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BORANG PENGESAHAN STATUS TESIS

JUDUL: Experimental Study on Process Parameter to Reduce Wrinkling In Sheet Metal Forming.

SESI PENGAJIAN: 2012/2013

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EXPERIMENTAL STUDY ON PROCESS PARAMETER TO REDUCE WRINKLING IN SHEET METAL FORMING

NIK MUHD HAZWAN BIN NIK ABD AZIZ

Report submitted in partial fulfillment of the requirements
For the award of Bachelor of Manufacturing Engineering with (Specialization)

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2013

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Manufacturing Engineering with "specialization".

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STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Deep drawing operations are crucial for metal forming operations. Obtaining a defect free final product with the desired mechanical properties is very important for fulfilling the customer expectations and market competitions. Flange wrinkling is one of the fatal and most frequent defects that must be prevented. This study focuses on understanding the phenomenon of flange wrinkling and prevention method that can be applied to avoid the flange wrinkling defect. MINITAB software was used to analyze parameters in order to understand level of flange wrinkling and effect in experiments against of sheet metal. Model of a cup are used to investigate with different thickness but the blank holder force depend on spring. This process also depends on calculation, and the material that we use is mild steel. Flange wrinkling instability is illustrated in energy diagrams of the process. Effect of anisotropy on flange wrinkling is also discussed by comparing with using different thickness. Besides experimental which is conducted as conventional deep drawing operation by a hydraulic press, numerical analysis verification is also performed and this yields will show the ability to understand the effect of blank thickness on flange wrinkling formation through experimental and numerical analysis. The wave formations different sized of blanks with same metals are illustrated.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Sheet metal forming is a process shaping by applying force to the blank. Metal forming is used for achieving complex shape products and improving the strength of the material. During forming, little material is wasted compare to other manufacturing processes and deep drawing is one of the metal forming processes, where In the deep drawing process, flat sheet of metal (called blank) is placed over the die, and with the help of the punch, blank is pressed into the die cavity. Blank holder applies pressure to the blank in the flange region during the deep drawing process. This method is widely used for producing various products in different places of industry. The parts manufactured by sheet metal forming are widely used in automotive and aircraft industries. Sheet metal forming is very important for metals because nearly %50 of metals is produced in sheet metals (Grote K.-H., Antonsson E.K., 2008.)

Deep drawing is affected by many factors, like material properties, tool selection, and lubrication Because of these factors, some failures may occur during the process and flange wrinkling are the one of failure types that can be seen in deep drawing, and the cause of this failure caused by compressive stresses. A part flange wrinkled during the deep drawing process, will not be accepted and most likely become a scrap, a total waste of both money and time. Because of these reasons, wrinkling must be prevented. There are two main methods used in order to prevent flange wrinkling. The former is using a blank holder and blank holder is a tool used for preventing the edge of a sheet metal part from flange wrinkling.

There is one type blank holder that is used namely, pressure blank holder. In the former, the sheet metal kept at several of thickness, by adjusting variable force between blank and die during the process, and flange wrinkling is prevented. In the latter, force is applied to the blank from the blank holder, called blank holder force (BHF), in order to prevent flange wrinkling. Adjusting the force and thickness of blank that is suitable is very important, because high or low force and thickness of blank that is not suitable will be cause of fracture at the cup wall and low (BHF) leads to wrinkling in the flange of the cup.

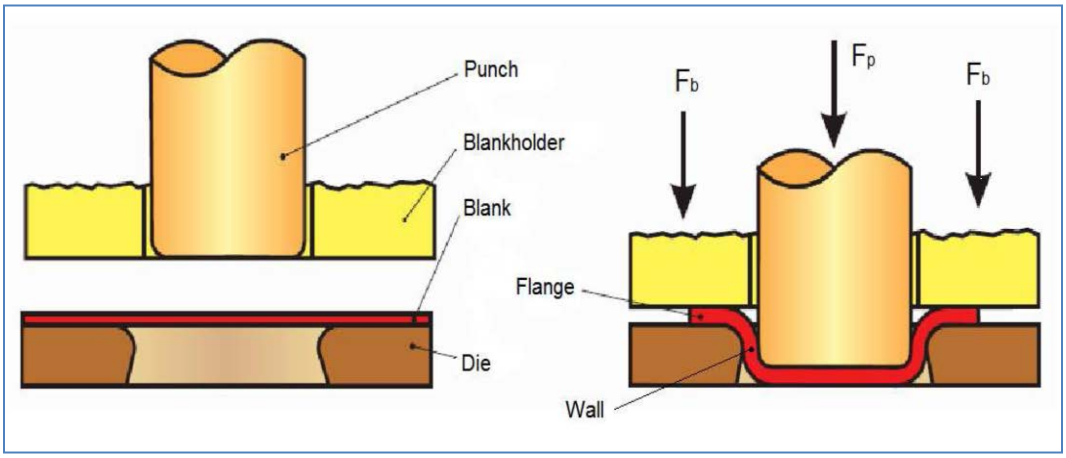


Figure 1.1: Deep Drawing Process

Metal Forming Handbook. (1998)

1.2 PROBLEM STATEMENT

In manufacturing processes the main goal is to obtain defect free end product. The first step of manufacturing is the designing process, which enormously affects the whole manufacturing process. The designer must have knowledge about possible problems and their solutions during production. Many researchers have been completed in various manufacturing processes because of the knowledge needed to achieve better quality product. This study helps to improve the performance of deep drawing process by using suitable parameter to reduce wrinkling in product. It is worth to understand the capability of punch force, blank of thickness and blank holder force during deep drawing process. This thesis will discuss about flange wrinkling problem and its prevention in the deep drawing process.

1.3 PROJECT OBJECTIVE

The objectives of this research are as following:

i. Study the effect of force, blank of thickness and blank holder force parameters on the flange wrinkling to reduce the flange wrinkling.
ii. Develop flange regression study interaction between force, thickness parameters and blank holder force which are termed response flange methodology.

1.4 SCOPE OF PROJECT

In this project, sheet metal is used as a specimen. The specification of the sheet metal will be identified using surface measurement. Deep drawing operation is performed using die. Deep drawing operation will be done on sheet metal based on force that is applied, blank of thickness and blank holder force. In this case spring of blank holder force is set base on calculation throughout the experiments. The flange wrinkles of each of the specimen will be studied and compared.

1.4.1 Project Specification

Sheet metal material	: Mild steel with 320GPa Young Modulus of Elasticity
Thickness of blank	: 1mm, 2mm,
Size of die	: 280mm x 280mm (L-R x F-B)
Blank size	: Ø105mm
Diameter of cup	: 50mm (outer diameter)
Part draw height	: 10 and 20mm
Cup outer radius	: 5mm
Machine tonnage	: 80 tonne

The success or failure of the forming process is influenced by many process parameters such as the drawing ratio in each stage, the difference of the drawing ratio within the cross-section, the shape of the die, the strain-hardening coefficient, material formability, the lubrication conditions and the degree of ironing. One of the key parameters affecting the forming process is the blank holder force (BHF). The advantage of varying the blank holder force during the forming process is the two primary model of failure which are wrinkling and tearing (Fig. 1.2) are avoided. This gives rise to improved formability, higher accuracy and better part consistency.

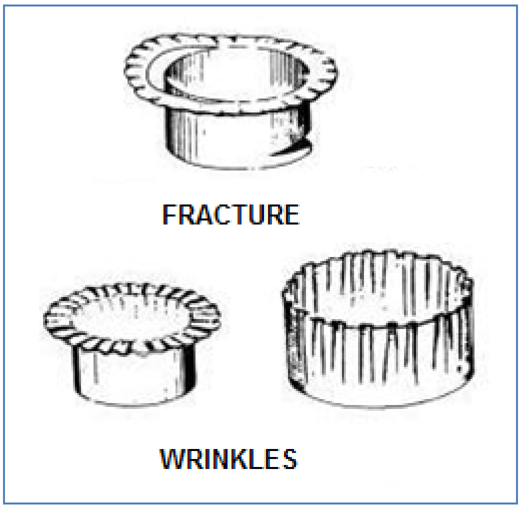


Figure 1.2: Wrinkling & tearing in deep drawing

Source: Huh H. and Kim S. (2001)

1.5 SUMMARY

Chapter 1 has been discussed briefly about project background, problem statement, objective and scope of the project on the effects of force that is applied and blank of thickness on the flange wrinkling of sheet metal using deep drawing operation. This chapter is as a fundamental for the project and act as a guidelines for project research completion.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents the literature search related to the current study. First, conventional deep drawing process will be discussed. Secondly, sheet metal formability concept is mentioned and possible failure modes are discussed. Then, Effect of various factors that lead to the wrinkling apparition and method how wrinkling can be prevent. At the end of the chapter, previous researches related to the mentioned concepts are presented.

2.2 MATERIAL PROPERTIES

The material which has been modeled as the blank in this research is a mild steel. A paper by (Dr. Waleed Khalid Jawa, 2007) investigates the effects of contact in the deep drawing process and models the blanks from very similar mild steel as required in this instance. The properties as which were specified in table 2.1.

Table 2.1: Property table for blank being formed

Annealed mild steel	
Property	**Value**
Carbon content	0.15%
Yield stress	320 MPa
Tangent modulus	0.5 GPa
Modulus of elasticity	320 GPa
Poisson's Ratio	0.3
Friction Coefficient	0.1

Source: Dr. Waleed Khalid Jawa. (2007)

A sheet which has a good drawability characteristic should have high resistance to thickness and low friction thinning in the desired cup-shape without a change in sheet thickness when it is formed. Value can be measured by tensile test and is the plastic strain ratio of width to thickness in a sheet (Wang M. Zhang, 1993).

2.3 DEEP DRAWING PROCESS

As mentioned in the introduction chapter, flat sheet of metal is formed into a 3-d product by deep drawing process. The main tools of the process are blank, punch, die and blank holder. In the simple circular cup drawing process with blank holder, the tools and tool geometries are shown in the Figure 2.1.

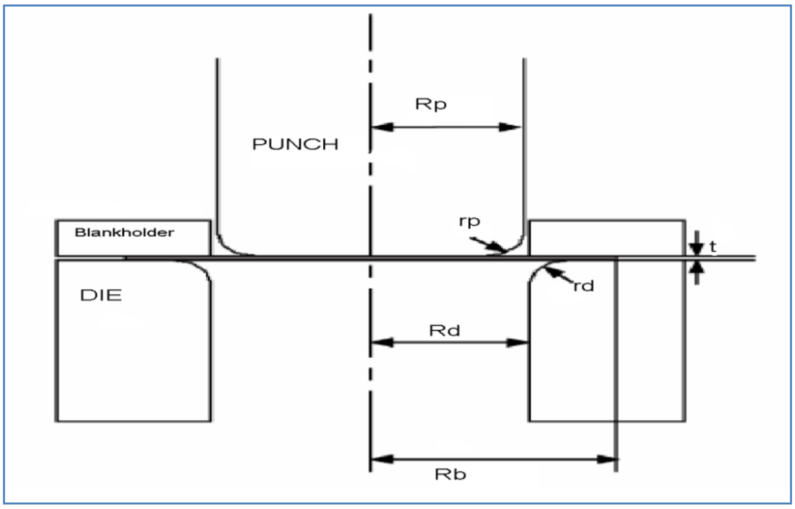


Figure 2.1: Geometry parameters for deep drawing tools

Source: T. Balun. (1993)

The tool geometry parameters are stated as;

- Punch Radius Rp
- Punch Edge Radius rp
- Blank Thickness t
- Blank Radius Rb
- Die Radius Rd
- Die Edge Radius rd

These parameters must be selected very carefully because the final product highly depends on these geometries. Shape of the fully drawn cup is obtained by selecting die and punch respectively. Clearance is also an important parameter, formulated as the difference between die radius and punch radius (c = Rd – Rp). If the clearance is not large enough, ironing will occur. Ironing is defined as thinning of the blank at the die cavity. In order to eliminate this problem, clearance should be %25 larger than the initial blank thickness. Also the punch edge radius and die edge radius effects the process (Carol Schnakovszky, 2007).

Larger corner radius lowers the punch load whereas smaller radius increases the needed punch load. Usually, the blank holding force has to increase along with the increase of the deep drawing depth, but we must take into consideration the fact that if its value is too big it can lead to cracks and even a break of the material. The main geometric parameters of the die which influence the wrinkling are (T. Balun, 1993). The diameter of the punch and punch edge radiuses. In the case of friction between the piece and the tool, the increase of the coefficient of friction determines the wrinkling to reduce, but high values of the coefficient can cause cracks and material breakage (Carol Schnakovszky, 2007).

In addition to the tool geometry parameters, there are also physical parameters in drawing operations (Carol Schnakovszky 2007). Some of these are classified as;

- Blank material properties
- Blank holder force
- Punch speed
- Lubrication
- Draw depth

2.3.1 Die Concept

Deep drawing die is a metalworking tool that is designed and built to convert raw material into parts that conform to blueprint specifications. Before proceeding with the fabrication, the fundamental of deep drawing process must be known first. In deep drawing, dies are placed into a stamping press and when the stamping press moves up, the die opens. As the stamping press moves down, the die closes. The raw material or blank moves through the die while the die is open, being fed into the die in a precise amount with each stroke of the press. As the die closes, the die performs its work on the metal.

The greater the die cavity depth, the more blank material has to be pulled down into the die cavity and the greater the risk of wrinkling in the walls and flange of the part. In stamping, most of the final part is formed by stretching over the punch although some material around the sides may have been drawn inwards from the flange. As there is a limit to the stretching that is possible before tearing, stamped parts are typically shallow. To form deeper parts, much more material must be drawn inwards to form it. One of the most common examples of deep drawing is the cup drawing operation. It is used to produce products such as cartridge bases, zinc dry cells, metal cans and steel pressure vessels (Hosford and Caddell, 2007). It is also used as a method for formability test of sheet metals such as the Swift cupping test (Theis, 1999). Forming a simple cylindrical cup is shown in Figure 2.2.

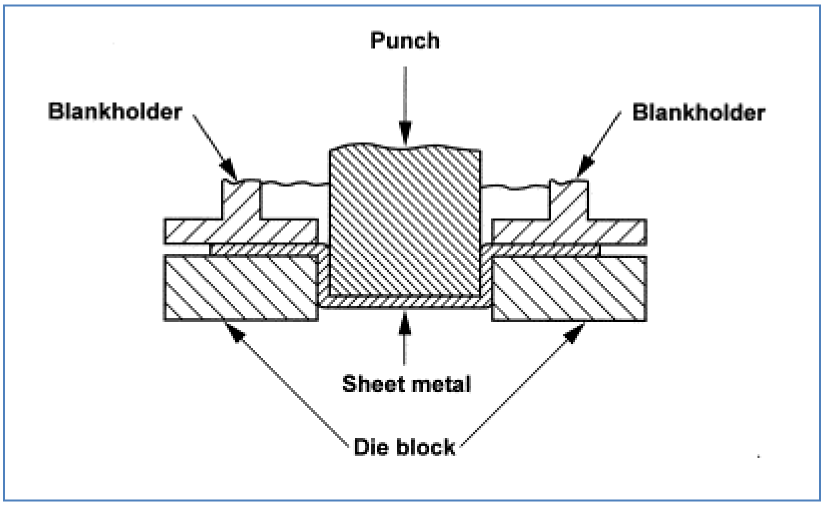


Figure 2.2: Cylindrical cup

Source: E.Chu. (June 2001)

2.3.2 Draw Ratio

The draw ratio is the key to understanding thermoforming processes. The part has a finite amount of surface area that needs to be covered by a flat two-dimensional sheet. When the sheet is forced over or into a mold it must stretch to conform to that shape. As the sheet stretches it thins out. Local design features on the part may cause the sheet to thin at a greater rate than in adjacent areas (Hansford WF 1993).

The draw ratio can be described numerically if the surface area can be calculated. The number of successive draws required is a function of the ratio of the part height, h to the part diameter, d. The formula for expressing the draw ratio is as follows;

$$N = \frac{h}{d} \tag{2.1}$$

Where:

N = number of draws

h = part height

d = part diameter

The value of N for the cylindrical cup draw is given according to table 2.2

Table 2.2: Draw Ratio table

h/d	<0.6	0.6 to 1.4	1.4 to 2.5	2.5 to 4.0	4.0 to 7.0	7.0 to 12
N	1	2	3	4	5	6

Source: Vukota Boljanovic. (2004)

2.3.3 Die Clearance and Radius

One of the factors that must be considered in determining a die dimensions is the amount of clearance (Fig. 2.3) between the punch and die members. A proper clearance of the die will give the desired force during the stamping process. The radius degree of the punch and die cavity edges control the flow of blank material into the die cavity.

Wrinkling in the cup wall can occur if the radius of the punch and die cavity edges are too large so if the radius is too small, the blank is prone to tearing because of the high stresses. Proper clearance application also depends on the material degree of hardness and thickness. (Vukota Boljanovic, 2004).

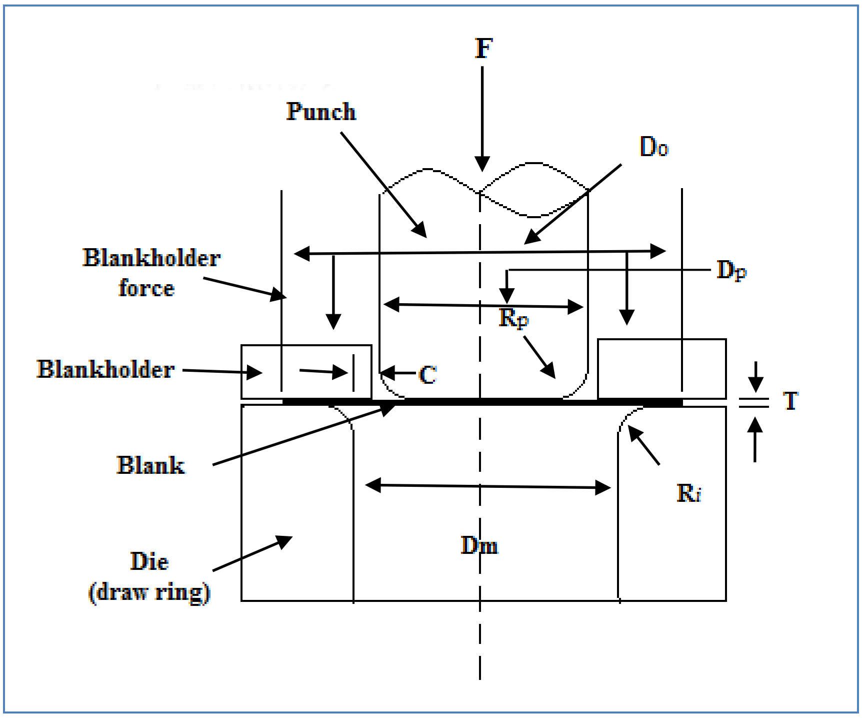


Figure 2.3: Punch & die clearance

Source: Vukota Boljanovic. (2004)

A similar conclusion was reached by (M. Colgan and J. Monaghan, 2003) who concluded that the geometry of the tooling is generally most important, especially the die radius. The smaller the die radius the greater the drawing force induced and the greater is the overall thinning of the cup sidewall.

Table 2.3 illustrates the absolute value for clearance depending on the type and thickness of the material. (Vukota Boljanovic 2004)

Table 2.3: Absolute value for clearance

Material thickness *T* (mm)	Material			
	Low Carbon Steel, copper and Brass	Medium steel 0.20 % to 0.25% Carbon	Hard steel 0.40% to 0.60% carbon	Aluminum
0.25	0.01	0.015	0.02	0.01
0.50	0.025	0.03	0.035	0.05
1.00	0.05	0.06	0.07	0.10
1.50	0.075	0.09	0.10	0.015
2.00	0.10	0.12	0.14	0.20
2.50	0.13	0.15	0.18	0.25
3.00	0.15	0.18	0.21	0.28
3.50	0.15	0.18	0.21	0.28
4.00	0.20	0.24	0.28	0.40
4.50	0.23	0.27	0.32	0.45
4.80	0.24	0.29	0.34	0.48
5.00	0.25	0.30	0.36	0.50

Source: Vukota Boljanovic. (2004)

2.3.4 Punch diameter

A tool called a punch moves downward into the blank and draws, or stretches, the material into the die cavity. The movement of the punch is usually hydraulically powered to apply enough force to the blank. Both the die and punch experience wear from the forces applied to the sheet metal and are therefore made from tool steel or carbon steel. The process of drawing the part sometimes occurs in a series of operations (T. Balun 1993). The formula for expressing the punch diameter is as follows;

$$C = \frac{Dm - dp}{2} \tag{2.2}$$

Where:

C, Clearance per side

Dm = diameter of die

dp = diameter of punch

2.3.5 Punch force and die radius

However it is not easy to eliminate the defects because of complexity of deformation behavior and there are couple of process parameters like die radius, punch radius and punch speed which affects the result of the process, i.e., tearing, wrinkling and thinning. Even a slight variation in one of these parameters can result in defects (Jamal Hematian January 2000).

Table 2.4: Min die entry radius for round draws involving various thicknesses

Sheet Metal Thickness (mild steel) (In)	Min Radius (In)
0.020 - 0.030	0.125
0.030 – 0.040	0.137
0.040 – 0.050	0.157
0.050 – 0.060	0.177
0.060 – 0.070	0.196
0.070 – 0.080	0.216
0.080 – 0.090	0.236

Source: Art Hedrick. (2001)

Other important factors for successful deep drawing are the size, accuracy, and surface finish of the die entry radius. Decisions regarding the die entry radius should be based on material type and thickness.

If a die entry radius is too small, material will not flow easily, resulting in stretching and, most likely, fracturing of the cup. If a die entry radius is too large, particularly when deep drawing thin-gauge stock, material begins to wrinkle after it leaves the pinch point between the draw ring surface and the binder. If wrinkling is severe, it may restrict flow when the material is pulled through the die entry radius By (Art Hedrick 2001)

2.3.6 Blank Size

The deep drawing process requires a blank. It's a part of metal stamping process (Vukota Boljanovic, 2004). The blank is a piece of sheet metal, typically a disc or rectangle, which is pre cut from the stock material and will be formed into the part (Wang Xi & Cao J, 2000). The volume of the developed blank before drawing should be the same as the volume of the cup after drawing. Provided that the thickness of the material remains unchanged, the area of the workpiece will not change. Thus, the blank diameter may be found from the area of blank before drawing. The cup in table 2.5 may be broken into matching components and table 2.6 illustrates the area of each component that need to be calculated.

Table 2.5: Draw element

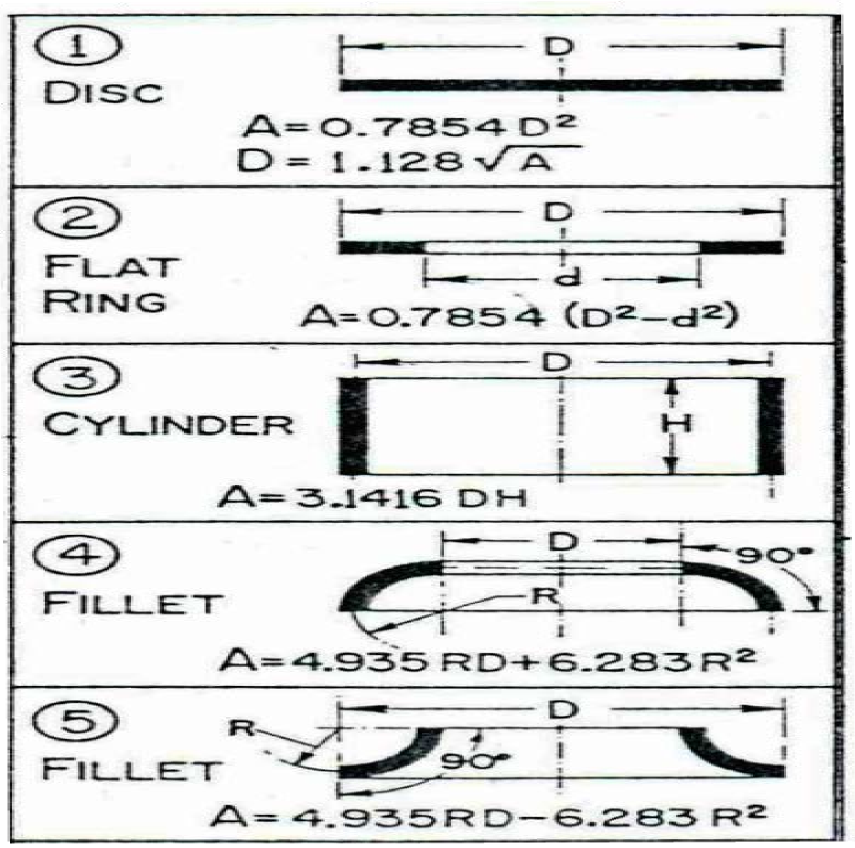
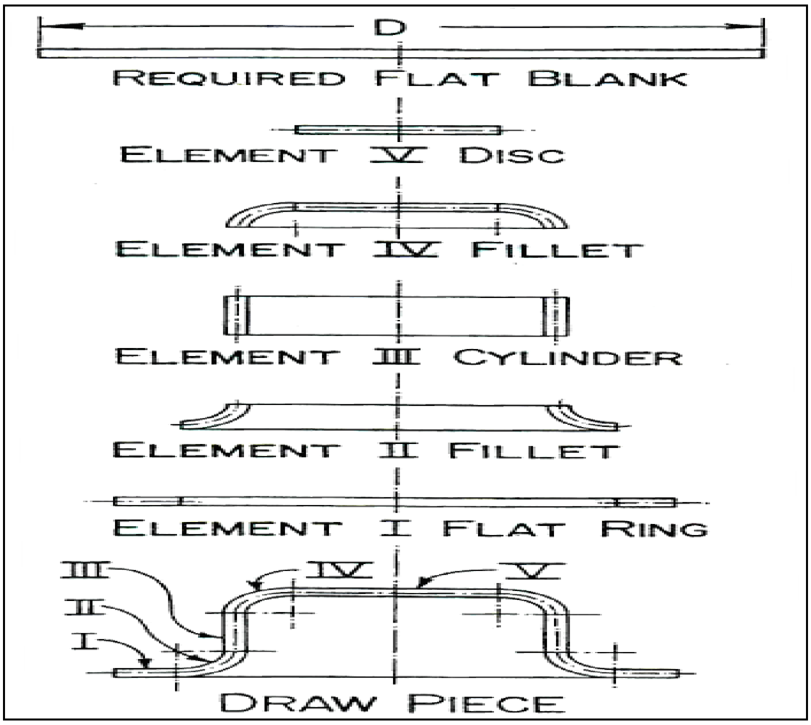


Table 2.6: Draw area



2.3.7 Drawing Force

The correction value *n* (Table 2.7) takes into account the ratio of drawing tension to tensile strength. It depends mainly upon the actual draw ratio, which comes from the dimensions of the drawn part (Heinz Tschaetsch (2006).

Table 2.7: Correction value, *n*

n	0.5	0.7	0.9	1.1	1.3	1.5	1.7
β actual= $\frac{D}{dp}$	1.4	1.6	1.8	2.0	2.2	2.4	2.6

Source: Heinz Tschaetsch. (2006)

$$\beta\text{actual} = \frac{D}{dp} \tag{2.3}$$

D= diameter blank

dp= diameter punch

The drawing force is calculated using this formula:

$$F_{dr} = C \cdot s \cdot R_m \cdot n = d \cdot \pi \cdot s \cdot R_m \cdot n$$

F_Z	in N	drawing force
C	in mm	circumference of the drawing punch
d	in mm	punch diameter
s	in mm	sheet thickness
R_m	in N/mm^2	tensile strength
n		correction value

(2.4)

2.3.8 Blank holder force

The failure of sheet metal parts during deep drawing processes usually takes place in the form of wrinkling and/or necking. Wrinkling normally occurs at the flange and is generated by excessive compressive stresses that cause the sheet to buckle locally. For a given problem, many variables affect the failure of a stamping. (K. Kuzman 2007). These include material properties, die design, and process parameters such as friction conditions, the drawing ratio as well as the blank- holder force (BHF), and the careful control of these parameters can delay the failure of the part.

Among these process and design variables, one in particular, the blank-holder force (BHF) scheme, has been shown to greatly influence the growth and development of part defects. Studies have shown that a deep drawn part's quality is affected significantly by the flow of metal into the die cavity .The force exerted by the blank holder on the sheet supplies a restraining force which controls the metal flow. (E.J. Obermeyer 1998). Excessive flow may lead to wrinkles within the part, while an insufficient flow can result in tearing. Conventionally, constant BHF were used and their results were compared in relation to failure due to wrinkling of the formed part and an optimum value of the BHF was reached (H. Gharib, 2006).

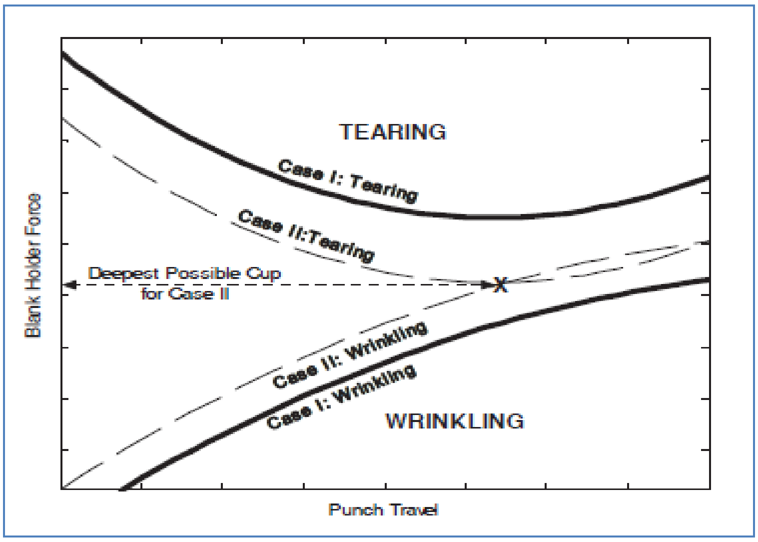


Figure 2.4: Forming Process Window

Source: H. Gharib. (2006)

Blank holding force: $F_N = A_n . P_N$

where F_N = blank holding force (N)

A_n = blank holder area (mm^2)

$\frac{\pi}{4}(D_b^2 - d_p^2)$ (mm^2)

P_N = Unit blank holding pressure (N/mm^2)

$$[(\beta - 1)^2 + \frac{d_p}{200.t}] \frac{\sigma_B}{400} \quad (2.5)$$

Blank holder force (BHF) is very important parameter in the deep drawing process. It is used to suppress the formation of wrinkles that can appear in the flange of the drawn part. When increasing the BHF, stress normal to the thickness increases which restrains any formation of wrinkles (N. Kawai, 1961). The range of suitable values is called the process window which can be shown in Fig. 2.4, which is shown for two cases. The first case (bold lines) has a large range of values for the BHF that gives a complete cup without hitting any of the two limits. The second case (dashed lines) has overlapping process limits, which limits the maximum possible punch stroke above which wrinkling and/or tearing would occur.

2.3.9 Total Drawing force

Total drawing force: $F_G = F_Z + F_N$

where F_G = total drawing force
F_Z = drawing force
F_N = blank holding force

(2.6)

2.4 LUBRICANT

Lubricant is one of the materials which are can use to reduce friction in deep drawing process. In order to reduce friction and minimize sheet failure, lubricants are typically applied to portions of the workpiece that undergo severe contact with dies. In fact, lubrication is still the most economical and effective method for reducing the harmful effects of large interfacial friction forces that can develop in stamping operations. The type of applied lubricant is a critical parameter in determining the overall quality of the final part. When lubricants, such as oils and greases are applied to the workpiece, the frictional resistance of the sheet material decreases and the strain uniformity of the sheet increases, this ultimately improves the overall formability and surface quality of the workpiece. (Z. Deng, X.J. Wang, H.Z. Chen, 1993).

2.5 MINITAB SOFTWARE

Minitab software is among the most widely used programs for statistical analysis in experimental and it is a computer program used for survey authoring and deployment from Data Collection and also has scores of statistical and mathematical functions, scores statistical procedures, and a very flexible data handling capability. It can read data in almost any format (e.g., numeric, alphanumeric, date, time formats), and version 16 onwards can read files created using spread sheet/data base software. Data mining, text analytics, statistical analysis, and collaboration deployment batch an automatically scoring service. An Minitab program are used for enables an experimental conduct the same procedure repeatedly, without having to remember which pull-down menus or commands to click and choose in order to set up the needed series of procedures. That saves time when organizing and analyzing data. Those programs also can be modified to run different statistical models, examine different variables, or access different data files.

Minitab software also can builds models that more realistically reflect complex relationships because any numeric variable, whether observed or latent (such as satisfaction and loyalty) can be used to predict any other numeric variable. Visual framework lets out to easily compare, confirm and refine models. Besides that Markov chain Monte Carlo (MCMC) is the underlying computational method for Bayesian estimation. The MCMC algorithm is fast and the MCMC tuning parameter can be adjusted automatically.

Perform estimation with ordered categorical and censored data Create a model based on non-numerical data without having to assign numerical scores to the data. Or work with censored data without having to make assumptions other than the assumption of normality. We can also impute numerical values for ordered-categorical and censored data. The resulting dataset can be used as input to programs that require complete numerical data.

2.5.1 Advantage of Minitab Method

The development in the Minitab analysis is really an advantage in engineering especially in analyze manufacture products and experiment. This is because Minitab software makes it easy to conduct test on products and materials virtually before even manufacturing the real products. The figure of the number in graphs can be more relevant and presentation of the graphs will be easy to understand. Drawing of experiment (DOE) can be produce easily without any combination of mistakes. This allows the analysis can be done and the fault on the parameter or the material can be identified easily. In using Minitab, we can perform many data management and statistical analysis tasks with more efficient. Minitab also allows detailed visualization produced on the graph, and indicates the distribution of stresses and displacements.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discussed the idea and how to implement this research. In this research a single stage deep drawing tooling was used to carry out the experimental work required to produce a cylindrical cup of 50mm (outer diameter) formed from a circular flat blank of 105mm diameter. There are three categories in this methodology, first is the thickness of work piece (mild steel) used, calculation of force to apply at the work piece and the blank holder force which is based on calculation used, then continued with the use of Minitab to analyze the data from experiments to obtain a suitable parameter for the product produced in accordance with the thickness of the work piece.

3.2 PROCESS PLANNING FLOW CHART

Process planning is important in this project in order to make sure this project completed on time. Process planning help to make sure all the tasks run systematically. Figure 3.1 shows an overview of overall steps during this research. Based on the literature review from the journals and books, calculation, the preparation of work piece, and experimental works are developed.

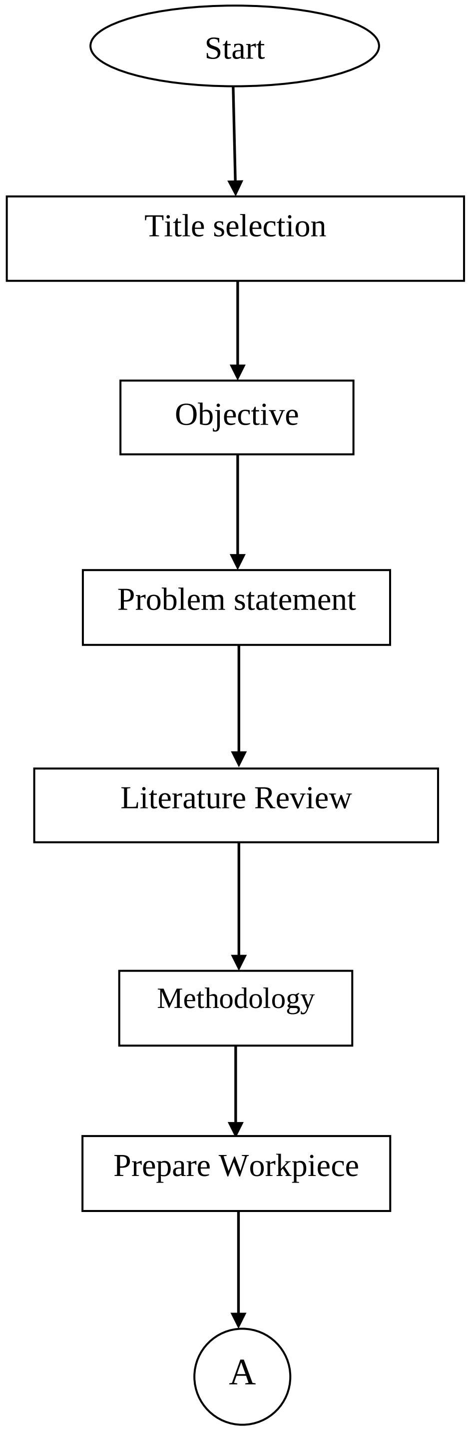


Figure 3.1: Process planning Flow Chart (a)

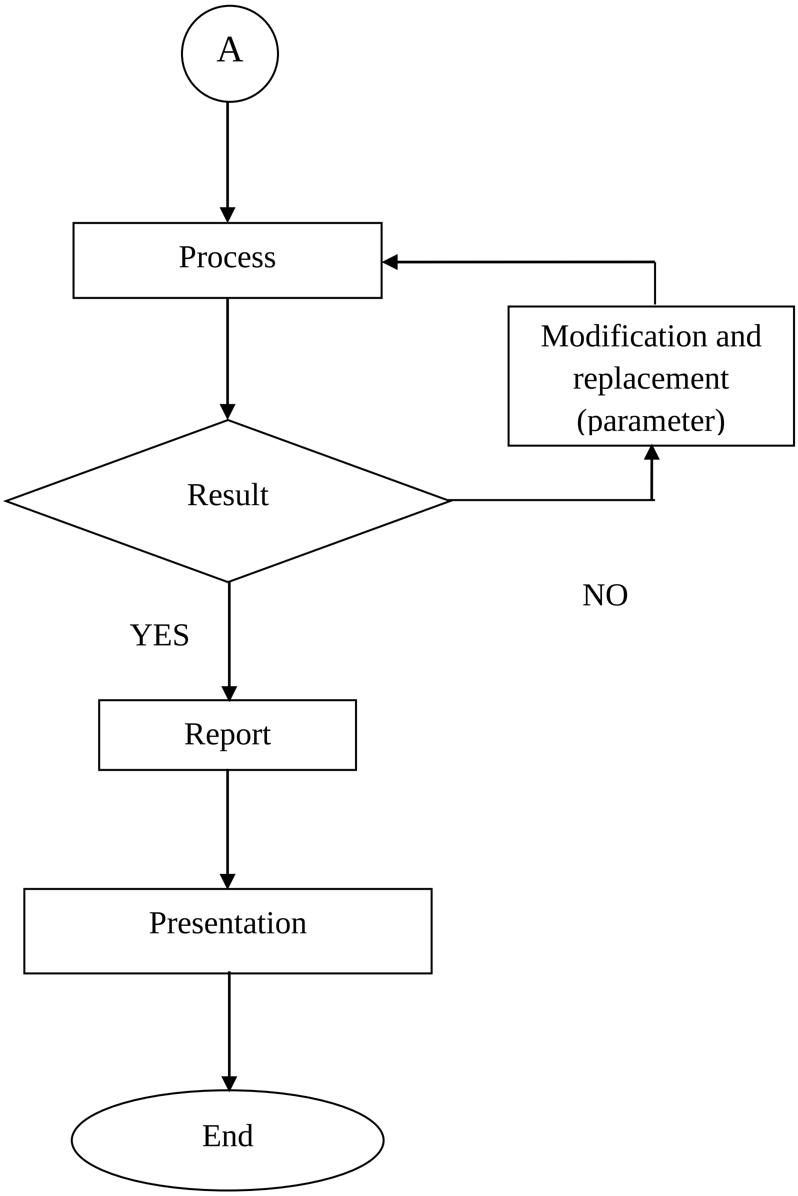


Figure 3.2: Process planning Flow Chart (b)

3.3 CYLINDER CUP SIZE

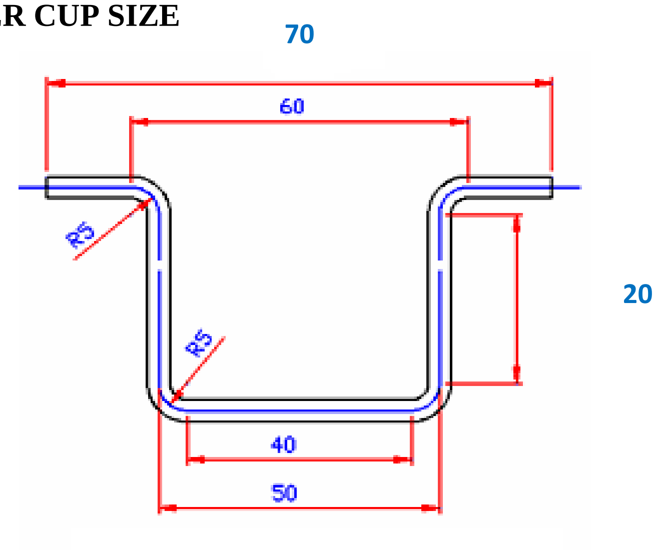


Figure 3.3: 2D cylinder cup

The cylinder cup that use to make experiment base on die that already have in lab to save time and energy. So if new die is produced to make a deep drawing for this experiment of course need more time to produce the die before proceed the experiment, besides that, money also can be save because just have a few modification to follow scop of the experiment.

3.3.1 Calculation Surface Area

a) <u>Element I (Ring)</u>

Area $= 0.7854 \times (D^2 - d^2)$

$= 0.7854 \times (70^2 - 60^2)$

$= 1021.02 \text{ mm}^2$

b) <u>Element II (Inner Fillet)</u>

Area $= (4.935 \times R \times D) - (6.283 \times R^2)$

$= (4.935 \times 5 \times 60) - (6.283 \times 5^2)$

$= 1323.4 \text{ mm}^2$

c) <u>Element III (Cylinder)</u>

Area = 3.1416 x D x H

= 3.1416 x 50 x 25

= 3927 mm2

d) <u>Element IV (Outer Fillet)</u>

Area = (4.935 x R x D) + (6.283 x R^2)

= (4.935 x 5 x 40) + (6.283 x 5^2)

= 1144.1 mm^2

e) <u>Element V (Disc)</u>

Area = 0.7854 x D^2

= 0.7854 x 40^2

= 1256.7 mm^2

Total surface area = Sum of Element I to V

= 8672.22mm^2

Area of flat blank = 0.7854 x D^2

Diameter of flat blank = √ Area / 0.7854

= √ 8672.22/ 0.7854

= 105.08mm

= 105mm

3.3.2 Punch Diameter Calculation

The Punch diameter Calculation is based on equation (2-2)

Clearance per side 1.1 (thickness 1mm)

$$1.1 = \frac{50mm - dp}{2}$$

dp = **47.80 mm Ø**

Clearance per side = 2.2 (thickness 2mm)

$$2.2 = \frac{50mm - dp}{2}$$

dp = **45.60 mm Ø**

3.3.3 Draw Ratio Calculation

The draw ratio calculation is based on equation (2-1)

$$\frac{h}{d} = \frac{20mm}{50mm} = 0.4$$

Where:

0.6 > 1 (one draw ratio)

3.3.4 Drawing Force Calculation

The β_{actual} Calculation is based on equation (2-3)

Ultimate Tensile Strength of sheet metal, UTS = 320Mpa (mild steel)
Diameter of punch, d= 47.80 mm
Sheet thickness, t = 1mm

$\beta_{actual} = \frac{105}{47.80}$ = 2.196, then drawing coefficient, n or K= 1.3

Diameter of punch, d= 45.60 mm
Sheet thickness, t = 2mm

$\beta_{actual} = \frac{105}{45.60}$ = 2.303, then drawing coefficient, n or K = 1.4

The Drawing Force Calculation is based on equation (2-4)

Thickness 1mm and n=1.3

Fdr (max) = 1.3 x 3.142 x 47.8mm x 1mm x 320MPa

Fdr (max) = 62469 N

= 6.25 ton

Thickness 2mm and n=1.4

Fdr (max) = 1.4 x 3.142 x 45.60mm x 2mm x 320MPa

Fdr (max) = 128,357 N

= 12.84 ton

3.3.5 Blank holder force Calculation

The Blank holder force Calculation is based on equation (2-5)

For thickness 1mm

$$F_N = \left[\frac{\pi}{4}\left(105^2 - 47.8^2\right)\right]\left[(2.196-1)^2 + \frac{47.8}{200.t}\right]\frac{320}{400}$$

= (6.86x10^3) (1.43+0.239)(0.8)

= 9159 N

= 0.916 ton

Spring calculation: $\frac{9156}{4}$ = 2289 N = 229kgf for each spring.

For thickness 2mm

$$F_N = \left[\frac{\pi}{4}\left(105^2 - 45.60^2\right)\right]\left[(2.303-1)^2 + \frac{45.60}{200.t}\right]\frac{320}{400}$$

= (7.025x10^3) (1.698+0.114) (0.8)

= 10183 N

= 1.018 ton

Spring calculation: $\frac{10183.44}{4}$ = 2546 N = 255kgf for each spring.

3.3.6 Total Drawing Force Calculation

The Total Drawing force Calculation is based on equation (2-6)

FQ = FZ + FN

= [62469.94 N+128,357.94 N] + [9159.47 N+10183.44 N]

= 210,170 N

3.4 DESIGN OF EXPERIMENT (DOE)

Design of Experiments (DOE) is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. In statistics, these terms are usually used for controlled experiments. Formal planned experimentation is often used in evaluating physical objects, components, and materials. Table 3.1 shows the design of experiment that will be too used.

Table 3.1: Design of Experiment

Run	Punch Force (N)	Blank Holder Force (N)	Thickness of Blank (mm)
1	Low Punch force: 62469	9159	1
2			2
3		10183	1
4			2
5	high Punch Force: 128357	9159	1
6			2
7		10183	1
8			2

3.5 EXPERIMENT PROCEDURES

In this experiment punch force, blank holder force and thickness of blank were selected as the process parameters to analyze their effect on cylinder cup in deep drawing process condition. A total of 8 experiments based on factor and parameter that given (2^3) orthogonal array were carried out with different combinations of the levels of the input parameters. Among them, the settings of punch force include 62469.94 N and 128357.94 N; those of blank holder force include 9159.47 N and 10183.44 N; the thickness of blank is set at 1mm and 2mm. Experimental planning was prepared by using calculation and the information available in the literature.

The deep drawing process is carried out by selecting proper punch force, blank holder force and thickness of blank during each experimentation. On completion of each pass the cylinder cup is measured on the wrinkling. The depth of wrinkling will be measured. And the average values of flange wrinkling measured at four different locations and are considered as actual wrinkling value. Table 3.2 shows the levels of experiment.

Table 3.2: The Level of Experiment

Level / Parameter	Low	high	Depth of drawn	Depth of drawn
P. force	62469 N	128357 N	10mm	20mm
B. of Thickness	1mm	2mm	10mm	20mm
Blank holder force	9159 N	10183 N	10mm	20mm

3.5 MINITAB SOFTWARE

Minitab software is among the most widely used programs for statistical analysis in experimental and it is a computer program used for survey authoring and deployment from Data Collection and also has scores of statistical and mathematical functions. To analyze all the data in this experiment we used Minitab version 16. In using Minitab, we can perform many data management and statistical analysis tasks with more efficient. Minitab also allows detailed visualization produced on the graph, and indicates the distribution of stresses.

3.6 LUBRICANT

Lubrication is the process, or technique employed to reduce wear of one or both surfaces in close proximity and moving relative to each other. In this experiment, oil will be used as a lubricant between the surfaces of punch and blank to reduce the friction.

3.7 EXPERIMENT FLOW CHART

Figure 3.4 Show the experiment flow chart that will be followed to conduct this experiment from beginning to finish of the experiment.

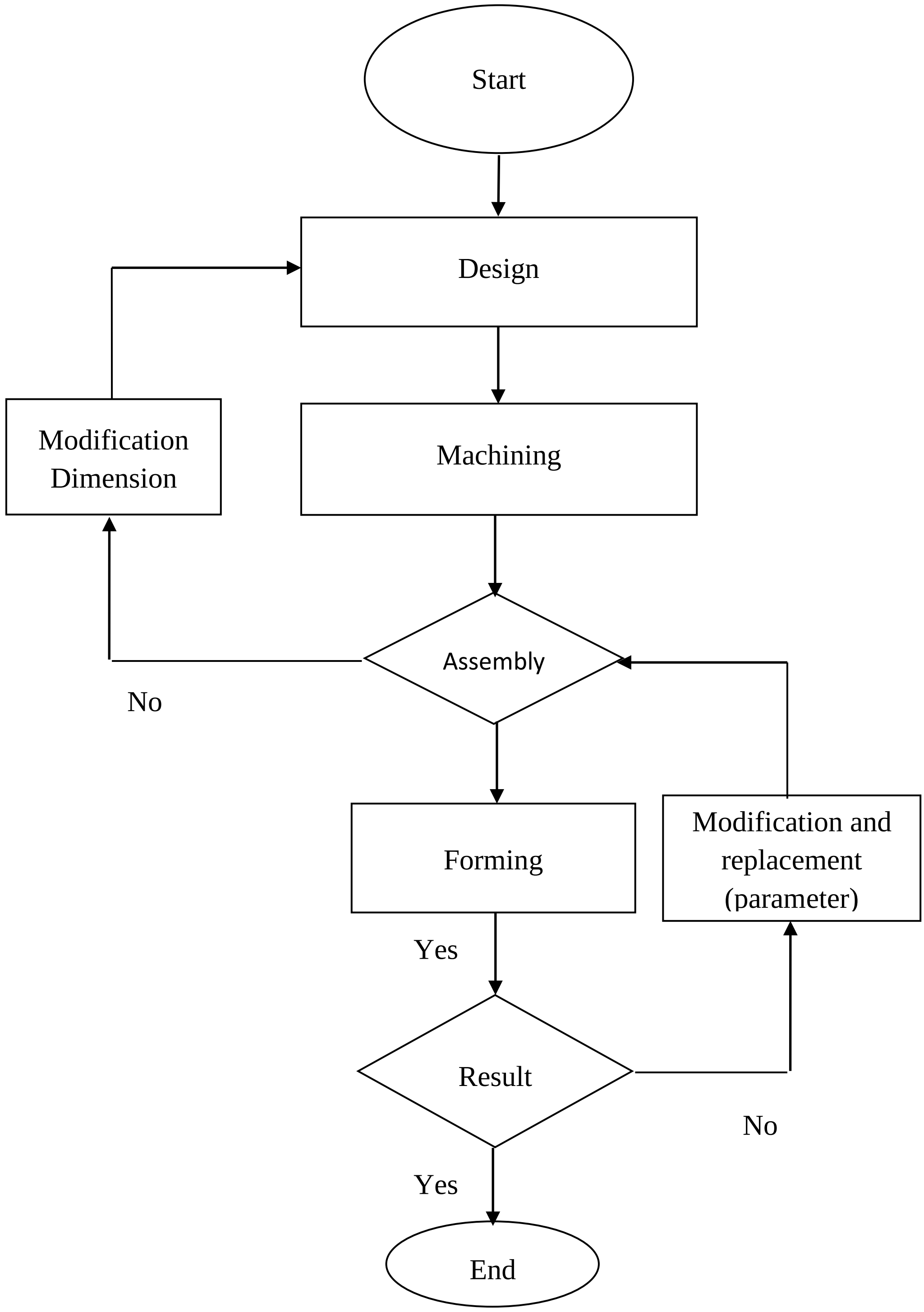


Figure 3.4: Experiment flow chart**.**

3.8 BILL OF MATERIAL

Table 3.3 shows the materials required for the experiment.

Table 3.3: Bill of material

Number	Quantity	Part Name	Dimension (L x W x T) mm	REMARK
1.	1	Mild steel	2438 x 1219 x 1mm	Mild steel with 320Mpa UTS Copper
2.	1	Mild steel	2438 x 1219 x 2mm	Mild steel with 320Mpa UTS Copper
3.	1 set 4pcs	Die spring	Load 1 = 2272 kgf F 8, d13.5 SWB 25-50	Medium Heavy Duty MISUMI
4.	1 set 4pcs	Die spring	Load 1 = 2556 kgf F 9, d13.5 SWB 27-50	Medium Heavy Duty MISUMI
6.	2	M8 screw	L: 60mm	
7.	4	M12 screw	L: 85mm L:55mm L:50mm	

3.9 THICKNESS OF SHEET METAL

In this experiment we decide for the thickness of sheet metal is 1mm and 2mm why, because base on to the sheet metal forming product, mostly the product from this operation is not more than 2mm.

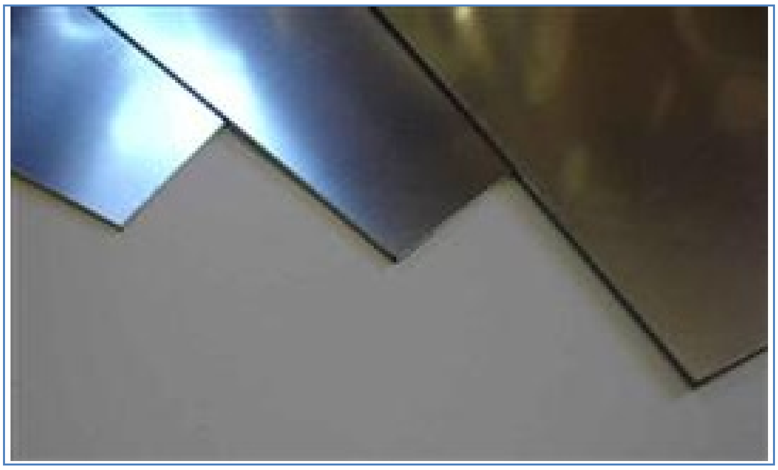


Figure 3.5: Mild steel thickness 1mm

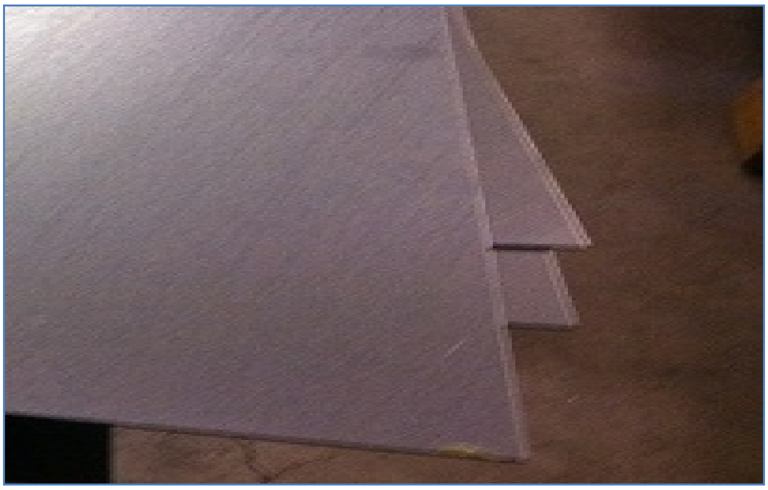


Figure 3.6: Mild steel thickness 2mm

3.10 EQUIPMENT (MEASURING)

A micrometer is a device used to measure very small distances, usually accurate to 1/1,000 of a millimeter, or a metric measure that is exactly 1/1,000 of a millimeter. It is a device widely used in mechanical engineering for precisely measuring thickness of sheet metal, outer and inner diameters of shafts and depths of slots. In this experiment, micrometer is used to measure wrinkles and to get the level of wrinkles from experiments performed.

Figure 3.7: Micrometer

3.11 TYPE OF SPRING

A spring is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. Small springs can be wound from pre-hardened stock, while larger ones are made from annealed steel and hardened after fabrication.

When a spring is compressed or stretched, the force it exerts is proportional to its change in length. The rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. For this experiment of deep drawing process for the blank holder force, the type of spring that will be used is super heavy load SWG 25-50 and extra heavy load SWB 25-50.

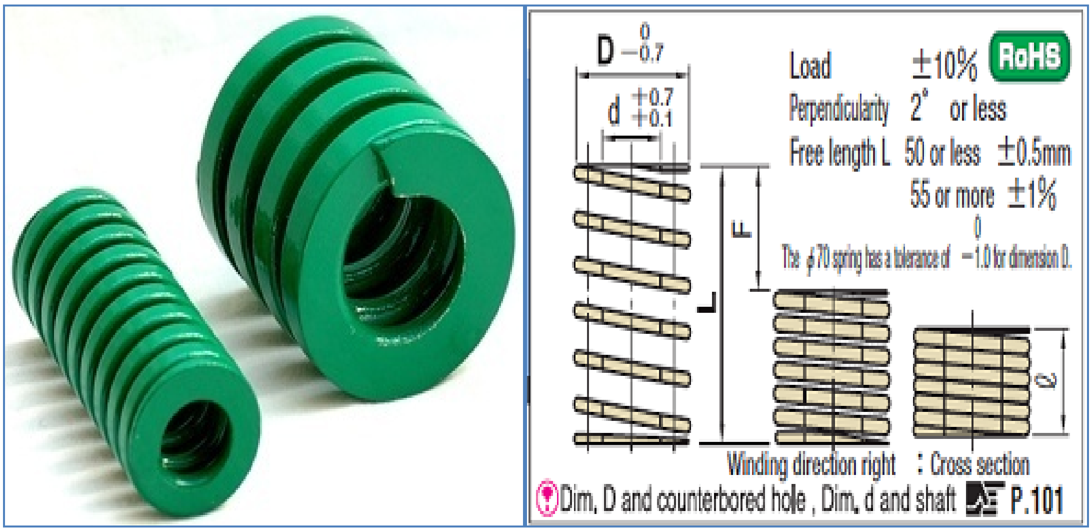


Figure 3.8: Spring

3.12 DIE (DEEP DRAWING)

Deep drawing is a sheet metal forming process in which a sheet metal blank is radial drawn into a forming die by the mechanical action of a punch. It is thus a shape transformation process with material retention. The process is considered "deep" drawing when the depth of the drawn part exceeds its diameter. This is achieved by redrawing the part through a series of dies. The flange region experiences a radial drawing stress and a tangential compressive stress due to the material retention property. Figure 3.6 shows the die (deep drawing), which will be used for deep drawing operation.

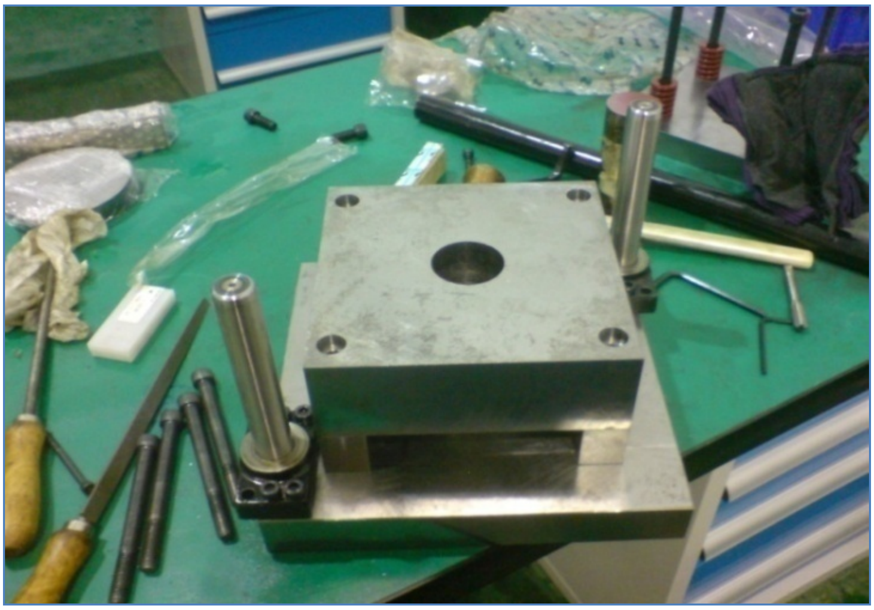


Figure 3.9: Die

3.13 PROCESS OPERATION AND MACHINES UTILIZATION.

3.13.1 Lathe Machine

A lathe is a machine tool which turns cylindrical material, touches a cutting tool to it, and cuts the material. The lathe is one of the machine tools most well used by machining. Through this machine, the different sizes of punches deep drawing with 5mm radius will be produce.

Figure 3.10: Lathe Machine

3.13.2 Hydraulic Press Cutting

Hydraulic press is the most efficient form of presses. It applies hydraulic mechanism for applying a large lifting force or compressive force. The press has one or more than one hydraulic pump and hydraulic cylinder. This machine used to cut of sheet metal to get the suitable size. Hydraulic press also allows easily configured job parameters like travel distance, force and return position to perform a variety of jobs.

Figure 3.11: Hydraulic cutting press

3.13.3 Drilling Machine

A Drilling Machine is primarily used in Design & Technology for accurate drilling of holes. A Drilling Machine consists of a base that supports a column that in turn supports a table. Work can be supported on the table with a hold down clamps, and the table also can be used to allow tall work supported directly on the base. This machine will be used to make holes for the sheet metal which will tie to EDM wire cut process

Figure 3.12: Drilling Machine

3.13.4 EDM Wire Cut

In wire electrode discharge machining or wire-cut EDM, a thin single-strand metal wire is fed through the workpiece. This process is used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are too difficult to machine with other methods. This machine is used to cut sheet metal in circle shapes. This gives the wire-cut EDM the ability to be programmed to cut very intricate and delicate shapes.

Figure 3.14: EDM wire cut

3.13.5 Mechanical Press Machine

Mechanical presses transform the rotational force of a motor into a translational force vector. Therefore the energy in a mechanical press comes from the motor. Mechanical presses are generally faster than hydraulic or screw presses. When performing a manufacturing operation using a mechanical press, the correct range of the stroke is essential. Presses are chosen based on the characteristics of the manufacturing process, for example this machine can operate fast, quickly repeatable application of force over a limited distance is what is needed for that type of manufacturing operation. These types of presses are commonly used in forging manufacture, and sheet metal working. in this experiment the machine is used to form cylinder cup by using deep drawing process.

Figure 3.15: mechanical press machine

3.13.6 Band Saw

A band saw is a power tool which uses a blade consisting of a continuous band of metal with teeth along one edge to cut various workpieces. The band usually rides on two wheels rotating in the same plane, although some band saws may have three or four wheels. Band sawing produces uniform cutting action as a result of an evenly distributed tooth load. Band saws are used for metalworking, or for cutting a variety of other materials, and are particularly useful for cutting irregular or curved shapes, but can also be used to produce straight cuts. By using this machine, the products which are produced through deep drawing process will be cut and this product will be analyzed to measure level of flange wrinkling.

Figure 3.16: Band Saw Machine

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter shows all the results obtained from this project. Tables of results, graphs, and figures are included. Detailed explanation of graphs and figures are also provided. The data collected after the deep drawing process had been done which is the wrinkling measurement have been collected. The optimum condition of deep drawing process will recorded, parameter results are obtained based on detailed study of software usage. In this project, Minitab 16 software is used in order to get the graphical analysis and the optimum condition for the deep drawing parameter base on calculation, level and factor that have been set. This software is really user friendly and reliable.

4.2 RESULT OF EXPERIMENTAL

The experiments are conducted using an existing die in the lab by doing some of renovation. This experiments using 80 tonnage stamping machine to validate the result obtained from the calculations that have made. The die is used to Study on Process Parameter to Reduce Wrinkling in Sheet Metal Forming. Based on the calculation, the draw height of blank are 10 and 20mm do not tearing but it have the wrinkle defects when using the blank holder force 0.9 and 1 tonnage. Due to the blank holder force exerted on the workpiece was not enough to hold the material during this process. This is one cause of wrinkling other than that, there have many other factors of wrinkles. But if the blank holder force is too excessive, tearing will occur between the wall and the flange.

Table 4.1: Parameter Settings

PARAMETER	LOW	HIGH
(A) Punch Force	62470	128358
(B) Blank Holder Force	9160	10183
(C) Thickness of Blank	1	2

Table 4.2: Result of experiments.

RUN	A	B	C	RESULT	
				Depth 10	Depth 20
1	Low	Low	Low	1.02	1.03
2	Low	Low	High	2.04	2.08
3	Low	High	Low	1.12	1.22
4	Low	High	High	2.03	2.08
5	High	Low	Low	1.02	1.04
6	High	Low	High	2.06	2.10
7	High	High	Low	1.16	1.26
8	High	High	High	2.04	2.10

From Table 4.2, the data of the flange wrinkling have been tabulated after doing deep drawing process on mild steel by follow the DOE table. This data have been summarized and get the average reading of the wrinkling. To get the accuracy data, the readings of wrinkling have been collected for three times. In surface measurement concept, the lowest value will indicate the better result in measuring flange wrinkling. The table 4.2, the smallest value of the flange wrinkling is about 1.03 mm, by use punch force 62469 N and BHF is 9159 N. While the highest of flange wrinkling is about 2.10 mm, by use high speed with force 128357 N, thickness 2 mm and the BHF is 9159 N.

Figure 4.1: 10mm draw depth and 1mm thick of steel plate

Figure 4.2: 20mm draw depth and 1mm thick of steel plate

Figure 4.3: 10mm draw depth and 2mm thick of steel plate

Figure 4.4: 20mm draw depth and 2mm thick of steel plate

4.3 REGRESSION ANALYSIS.

Multiple regression analysis is performed to indicate the fitness of experimental measurements as presented in Figure 4.5 and 4.6 with statistical software (Minitab 16). This analysis is focus on how the relationship between the dependent variables reacts with the independent variable during the process. Figure 4.5 below show the regression analysis that has been plotted with a depth of 10mm.

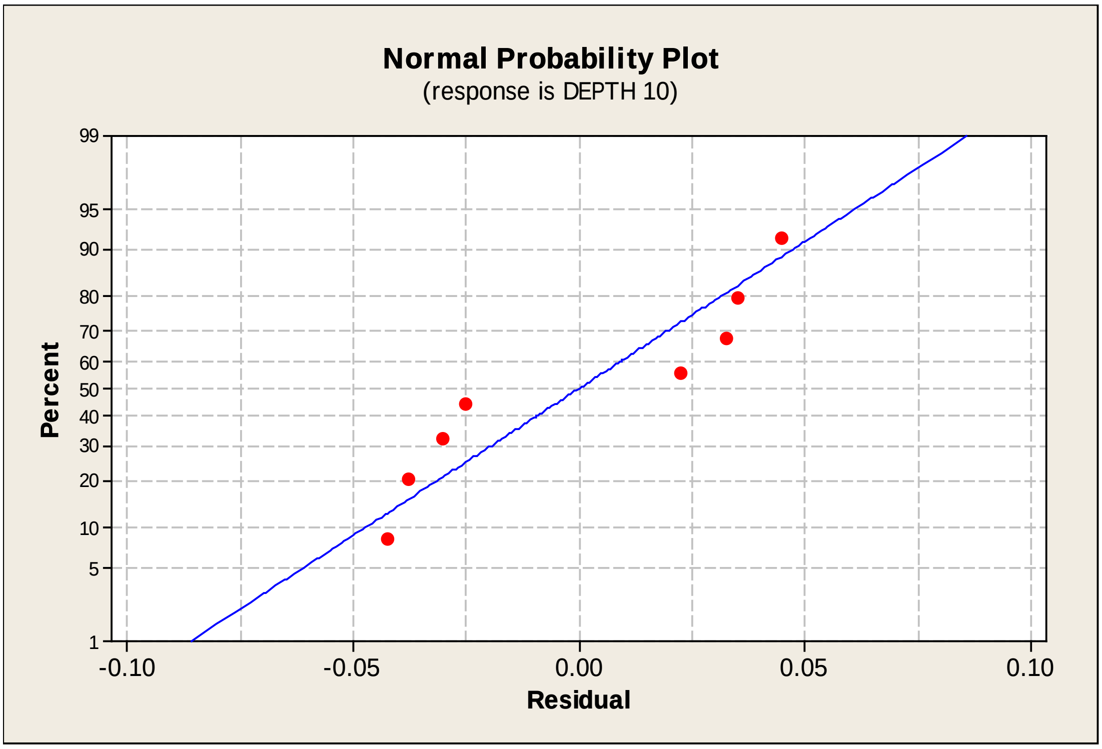


Figure 4.5: Normal Probability Plot

In this project, the independent variables like Punch Force, Blank Holder, and Thickness of Blank react with dependant variable which is flange wrinkling. Figure 4.6 below show the regression analysis that has been plotted with a depth of 20mm.

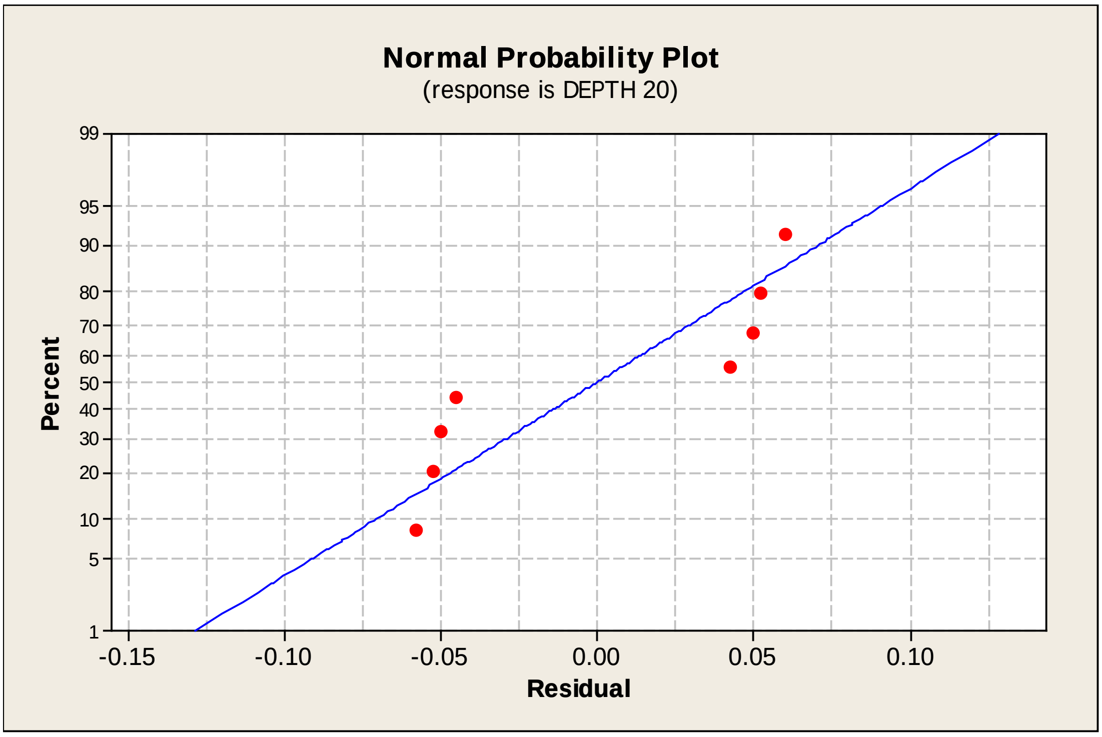


Figure 4.6: Normal Probability Plot

Table 4.3: Regression analysis DEPTH 10 and 20

	Depth 10	Depth 20	Depth 10	Depth 20	Depth 10	Depth 20	Depth 10	Depth 20
Predictor	Coef		SE Coef		T		P	
Constant	-0.404	-0.816	0.3346	0.4992	-1.210	-1.630	0.294	0.178
A - PF	2.7E+7	3.4E+7	5.2E+7	7.8E+7	0.510	0.440	0.639	0.685
B - BHF	5.1E+5	1.0E+4	3.4E+5	5.0E+5	1.520	1.990	0.203	0.118
C - TB	0.9625	0.9525	3.5E+2	5.2E+2	27.86	18.480	0.000	0.000

Table 4.3 indicates the regression analysis data that have been tabulated by the Minitab 16 software. The R-Squared value for this project is about 79.8% and for the R-squared adjusted is about 32.14%. R-squared value determine how strong the relationship between the independent variable and dependant variable in this project. From this project the value of R-squared is about 79.8% that indicate the dependant variable and independent variables have a good relationship. For the R-Squared adjusted is a modification of R-squared for the number in term of model for the future.

The regression equation for above variables depth 10mm is.

Wrinkles = - 0.404 + 0.000000 A + 0.000051 B+ 0.962 C

The regression equation for above variables depth 20mm is.

Wrinkles = - 0.816 + 0.000000 A + 0.000100 B + 0.952C

4.4 ANALYSIS OF VARIANCE.

Analysis of variance (ANOVA) is used to investigate and model the relationship between a response variable and one or more predictor variables. The purpose of the ANOVA is to find the most significant deep drawing parameter that will affect the flange wrinkling.

Table 4.4: Analysis Of Variance (ANOVA)

Factor	Type	Levels	Values	
Punch Force (N)	fixed	2	62470	128358
Blank Holder Force (N)	fixed	2	9159.5	10183.4
Thickness of Blank (mm)	fixed	2	1	2
RUN	fixed	2	High	Low

Analysis of Variance for DEPTH 10, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Punch Force (N)	1	0.00061	0.00061	0.00061	0.26	0.639
Blank Holder Force (N)	1	0.00551	0.00551	0.00551	2.31	0.203
Thickness of Blank (mm)	1	1.85281	1.85281	1.85281	776.05	0.000
Error	4	0.00955	0.00955	0.00239		
Total	7	1.86849				

S = 0.0488621   R-Sq = 99.49%   R-Sq(adj) = 99.11%

Analysis of Variance for DEPTH 20, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Punch Force (N)	1	0.00101	0.00101	0.00101	0.19	0.685
Blank Holder Force (N)	1	0.02101	0.02101	0.02101	3.96	0.118
Thickness of Blank (mm)	1	1.81451	1.81451	1.81451	341.56	0.000
Error	4	0.02125	0.02125	0.00531		
Total	7	1.85779				

S = 0.0728869   R-Sq = 98.86%   R-Sq(adj) = 98.00%

From the Table 4.4 the P factor will indicate the significant factor that will determine the best parameter that produces better flange surface. The DF can be called as the degree of freedom is the level for the experiment which is 8 so, the total DF is 7. SS stand for the sum of squares between groups (factor) and the sum of squares within groups (error). F can be find by dividing the factor MS by the error MS, from F, the P value can be determined whether a factor is significant or not. Form this table the factor is not significant because the P value is greater than 0.05. But if take the smallest reading, the most affected the flange wrinkling is blank holder force.

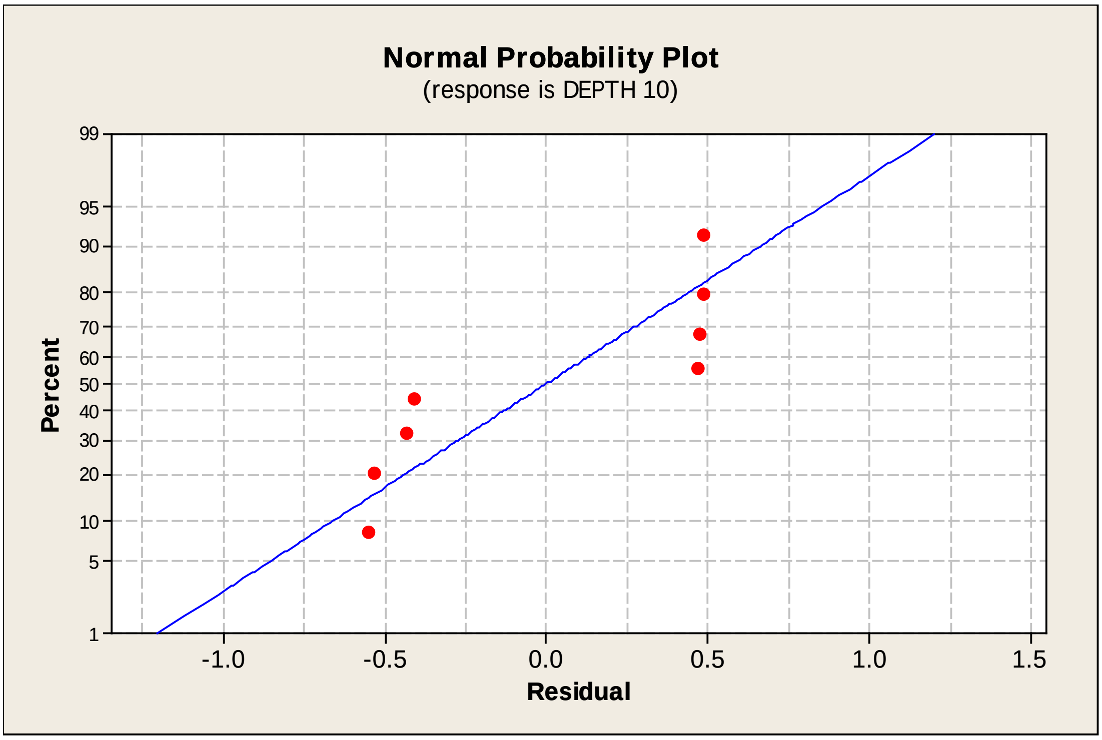


Figure 4.7: Normal Probability Plot for flange wrinkles.

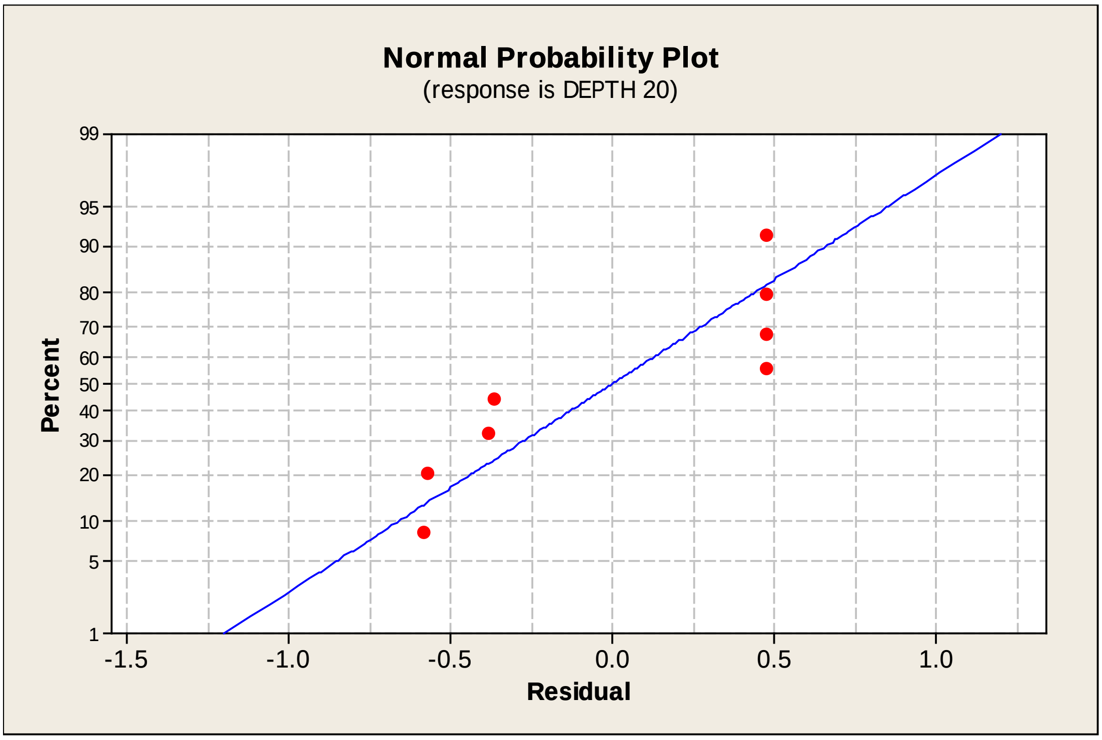


Figure 4.8: Normal Probability Plot for flange wrinkles.

Figure 4.7 and 4.8 show increase or decrease wrinkling which is happened when the blank holder force and punch force changing according to the thickness of blank.

4.4.1 Observation Order Effect on Flange Surface Depth 10mm and 20mm.

The wrinkling amplitude measured at all of flange which has a wrinkle because the form wrinkles for a given part don't have the same amplitude, the values presented here describe the maximum limit of those measured.

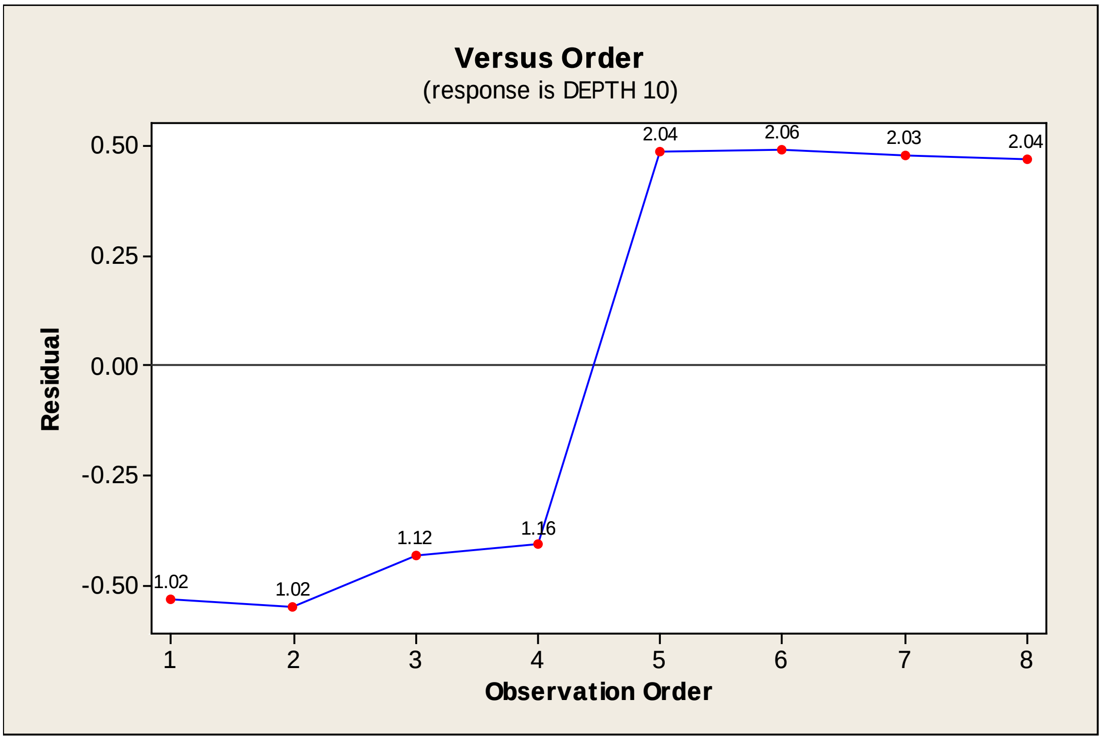


Figure 4.9: observation order with is low and high

Figure 4.9 and 4.10 shows the wrinkles height decreases when the blank holder force is increasing, but when a certain value is enhanced then cracking and braking of the material will occur. This fact can be observed especially when an increase the value 9159 N to 10183 N on the blank holder forces. The increase of the blank holding force must be made up to an optimal value, besides that, this chart shows that the wrinkle height increases along with the deep drawing depth.

The experimental value and results which are presented in figure 4.9 and 4.10 respectively observed that the friction forces are low, the wrinkling is more pronounced, but if the friction forces are too high the material can break. For this matter, a kind of lubricant used to reduce friction, depending of the die construction, geometry part (radius of die and punch) and the blank holding force.

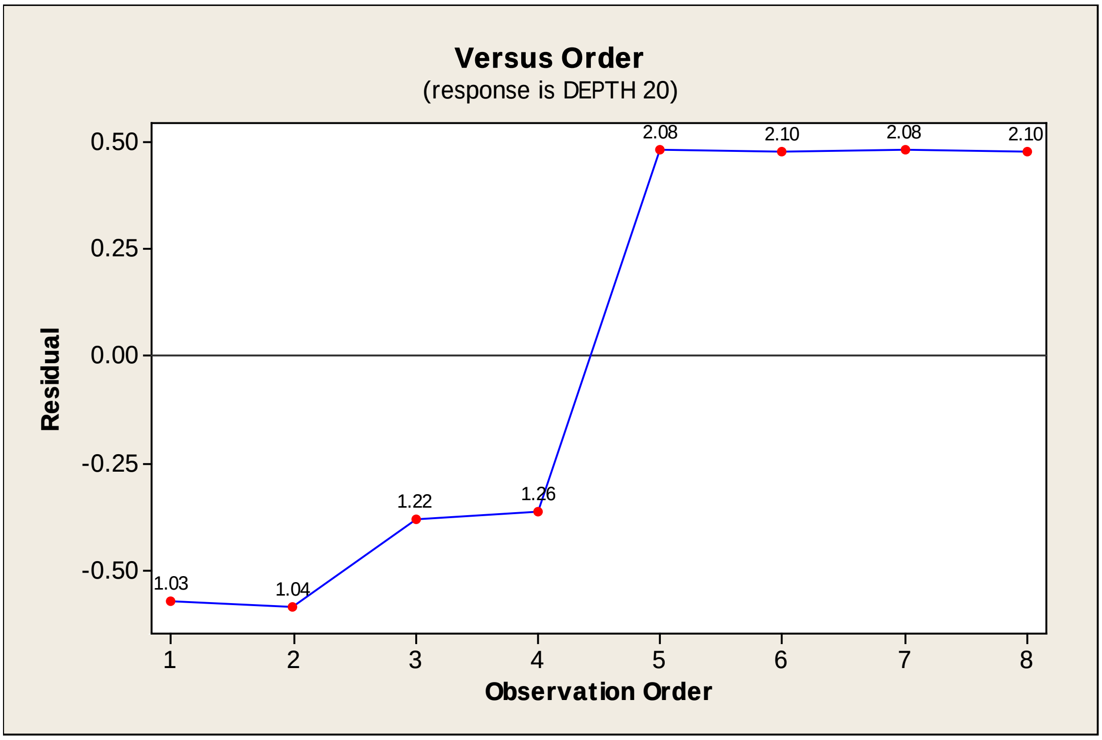


Figure 4.10: observation order with is low and high

As it can be observed from Figure 4.10, the less value of wrinkling is 1.03 and 2.08 but it depends on value of punch force and blank holder force which is most suitable to minimize the flange wrinkling. The value of force increases depend on thickness of blank. Force of punch is very important depend on thickness of blank, other than ancillary factors that must be considered because it also can impact to the flange wrinkling in deep drawing process.

4.5 DISCUSSION

In conclusion, based on the analysis and results obtained, the height of the wrinkles is reduced by increasing the blank holding force, increasing the tools edge radius and reducing deep-drawing depth all together in one operation.

Table 4.5: The suitable parameters to reduce wrinkles in this experiment are:

drawn depth	punch force	blank holder force	thickness
20mm	6.25 tonnage	0.9 tonnage	1mm
	12.84 tonnage	1.0 tonnage	2mm

According to this table, the value of BHF is low will lead to wrinkle defect, while a higher value of BHF will lead to thinning and tearing defect.

CHAPTER 5

5.1 CONCLUSION

In conclusion, the height of the wrinkles can be reduced by increasing the blank holding force, decrease friction, increasing the tools edge radius and reducing the depth of deep drawing process in one operation. The most important, to avoid wrinkling of blank is by selecting the correct BHF. The first objective of this research is achieved with study the effect of force, blank of thickness and blank holder force parameters on the flange wrinkling to reduce the flange wrinkling. The second objective of this experiment which is to develop flange regression study interaction between force, thickness parameters and blank holder force which are termed response flange methodology. This objective is successfully achieved, as wrinkles defect can be reduced by compare wrinkling which is happened at thickness 1mm and 2mm by using a suitable blank holder force and low punch force. The optimum value of blank holder force is important during deep draw process because a lower BHF will lead to wrinkle defect while a higher BHF will lead to tearing defect.

5.2 RECOMMENDATION

The following recommendation is suggested in order to improve the study, for future experimental work in this project:

i. In order to get the accuracy of blank holder for this experiment. use hydraulic system is more suitable to control force which is needed, to ensure blank holder force is accurate.

ii. Use a higher malleability material such as aluminum for the blank.

iii. Use a lubricant to avoid from friction, harden punch and die especially surface at the contact area, blank with die and punch with blank, because rough surface of the die and punch will lead to high friction during forming process.

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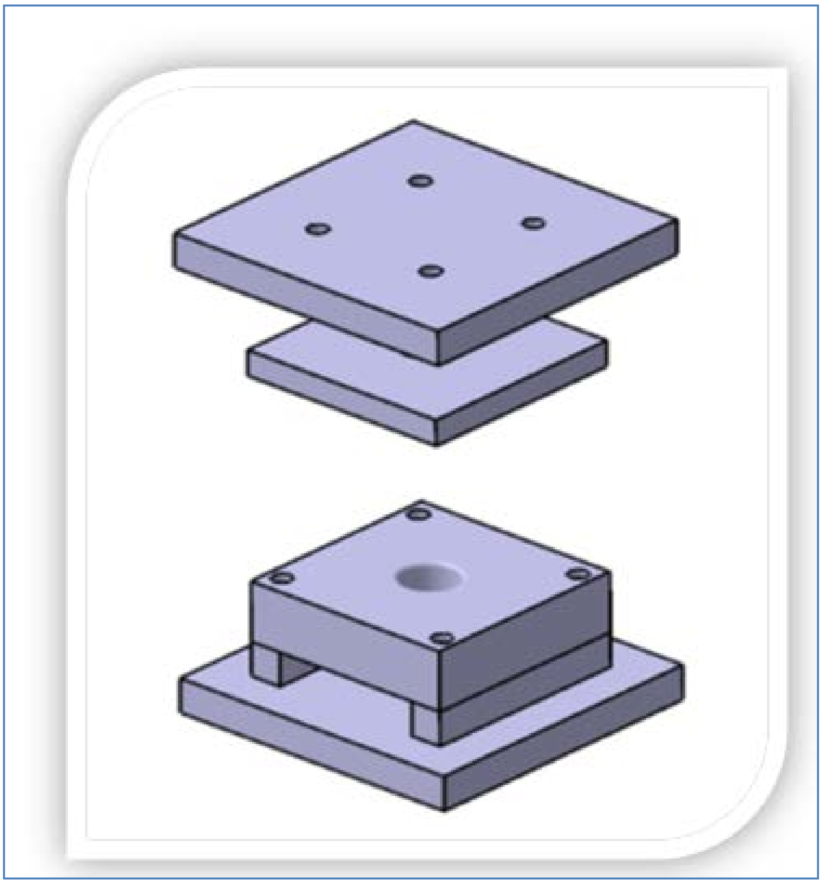
APPENDIX A

APPENDIX A1



Design (deep drawing)

APPENDIX A2

Die (cup 50mm⌀)

APPENDIX A3

Before (punch)

After (punch)

APPENDIX A4

Thread M8

Blank size 105mm⌀

APPENDIX A5

Stopper L=20mm

APPENDIX B

APPENDIX B1: GANNT CHART FYP 1

Activity	Target	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Week 12	Week 13	Week 14
Literature Research	**Plan**														
	Actual														
Chapter 1	**Plan**														
	Actual														
Literature Review Summary	**Plan**														
	Actual														
Chapter 2 Methology	**Plan**														
	Actual														
Chapter 3	**Plan**														
	Actual														
Report Draf	**Plan**														
	Actual														
Presentation Report Finalize	**Plan**														
	Actual														

APPENDIX B2: GANNT CHART FYP 2

Activity	Target	Week 01	Week 02	Week 03	Week 04	Week 05	Week 06	Week 07	Week 08	Week 09	Week 10	Week 11	Week 12	Week 13	Week 14
Machining	**Plan**														
	Actual														
Assembly	**Plan**														
	Actual														
Forming	**Plan**														
	Actual														
Results And Discussion	**Plan**														
	Actual														
Presentation poster	**Plan**														
	Actual														
Report Draf	**Plan**														
	Actual														
Report Finalize	**Plan**														
	Actual														