DESIGN AND SIMULATION OF DIE AND PUNCH FOR SHEET METAL ON ROUND BENDING

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ABSTRACT

The deflection between FEA simulation and experiment test results still exist which affects the quality and accuracy of the results. Addressing it has become more challenging due to more stringent demands on simulation processes. It is becoming necessary to very rapidly identify sources of unnatural deflection for diagnostic and intervention purposes. The problem include the less efficient design for die and punch, limited die and punch for complex shape, and the unknown displacement control for round shape bending process of sheet metal. For methodology, a v-shape bend experiment and a v-shape bend simulation is done to show result. Comparison between the results of experiment and simulation to measure Algor's analysis accuracy which is applied to simulate round shape bend of sheet metal. Characteristics of sheet metal such as springback are observed during the simulation analysis. In addition, several designs are proposed for round shape bend and to determine which design is best for bending 62.5 mm radius sheet metal. A data sheet containing the displacement control of the press brake machine is developed from the simulation. The framework used to develop the data sheet is general enough for further investigation by either evaluating other designs of its components or by extending its application to other problems.

ABSTRAK

Perbezaan nilai wujud diantara keputusan simulasi FEA dengan keputusan eksperimen dan ini telah mempengaruhi qualiti dan kejituan keputusan akhir. Penerapan teknik tersebut amat mencabar disebabkan oleh permintaan yang menyulitkan. Teknik ini juga perlu untuk mengesahkan punca perbezaan untuk diagnostik. Masalah projek termasuk kecacatan reka bentuk acuan dan penekan, kekurangan acuan dan penekan untuk reka bentuk rumit, dan nilai-nilai untuk sesaran penumbuk dalam proses membentuk keping besi bentuk bulat. Dalam proses perkaedahan, keputusan eksperimen dengan simulasi membengkok keping besi bentuk 'V' telah dibandingkan untuk mengesahkan kejituan kaedah simulasi tersebut. Kemudian, kaedah simulasi ini digunakan untuk analisa prosess pembentukan keping besi bentuk bulat. Ciri-ciri keping besi seperti 'springback' dilihat semasa simulasi. Selain itu, beberapa reka bentuk telah dibandingkan untuk mendapatkan reka bentuk acuan dengan penekan yang sesuai untuk membengkok keping besi pada 62.5 mm jejari. Satu jadual data sesaran untuk mesin telah dihasilkan daripada simulasi keping besi bentuk bulat. Rangka untuk menghasilkan jadual tersebut adalah memadai untuk melanjut penyelidikan dengan menilai rekabentuk lain atau digunakan untuk masalah lain.

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LIST OF SYMBOLS

L_b	-	Bend allowance
a	-	Bend angle
R	-	Bend radius
k	-	Constant
T	-	Sheet metal thickness
e	-	Minimum bend radius

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The project is expected to design and analysis the die and punch for sheet metal on v-shape and round shape bending. The sheet metal bending is a major process in many sectors of industry. Throughout the years, technological advances have allowed the production of extremely complex parts. However, the evolution of die design and ultimate tryout has been a slow, cautious process based on the trial-and-error and the experiences of skilled workers.

Because of its low cost and generally good strength and formability characteristics, low carbon steel is the most commonly used sheet metal. Incremental in-plane bending is a new and flexible manufacturing technology for short production runs in a variety of sizes and shapes. The strip of sheet is bent incrementally by an inclined punch beating according to the control program.

The incremental bending machine uses the numerical control technology. The cross-sectional ratio of width to thickness of the sheet metal and the pitch are important for in-plane bending conditions. The bending experiment is carried out and some experimental results such as beating force, bending radius and strain distribution are experimentally examined. The forming properties of in-plane bending are clarified in this study.

The sheet metals are usually bent by a punch and die as base. There are various manufacturing methods, either singly or in combination, are used in making dies. These processes include casting, forging, machining, grinding, and electrical and electrochemical methods of die sinking. Dies are usually heat treated for greater hardness and wear resistance. When necessary, their surface profile and finish are improved by grinding and polishing either by hand or by programmable industrial robots.

1.2 Problem Statement

The problems of the current project are:

i. The design for die and punch are less efficient.

ii. Limited die and punch for complex shape.

iii. The displacement control for bending process of sheet metal are unknown.

1.3 Project Objective

i. Experiment and analysis of v-bend characteristics using the Trumabend V85S.

ii. Design and simulate of die and punch for sheet metal on round bending.

iii. Develop of round shape bend Data Sheet Reference for sheet metal.

1.4 Project Scopes

For the main purpose of this research, the following scopes are created:

i. Collecting the data from various sources for reference and analysis for literature. The data collecting process is done manually or automated depending on the situation.

ii. Develop the most efficient and simple design of the punch and die so that they are easy to manufacture, complex shape and sizes are not recommended.

iii. The next scope is geometry measurement which involves the dimensions of a design including the length, width, thickness, height, angle between lines, diameter etc. The dimensions of the design of the die and punch are measured to form a 3-D view to get clearer picture.

iv. Perform analysis by F.E.A and validation. Validation is the process of checking if something satisfies a certain criterion. Validation is important because it disallows data that can not possibly be either true or real to be entered into a database or computer system.

v. Develop the methodology of the proposed design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A critical literature review within a specific field or interest of research is one of the most essential activities in the process of research. In order to produce a more productive literature review, it is recommendable to include whole process of selecting resources, reading and writing about previous research studies chosen which includes the discussion about the drawing methods or techniques which are applied to the modal to achieve maximum efficiency and save time. In addition, this section also includes argument of the designs of die to find out which design provides the best performance. Besides that, the manufacturing process and parameters are also discussed. Vital information is transferred from external source into this section such as the internet, reference book, and scientific journals edited by well known professors around the world. Hence, this section acts as a platform for the whole research to support and define each action performed during analysis and experiment.

2.2 Sheet Metal Processes

Sheet metal parts are light weight and can have versatile shape due to its low cost and generally good strength and formability characteristics. Thus, low-carbon steel is the most commonly used sheet metal (Bruce *et al.*, 2004).

Many Sheet Metal Forming processes are used to produce parts and shapes and there is usually more than one method of manufacturing a sheet metal from a given material. The broad categories of processing methods for materials are as followed:

a). Roll forming: Long parts with constant complex cross-section.

b). Stretch forming: Large parts with shallow contours that is suitable for low quantity production.

c). Drawing: Shallow or deep parts with relatively simple shapes for high production rates.

d). Stamping: Includes punching, blanking, embossing, bending, flanging, and coining.

e). Spinning: Small or large axisymmetric parts with good surface finish and low tooling cost (Kalpakjian and Schmid., 2001).

2.2.1 Shearing

Sheet metal is usually removed from a large sheet or coil by shearing. The sheet is cut by shear cutting tools, typically ones created by a punch and a die. Several cutting operations are based on the shearing process include punching and blanking. Punching is identified when the sheared slug is discarded while in blanking usually the slug is the part and the rest is thrown (Bawa, 2004).

Die cutting is one of the most common operations used in the industry. Die cutting is a shearing process that consist of the following:

i) Perforating – punching a number of holes in a sheet.
ii) Parting – shearing the sheet into two or more pieces.
iii) Notching – removing pieces from edges.
iv) Lancing – leaving a tab without removing any material (Kalpakjian and Schmid., 2001).

2.3 Sheet Metal Characteristics

Basically, the sheet metal forming uses various dies and tools to stretch and bend the sheet. However, certain characteristics of sheet metals must be checked before considering the processes. Among the important effects of the characteristic are as followed:

i) Grain size is to determine the surface roughness of the stretched sheet.
ii) Springback can cause distortion of part and affect the dimensional accuracy of the sheet.
iii) Elongation is to determine the capability of the sheet metal to stretch without failure and necking
iv) Yield point elongation also called Lueder's band or stretcher strains which causes flamelike depression on the sheet surface (Crowson, R *et al.*, 2006).

2.4 Sheet Metal Bending

Sheet metal bending imparts stiffness to the part by increasing its moment of inertia. For example, the flanges, beads, and seams increase the stiffness of structure without adding any weight. The terminology used in bending of sheet or plate is shown in Figure 2.1. (Giudice *et al.*, 2006).

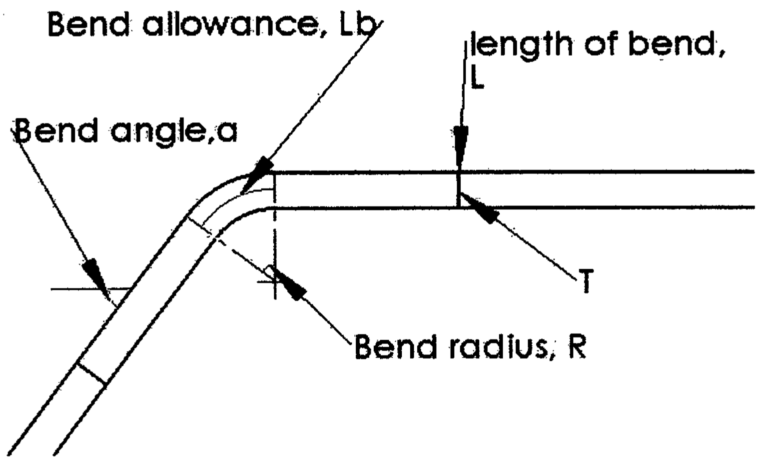

Figure 2.1 Bending terminology

From the figure above, the bend allowance, Lb is the length of the neutral axis in the bend. The position of L_b depends on the radius and the bend angle according to the formula below:

$$L_b = a\,(R + kT) \quad (1)$$

where 'a' is bend angle, T is sheet thickness, R is bend radius, and k is a constant.

Besides that, bending also considers the minimum bend radius. The minimum bend radius refers to the radius at which the first crack appears at the outer fibers of a sheet being bend. The minimum bend radius is given by the expression

$$e = 1/\left((2R/T) + 1\right) \quad (2)$$

When the ratio of bend radius to thickness decreases causing tensile strain at the fiber to increase and develop cracks (Parmley, 1997).

In addition, sheet metal bending also depends on the springback effect. All material have modulus of elasticity, when recovery of a bent sheet metal occurs is known as springback. One of the methods of overcoming springback is by overbending the part (Speck, 1997).

The Press-brake bending machine utilizes long dies and hydraulic press and suitable for small production. The tooling is simple yet effective; their movement is limited to up and down. However, they are easily adaptable to a wide range of shapes. Moreover, the process can switch to automated to reduce cost and for high production runs (Childs, 2004).

2.4.1 Added Bending Operation

There are a variety of processes of sheet metal bending. Among them are as described below:

i) One of the most common is roll bending where the plates are bent using a set of rolls. By modifying the distance between the rolls to create various curvatures.

ii) 4-Slide Bending Machines are used for short pieces. These machines comes with a variety of designs.

iii) The next operation is known as beading where the periphery of sheet is bent into the cavity of the die.

iv) The roll forming process is used for forming continuous lengths of sheet and suitable for high production runs (Schey, 2000).

2.5 Press Brake Machine

Sheet metals that are 2 meters in width or smaller and other narrow pieces are usually bent in a press brake. This machine have long die and punch holders in a mechanical or hydraulic press and is also suitable for low production runs. Besides that, the dies and punches are inserted on the holders depending on the size of the sheet metal to be bent (Walsh, 1999).

The press brake machine requires simple tooling and it is adaptable to a wide variety of shapes. In addition to that, the press brake can be automated with the computerized control system. The materials of the dies and punches range from hardwood to carbides depending on the sheet. For most applications, carbon steel are generally used (www.globalspec. com/ LearnMore/ Manufacturing_ Process_ Equipment /Machine_Tools/Milling_Machines).

2.6 Materials Selection and Materials in Design

The selection of the suitable material for a design is a crucial step in manufacturing. The recognition of the importance of materials selection in design can be seen in the present day product design which supports the fact that materials and manufacturing are closely linked in determining the product performance (Charles *et al.*, 1999).

A wrong selection of material can lead to failure of part and also to unnecessary life-cycle cost. However, selecting the best material for a part involves more than just selecting the suitable material with the properties to provide the wanted performance. Besides that, it is also connected with the processing methods of transforming the material to the final part. In addition, the wrong material will increase manufacturing cost and increase the cost of the part. The solution is to perform simplification and systemization (Ashby, 1992).

2.6.1 High Speed Steels

High speed steels or (HSS) contain the highest alloy percentage tool and die steels. First developed in the 1900s, HSS are well known for hardness and strength at elevated temperatures. There are two types of HSS: (Nayar, 2003).

a). The M-series steels: The M-series steels have up to 10% molybdenum with chromium, vanadium, tungsten, and cobalt.

b). The T-series steels contains about 12 to 18% tungsten with chromium, vanadium, and cobalt.

The M-series steels generally have higher abrasion resistance compared to the T-series steels and undergo less distortion in heat treatment plus they are less expensive. (Budinski and Budinski., 2002).

There are also hot-work steels which are designed for use at elevated temperatures. They have high toughness and resistance to wear and cracking. The alloying elements are consist of tungsten, molybdenum, chromium, and vanadium. (Brady *et al.*, 2002).

2.7 Engineering Design

Engineering design is known as the process of devising a system, component, or process to meet desired needs. It is a decision-making process in which basic sciences, mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objective and criteria, synthesis, analysis, construction, testing, and evaluation (Hyman, 1998).

2.7.1 Conceptual Design

Sketching is the simplest form of drawing and also one of the fastest ways to express ideas and creativity. The drafter uses the sketches to help simplify and solve problems. It is also used to illustrate concepts to other people in discussion of mechanical parts and mechanisms. In addition, sketching is necessary in drafting because the drafter in industry frequently sketches ideas and designs before converting them into drawing on CAD (Jensen *et al.*, 2002).

The product is designed in broad outlines to fulfill its intended function which is to operate satisfactorily over its expected life and to fill the needs of the customer. The design must make the product suitable for manufacture in flexible manufacturing system.

There are many benefits to work with solid modeling software. The most apparent reason is ease of use. If a designer currently working in the 2D world, an immediate benefit would be the ability to see the part as a 3D image as it is being created. Many mechanical parts contain features that are very difficult to visualize in 2D. Because it is possible to add features directly to a 3D model, it becomes possible to see the model grow and evolve into a creation that is built (Murray *et al.*, 2003).

As a result of knowledge gained during conceptual design stage, the problem can be divided into several systems for individual design efforts. Hence, the single problem can now be many subproblems and the concepts generated for each subproblem need to be developed into manufacturable products (Ullman, 1992).

In solving any complex problem, a recommended solution is to divide the problem into smaller parts that are easier to manage. When breaking the system into subsystems, always keep in mind that the connections of elements in terms of structure and function within the group are stronger than the ones between them. Typically, a product will break into components (Dieter, 2000).

2.7.2 Designing for Manufacturability

Manufacturability is regarded as the art and science of designing a product so that it is easy to manufacture. Manufacturability starts from earliest stages of the design concept phase to the assembly stage. Besides that, the manufacturing engineer must always be a part of the design and development process. The problem or potential problems regarding manufacturing process must be found and corrected before the design is finalized and drawings are released. Manufacturability also includes materials. For standard materials, standard parts and standard hardware means standard cost and procurement lead times. As a conclusion, it is the product design that determines the cost of manufacture. The improved methods including process and tooling have minimum impact on the product (Tanner, 1991).

In the simplest term, design for manufacturing is to solve functional, material and visual requirements of a problem. Whether it is a dining chair or a structure to support a highway sign, the solution must meet the requirements mentioned. Function requires that the chair support the human comfortably and the highway sign be contained securely. Material considerations include a sufficiently durable chair frame, and a sign construction to withstand the forces of nature (Lindbeck et al., 1990).

2.8 Finite Element Analysis

Finite Element Analysis (F.E.A) is a powerful technique used for solving complicated mathematical problem of engineering and physics such as structural analysis, heat transfer, fluid flow, mass transport and electromagnetic potential. Modern F.E.A. generated by computer software allows engineer to subject a computer model of structure to various loads to determine how it will react. It also enables designs to be quickly modeled, analyzed, changed, checked for feasibility and structural integrity, redesigned or discarded if they do not work (Chew, 1995).

2.8.1 Algor's Simulation

When performing finite element analysis (FEA), a virtual model of a real-world situation is set up to see how a product will react in its environment. The environment is defined through a combination of loads and constraints and the decisions or assumptions that about those loads and constraints are very important to the overall accuracy of the simulation. The complicating factors related to defining loads and constraints such as:

i) Difficult placing of loads and constraints particularly for situation involving motion, impact, time-dependent changes or multiphysics phenomena. Historically, engineering experience and judgment was relied upon to determine loads and constraints and how to best apply them. However, even experienced engineers can have difficulty determining accurate values for these critical inputs.

ii) Artificial loads and constraints complicate results evaluation by introducing "hot spots" in the model. For example, if the user constrain a point, the nearby results will be artificially spiked. There is no way around this