Die design optimization on sheet metal forming with considering the phenomenon of springback to improve product quality

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Abstract. The process of sheet metal forming is one of the very important processes in manufacture of products mainly in the automotive field. In sheet metal forming, it is added a certain size at the die to tolerate a result of the elasticity restoration of material. Therefore, when the product is removed from the die then the process elastic recovery will end within the allowable tolerance size. Extra size of the die is one method to compensate for springback. The aim of this research is to optimize the die by entering a springback value in die design to improve product quality that is associated with accuracy the final size of the product. Simulation processes using AutoForm software are conducted to determine the optimal parameters to be used in the forming process. Variations the Blank Holder Force of 77 N, 97 N, and 117 N are applied to the plate material. The Blank Holder Force application higher than 97 N cannot be conducted because the Forming Limit Diagram indicates the risk of tearing. Then the Blank Holder Force of 37 N, 57 N and 77 N are selected and applied in cup drawing process. Even though a few of wrinkling are appear, however there is no significant deviation of dimension between the product and the design of cup.

1 Introduction

The forming process commonly called stamping plate in the industrialized world is the forming process for automotive components [1]. Its main basic material is in the form of sheet metal, this can be mild steel, aluminium alloy or titanium alloys [2-4]. One of the forming processes is deep drawing. Deep drawing is a compression-tension forming process with the greatest range of applications involving rigid tooling, draw punches, a blank holder and a female die. In this process the blank is generally constrained over the draw punch into the die to give required shape of cavity [5].

During the process, the blank sheet is likely to develop defects if the process parameters are not selected properly. Therefore, it is important to optimize the process parameters to avoid defects in the parts and to minimize production cost. Optimization of the process parameters for instance die radius, blank holder force, coefficient of friction, etc. can be concluded according to their degree of importance on the sheet metal forming characteristic [6].

At the end of the bending process, after the object removed from the die, the material's elastic energy will be received by the object that resulted objects trying to get back in shape. It was referred to as elastic recovery, which in the world of stamping referred to as springback. In this case, springback angle is defined as the addition of the product bent on stamping after being removed from the die.

The aim of this research is to optimize the die by entering a springback value in die design to improve product quality that is associated with accuracy the final size of the product.

2 Springback

Springback phenomenon always occurs in the process of sheet metal forming (SMF), because of the nature of the material elasticity. Thus, springback cannot be eliminated, but can be minimized or compensated in the die. Therefore, the handling of springback is very important in the design of the die to produce a product with a very high accuracy measurement [7]. Illustration of the springback phenomenon can be seen in Fig. 1, where R_a is radius after springback and R_b is radius before springback.

Various methods are used to reduce the springback. The traditional method of experiments on die requires a very large cost, because the wrong die is disuse anymore, while the manufacturing cost is very expensive. Then the more modern method is come by using computer equipment and software to simulate springback process. After that, it is made a design change in the die before it is produced. As it is known that the development of computers so rapidly so that computer become a tool to perform computation in a very large scale. Finite Element Method (FEM) is one of the popular way in solving the problems of static, dynamic and vibration in the design of a component.

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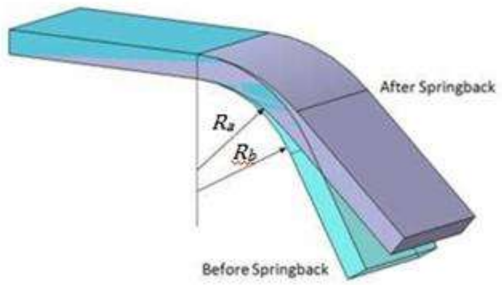

Fig 1. The phenomenon of springback in bending process.

FEM for numerical analysis and simulation has become an important tool in predicting material behaviour, collapse, cracking, fracture and fatigue [8, 9]. Furthermore, developing analytical models sometimes can be assisted by finite element results [10, 11].

3 Cup Drawing

Cup Drawing is a series of processes plat shaped like a bowl or a hat with a metal stamping which is often called deep drawing. Schematic of cup drawing can be seen in Fig. 2. On the Cup Drawing process, it is found many defects in the workmanship such as fracture, wrinkling, and thinning [12].

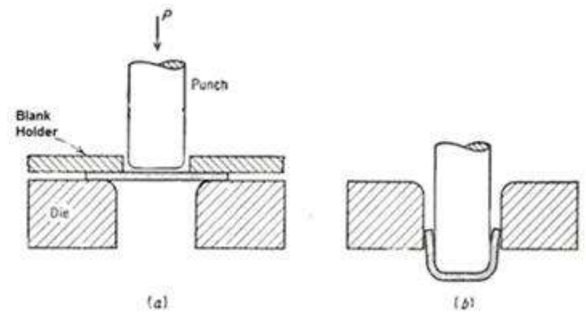

Fig 2. Cup drawing process (a) before process (b) after process.

The forms of these defects should be prevented or even avoided as much as possible in order to reduce production cost. In general, to avoid these problems, manufacturers require trial and error experimentation steps that would cost quite large. Therefore simulations need to avoid the occurrence of defects in the process Cup Drawing. Among them is to avoid defects wrinkling and thinning.

Wrinkling is undesirable defects that occur in the process Cup Drawing [13]. This defect occurs at the edges (flange) and the side wall of the cup.

Effects thinning or thickness variation in the cup drawing process cannot be avoided, because the thinning occurs as a result of push by the punch so that the plate which is clamped between the blank holder and dies will be pulled and will cause different thickness in some parts.

The main reason of the disability of wrinkling is the inability to resist Blank Holder Force (BHF) [14]. The optimization of BHF can be conducted by using FEM to find the BHF which minimum of wrinkling and thinning [15].

Appropriate BHF evolved through a process results in controlling the thickness variations in a deep drawn part and thus the quality of the part [16, 17].

4 Materials and Methods

The material used in this study is the aluminium alloy plate. Tensile testing in accordance with ASTM E8 standard performed on this material.

Design drawing is a step performed prior to the manufacture of workpiece machining. It is intended to minimize errors during the process of manufacturing or production. Solid Work 2013 is used to draw a design of a cup die. Die design refers to the standard Numisheet 2014 Benchmark Model 4. The schematic of tools and the dimension of die, punch, blank holder and blank sheet of cup drawing that will be used in the experiment are described in Fig. 3. All models are created in surface design and then save as IGES files. The files are common use to change ability.

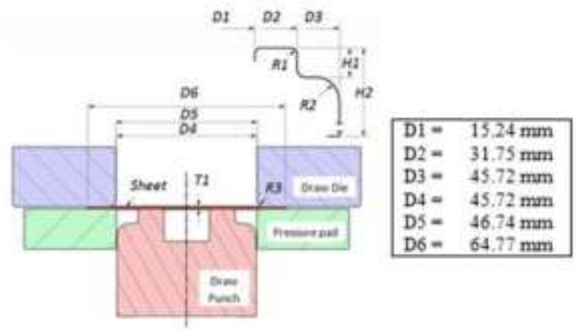

Fig 3. Schematic view of tools for the drawing process.

Manufacture of die sets consisting of die, blank holder and punch, is conducted by using the ST37 steel material in the form of a cylinder with a diameter of 150 mm. The material is processed with turning machine or CNC lathe in accordance with the size of the design drawings that have been made.

Aluminium alloy is selected for the blank sheet. Aluminium alloy sheet with the thickness 0.32 mm are considered in the investigation. Four equally space bolts were prepared for BHF. The machine has hydraulic press of 1500 kN capacity.

To determine the optimal parameters to be used in the forming process, then simulation processes using Auto Form software are conducted. Variations BHF of 77 N, 97 N and 117 N as well as the variation compensation factor of 0.0, 0.3, 0.5, 1.0 and 1.5 are applied to the plate material. The Forming Limit Diagram (FLD) is used to predict whether the plate will tear or not.

Finally, after the simulation process, the Cup Drawing experiment is conducted by considering the result from simulation process.

5 Results and Discussions

Based on the data that has been obtained from simulations and experiments that have been done before, data processing and graphically statistic analysis of cup drawing testing will be performed.

Springback is taken into consideration by providing compensation factor to the die. Fig. 4 shows that the compensation factor of 0.5 provides the lowest springback of 1.5 mm while the compensation factor of 0.0 delivers the biggest springback of 2 mm. Therefore, the compensation factor of 0.5 is applied in the experimental process.

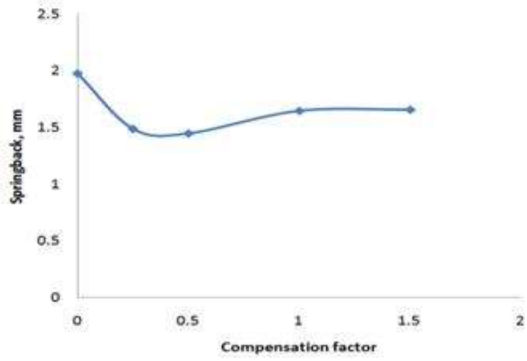

Fig 4. The Compensation factor versus Springback Curve.

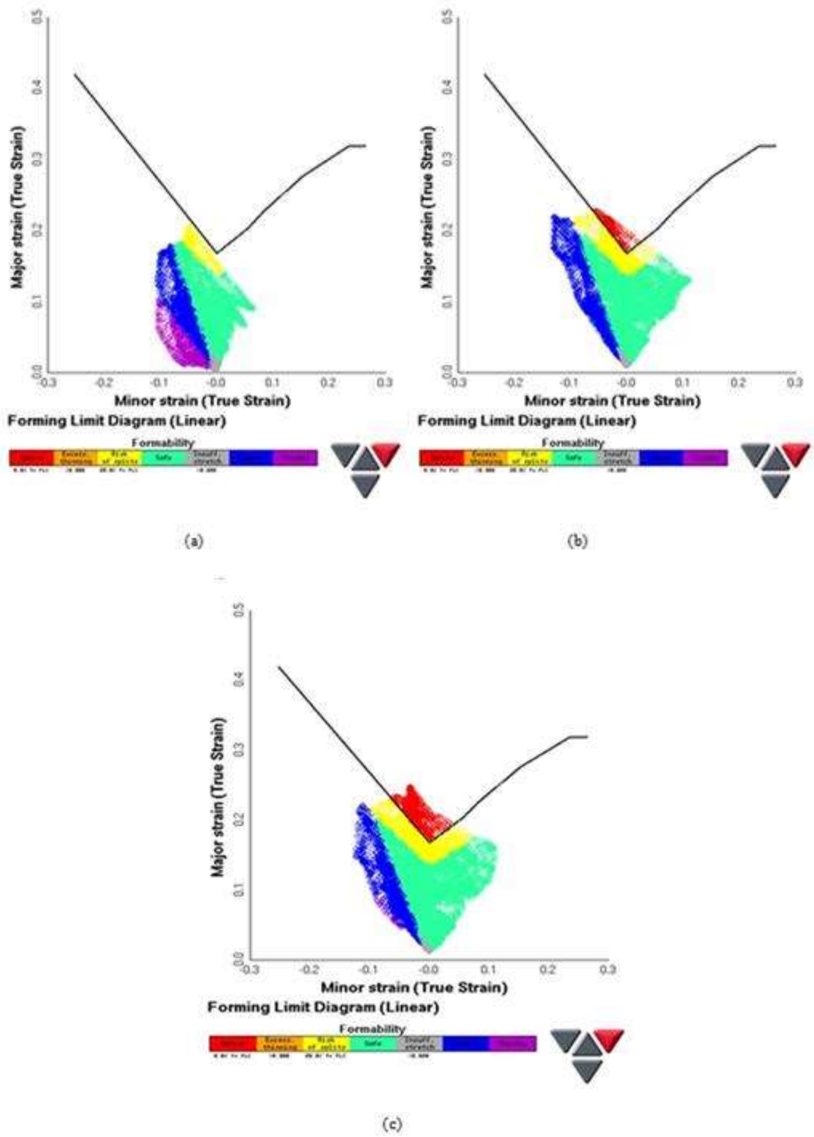

Fig 5. Forming limit diagram for BHF of (a) 77 N, (b) 97 N, and (c) 117 N.

The Forming Limit Diagrams which are resulted by using Auto Form software show that the process of cup drawing with BHF higher than 97 N will cause the plates to tear (see Fig. 5). Therefore, the BHF value under 97 is selected.

Experimental process of the cup drawing is conducted by applied the BHF of 77 N, BHF of 57 N, and BHF of 37 N with the compensation factor of 0.5. The study on the influence of the blank holding force over wrinkling has been made using dies that work according to the Table 1. Table 1 shows that the greater the BHF, the smaller the wrinkling that occurs. However it is still need awareness of the ultimate tensile strength of the material. Over this value the cracking and braking of the material occur.

In this Cup Drawing process, even though there is no tearing appears on the product, wrinkling defects in small size can be detected on the product of the cup drawing as can be seen in Fig. 6. It also can be seen clearly that the wrinkling are arise in the dome area and side wall.

Table 2 shows deviation of diameter of parameter D2 and D3. For Cup Drawing product, the deviation of diameter of parameter D2 and D3 are 0.78 % and 1.50 % respectively. These are considered as small deviation.

Table 1. Wrinkling on product of cup drawing process.

No.	Blank Holder Force (N)	Wrinkling (mm)
1	77	0.92
2	57	0.98
3	37	1

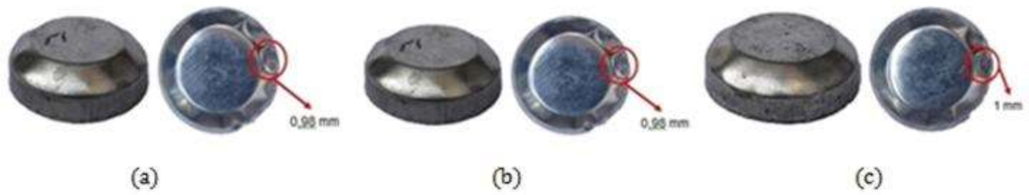

Fig 6. The Cup Drawing product of aluminium alloy with (a) BHF of 77 N, (b) BHF of 57 N, and (c) BHF of 37 N.

Table 2. Deviation of product diameter

Parameter	Design (mm)	Cup Drawing Product (mm)	Deviation of Cup Drawing Product (mm)
D2	31.75	32.53	0.78
D3	45.72	47.22	1.50

6 Conclusions

The following conclusions can be drawn from the research, by considering the springback phenomenon:

1. There is no tearing occur in the cup drawing test
2. There is no significant difference of cup dimension between the product and the design.

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