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Analysis of Material Thickness Effect on Die Clearance in Deep Drawing Process of Inner Body Components

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Abstract: This study investigates the effect of material thickness on die clearance in the deep drawing process of automotive inner body components. In sheet metal forming, improper parameter selection frequently leads to defects such as wrinkling, burr formation, and fracture, which reduce product quality and production efficiency. Despite extensive studies on stamping processes, the interaction between material thickness and optimal die clearance remains a critical issue in industrial applications. An experimental approach was conducted using a material thickness of 0.8 mm under controlled process conditions. Key parameters, including cutting force, stripping force, drawing force, springback, and material elongation, were measured and analyzed. The results indicate that the optimal die clearance lies within the range of −0.06 mm to +0.11 mm. At this condition, the cutting force reached 39,424 Kgf, while stripping and drawing forces were recorded at 1,971.2 Kgf and 5,708.8 Kgf/mm², respectively. The springback value was measured at 1.8 N/mm², and material elongation reached 3.67 mm. The findings demonstrate that die clearance must be carefully adjusted according to material thickness to ensure stable material flow and minimize defect formation. The novelty of this study lies in the experimental determination of a practical clearance range under actual production conditions. This research provides valuable insights for optimizing die design and improving manufacturing performance.

Keyword: Deep Drawing, Die Clearance, Sheet Metal Forming, Material Thickness, Springback.

INTRODUCTION

The increasing demand for high-precision components in the automotive industry has driven advancements in sheet metal forming technologies. Deep drawing is widely used due to its capability to produce complex geometries with high efficiency (Rao et al., 2024)(Monitoring et al., n.d.).

The quality of deep drawing products is strongly influenced by process parameters such as material thickness, die clearance, and forming forces (Singh & Agnihotri, 2015)(Reddy, n.d.). Improper parameter selection can lead to defects including wrinkling, tearing, and burr formation, which significantly reduce product quality (Skardžius, 2026).

Previous studies suggest that die clearance is generally defined as a percentage of material thickness, typically ranging from 4% to 10% depending on material characteristics (Wojtkowiak & Tala, 2019)(Prumanto & Anggrainy, 2022). However, in real industrial conditions, these theoretical values often require adjustment due to variations in material behavior and production constraints.

Several researchers have investigated the influence of clearance on forming quality. Insufficient clearance increases cutting force and tool wear, while excessive clearance leads to poor edge quality and burr formation (Forces et al., 2023) (Biasio et al., 2026)(Prumanto & Anggrainy, 2022). However, limited studies provide experimentally validated clearance ranges under actual production conditions.

METHOD

This study employs an experimental approach to analyze the relationship between material thickness and die clearance.

A. Research Variables

- Independent variable: Material thickness (0.8 mm)
- Dependent variables: Forces, defects, springback
- Controlled variables: Material type, machine, tooling

B. Experimental Procedure

The experimental procedure in this study was conducted systematically to ensure the accuracy and reliability of the obtained results. The overall process consists of several main stages, as described below:

a. Material Preparation

The material used in this study was prepared according to the required specifications. Sheet metal specimens were cut into predetermined dimensions, and their mechanical and physical properties were verified to ensure consistency throughout the experiment (Krisnadwipayana, n.d.)(Introduction et al., n.d.).

b. Clearance Calculation

The clearance between the punch and die was calculated based on the material thickness and its mechanical properties. Proper clearance selection is essential to minimize defects and achieve optimal forming quality (Agustin et al., 2024)(Purowenang et al., 2019).

c. Tool Setup

The deep drawing tools, including punch, die, and blank holder, were installed and aligned carefully on the press machine. All components were adjusted to ensure proper positioning and operational stability during the forming process (*Evaluation of Limiting Drawing Ratio (LDR) in Deep Drawing by Rapid Determination Method*, 2014) (Altan & Tekkaya, n.d.).

d. Deep Drawing Process

The forming process was carried out using a press machine under controlled conditions. Parameters such as forming speed, pressure, and stroke were maintained consistently to produce comparable results across all specimens (Altan & Tekkaya, n.d.)(Reddy, n.d.).

e. Observation of Defects

After the forming process, the produced parts were visually and physically inspected to identify defects such as wrinkling, tearing, and thinning. The observations were documented for further analysis(Altan & Tekkaya, n.d.) (Muhazir et al., 2020).

f. Measurement of Forces

The forming forces generated during the deep drawing process were measured using appropriate instrumentation. These measurements were recorded to evaluate the relationship between process parameters and forming behavior (Krisnadwipayana, n.d.) (Introduction et al., n.d.).

g. Data Analysis

The collected data were analyzed using both qualitative and quantitative approaches. The analysis focused on identifying trends, evaluating defect formation, and determining the optimal process parameters for improved product quality (Altan & Tekkaya, n.d.).

C. Data Analysis

Experimental results are compared with theoretical expectations to determine the optimal clearance range.

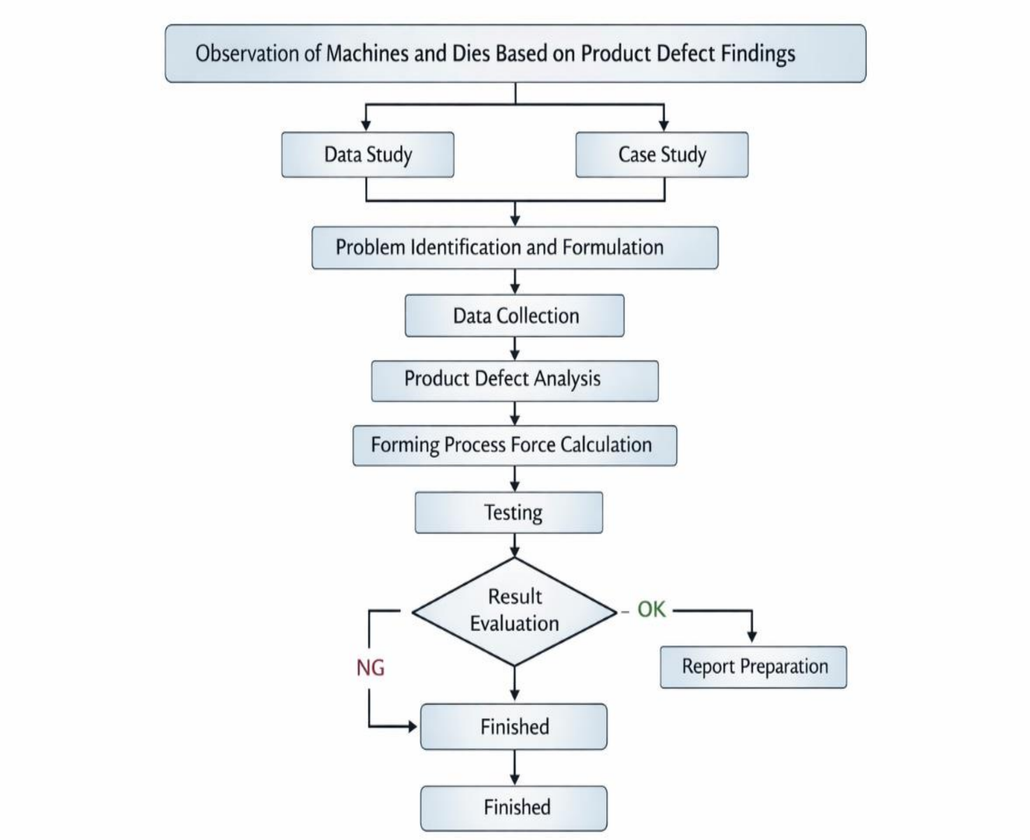


Figure 1. Research Flowchart

D. Research Procedure

The testing process is carried out using the dies draw with the deep drawing process with the emphasis on the clearance between the dies draw and the product and the results of the deep drawing process (Reddy, n.d.)(Singh & Agnihotri, 2015).In this study, the author certainly found various kinds of obstacles due to the limitations of several factors, thus affecting the accuracy of the research results, including the condition of the tools used for the continuous production process.

RESULT AND DISCUSSION

Results

This research began with the collection of data related to the deep drawing process on the inner body components made of sheet metal. The material used is SPC270 with a thickness of 0.8 mm and dimensions of 600 mm × 230 mm.

Figure 2. Plat SPC270

The forming process is carried out using a 600-ton AIDA press with the main specifications in the form of a press capacity of 600 tons, a stroke length of 250 mm, and a speed of 30–70 spm. The dies system used is a tandemdies.

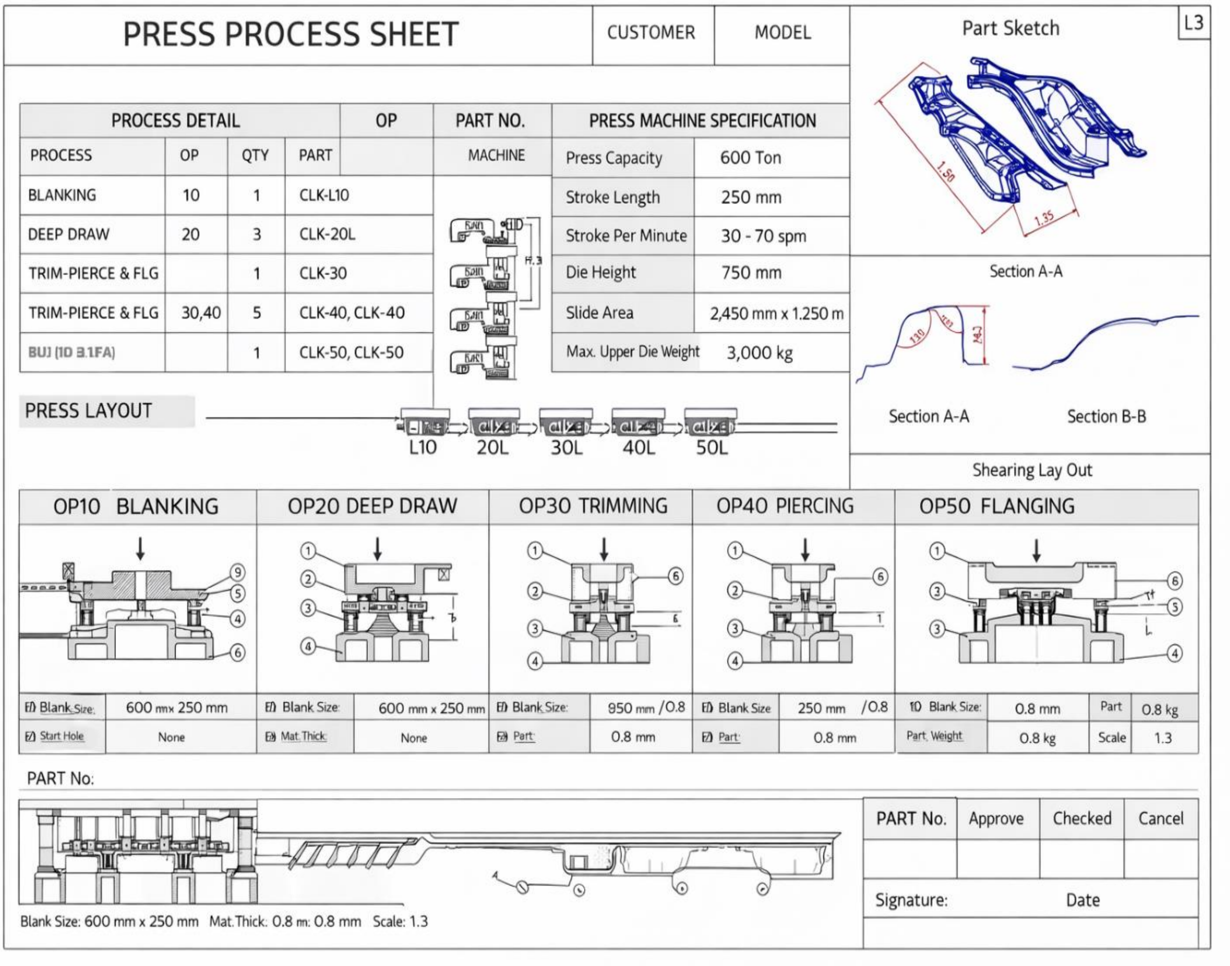
Figure 3. Mesin *Press* AIDA

Table 1. Spesifikasi Mesin *Press* AIDA 600T

Deskripsi	Spesifikasi
Press Capacity	600 Ton
Stroke Length	250 mm
Stroke per minute (no load)	30-70 spm
Die height	750 mm
Slide area	2.450 mm x 1.250 mm
Max. upper die weight	3.000 kg

The planning sheet process serves as a reference process to ensure that each stage of production is controlled and makes it easier to identify if a product defect occurs.

Tabel 2. planning sheet process



Discussion

Calculation of dies diameter

- Clearances are exactly 2% of material thickness.
- Clearance on die diameter = 2 x 4% = 8% of material thickness
- Clearance diameter dies = 0.08 x 0.8 mm = 0.064 mm.
- Punch diameter = Ø 25+0.05
- Maximum dies diameter = 25.05 + 0.064 = 25.114 mm
- Minimum dies diameter = 25.0 + 0.064 = 25.064 mm

Cutting forces

P = (L x t x σβ)

P = (1540 x 0,8 x 32)

P = 1.540 x 0,8 x 32 = 39.424 Kgf

Stripping forces

Pst = (5% - 15%) x P

Pst = 5% x 39.424

Pst = 1.971,2 Kgf

Drawing forces

P_1 = σβ . t . (2π. r_1.C_1 + I1 . C_2

= 32. 0,8. (2. 3,14. 4. 2,5 + 160. 0,2)

= 25,6 . 223

= 5.708,8 Kgf/mm^2

Springback

$$KR = \frac{\propto_1}{\propto_2} = \frac{ri_1 + 0{,}5 \times s}{ri_2 + 0{,}5 \times s} \ldots$$

$$KR = \frac{90°}{90°} = \frac{4 + 0{,}5 \times 0{,}8}{2 + 0{,}5 \times 0{,}8}$$

$$KR = \frac{4{,}4}{2{,}4} = 1{,}8 \text{ N/mm}^2$$

Table 3. Process Parameters

Parameter	Value	Unit
Cutting Force	39,424	Kgf
Stripping Force	1,971.20	Kgf
Drawing Force	5,708.80	Kgf/mm²
Springback	1.8	N/mm²
Elongation	3.67	mm

Based on observation and production data, four main types of defects were obtained, namely crack, uneven deformation, dimensional inaccuracy, and wrinkling. The defect distribution indicates that:

- Crack is the most predominant defect (~35–40%)
- uneven deformation (~25–30%)
- Dimensional mismatch (~20%)
- Wrinkling (~10–15%)

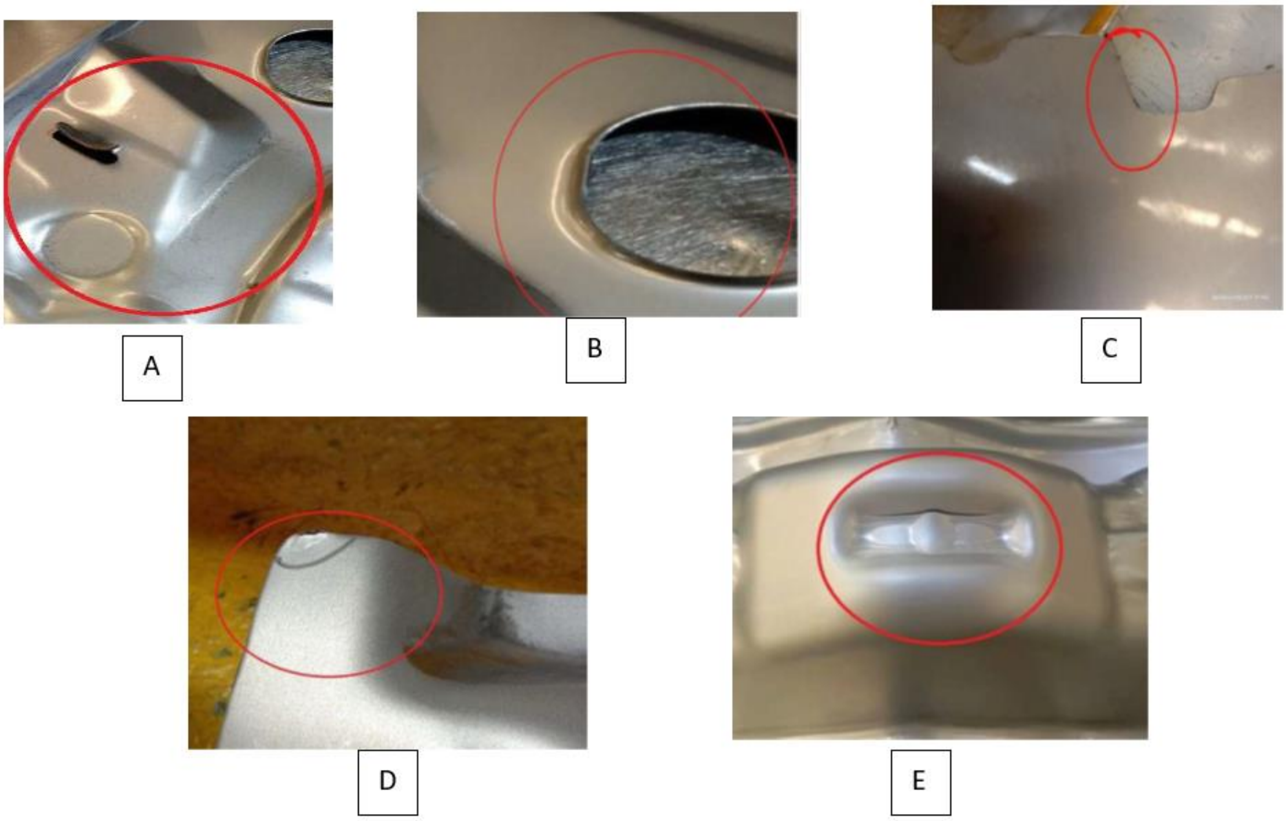


Figure 3. Defect Wrinkling, B. Defect Cutting Tidak Rata, C. Defect Piercing, D. Defect Burr, E. Defect Pecah (sobek)

The high proportion of crack defects indicates a strong indication that the process is experiencing an excess of forming forces or uneven stress distribution. This is due to the diameter of the die being worn (elliptical), resulting in a defect.

CONCLUSION

Based on the results and discussion of the deep drawing process on SPC270 sheet metal with a thickness of 0.8 mm, it can be concluded that process parameters and tool conditions have a significant influence on product quality. The forming process using a 600-ton AIDA press with a tandem dies system has generally been able to meet production requirements; however, several defects still occur and dominate the final product quality.

The analysis shows that crack defects are the most dominant (≈35–40%), followed by uneven deformation (≈25–30%), dimensional inaccuracy (≈20%), and wrinkling (≈10–15%). The high occurrence of cracks indicates that the forming process experiences excessive forming forces and/or non-uniform stress distribution. This condition is strongly influenced by the wear of the die, particularly the change in die diameter to an elliptical shape, which leads to stress concentration and ultimately material failure.

In addition, other defects such as uneven deformation, dimensional mismatch, and wrinkling are closely related to improper parameter settings, including drawing force, stripping force, and material flow control during the forming process. These findings emphasize that controlling process parameters and maintaining tool condition are critical factors in minimizing defects.

Therefore, improvements can be achieved by optimizing forming parameters, ensuring proper clearance between punch and die, and performing regular maintenance or reconditioning of dies to maintain geometric accuracy. With these actions, defect rates can be reduced and overall product quality can be significantly improved.

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