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FAILURE INVESTIGATION OF BLANK HOLDER FORCE (BHF) CONTROL IN THE OUTSIDE BRACKET FOR FRONT SEAT

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ABSTRACT
This study investigated the failure of the Blank Holder Force (BHF) control in the outside bracket for the front seat. The production process involved progressive dies consisting of nine stations: first pierce, first trim, second trim, idle, flange, idle, second pierce, idle, and parting. However, at the 7th-9th station, the pilot hole in the product deforms into an oval shape, which is undesirable. Gemba-Kaizen methods were used in this study, and primary data were collected by comparing the design and actual progressive dies. The results showed that product defects are primarily caused by an unbalanced BHF and inadequate piercing clearance. A uniform distribution of force during the forming process is obtained by reducing the spring number on the blank holder. This reduces the force generated during the process. Furthermore, the die clearance was increased from 0.01 mm to 0.1 mm, making press and die alignment less critical and requiring less cutting and stripping forces.
Keywords: *progressive dies, blank holder, gemba-kaizen*

1. Introduction

The coronavirus COVID-19 has disrupted global supply, demand and logistics infrastructure (Ivanov, 2020; Min, 2023; Quan et al., 2023). Among Southeast Asian countries, Indonesia has a relatively large population and territorial area, which makes it an ideal destination for a manufacturing shift (Ran et al., 2023). According to Indonesian Central Statistics Agency, the manufacturing industry is contributing around 20% of GDP (Sparrow et al., 2020), while the automotive industry is driving around 1.76% or equivalent to Rp 260.9 trillion (Statistics Indonesia, 2020; Usman, 2020). Therefore, it is important to perform all operations so that all resources are used efficiently (Kumar and Patnaik, 2017). Press tools are used to manufacture large quantities of components from sheet metal, and it consists of several steps that must be followed to achieve efficient and acceptable results. Stamping process is essential due to its efficiency, the use of unskilled workers, and high precision (Annigeri et al., 2017).

Fig. 1. Bracket for Front Seat

One of the products that are produced by stamping process is the Outside Bracket for the Front Seat. This bracket functions as a holder on the seat track in the car and is shown in Figure 1. Due to the high rate of productivity, the Outside Bracket for Front Seat were manufactured on a progressive die. Progressive dies are most used in press shops because they are ideal for custom products that require multiple operations in a row (Priyadarshi et al., 2021). Progressive dies allow to do cutting operations (blanking, piercing, trimming, etc.) and forming operations (bending, drawing, etc.). These types of dies are primarily designed for a single function and are superior to simple dies that only perform a single action on a workpiece with a single stroke (Bhawar et al., 2017). Further, progressive dies for the product have 9 stations that is; 1st pierce, 1st trim, 2nd trim, idle, flange, idle, 2nd pierce, idle, part, and have 3 different blank holders, cutting stripper, forming stripper, and parting stripper (Figure 2).

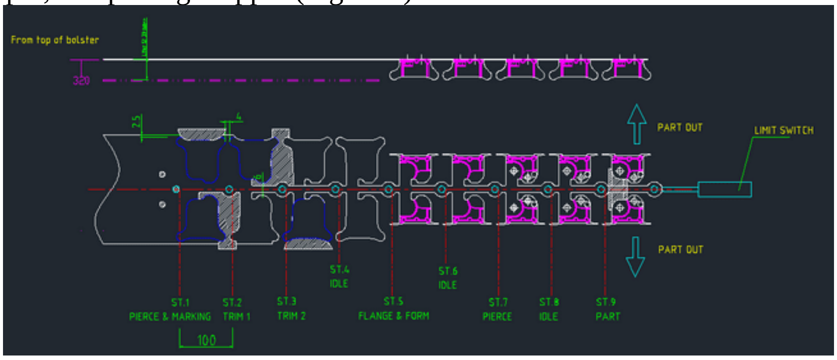

Fig. 2. Strip Layout Process of Bracket for Front Seat

However, product defects were reported. The holes in the product are not perfectly round. This caused problems and decreased product quality. The problem occurs at the 7th – 9th station, as shown in fig 3. The pilot hole in the product deformed into an oval which is undesirable. Meanwhile, the quality of sheet metal products depends largely on the rate at which sheet metal is drawn into the die. The force applied to the sheet metal by the blank holder/stripper provides a binding force that controls the flow of metal (Wifi and Mosallam, 2007). The wrinkle and cracks were eliminated in the deep drawing process by using FEM, and Multi-segment blank holder (Chen et al., 2022; Zhang, 2022).

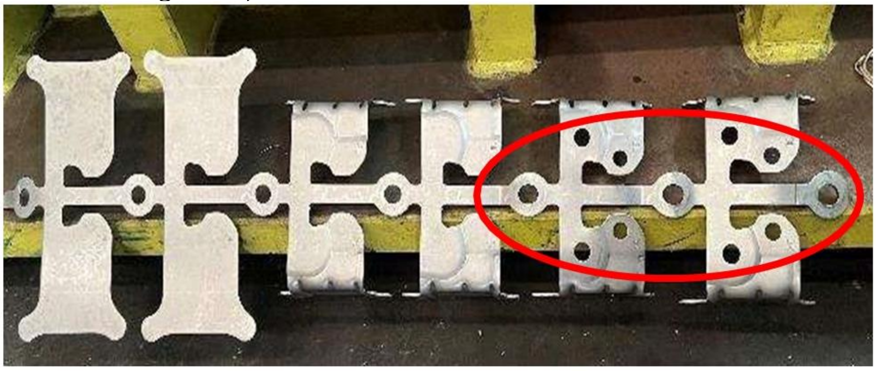

Fig. 3. Defect oval shape hole in the product

A failure investigation of blank holder force (BHF) control is presented in this study by using the Gemba-Kaizen method. Studies showed that Gemba-Kaizen in automotive industries effectively reduces cycle times (Reis et al., 2023), waste (Zvidzayi, 2021), and production cost, (Sadiku et al., 2023), improves the quality of products (Wan and Leirmo, 2023) and increased productivity (Sadiku et al., 2023). The data were collected by comparing the design and actual progressive dies. Further, analysis and optimization are carried out on the design/process

2. Literature Review

Progressive Dies

Many types of dies can be classified based on their elements and designs. Manufacturing processes classify dies as blanking, punching, bending, deep drawing, etc. There are a variety of operations, including single-operation (simple) and multi-operation (combination) dies, as well as stations (Vukota, 2004).

A progressive die consists of two or more stations. At each station, a different operation is performed on the workpiece. An idle station is provided so that the workpiece can be completed when the last operation is completed. As each stroke of the press is executed, another finished part is produced after the first part has traveled through all the stations. During the process of designing a die, the sequence of operations for a strip and the details of each operation must be carefully considered. During the development of the final sequence of operations, the following items should be considered. (Vukota, 2004):

1. The first station should be punched with pilot holes and notches. There may be other holes punched that will not be affected by subsequent non-cutting operations.
2. Provide a free-moving blank for drawing or forming operations.
3. Punching areas should be distributed over several stations if they are close to one another or near the die opening edge.
4. Determine whether the blanked areas of the strip can be divided into simple shapes based on their shapes. For simple contours, standard punches may be used.
5. It is recommended to use idle stations in order to strengthen die blocks and stripper plates and facilitate strip movement.
6. Identify whether the direction of strip grain will adversely affect or facilitate any particular operation.
7. Consider bending or drawing operations in either an upward or downward direction to ensure the most efficient die design and strip movement.
8. It may be necessary to carry out the cutoff operation before the last non-cutting operation, depending upon the shape of the finished piece.
9. Ensure that carrier strips or tabs are adequate.
10. Verify that the strip layout is designed to minimize scrap.
11. Locate cutting and forming areas to provide uniform loading of the press slide.
12. Design the strip so that the scrap and part can be ejected without interference.

Blank Holder Force

A blank holder is designed to prevent wrinkles from appearing on the top flange of the shell (Zhang and Wang, 2022). It is possible for wrinkles to appear if there is not sufficient pressure applied to the blank holder, or if the radius of the punch or draw rings is too large. When there is insufficient clearance between the punch and the die, wrinkles can form as too much metal crowds over the draw ring (Atul S and Babu, 2019). The blank holder force can be calculated by the following formula (Vukota, 2004):

• For the first drawing operation:

$$F_{d1} = \frac{\pi}{4}[D^2 - (d_{p1} + 2R_{p1})^2] \cdot p_{d1}$$

• For subsequent drawing operations

$$F_{di} = \frac{\pi}{4}[d_{i-1}^2 - (d_1 + 2T)^2] \cdot (1 + \mu ctg\alpha) p_{di}$$

where:

D = blank diameter

T = material thickness

d_i = inside cup diameter after the first drawing operation

p = blank holder pressure

Numerous novel processes have been developed by designed variable system of BHF, giving lubricant to the products (Zhang and Qin, 2022), and predicting the critical fracture parameters of modified Mohr-Couloumb (MMC) by FEM (Chen et al., 2022). Other researchers developed the power source of BHF by using degressive gas, hydraulics, electro-hydraulic load sensing, electro-mechanical die cushion, and the electromagnet blank holder (Chen et al., 2022).

Although the aforementioned developments in technologies improve the forming process, industrial facilities often have limitations. Therefore, available resources must be optimally utilized to solve problems. In theory, the Blank Holder Force (BHF) is evenly distributed throughout the product area, but in practice, it is not always the case. Material flow in complex parts must be controlled, called multipoint BHF (Zhang, 2022). Multipoint BHF control can be achieved by positioning the blank holder springs according to the tool's center of gravity. The theoretical calculation of the tool's center of gravity is as follows.

$$X(center) = \frac{L_1X_1 + L_2X_2 + L_nX_n}{L_1 + L_2 + L_n}$$

$$Y(center) = \frac{L_1Y_1 + L_2Y_2 + L_nY_n}{L_1 + L_2 + L_n}$$

where:
X, Y = coordinates of the center of the die pressure,
X1, Y1 = coordinates of the center of gravity of a partial length of cut edge
Li = partial length of cut edges.

Besides, by using the center of gravity feature in software the calculation of the center of gravity can be done (figure 4).

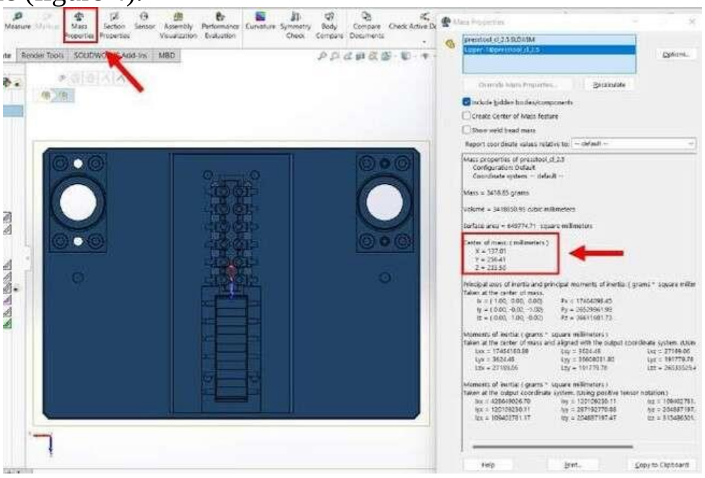

Fig. 5. Calculation of the centre of gravity in software

3. Research Methods

Gemba-Kaizen was used in the present study as an optimization and experimental method. There are two fundamental principles of Lean that identify and eliminate waste in all work processes. The research methodology was developed in accordance with the research approach developed by (Cherrafi et al., 2019)and is shown in Figure 5.

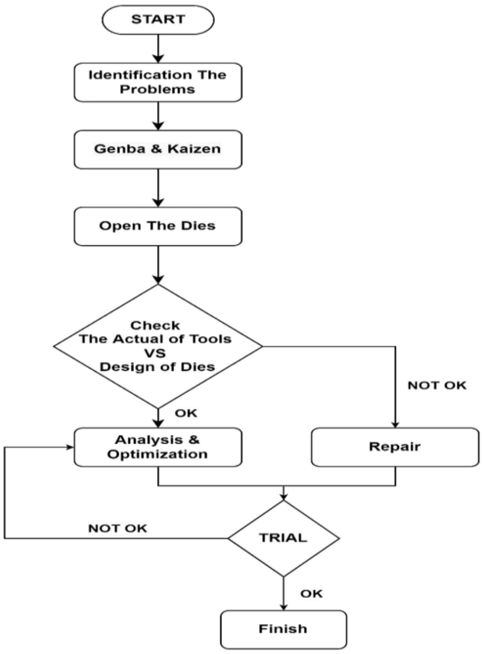

Fig. 5. Research methodology

First, it began with problem identification. As mentioned in the previous part, the fault caused the product to have an oval-shaped hole. The product material used is SCGA 440-45 with 2 mm thickness and confirmed by optical Emission spectrometry (OES) shown in Table 1.

SGC440 steel is a high-strength hot-dip galvanized cold-rolled steel for structural uses according to JIS standard material (Alvi, 2013).

Table 1 - Material composition and properties of SCGA 440-45

Specification			Units
Chemical Composition	C	0.25	Max. %
	Mn	2	
	P	0.2	
	S	0.050	
Mechanical Properties	Ultimate Strength	440	N/mm^2
	Yield Strength (min.)	335	N/mm^2
	Elongation (min.)	18	%

Then, Gemba should be done after the problems have been identified. Gemba (or Genba) refers to "the actual place where something happens" in Japanese. In the context of business-process improvement, the gemba is the source that value is created, especially in the manufacturing area or a workshop in Japanese company. Gemba management is often associated with the integrated application of kaizen, resulting in the term "Genba-Kaizen" which mean "complete and continuous improvement of site conditions" (Macpherson et al., 2018).

In this case, the purpose of gemba is to directly see the problem that occurs on the shop floor without intermediaries. By looking directly at the shop, it will help to identify what things have deviated from the initial procedure (Cherrafi et al., 2019). The production head, designer and QC staff do gemba, and the dies should be open. It will help to see the problems more comprehensively. The upper dies and the lower dies are placed side by side so that the observation can be carried out simply.

Matching field processing shall be done. The actual condition of tools and die design should be compared (Singh et al., 2023). A discrepancy between the design and the actual tools in the workshop must be checked. When the design and tool are appropriate, the next step is to analyze and optimize the design or the process. InspireForm is used to assist in design and process optimization, especially to simulate and control blank holder force (BHF). Nevertheless, if the design and the tools are different, the necessary repairs should be done. Last, the trial is led to ensure simulation and optimization succeed

4. Results and Discussions

Genba was conducted and the following results were found. The observations during the production process show that blank holder 3, which is where failure occurs, experiences a delay (Figure 5). Blank holder 3rd is also used for the piercing and parting processes. A blank holder is a part that pressing and preventing wrinkles in the material (Ahmetoglu et al., 1992). The delay that occurs on the blank holder can be caused by several factors, such as the material being formed (Zhang and Wang, 2022), positioning of springs, insufficient blank holder force (Brun et al., 2021; Gavas and Izciler, 2006), the presence of obstructive scrap, and insufficient clearance (Sontamino and Nitnara, 2022).

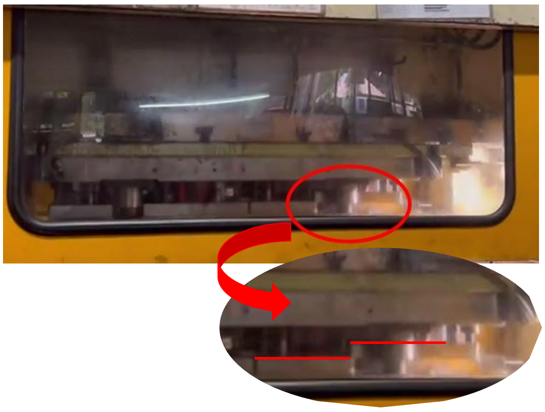

Fig. 4. Research Methodology

According to (Takatsu et al., 2022), SCGA 440-45 has the same properties as JIS 3302, which indicates that this material is suitable for sheet metal forming. Then, the examination is continued by comparing BHF between existing calculations and software (Zhang and Wang,

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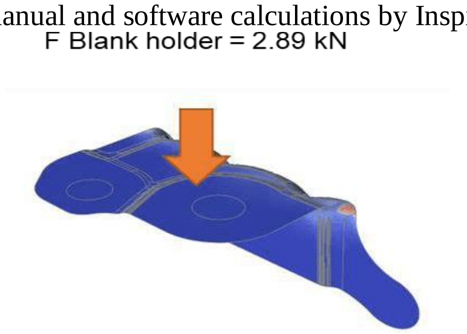
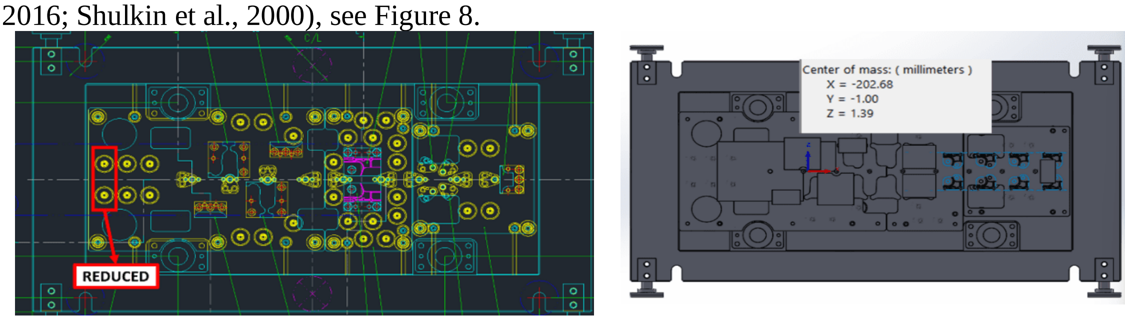
2022). BHF has a significant impact on the success of sheet metal forming. It should be sufficient to prevent excessive wrinkling (or buckling), but not so large that it would tear, split or fracture.(Ahmetoglu et al., 1992; Takatsu et al., 2022; Zhang and Qin, 2022). Figure 7 shows BHF is compared between manual and software calculations by InspireForm.



Fi.g 5. Blank Holder Force Total Calculation by InspireForm

The existing blank holder force is 2.79 kN while the calculation using software is 2.89 kN. As the difference between the two methods is not significant, it means that the problem cannot be attributed to die design, which is why the investigation into the die design continues (Budiarto et al., 2022).

Afterward, the design layout shows that the center of gravity is -202 to the X-axis. Additionally, the position of the spring is relatively far from the piercing area (figure 8). It is critical to note that a center of gravity that is located too far in the blank holder will result in a distribution of force that is not equally distributed, which will result in a reduction in material flow in one place (but not in other places) that will adversely affect product quality (Feng et al., 2019; Sontamino and Nitnara, 2022; Zhang and Qin, 2022). In order for the BHF distribution to be even, the blank holder spring is reduced (Ahmetoglu et al., 1992; Koowattanasuchat et al., 2016; Shulkin et al., 2000), see Figure 8.



(a) Layout Design of Tool (b) Centre of Mass Tools

Fig. 6. Design Existing of Tools

Furthermore, the investigation found that the clearance between the pilot and the bush is too small. So, it was enlarged to 1/10 from originally 1/100. Figure 9 shows the changes in dies. A die clearance that is too small or too large will result in edge cracks (Budiarto et al., 2022; Pätzold et al., 2023; Preedawiphat et al., 2020). In the hole expansion test, (Mori et al., 2010) investigated the effect of die clearance and associated work hardening on the expansion ratio limit. For small die clearances and high work hardening, the expansion ratio decreased dramatically.

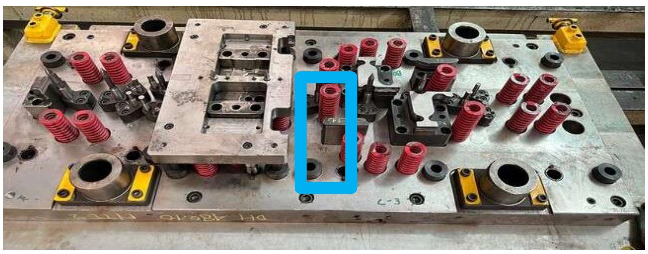


Fig. 9. The Reduction of Springs from Dies

Last, the trial on the press machine shows that the blank holder can move together after reducing the number of springs. In addition, once the products have been manufactured, they are then checked with a checking. The test confirms that the product is “okay”, as shown in figure 9.

Checking fixtures is essential for the accurate and efficient inspection of products, ensuring they meet the required quality standards fixture (Mitra, 2016; Vishal et al., 2022). Through the implementation of these steps, manufacturers can guarantee that their products are of the highest quality (Özgüven, 2022).

(A) Trial on Machine After Repaired (B) Checking on Checking Fixture

Fig. 10. Quality Checked on Machine and Checking Fixture

5. Conclusion

An investigation has been completed. Gemba-Kaizen has proven to be effective in identifying problems in the field so that product defects are successfully eliminated. Gemba-Kaizen results show that there are 2 factors that are the main cause of product defects. There are two factors for this: an imbalance of BHF against the center of gravity of the tool. Therefore, BHF control needs to be done by reducing the number of springs and the clearance enlarge from 0.01 to 0.1 mm.

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