/H Ratio: The optimization of blank dimensions and the D/H ratio specific to the R-ornament #3D40x40 product is a crucial step in enhancing the

efficiency of the manufacturing process.

d. Preparation of Materials: This phase involves the procurement and preparation of materials, including SKD-11, SPHC, SPCC-SD materials, and fastener die components required for the deep drawing process.
e. Machining and Hardening: The materials undergo machining processes and heat treatment to achieve the desired hardness levels, as shown in **Table 3**.
f. Assembly and Setup: Punches and dies are assembled and configured for the deep drawing.
g. Trial Process: This stage involves conducting trial runs to manufacture R-ornament #3D40x40 product, applying the optimized processes and materials (**Figure 10**).
h. These stages collectively contribute to the successful implementation of deep drawing technology, streamlining the production of R-ornament #3D40x40 with increased efficiency and effectiveness.

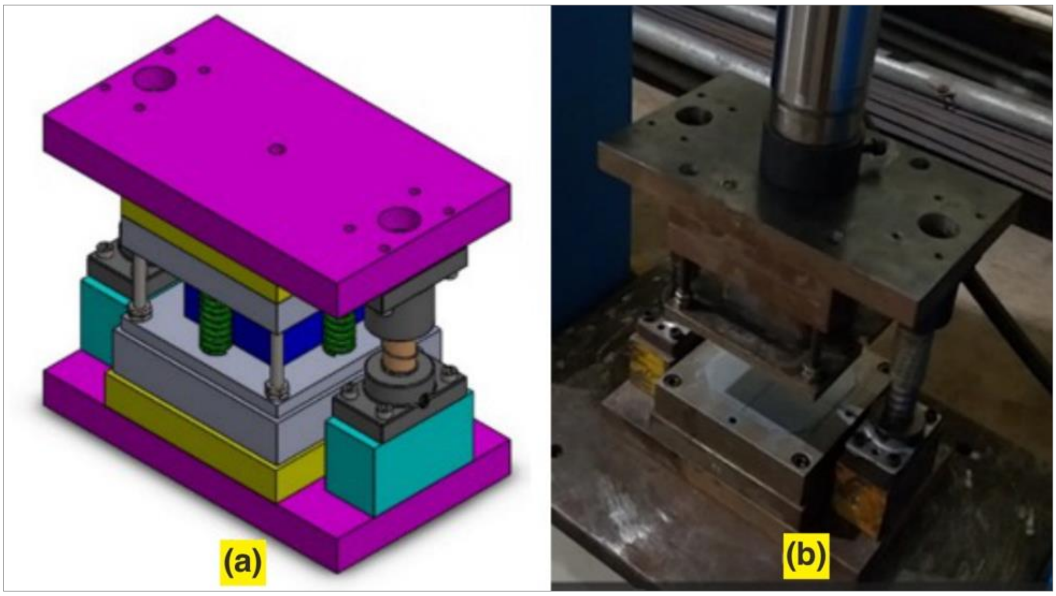


Figure 10. The main output of the community partnership program (PKM): (a) Square cup drawing design, (b) Dies & Punch square cup drawing

3.5. Mentoring and Its Impact on Improvement Results

Achieving process efficiency is realized through the elimination of the trimming process. The project has effectively reduced die investment costs and eliminated the die setup process by removing the need for trimming. This accomplishment has resulted in estimated savings of approximately IDR 15,000,000 and an additional estimated IDR 2,160,000 in savings for the die setup processes for each batch of 5,000 units produced. These cost savings significantly contribute to the overall efficiency and cost-effectiveness of the R-ornament #3D40x40 production process. **Figure 11** illustrates the trial implementation and setup of the dies, delivery of the primary output, R-ornament #3D40x40 product, and photographs of the PAR team with partners.

Figure 11. Monitoring and improvement: (a) The setup, trial, and handover of dies and punches, (b) R-ornament #3D40x40 product , (c) A photo featuring the UBP Karawang and IJT teams

4. Conclusion

An optimization strategy focusing on empty dimensions has been successfully implemented in the context of community service through a community partnership empowerment scheme. Identifying the correct blank dimensions was crucial in eliminating the need for the trimming process, resulting in significant cost savings and reduced production lead times for R-ornaments #3D40x40. The comprehensive analysis of blank dimensions in drawings involved meticulous selection of appropriate dimensions to achieve optimal outcomes. This community partnership program's primary objective was to enhance partners' competency in developing metal forming technology, a goal that was successfully achieved. The optimization of blank dimensions in the deep drawing process for creating R-ornaments #3D40x40 was effectively carried out, preventing defects, enhancing product quality, and streamlining process efficiency.

Acknowledgments

The author expresses gratitude to Ristek Dikti for funding the dissemination of metal forming technology through contract numbers: 020/SP2H/PPM/LL4/2023, 01/LPPM/PKM/VII/2023. Additionally, we extend our thanks to the team at Bengkel Isalindo Jaya Teknik and all parties who have contributed to the metal forming technology dissemination program.

Authors' Declaration

Authors' contributions and responsibilities - The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation, and discussion of results. The authors read and approved the final manuscript.

Funding – Ristek Dikti with contract numbers: 020/SP2H/PPM/LL4/2023, 01/LPPM/PKM/VII/2023.

Availability of data and materials - All data are available from the authors.

Competing interests - The authors declare no competing interest.

Additional information – No additional information from the authors.

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