INFLUENCE OF THE WORK HARDENING ON SPRINGBACK OF THE U-BEND 316L STAINLESS STEEL

NAJIHAH BINTI ABD MUIN

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DECLARATION

I declare that this project report entitled “Influence of the work hardening on springback of the U-bend 316L Stainless Steel” is the result of my own work except as cited in the references

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

For my beloved family and friends

ABSTRACT

This research purpose is to study the influence of the work hardening on springback of u-bend stainless steel by using Hv Profile and surface morphology analysis. Springback is known as elastic recovery of formed part after unloading of the stainless steel material. Besides that, springback is a phenomena that occur after the material is rolled and bend until certain point. It is a geometrical changes in the final bending angle in the materials. Springback is influences by sheet thickness, yield strength, elastic modulus and bend radius. The material used in this project is known as 316L Stainless Steel which falls in ferrous alloys material. 316L stainless steel has been applied in many applications especially in surgical implant devices. Most of engineering part especially in medical implants, it consist of variety of shape, thickness and geometry. The metal forming processes were used to fabricate the plate either in straight or curve shape. For curve plate, there is thickness variation from 2.0 mm to 1.0 mm. for curve plate, it will introduce springback phenomenon and it can be analyse using experimental approach. For the experimental approach, there is an opportunity to investigate the relation between springback and other properties such as microhardness profile and the surface morphology of the metal.

ABSTRAK

Kajian ini dijalankan adalah bertujuan untuk mengkaji kesan "work hardening" terhadap "springback" keluli tahan karat berbentuk U melalui Mikro-Hardness profile dan analisis permukaan morfologibahan tahan karat. "Springback" dikenali sebagai pemulihan elastik dalam pembentukan bahagian bahan keluli tahan karat selepas beban dilepaskan terhadapnya. Selain itu, "springback" adalah phenomena yang berlaku selepas bahan dikenakan proses penggolekkan dan pembengkukkan pada sesuatu tahap. Ia adalah perubahan geometri pada sudut akhir pembengkukkan pada bahan keluli tahan karat. "Springback" dipengaruhi oleh tebal kepingan bahan, kekuatan hasil (yield strength), modulus elastik, dan sudut pembengkukkan. Dalam projek ini, bahan yang digunakan adalah dikenali sebagai bahan keluli tahan karat jenis 316L dan di kelaskan dalam kelas bahan logam ferus. Bahan keluli tahan karat jenis 316L telah diaplikasikan dalam pelbagai bidang terutamanya dalam bidang pembedahan alatan ortopedik. Kebanyakan barangan mekanikal terutama dalam bidang perubatan, ia terdapat dalam pelbagai bentuk, ketebalan dan geometrinya. Proses pembentukan besi digunakan untuk menghasilkan kepingan plat sama ada dalam bentuk lurus atau dalam bentuk lengkung. Kepingan plat berbentuk lengkungan, ia mempunyai ketebalan yang variasi dari 2.0 mm kepada 1.0 mm. Kepingan plat berbentuk lengkung akan memperkenalkan phenomena "springback" dan ia boleh diuji melalui pendekatan experimen. Melalui pendekatan eksperimen, ia akan mewujudkan peluang untuk menyiasat hubungan antara "springback" dan unsur yang lain seperti Mikro-Hardness profile dan permukaan morfologi bahan keluli tersebut.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Springback is known as “elastic recovery” of formed part in unloading of the stainless steel material. Springback occurs in various form such as bending, torsion, twist and etc. It causes the shape error in final product of sheet metal forming processes. There are various factors that affecting the springback such as blank holding force, punch velocity, orientation and temperature. In addition, during product designing phase, springback is influences by several factors such as sheet thickness, elastic modulus, yield stress and work hardening exponent. The springback effect caused the changes in the final bend angle after the 316L stainless steel material undergoes bending process by the release of elastic component of the bending moment.

Springback is a phenomenon that occur when the material tries to return back to its original shape after being bent. This bending angle is angularly exceed beyond the material’s maximum yield stress and required bent angle which resulting in springback phenomenon. Figure 1.1 shows how the springback effect is presented in the sheet metal forming. The bending angle at the beginning is the over-bending action and the metal spring back to the desired bent angle.

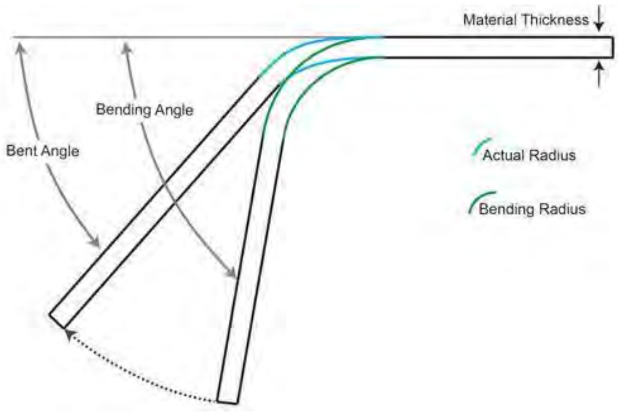


Figure 1.1: The sheet metal forming condition after over-bending action applied and how the metal spring back to its desired bent angle.
(Source: Steve Benson, The Fabricator, July 9, 2014)

Springback happened as it was influenced by the tensile strength and the thickness of the material. As the material bent, the inner region having a compression while the outer region of the material is being stretched by tension. Therefore, the molecular density of the material on the inner region is higher than on the outer region. The material try to return to its original position is caused by the compressive force that is less than the tensile force on the outer region of the bend material. Type of tooling and type of bending are also influence the springback. Prediction and the best solution accounting for springback are critical, especially when working with intense radius of bending as well as thickness reduction and high strength of material.

Thickness reduction of 316L stainless steel material was done by using metal-working method which is rolling. Rolling is the process when one or more pairs of rolls used to reduce the thickness and to make a uniform thickness of a metal. In this project, cold rolling is introduced. Cold rolling is the process where the temperature of the metal is below its recrystallization temperature which usually a temperature at room temperature. Cold rolling causes increase in strength and strain hardening up to 20%. It is also improve the surface finish of the material and holds tighter tolerances.

The plastic – elastic characteristics of a metal is typically known that any deformation of metal sheet at room temperature, it will have both elastic and plastic deformation. An elastic deformation will be release after the metal work is removed from the bending tools and only plastic deformation will remained. Springback has to be compensated in order to achieve an accurate result. Springback is usually happened due to over-bending of the material correspondent to the magnitude of the springback and delivers a plastic deformation at desired bending angle.

In the case of complex tools of the springback, the microhardness profile work correlation have been studied. The surface morphology analysis is used to inspect crack lines at the springback region and the crack line is produced are perpendicular to the direction of rolling process. The analysis is conducted by using microscope image analyzer and scanning electron microscope (SEM). Besides that, practical experiment will be done using trial – and – error method to get the desired results. In this study, work hardening study on springback of the u – bend 316L stainless steel have been performed in order to go deep in the understanding of the behavior between the microhardness profile of the material used and the surface analysis at the springback region. The following are general mechanical properties of material type ferrous metals and alloys for Stainless Steel group:

- General applications: transport, chemical and food processing plant, nuclear plant, domestic ware (cutlery, washing machines, stoves), surgical implemnets, pipes, pressure vessels, liquid gas containers
- Melting temperature or glass temperature, $T_m or\ T_g^1 = 1375 - 1450$ ℃
- Density, $\rho = 7.6 - 8.1\ Mg/m^3$
- Young's Modulus, $E = 189 - 210\ GPa$
- Yield Strength, $\sigma_y = 170 - 1000\ MPa$
- Tensile Strength, $\sigma_{ts} = 480 - 2240\ MPa$
- Fracture Toughness, $K_{IC} = 62 - 280\ MPa\sqrt{m}$

(Ashby, Shercliff and Cebon, 2014).

Based on the studies, the metallurgy and application of stainless steel and alloy for surgical implants has been continued since 1900s. Medical implant or orthopedic implants is a medical device that was designed to replace a missing joint and to support a missing biological structure or damaged bone. Orthopedic medical implants mainly manufactured from austenitic stainless steel, titanium, titanium alloy and cobalt-based alloy. In this project the material used is stainless steel.

For material type 316L stainless steel, it is commonly used in surgical procedures to replace biological tissues. The medical implants manufactured from this material helps to stabilize a biological structure such as bone tissue to aid the healing process. This material mostly important to corrosion resistant when in direct contact with biological fluid. By adding 16% of chromium element to stainless steel, this metal become corrosion resistant. This is important because for the purpose of surgical implants the 316L stainless steel contain approximately 17% to 19% of chromium and 14% of nickel element as surgical implant does not susceptible to corrosion when placed inside the human body. This will prevent any infection occurring in the human body and with the existence of molybdenum added to the stainless steel it forms a protective layer sheltering the metal from exposure to an acidic environment. Material type 316L stainless steel is very ideal as it is particularly effective orthopedic implants when in cold-worked condition. Besides that, material type 316L stainless steel is also ideal because lack of inclusion in the material. Material with inclusion contain sulfur that encourage corrosion.

In application of springback in medical implants, the material type 316L stainless steel is a material used for internal fracture fixation. An internal fixation is an operation in orthopedics that involve implementation of implants for the purpose of repairing bones. Example of type of medical implant used to anchor fractured bones while they heal is semi tubular plate. Figure 1.2 shows the common semi tubular plate used in medical implants.

Figure 1.2: Semi Tubular Plate

(Source: Anonymous, 2016)

Semi tubular plate was designed in the shape of half tube plate. The physical characteristics of semi tubular plate are; it has 1-12 holes with holes spacing between 16 mm and 26 mm, and the thickness of semi tubular plate is around 1mm with width 11mm. This semi tubular plate is commonly used in the area where they are subjected to tensile forces. The oval plate holes allow axial compression if 4.5mm cortex screws are inserted eccentrically on each side of the fracture. Next, the arc underside design is designed for better load support. There are several advantages of using semi tubular plate which are the deep penetration of unthreaded neck of screw into the cortex, which entails in some risk of cortical splitting. The enlarging cortex to 4.5mm as mentioned could prevent such splitting. Nowadays, the semi tubular plate is occasionally used as extension bond plate in open pelvic injuries or as second plate in the metaphysis of long bone.

1.2 Problem statement

In the area of using bending technology, the most common problem occur is achieving accurate and repeatable bending angle. In this project, in processes of sheet metal 316L stainless steel the elastic springback occur after the sheet was rolled and bend at different thickness reduction. As mentioned before, the springback effect occur due to elastic recovery after the unloading of the stainless steel material. Theoretically, when the cold rolled increase from 0% to 50% of thickness reduction, the springback of the u – bend 316L stainless steel will increase.

Besides that, bending process can affect the mechanical properties and the morphology of the material. Therefore, rolling and bending process may be the factors that can manipulate the relationship between mechanical properties of a material and its surface morphology analysis of the internal crack around the springback region and the crack line is produced following the direction of the rolling process.

1.3 Objectives

The objectives of this project are as follow:

1. To observe the surface morphology of u-bend after bending.
2. To determine the microhardness profile of the U – bend 316L Stainless Steel structure at the maximum U - bending region.

During the experiment, there are four different thickness reduction of 316L stainless steel and both sides of the specimen of the similar thickness specimen will be used. The experiment will be conducted two to three times to collect average result for each specimen. Since the material have different thickness reduction, the different springback angle after unloading will be observed.

1.4 Scope of project

The scope of this project are as follow:

1. This thesis project will covers a literature researches of work hardening on springback.
   The concepts and theories are reviewed from different sources such as text books, journals, standard references and web search.

2. The project will covers the develop preparation and experiment on the test specimen due to an influence of work hardening on springback of the U-bend 316L Stainless Steel.

3. The Microhardness Testing and Morphology Analysis are only taken at different thickness reduction from 2.0 mm, 1.4 mm, 1.2 mm and 1.0 mm.

4. Next, data from both tests will be collected and analysed accordingly.
   This project only focused on the result on the Microhardness Profile Testing at the maximum bending region. Therefore, method of Measure Strain Distribution using Digital Image Correlation (DIC) does not covered in this project.

1.5 General methodology

The general actions that need to be carried out to achieve the objectives of this project are as follows:

1) Literature review
   a) Different researches, journals and articles regarding the project will be reviewed. All information collected will be cited accordingly.
2) Specimen preparation
   a) The U – bend of 316L stainless steel at different thickness reduction was prepared after undergoes cold rolling process and bending process.

b) Both sides of each specimen of different thickness reduction will be used as to do repeated experiment to find the average results.

3) Specimen measurement

a) The specimens will undergo hand grinding and polishing procedure to remove corrosion and scratches.

b) Before taken for Microhardness Profile Testing, the specimens will be taken for microscopy inspection to ensure all scratches have been removed and the texture is smooth and clean enough to be taken for Microhardness Profile Testing.

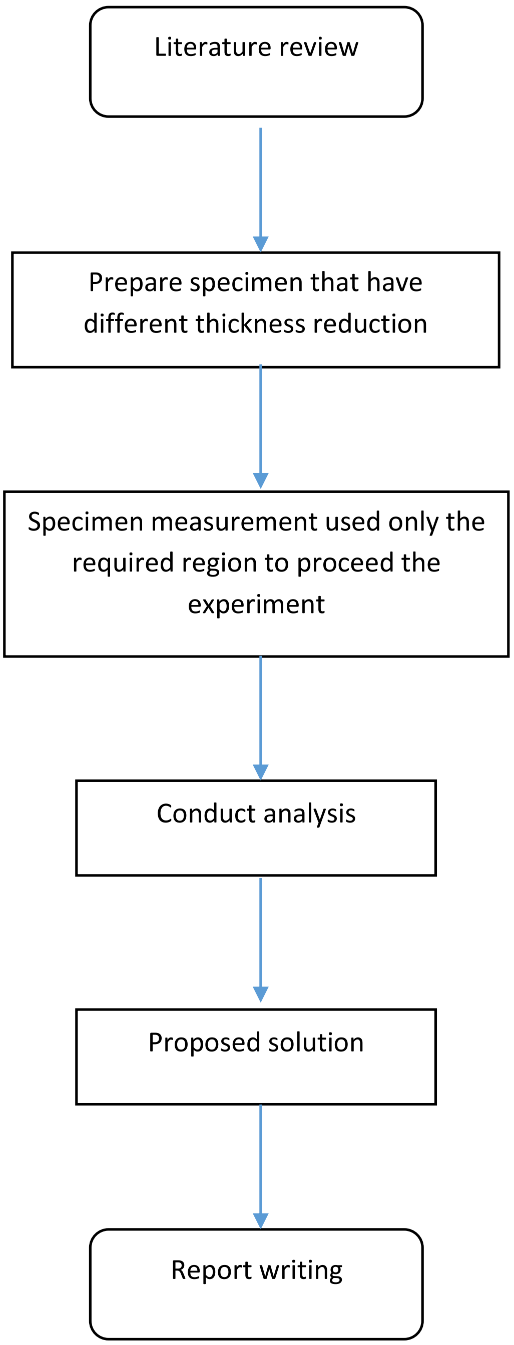
4) Analysis and proposed solution

a) Analysis will be represented on how the crack lines are presented after undergo bending and the exact location of the springback of the 316L stainless steel material happen after bending. The result of microhardness profile will determine the constant value in the 316L stainless steel material. The constant value is assume to be the starting point of the springback occur in the material. Therefore, suitable solution will be proposed based on the result obtain from the analysis.

5) Report writing

a) A proper report on this project will be written at the end of this project.

The general methodology is summarized accordingly in the flow chart below.



CHAPTER 2

LITERATURE REVIEW

2.1 Forming process

Forming process involves shaping of materials into desired shape. While the specimen is subjected to shape changes, in sheet metal forming operations, the cross-section of the specimen remains unchanged because sheet metal forming is a process of converting a flat sheet metal into any desired shape without fracture or excessive localized thinning. The tooling that is usually used is punch or die where the forming process requires a sheet metal with less than 6 mm thickness. Sheet metal forming involve bending, punching, drawing, and stretching. Common failures encountered during sheet metal forming are wrinkling, puckering, and shape distortion factors. Besides that, this forming process are very diverse in type, extent and rate. No single test can provides an accurate indication of the formability of the material in all situation. Factors influence on overall operation of forming processes are stretching, elongation, anisotropy, and grain size. In addition, there are typical mechanical property of sheet metal such as thickness, process condition, surface finish, material properties. (Abhinav, Annamalai, January 2013)

2.2 Work Hardening and Springback

"*Strain hardening is a phenomena whereby a ductile metal becomes harder and stronger as it is plastically deformed*". A work hardening or cold working are another termed for strain hardening phenomena. Work hardening happened when the deformation takes place at cold temperature that relative to absolute melting temperature of the metal, which also known as cold working. (Callister, *Materials science and engineering* (8^{th} Ed.), 2010). Work hardening is a process that makes the metals become harder and stronger through plastic deformation. This happened as the metals plastically deformed, dislocations within a material is generated. The more interaction of the dislocations become pinned or tangled. As a result, the mobility of the dislocations become decrease. Thus, increase or strengthening the material itself.