SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis 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 (Design and Innovation)"

Signature : …………………………….
Supervisor : Dr. Hady Effendy
Date : …………………………….

DESIGN AND SIMULATION
OF THREE DIMENSIONAL BENDING MACHINE

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This thesis is fulfillment of the requirement for the award of Bachelor Degree in Mechanical Engineering (Design and Innovation)

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Universiti Technikal Malaysia Melaka

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature : ……………………

Author : NG SZE LING

Date : …………………….

This project is dedicated to my lovely parents who have always giving me moral support during the time I developing the design and finishing the project. They have never left my side but constantly giving me encouragement which give me tenacity to done my project. Furthermore, I also dedicate this work to my siblings as they providing some recommendation to me especially teaching me that even the largest task can be accomplished if it is done in step by step. Thanks to them for their love and the strength that they gave to me in achieving my goal. Last but not least, thanks God give me His wisdom to arrange all the time and gather all the information to done the project.

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ABSTRACT

In sheet metal forming, a simple shape profile is formed between tools or dies to obtain a complex geometry with the properties and desired tolerances. Nowadays, three-dimensional U-bending process is widely applied in many manufacturing industries, that it could be fabricated with a low production cost. However, after three-dimensional U-bending process, it usually produces spring back problem, little scrap, high percentage of deflection and change of the characteristic of the sheet metal. As a result, three-dimensional U-bending machines is designed and develop with a minimum amount of errors. Furthermore, Finite Element Method (FEM) with commercial software CATIA V5, computer based simulation is an absolute necessity to check the errors and the effects of the process parameters. A study of the principle variables of the sheet metal forming processes and their interactions is essential for this project. These variables include the flow behavior and formability of the formed sheet material under processing conditions, material, coatings and geometry of the die, friction and lubrication, the mechanics of the deformation, stresses, strains and forces, and last are characteristics of the specimen forming presses and tooling.

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LIST OF SYMBOLS

FEM = Finite Element Method

HOQ = House of Quality

n/a = Not Applicable

%RT = Percentage of Reduction in Thickness

avg. = Average

max. = Maximum

CHAPTER 1

INTRODUCTION

1.0. INTRODUCTION

Bending is a metal forming process which a force is applied to a sheet metal to forming an angled or sheet profile. A bending operation causes deformation along one axis. Bending dies is to classify according to their design. To perform a single bending operation, dies are designed which may include L, V, U or Z bends or other profiles. (Vukota Boljanovic, 2004) The parameters of U-bend profiles are shown in **Figure 1**: (CustomPartNe, 2009)

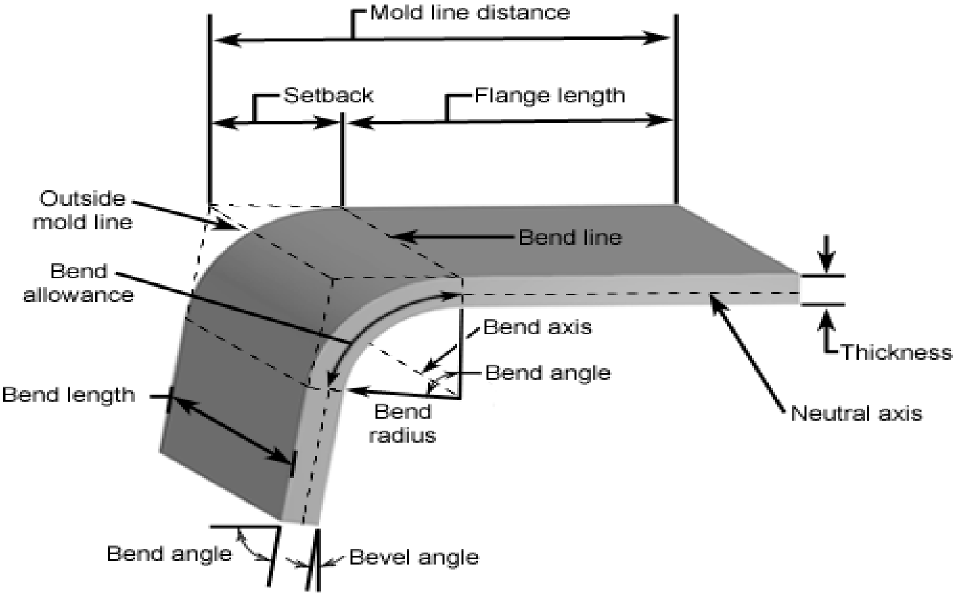

Figure 1: Sheet metal bending profile
(Source: CustomPartNet, 2009)

Simulation is very significant in a U-bending design process. Simulation enables to analyze the design in factors of quality, performance, characteristics, and properties of the U-bending before development process. In simulation, finite element method, FEM is used to investigate the precision of U-bending process. The FEM simulation enable to make a clearly identified of the stress distribute in specimen and the parameters changed after visual U-bending process.

1.1. OBJECTIVES

- To develop and design the three dimensional U-bending machine.
- To simulate U-bending process of Stainless Steel 316L by software CATIA V5.
- To analyze the result from experiment to commercial software CATIA V5.
- To understand the characteristics of the Stainless steel 316L after U-bending process.

1.2. SCOPES

Study on the development of three-dimensional U-bending machine. It is design for manufacture of Stainless Steel 316L U-bending specimen test. For the design of the machine, simulation of U-bending process and structural analysis are carried out. The analysis is carried out by FEM simulation using the commercial software CATIA V5.

1.3. PROBLEM STATEMENT

There is imperfection on the current three-dimensional U-bending machines, which leads to high percentage of deflection, spring back problem, and characteristic changed from theoretical result. Therefore, a design of three-dimensional U-bending machine is significant to minimize the errors. After that, a study on the simulation of three-dimensional U-bending process is to be conducted. It is conduct by Finite Element Method, FEM simulation by using the commercial software CATIA V5.

1.4. FLOW CHART

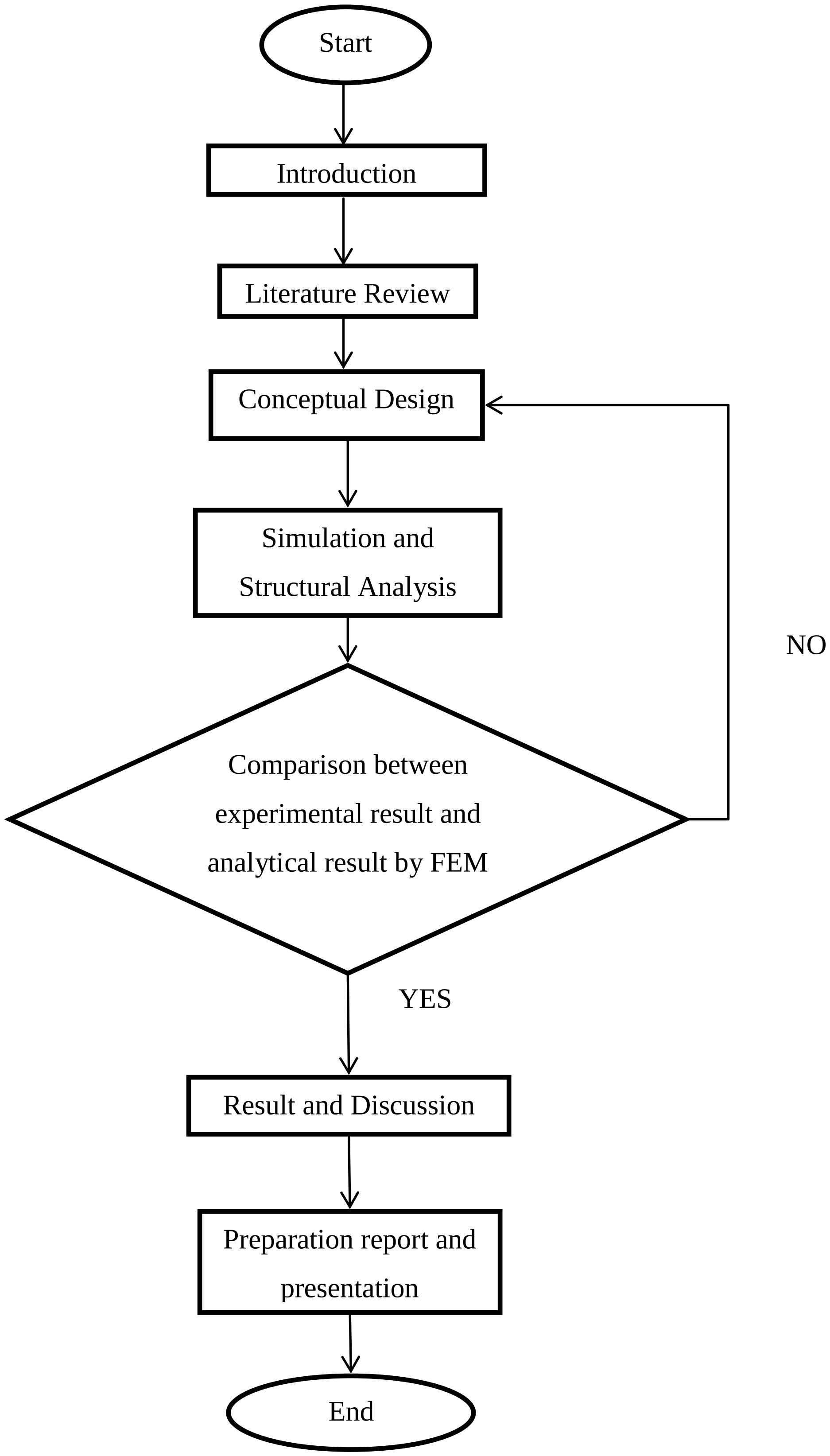

Figure 2: Flow chart of the project

CHAPTER 2

LITERATURE REVIEW

2.0. LITERATURE REVIEW

This chapter will discuss about the theory and information that related to the project. The information is gathered though journals, books, articles, online documents, and some website. This chapter is significant to done the project, this is because the ideas, concepts and some theory can easily generate and get from the information that have gathered. From the information, research and the experience that have done by others, it is very benefit and save the time to do the research and design for three-dimensional U-bending machine.

2.1. THE MECHANICS OF U-BEND DEFORMATION

The mechanics of deformation are significant to consider in designing a bending system. For example,

- Bendability assessment.
  (Determining minimum bend radius without fracture).
- Prediction of bending forces.

- Control of the dimensional, spring back, tolerances, residual stresses, wrinkling, and splitting.
- Sheet metal properties
  (Thickness, properties, and surface finish)
- Equipment / machine used
  (Control and capacity)
- Tools
  (Material and coating)
- Deformation work zone
  (Strain, stress, and force)
- Product
  (Dimensions and quality)
- Environment
  (Handling and safety) (Taylan Altan *et al*. 2012)

Normally U-bending process is containing high elastic and plastic strain. However, sometime for a very thin sheet or very small diameter wire it is possible produce only elastic strain only for U-bend process. Furthermore, U-bending provides one of the most severe tests available for smooth which are as opposed to notched or precracked, stress-corrosion test specimens. The specimens that contain single stressed are not suitable for study on the effects of different applied stresses on stress corrosion and mirror effect on cracking. The advantages of the U-bending process are simple and economical to make and use. **Figure 3** is shows the typical U-bending configurations with several different of maintaining the applied stress. (ASTM, 2003)

The parameters are very important to determine the failure of the U-bending process to a very small radius. There are depending on the sheet thickness, ductility of the material, bending angle, and loading conditions. U-bending severity is expressed as the R/t ratio, where R is the U-bend radius, and t is the thickness of specimen.

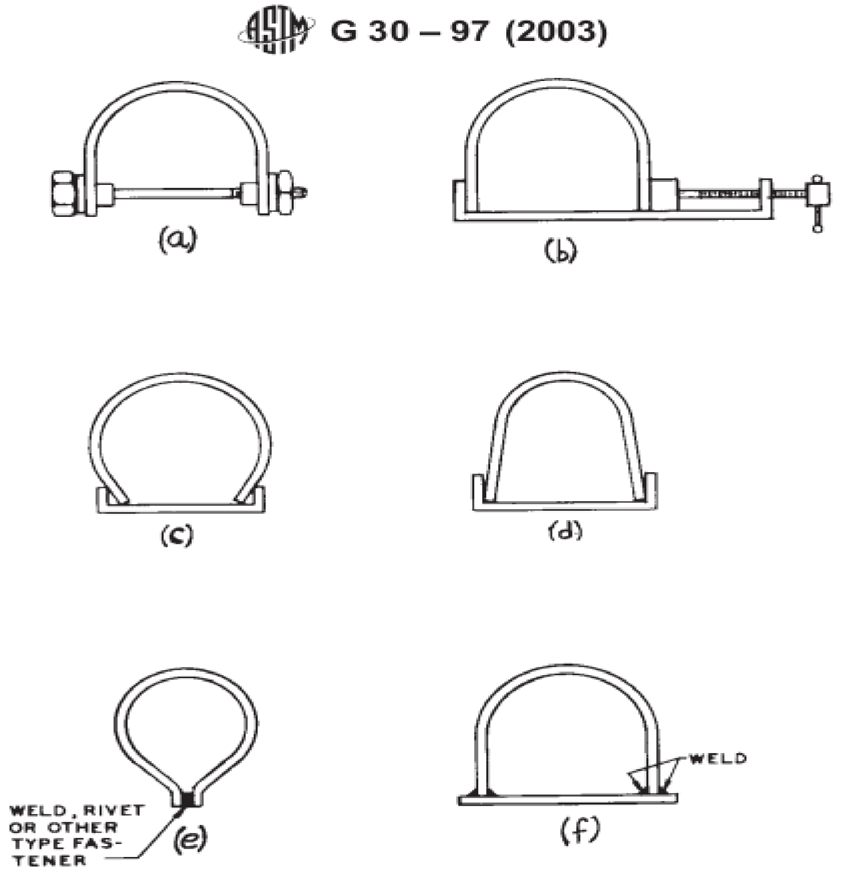

Figure 3: Typical stressed U-bending
(Source: ASTM, 2003)

U-bending processes that get high rates of crack propagation usually is the material that having high strength. Due to the highly stressed condition in a U-bending process, these pieces may give high velocity on specimen and this is very dangerous. For the specimen dimensions of U-bending, **Figure 4** shows examples of typical test specimen and lists. From the examples, some dimension combinations that haven been used successfully to test a wide range of materials.

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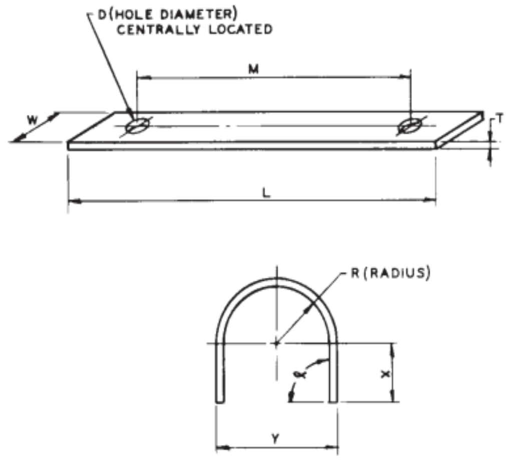

Examples of Typical Dimensions (SI Units)

Example	L, mm	M, mm	W, mm	T, mm	D, mm	X, mm	Y, mm	R, mm	α, rad
a	80	50	20	2.5	10	32	14	5	1.57
b	100	90	9	3.0	7	25	38	16	1.57
c	120	90	20	1.5	8	35	35	16	1.57
d	130	100	15	3.0	6	45	32	13	1.57
e	150	140	15	0.8	3	61	20	9	1.57
f	310	250	25	13.0	13	105	90	32	1.57
g	510	460	25	6.5	13	136	165	76	1.57
h	102	83	19	3.2	9.6	40	16	4.8	1.57

Figure 4: Example of typical specimen dimensions

(Source: ASTM, 2003)

2.2. BEND ALLOWANCES

According to Kutz (2002), dimension is changed after bending, increased in length. It is significant to take consideration the length tolerance for the processes of product and die designing. From **Figure 1,** bent length can be calculated by the equation of

$$B = \frac{A}{360} \text{ X } 2\pi \, (R_i + Kt) \qquad (2.1)$$

Where,

B = bend allowance (along neutral axis)

A = bend angle

R_i = Inner bend radius

t = specimen thickness

K = 0.33 when R_i is less than 2t

= 0.50 when R_i is more than 2t

2.3. STRESS AND STRAIN CONSIDERATION

The principal interest of stress in the U-bending process is circumferential. Due to there is a stress gradient, stress become non-uniform and produce a stress gradient. Outer surface will undergo tension force, and the inner surface will undergo compression. Hence, length in neutral axis is remains constant, there have no any change of length. However, there having a neutral axis between the inner and outer surface. In a neutral axis, it is undergo free of stress, which no tension or compression force. **Figure 5** is shows the stress profile on a bending specimen. K-factor is to calculate the location of the neutral axis. K-factor is depending on the material, bending operation, bend angle and others. K-factor cannot greater than 0.50 and normally is greater than 0.25.

$$\text{K-factor} = \frac{t}{T} \qquad (2.2)$$

Stress gradient will go thought the thickness to a maximum compression on the inner surface from a maximum tension on the outer surface. The gradient stress is from the ends of the specimen, zero to a maximum at the neutral axis. Stress gradient will vary across the width of the specimen bending. (Consultants, 2007)

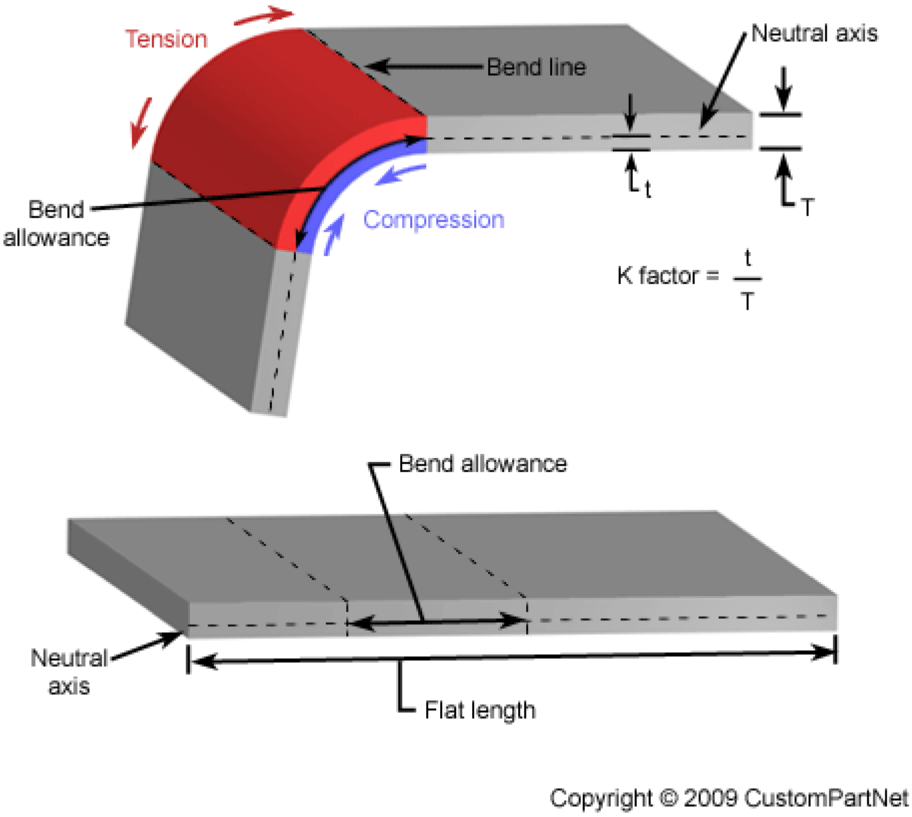

Figure 5: Stress profile

(Source: CustomPartNet, 2009)

For a U-bending specimen is stressed, outer surface of the material may undergo plastic deformation of the true stress-strain curve. **Figure 6(a)** is shown. **Figure 6(b)** to **6(e)** are show several stress-strain relationships that may exist in the outer surface of the U-bending process. Method of the stressing is influence the actual relationship.

The total strain, ε on the surface of the bend can be approximated to the equation of

$$\varepsilon = \frac{T}{2} R, \text{when } T \ll R \qquad (2.3)$$

where T = specimen thickness, and R = radius of the bend curvature.

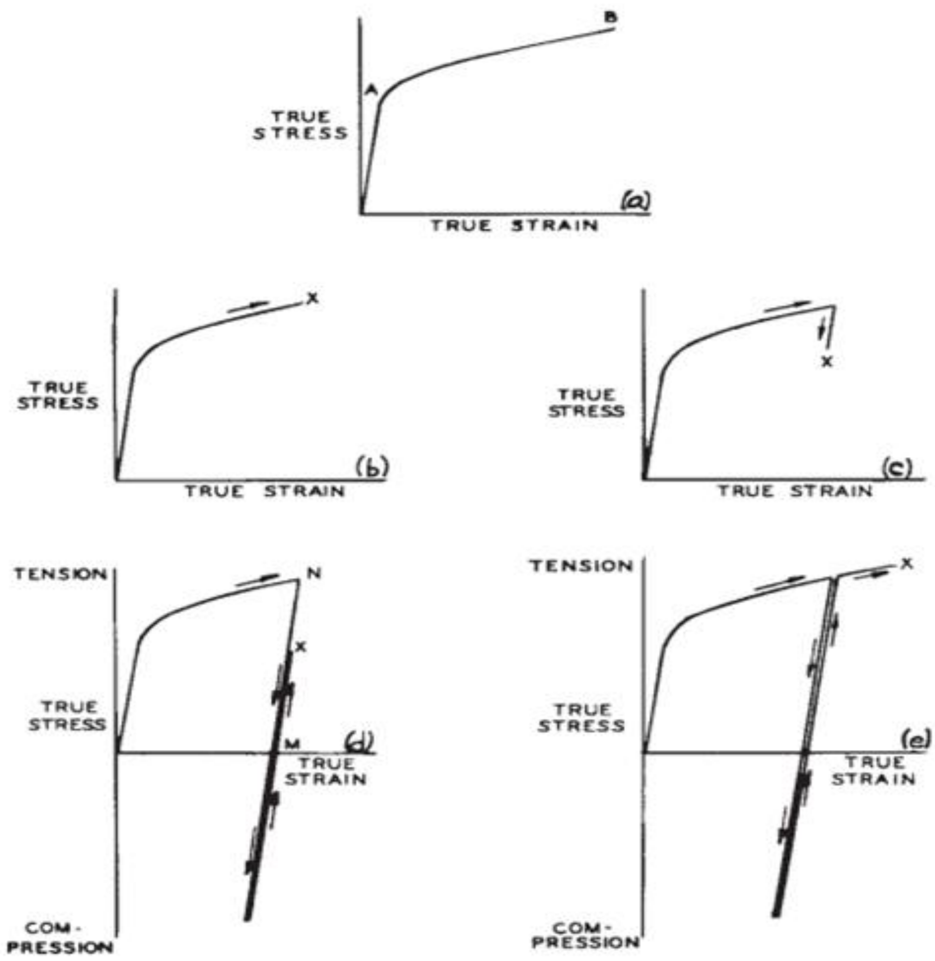

Figure 6: True stress-strain relationship for U-bending

(Source: ASTM, 2009)

There have two method of stressing on specimen. There are single stage stressing and two stage stressing. Single stage stressing is an accomplished by bending of the specimen relaxation of the tensile elastic strain. Single stage stressing is also defined as point X in **Figure 6(b)** and **Figure 6(c)**. Furthermore, for a single stage stressing, there allowing slightly spring back at the end of the stressing sequence for some elastic strain relaxation has occurred. The examples for methods of single stage stressing are shown in **Figure 7**. **Figure 7(a)** is shows the tension testing machine. It is more suitable for large thickness or high strength material or both. **Figure 7(c)** shows the U-bending method which is more suitable for thin or low strength material or both. However, it may lead from greater lack of control of the bend radius, spring back problem. (ASTM, 2003)

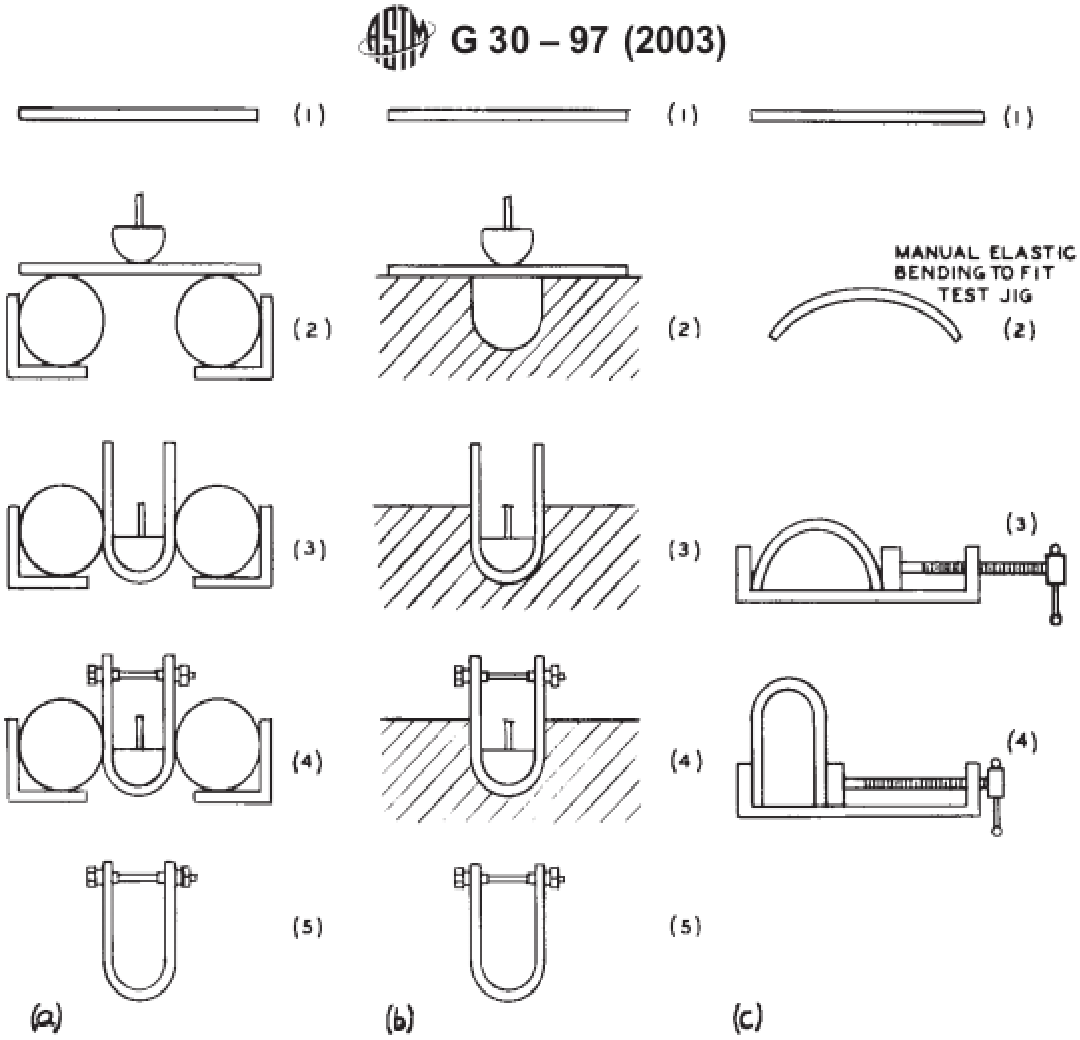

Figure 7: Single stage stressing and the methods

(Source: ASTM, 2003)

For the two-stage stressing methods are shows in **Figure 8.** This method is involves first forming the approximate U-shape, then allowing the elastic strain to relax completely before the second stage of applying the test stress. For the second stage stress is apply, it may result the percentage of tensile elastic strain during U-bending process as shown in **Figure 6(d).** It is also involve additional plastic strain as shown in **Figure 6(e). Figure 8(b)** is first stage stress to perform the approximate U-shape. **Figure 8(c)** and **Figure 7(d)** are to maintain the stress and avoid spring back problem of the U-bending legs. (ASTM, 2003)