UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SPRINGBACK EFFECT ON VARIOUS THICKNESS OF MILD STEEL, STAINLESS STEEL AND ALUMINIUM SHEET.

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

(Signature of Supervisor)

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(Official stamp of Supervisor)

(Signature of Co-Supervisor)

……………………………..

(Official stamp of Co-Supervisor)

DECLARATION

I hereby, declared this report entitled “Springback Effect on Various Thickness of Mild Steel, Stainless Steel and Aluminium Sheet ” is the results of my own research except as cited in the references.

Signature	:	………………………………………….
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Date	:	…………………………………………

DEDICATION

Special thanks, I dedicated to my beloved family, especially to my mother, Khadijah Dualis Binti Abdullah for their advices and continuous support to me in performing this difficult task and journey does not end here. Special dedicated to my supervisor, Mohd Fairuz bin Dimin @ Mohd. Amin and to all my fellow friends. This project is completed and achieved cannot be done without all of you.

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ABSTRACT

The purpose of this research is to conduct an experimental study springback effect and thinning effect on various thickness of Mild Steel, Stainless Steel 304 and Aluminium Alloy 6061 Sheet. The springback effect is measured on with a different thickness for Stainless Steel 304, Mild steel, and Aluminium Alloy 6061. The thinning effect also measured by using a different thickness for Stainless Steel 304, Mild steel, and Aluminium Alloy 6061. The optimization value for each response, springback and thinning effect is obtained through optimization model in Minitab 17 software. For springback effect, optimize setting is gained by using Aluminium Alloy 6061 with a thickness of 1mm. At the same time, the optimize setting for thinning effect is by using a Stainless Steel 304 with a thickness of 1mm. The springback and thinning effect are measured and the analysis Multi Regression analysis is conducted. By using an analysis tool in Minitab 17, the relationship between the variables and responses can be obtained. The result showed the variables which are thicknesses and materials and the responses which is springback and thinning effect are statistically significant. The p-value for springback effect is equal to 0.002. While, R-squared value obtained for springback effect is equal to 93.56%. For thinning effect, the p-value is less than 0.001 and the R-squared value computed is equal to 99.63%.

ABSTRAK

Tujuan kajian ini adalah untuk menjalankan eksperimen tentang pengaruh *springback* dan kesan *thinning* terhadap pelbagai ketebalan bahan seperti keluli lembut, keluli tahan karat 304, dan kepingan Aluminium Alloy 6061. *Kesan springback* dinilai melalui 3 jenis bahan iaitu keluli lembut, keluli tahan karat 304, dan kepingan aluminium alloy 6061 dengan setiap bahan mempunyai 3 ketebalan yang berbeza. *Kesan thinning* juga dinilai dengan menggunakan cara yang sama untuk menilai *kesan springback.*Nilai pengoptimuman untuk setiap respon, *springback* dan kesan *thinning* diperolehi dengan menggunakan perisian Minitab 17. Untuk kesan springback, aturan optimum yang diperolehi adalah dengan menggunakan kepingan Aluminium Alloy 6061 dengan ketebalan 1mm. manakal untuk kesan *thinning,*aturan optimum diperolehi adalah dengan menggunakan keluli tahan karat 304 dengan menggunakan ketebalan 1mm. *springback* dan kesan *thinning* dinilai dan analisa *Multi Regression* dijalankan. Dengan menggunakan perisian Minitab 17, perhubungan di antara pembolehubah dan respon boleh diperolehi. Keputusan yang diperolehi menunjukkan pembolehubah seperti ketebalan dan jenis bahan dengan respon seperti *springback* dan kesan *thinning* mempunyai perhubungan statistik yang signifikan. Nilai p untuk kesan *springback* bersamaan dengan 0.002. Manakala, nilai R-kuasa dua diperolehi adalah bersamaan dengan 93.65%. Unuk kesan thinning, nilai p adalah kurang daripada 0.001 dan R-kuasa dua didapati adalah bersamaan dengan 99.63%.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

1.1 Overview of study

This report issue associated with the springback effect on various thickness of Stainless Steel 304, Mild steel, and Aluminium Alloy 6061. In this report, the influence of thicknesses of sample onto springback effect and thinning effect is conducted .

1.2 Background

In early of 1958, the springback corrections' generalized mathematical analysis in the metals pure bending for example, aluminium, nickel, ferrous alloys, and titanium. Johnson and Yu (1982) conducted a research to produce springback's theoretical analysis for the elastic–plastic, rectangular plate's bi-axial pure bending. Ayres (1984) suggested a process named "shape-set" with a purpose to decrease side-wall curl springback that always happen to high-strength steel (HSS) rails. Prasad and Somasundaram (1993) created a plane-strain sheet bending models with a reason to foresee the springback, minimum value of bending ratio, bendability, maximum forces on the punch and the die, and the strain and stress distributions. The empirical methods to calculate the bend allowance is evaluated by them. They also developed and created a mathematical model to identify the bend allowance according on the properties of material for example, the tool geometry and the strain-hardening exponent and yield stress of the material. Leu (1997) analyzed The Hill's theory in anisotropic materials and he had proposed an equations with a purpose to calculate the springback and bendability in plactic bending based on anisotropic sheet metals. It is hard to gain very detailed and accurate outcomes in metal forming, arisw from the variables and the forming conditions of the sheet metal when using a traditional analytical methods.

Noordalila (2011) stated that springback is a simply the total of the strain returned to the part as the stress returns to zero. It can be estimated with this formula:

$$e_{sb}=S/E \qquad 1.1$$

where;

e_{sb} = Springback.

S = Forming stress.

E = Elasticity Modulus.

while the forming stress at any point is not easy to determine, the usage of proxy stress can be used to determine the forming stress. It can ease to understand by simplifying the forming stress (S) by assumption that all parts must in condition where the parts is stressed beyond their yield point:

$S \geq YS$, therefore, $e_{sb} = YS/E$

Where;

Y = Yield point.

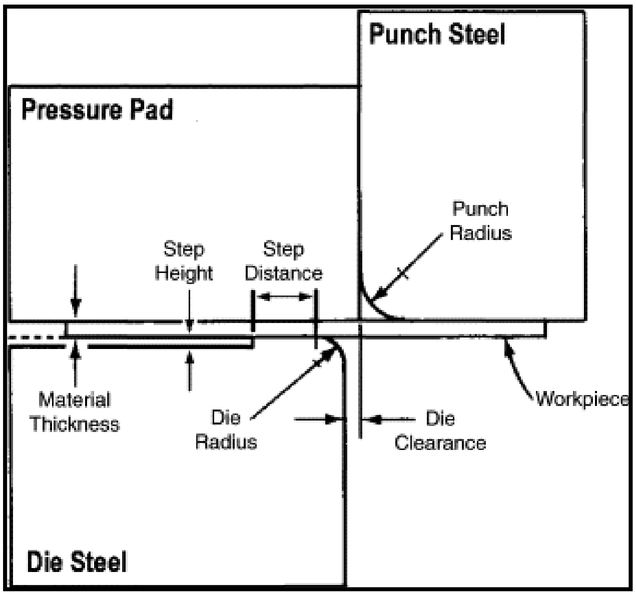

Figure 1.1: Definition of die parameters. (Leu, 1997)

1.3 Problem Statement

Bending process is one of the common process used in industry such as automotive industry, construction industry and others industries. However the accuracy and desired geometry the sample of is influence by the springback effect and thinning effect. There is a lot factors that influence the springback effect and thinning effect usch as thicknesses of sample, material properties, die's radius, die's clearance, ratio of bend radius to sheet thickness, and anisotropy of the material and others factors. Nevertheless, the thickness of the sample and the type of material provides a greater effect on the accuracy of this process. Will various thickness of this three type of material which is Stainless Steel304, Mild steel and Aluminium Alloy 6061 affect the springback effect and thinning effect? To gain complete information on this matter, a research is proposed and conducted.

1.4 Objective

1. To measure the thinning effect during bending process with a different thickness for Stainless Steel 304, Mild steel, and Aluminium Alloy 6061.
2. To measure the springback effect during bending process with a different thickness Stainless Steel 304, Mild steel, and Aluminium Alloy 6061.
3. Optimization of springback effect and thinning effect by manipulation of thickness on Stainless Steel 304, Mild steel, and Aluminium Alloy 6061.

1.5 Scope of Study

This research focus on the one of the parameter that greatly influence the springback effect and thinning effect which is the thickness of the sample on three type of material which is Stainless Steel 304, Mild steel, and Aluminium Alloy 6061. The three different materials used in this experiment is to investigate the relationships between the springback and thinning effect. The material properties of the samples are also one of the parameter that influences the springback and thinning effect. The research will provide a great information regarding to the springback effect and thinning effect on a various thickness for three type of material that have been stated. However, the research is conducted by bending the materials into 90° and no other way involve in this research. The springback effect and thinning effect on various thickness for a different shape is not available. The mould and the radius of the die is fixed and unchangeable.

CHAPTER 2
LITERATURE REVIEW

This literature review will discuss in detail on the issue about the reviews from previous researches that is related with the step approach for identify the springback effect on various thickness of steel, stainless steel and aluminium sheet. This chapter is included explanation about the related study based on this project.

2.1 The Sheet Metal

Sheet metal is a flat, and thin pieces formed by an industrial processes. In metalworking, this form is very important because it can be bent and cut into a many type of shapes. Objects that have been used in everyday life are composed with sheet metal. The thicknesses can be differ significantly, leaf or foil is an extremely thin and plate is and a piece that thicker than 6mm are treated as a plate. The sheet metal can be found in coiled strips or flat pieces. The coils are formed by continuously running a set of length of sheet metal through a roll slitter. There are various types of metals can be formed to sheet metal, such as brass, aluminium, nickel, tin, steel, titanium and copper. For aesthetic function, significant sheet metals such as platinum, silver, and gold. Sheet metal made of platinum can be used as a catalyst. Application of sheet metal is vary from airplane wings, car bodies, roofs for buildings, table for medical purposes and other applications (Lodhi & Jain, 2014).

2.2 Springback Effect and Thinning Effect.

Spring back effect always haunted a sheet metal forming industry. The springback effect is an undesired form of metal after unloading phase lead to the unwanted dimension. Springback phenomenon occurs because of the elasticity of the bent material. Wagoner, Lim, & Lee (2013) said nowadays, springback is known as a change in shape which is driven elastically that happens following in operation of sheet forming when the forming loads which holding and reshape the work piecec are withdrawn from the work piece. Usually this event is undesireable, lead to the problems for example the tolerances is increased and the variability in the sequence forming operations, in fabrication and assembly, and in the concluding part. Typically, this effects downgrade the quality and appearance of manufactured products. Papadakis (2008) state that the definition of Springback is the driven alteration in shape of a component part upon unloading after forming. This problem is increase as have a tendency to progressively rely on upon materials with higher strength-to-modulus ratios compare to the traditional low-strength steel. Mostly in FE-codes for sheet metal forming simulation, the strain recovery is assume to be linear and elastic, and the code do not weight out the the inelastic effects occur during calculation of springback.

Burchitz (2008) stated springback as an phenomenon driven elastically that change the shape of the part being deformed upon removal of the loads. This phenomenon caused the the deviation of the geometry of the real product from the desired design and resulted a significant problem in process of assembly. It is a phenomenon with a complex physical which is mainly due to the stress state gained after the deformation process.

While Smith (2005) said springback happen after a trim, flanging, and draw on the panel caused by the unbalanced residual stresses. The geometry of the panel is deviate from the desired shape caused by the after effect of springback. The previous definition supported by Duhovnik, Demšar & Drešar (2014) stated the sheet-metal thickness affect the bend radius in the sense that it takes account of a certain factor (e.g., 0.8-2.0 x d). The most common ratio used is 1.0, for example, the thickness of sheet-metal same as the bend radius of the sheet metal after deforming. Bending forces are rapidly increasing, especially the residual stress in a material because of the deformations of plastic when a small radius of die is used. It causes increased return deformations after bending—the so-called “spring-back” effect. Resetting certain features can be done.

The definition given by Indian Space Research Organisation Antenna Systems Group (2005) said that the shaping a structure of laminated composite in contact with the mould involves distortion of geometric on the structure, which is commonly called as reverse springback or spring-in. Jin & Lin (2012) stated that any types deformation of plastic on the sheet metal under outside loads comprise of the elastic deformation and deformation of plastic. When the external loading is removed, parts are deform induced by the plastic deformation of materials that memorise the residual deformation. However, the sizes of the deformation is shifted in the opposite direction after the load changes caused by the elastic deformation, plastic deformation and elastic recovery of elastic deformation part of the elastic recovery of its shape, this event is called as springback, which likely happen in all types of the stamping process. Categorically in order with the non-conventional forming stamping, and sheet metal bonding forming involved bulging, flanging, bending, local shape, flaring, bending, and necking, etc. The most familiar in in the bending process is the springback after unloading is the most crucial.

Lemeš (2010) stated springback can be defined as a dimensional change occur when the pressure from forming tool has been set free. Hambli & Kobi (2002) said after bending, springback occurs simultaneously with the tool removal. The total of the elastic recovery relies on the modulus of elasticity, E of the material and the level of stress. The diversity of the thickness of the sheet metal after bending process and mechanical properties of the material shows the problems faced concerning the calculation to gain the prediction of the springback of the bent part and required punch displacement. This lead to the bend angle arc repeatedly not accurate enough to fulfil today’s requirement of high tolerance. To enhance the air bending process accuracy, the variety of material properties at the time and after bending process should be foresee especially the damage contour in the sheet. The paper explains an L-bending in the finite element model to predict the springback elasticity. While Suchy (1998) defined springback as a total of elastic distortion a material has to undergo before it is deformed permanently, or formed. The total of elastic tolerance, which is exist almost in every material, even if it is a ductile, hard-strength maraging steel or an annealed metal. In ductile materials, the springback is much lessened compare to the hard metals, based on the Young modulus (also called as modulus of elasticity) of a certain material. High yield strength or the material's strain-hardening tendency resulting increase greatly the amount of springback. The amount of springback in the material can be increased by using a heat treatment and cold treatment. By comparing the low-strength steel material spring back, it will be smaller compared to the high-strength steel and yet the aluminium's springback will be higher to two or three times higher. Springback happens in all types of bent-up or formed parts when punch withdrawal and a forming pressure is released. The material with predetermined placement influenced by two elements and the outside restrictions suddenly removed and instantly performs an attempt to restore its original form and shape.

According to Altan & Tekkaya (2012) Springback is a usual phenomenon that leads to a deviation of shape from desired design geometry and that happen after deformation of elastic-plastic of the part during process of stamping, springback escalate corresponded with the magnitude of the flow stress, which is local strains, and it's decline corresponded with the magnitude of the geometric restrain produced from the shape of the formed part. After the forming load is removed, or when the part is cut back, the elastic stress exists in various places on the part are released. The part's geometry, however, prevent all the strains to equal to zero. Thus, springs back only partially or the part is relaxed, while remaining residual stress left in the part after the spring occur. While Demeri (2013) stated that Springback is the shift of the shape from that of the part after the die is released and after the forming occurred. Therefore, it is a final product form's deviation from the desired shape. Springback arises during operations of drawing because they consists of drawing and stretching components. The both components are accountable for springback. During bending the outmost surface of the bent sheet is in tension condition, while, the inner surface is in compressed condition. As the bending process develops, at the centre of the cross section of sheet metal, the neutral axis moves toward the direction of the inner surface (compression side). After the load is released, elastic recovery leads to the springback. However, in stretching forming, practically the springback is negligible because the tensile deformation in both the inner and outer surfaces of the sheet thickness.

2.3 Springback effect and Thinning Effect on various thickness

One of the parameter of the springback effect which is thickness of the material. According to Davis (2004) geometrical factors enormously influenced the springback, and ratio of bend radius and bend angle to thickness of sheet increase. Dixit, Narayanan, & Ganesh (2013) said that the results related to the effect of caused by the another parameters such as Young's modulus and the thickness of the sheet were expected. The radius of the punch nose and the sheet thickness was proved to have a noticeable effect on springback. The texture of the surface is spoilt caused by the orange peeling which is the common problem in bent parts. A size of coarse grain is relative to the thickness of sheet (a high d/t ratio) is established fact to bring this defect. The sheet thickness, initial grain size, rate of roughening, true strain, and initial surface roughness define the roughness of the surface. The effect of initial surface roughness and grain size for a sheet thickness with 1.27mm is deem to be significant. Substantial roughening resulted from an addition of the size of grain within range of 50 pm to 200 pm., while a initial surface roughness with a wide range done a little effect. According to Lemeš (2010) said the strain change caused by the elastic recovery is one of the parameter of springback. The other factors that will increase the springback is The strength of the material is higher, the radius of the die is larger, lower Young's modulus, and higher wipe steel clearance. Advanced materials for example, high-strength steels and aluminium alloys have a higher tendency to display greater springback.

Gassara et al (2009) stated a case is presented to optimize three parameters which is the punch of the die, die clearance, the blank holder force and the radius of the die corner. While Kitayama, Huang, & Yamazaki (2012) mentioned there are a lot of factors affecting the springback, for example, the blank holder force (BHF), material properties, lubrication conditions of the interface and friction, number of integration points, die geometry, punch speed and so on. For Yeh, Li, & Tsay (2012), the springback primarily affected by the metal sheet’s thickness, radius of die profile, punch radius, and material parameters. According to Fu & Chan (2014) declared it is disclosed that the sprignback increase when punch-die clearance, die angle, and die radius increase. In addition, it is showed that the strip along the rolling direction displays a bigger springback than that of the transverse direction.

Gassara et al (2009) In L-bending process, the final shape of the workpiece is greatly influenced by the springback after the punch is removed. Since all materials have their own a finite modulus of elasticity, when the load/punch is removed, plastic deformation is followed by some elastic recovery. This phenomenon named springback (Figure 2.1).

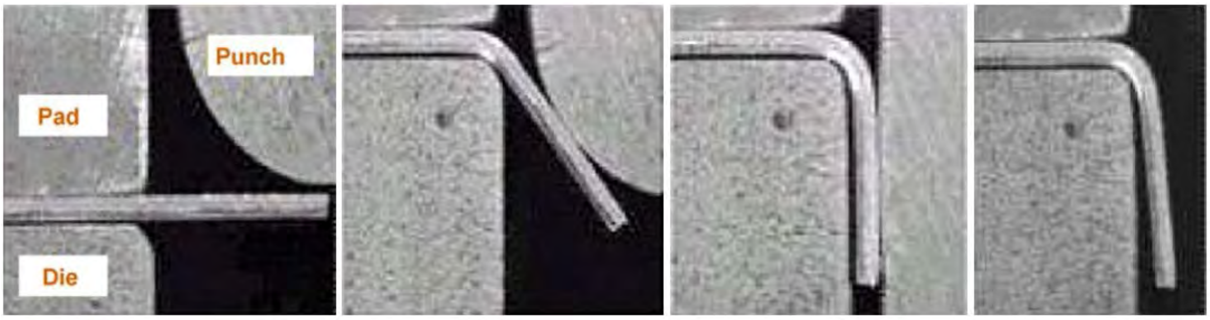

Fig.ure 2.1: Process steps during bending and springback (Gassara et al, 2009)

2.4 How to Optimize Springback Effect and Thinning Effect

Lemeš (2010) wrote to preclude or lessen the springback, a lot of methods is applied nowadays. The methods involve to prevent or reduce the springback is condering the design of the die, which may go through 3-10 expensive try and errors before a satisfactory geometry is acquired. Research on springback has been fixated to two major issues which is to efficaciously predict springback and to counterbalance the springback in tooling design. Numerical simulation of springback in complex auto-body panels need a lot of operation for example deep drawing and binder wrap, is use a lot of time and accumulated errors from each operation will impact negatively to the accuracy of the simulation. While according to Dilip Kumar et. al. (2014), to minimize the effect by the springback, several ways are used. The comprehensive compensation (CC) method regard about the fact of displacement and large rotation would happen during the springback, which is more familiar for panel stamping in automotive industrial. While the second method is displacement adjustment (DA) method which compensation of magnitude and direction are the two essential aspects, has been proven successful in practice. However, theory about DA is not present, tests in industrial show that the capability of this method relys on various parameters as well as process settings, part geometry, and material.

Fu & Chan (2014) stated Liu et al. (2010) carried out the three point bending tests using the copper foils to research interactive effect of specimen and grain sizes. It is found that the springback increases with the decreasing ratio of specimen thickness to grain size.. The similar result obtained by using brass foils is also reported by Gau et al. investigated the size effect on the springback based on L-bending using different size-scaled pure copper foils with similar microstructure. It is found that the springback decreases with foil thickness when the influence of surface grain dominates. When the foil thickness is decreased to a certain value, the strain gradient effect takes place and the amount of springback increases with the decrease of foil thickness." While Demeri (2013) stated that "The key to removing springback is to change the state of stress on the outside and inside surfaces of the sheet metal from tension/comprcssion to tension/tension. This is usually done by superimposing a small stretch at the end of the forming cycle."

According to Suchy (1998) "There are several methods of springback removal in bending, most of them utilizing either overbending or coining. In Figure 2.2, the formed part's sides are secured in their location after forming by a punch or die section, which most often coins the material.

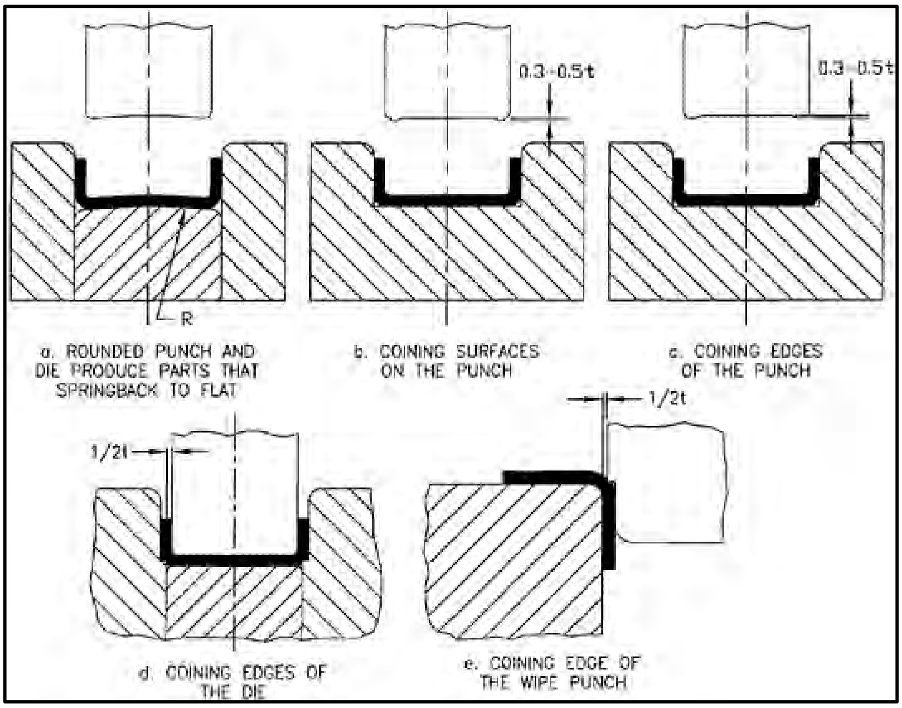

Figure 2.2: Methods of springback control in bending (Suchy, 1998)

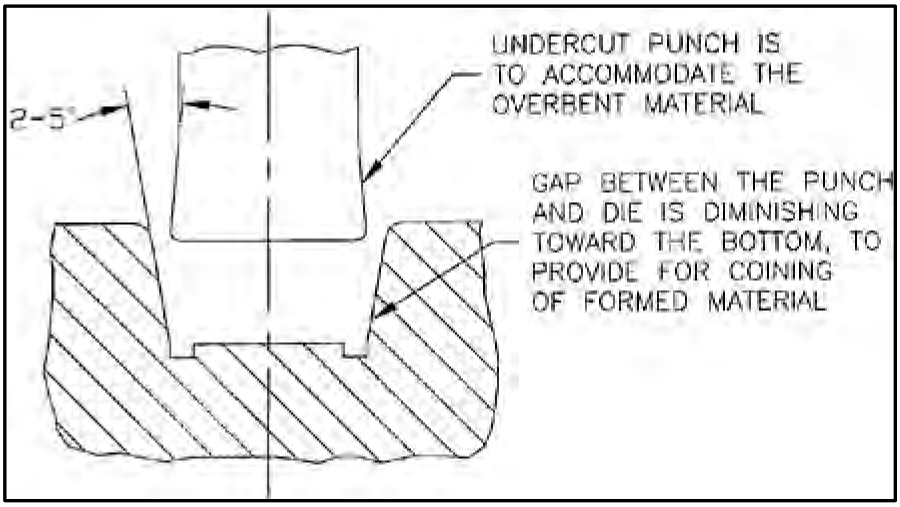

Figure 2.3: Gap between forming punch and die (Suchy, 1998)

The bending method counts on the die's curved bottom to return the formed part to its flat position on retrieval of the bending forces. This will also force the sides toward the center, eliminating the springback effect. In Figure 2.3 shown previously, a method utilizing ironing action against the bent up sides of the part is depicted."

According to conclusion by Panthi et al. (2010) "The following conclusions emerge from this study:

1. Springback highly depends on material properties (yield stress, Young's modulus, strain hardening) and geometric parameters (thickness of sheet, die radius, sector angle) at minimal load condition and it decreases with increase in compression depth. It shows that near net shape can be achieved by proper controlling the forming load. It is observed that any combination of material and geometry becomes irrelevant after a certain forming load/compression depth.
2. Springback increases with increase in sector angle.
3. Friction has negligible effect on springback.
4. The springback increases with increase in yield stress, strain hardening but it decreases with increase in Young's modulus.

While Altan & Tekkaya (2012) stated that the way to reduce the springback effect is "Compensation for Springback. Springback can be compensated for by changing the die sur-face (overbending/overforming), locally deforming (bottoming), or stretching by a high restraining force at the binder drawbead. These springback compensation procedures are classified as geometry-based compensation, which involves change in the tool geometry, and mechanics-based compensation. Which compensates/reduces springback by controlling the factors affecting forming mechanism and springback.

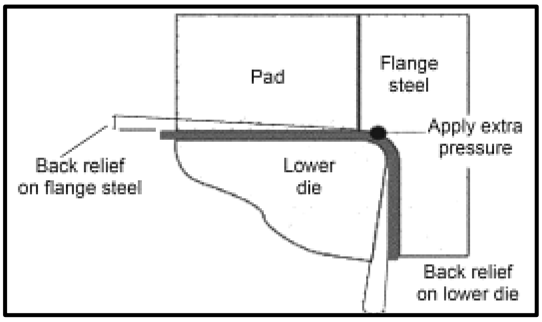

Figure 2.4: Schematic of overbending to compensate for spring back in bending (Altan & Tekkaya, 2012)