TWO DIMENSIONAL ROLL FORMING SIMULATION USING PLANE STRAIN ELEMENTS WITH SIMPLIFIED ROLLER CONTACT DEFINITION

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ABSTRACT

In the industrial today, roll forming was used for large production run. In the roll forming process, the sheet metal of workpiece was feed into successive pairs or set of roller until the desired cross section profile was achieved. The purpose of this study is to do the simulation of roll forming using plane strain element with simplified roller contact definition and also to determine percentage of elastic recovery occur in the roll forming process and design of the roller. This simulation was conducted using ALGOR software which is software for Finite Element Analysis (FEA) to know in deep the relationship between the strain and elastic recovery. This simulation was use five set of roller to shape the sheet metal until it becomes the product. The results of this study show that the strain in the material had give the effect and implication to elastic recovery. From this study also it can help and give the basic idea to designer to control and reduce the elastic recovery in the roll forming process.

ABSTRAK

Di dalam industri hari ini, proses roll forming telah digunakan untuk penghasilan produk yang sangat besar. Didalam proses roll forming, kepingan besi dibengkokkan menerusi pasangan atau set-set roda untuk mendapatkan bentuk yang dikehendaki. Tujuan penyelidikan ini adalah untuk mengkaji penggunaan elemen satah keregangan didalam kepingan yang dibengkokkan secara simulasi menggunakan sentuhan roda yang telah dipermudahkan dan juga menentukan peratusan penyembuhan elastik dan rekaan set roda didalam simulasi ini. Simulasi ini telah dijalankan menggunakan perisian ALGOR iaitu sejenis perisian FEA untuk mengetahui dengan lebih mendalam lagi hubungkait satah keregangan dengan penyembuhan elastik. Simulasi ini telah dijalankan menggunakan lima set roda secara berperingkat untuk membentuk kepingan besi menjadi bentuk yang dikehendaki. Penemuan kajian ini menunjukkan satah keregangan memberikan kesan dan implikasi kepada penyembuhan elastik. Daripada kajian ini juga dapat memberikan idea asas kepada pereka untuk mengawal dan mengurangkan jumlah penyembuhan elastik didalam proses roll forming.

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2-D	Two Dimensional
Y	Yield Stress
E	Young Modulus
T	Material Gage Thickness
Mm	Millimeters

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CHAPTER 1

INTRODUCTION

This chapter explains about the Roll Forming and mechanical properties involves. This chapter also explains about the problem statement, objectives of the project, project scopes and thesis outline.

1.1 Roll Forming

Roll forming process is used for forming continuous lengths of sheet metal and for large production runs. It is also called contour roll forming or cold roll forming. In it, the metal strip is bent in stages by passing it through a series of rolls. The parts are then usually sheared and stacked continuously. Typical products made are channel, gutters, siding, panels, pipes, door and picture frames and many more. The length of the parts is limited only by the amount of material supplied from the coiled stock. The sheet thickness usually ranges from about 0.125 mm to 20 mm and forming speeds are generally below 1.5 m/s, although they can be much higher for special application. The design and sequencing of the rolls, which usually are mechanically driven, requires considerable experience. Tolerances, springback, and tearing and buckling of the strip have to be considered. The rolls are generally made of carbon steel or of gray iron, and the may be chromium plated for better surface finish of the formed product and for better wear resistance of the rolls. Lubricants may be used to improve roll life and surface finish and to cool the roll and the workpiece.

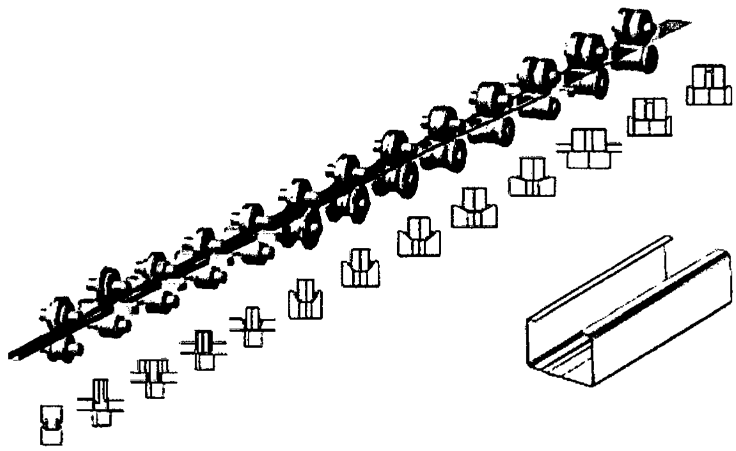

Figure 1.1: Gradually forming of a strip into finished section [1].

1.2 Definition of 2-D Element

2-D elements are 3- or 4-node isoparametric quadrilaterals which must be input in the global Y-Z plane. Figure 1.2 shows some typical 2-D elements. The element can represent either planar or axisymmetric solids. In both cases, each element node has two translational degrees of freedom.

When the element is used to represent an axisymmetric solid or shell, the global Z-axis is the axis of revolution. All elements must be located in the +Y half-plane where Y is the radius axis. Figure 1.2 illustrates these conventions.

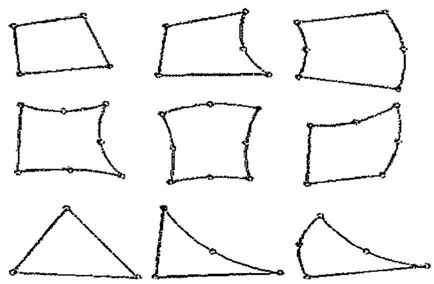

Figure 1.2: Node configurations for 2-D element

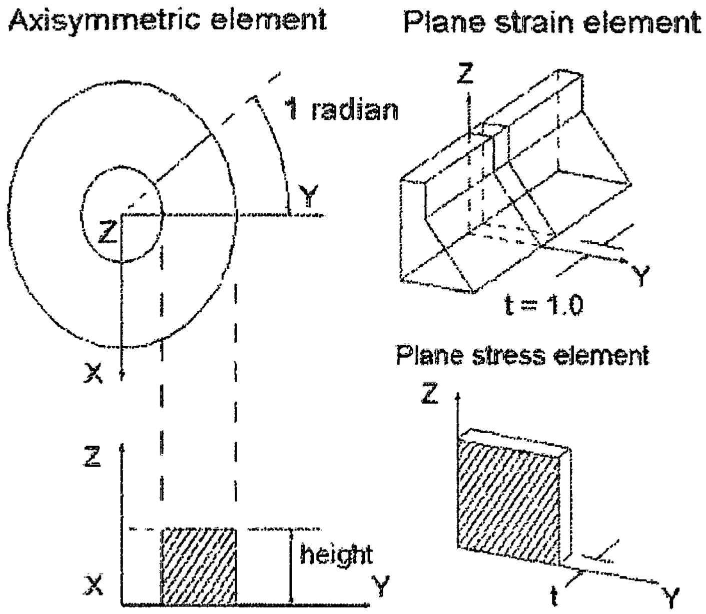

Figure 1.3: Applications of 2-D element

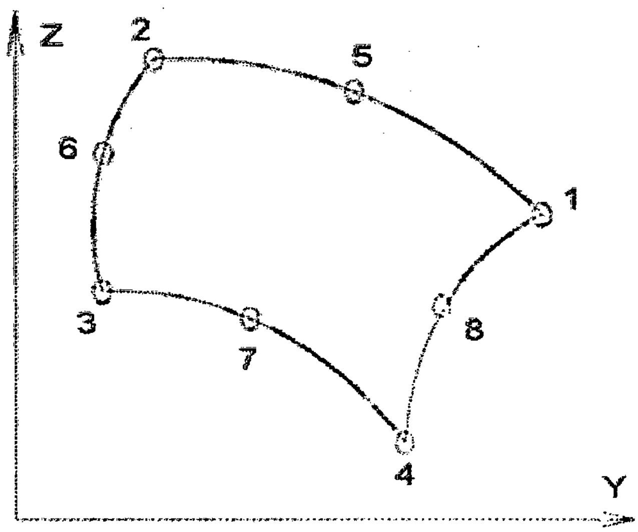

Figure 1.4: Sample of 2-D element

1.3 Project Background

Roll forming is a continuous sheet metal forming process of forming a length of sheet, strip or coiled stock into shapes of uniform cross section by feeding the metal between successive pairs of roller that increasingly shaping the flat metal until a desired cross section profile is achieved. In roll forming process, there is only 1 operation involved in order to change the shape of the sheet metal; bending operation. The sheet metal will tend to bend in stages by passing it trough a series of rollers. Because of all materials have a finite modulus of elasticity, plastic deformation is followed by some elastic recovery called springback. In order to ensure the roll forming process is successful, some conditions must be considered such as springback, roller profile design and number of stages

1.4 Project Objectives

The overall aim of this project is to perform a simulation using Algor software. This project has some other objectives to achieve such are:

1. To perform roll forming simulation for simple roll forming shape using plane strain element

2. To determine the springback using pre-stages for simple roll forming shape.

1.5 Project Scope

The project actually to simulate the roll forming bending in the industry. The first step is to consider the stages use in roll forming and do the simulation using ALGOR, finite element software package.

To do the simulation, the material of sheet metal must determine first and in this project, the material use is Aluminum 6061-O.

In this project, there will be no experimental validations. This project is concentrated in simulation of 2-D roll forming.

1.6 Thesis Outline

Chapter 1 explains about the Roll Forming. This chapter also explains about the problem statement, objectives of the project, project scopes and thesis outline.

Chapter 2 explains about the literature review including the applications in industry. It also includes review articles of the past project from other party.

Chapter 3 discuss about the methodology that have been taken to develop this project. This methodology is important to make sure the project is finish on time.

Chapter 4 is for result got from this project and also the discussion make including problem faced during do this project.

Chapter 5 concludes this project and the future enhancement that can be done on this project.

CHAPTER 2

LITERATURE REVIEW

This chapter review about the practices roll forming, material properties and etc.

2.1 Introduction

Cold roll forming is a bending process where the bending occurs gradually in several forming steps from an undeformed strip to a finished profile. The process is very interesting for the sheet metal industry due to the high speed in which the profile can be produced [5].

Typical products made are channel, gutters, siding, panel, door and picture frames, and pipes and tubing with lock seams. The length of the part is limited only by the amount of material supplied form the coiled stock. The sheet thickness usually ranges from about 0.125 mm to 20 mm (0.005 in to 0.75 in). Forming speeds are generally below 1.5 m/s, although they can be much higher for special applications [1].

The design and sequencing of the rolls, which usually are mechanically driven, requires considerable experience. Tolerances, springback, and tearing and buckling of the strip have to be considered. The rolls are generally made of carbon steel or of gray iron, and they may be chromium plated for better surface finish of the formed product and for better wear resistance of the rolls. Lubricant may be used to improved roll life and surface finish and to cool the rolls and the workpiece [1].

2.2 Existing Practices in Roll Forming

During roll forming, the strain (elongation) of the outside fiber of the strip must remain below the uniform engineering strain. Therefore, the roll designer must know the yield strength, maximum tensile strength, and elongation of the material. These data are usually available from the supplier. In low carbon steel, the correlation between hardness and tensile strength is reasonably good. Therefore, hardness is sometimes used to "check" the incoming material and "screen out" the too "hard" or the too "soft" steel. However, "good hardness" does not guaranty good formability. Cold work (plastic deformation under the annealing temperature) such as bending, tensioning, compressing, and other operations will increase the yield and tensile strengths and reduce elongation. Cold working of some materials, for example, certain stainless steels, zirconium, and other special alloys significantly increases the yield and tensile strength. Based on past experience, the roll designer can usually judge the anticipated formability of the material, including the minimum radius and springback. However, the highly work-hardening materials may have similar mechanical properties to mild steel before roll forming, but by the time bending is completed, the properties are closer to high strength steels. The result can be a 15^0 to 25^0 springback at a 90^0 bend instead of 1 to 28 normally associated with material having similar starting mechanical properties. Materials having high yield strength, small difference between tensile and yield stresses, and small elongation require more forming passes [2].

2.3 Springback

Because all material has a finite modulus of elasticity, plastic deformation is followed, when the load is removed, by some elastic recovery. In bending, this recovery is called springback. It is easily to observe by bending then releasing a piece of sheet metal or wire. Springback occurs not only in flat sheet and plate, but also in rod, wire and bar with any cross-section [1].

2.3.1 Material Deformation on Bending

During a typical roll forming process, the major types of deformation that occur are transverse bending and lateral deformation, although some unwanted longitudinal deformation is induced. In order to understand the material deformation in this type of forming process, a pure bending process, such as press brake forming, was examined [6].

After the bending tooling is removed, the elastic deformation is released, allowing the material strip to recover from the formed shape. This recovery of deformation is known as springback. The amount of springback depends on the amount of elastic deformation relative to the total deformation (elastic deformation plus plastic deformation) [6].

The elastic deformation produced during the bending process is controlled by the mechanical properties of the material, namely, Young's modulus and yield strength. The relative amount of elastic deformation in a formed part also depends on the size (such as gage thickness) of the part being formed. For a material with a given yield strength and centerline radius the total amount of deformation during the bending process decreases as the material gage thickness decreases. The amount of permanent deformation also decreases since the amount of elastic deformation remains the same. The relative amount of elastic deformation, however, increases. As a result, the amount of springback increases [6].

2.3.2 Estimation of Springback Angle

The amount of springback depends on the stress level to which the material is subjected during forming and the mechanical properties of that material (Young's modulus and yield strength).Springback can be calculated approximately in terms of radii R_i and R_f [1]:

$$\frac{R_i}{R_f} = 4\left(\frac{R_i}{E}\frac{Y}{T}\right)^3 - 3\left(\frac{R_i}{E}\frac{Y}{T}\right) + 1$$

where R*i* and R*f* are initial inner radius and final inner radius after springback, respectively Y is yield stress (or yield strength); E is Young's modulus and T is the material gage thickness. Consider a forming corner with an arc length, L. The forming radius has the following relationship with the forming angle [6]:

$$L = \alpha_i \left(R_i + \frac{T}{2}\right) = \alpha_f \left(R_f + \frac{T}{2}\right)$$

where αi and αf are the initial bending angle and final bending angle, respectively. From this relationship, springback angle can be calculated by the following equation [6]:

where

$$\alpha_i - \alpha_f = \left(1 - \frac{\frac{2R_i}{T} + 1}{\frac{2R_i}{TA} + 1}\right) \alpha_i$$

$$A = 4\left(\frac{R_i}{E}\frac{Y}{T}\right)^3 - 3\left(\frac{R_i}{E}\frac{Y}{T}\right) + 1$$

Neglecting the effect of small longitudinal deformation, the springback angle for roll forming can be calculated for a high-strength material with a given Young's modulus and yield strength, radius-to-gage thickness ratio and initial forming angle using these above formulas [6].

2.4 Material Properties

Factors that affect springback include variation in both material and process parameters such as material properties, sheet thickness, friction condition, binder force and tooling geometry. The relationships that exist between springback and these parameters are extremely nonlinear with multiple interactions [8].

Materials are tested for their mechanical properties by applying tension (pulling force) on the test specimens. The test (tensile) specimens are cut and machined out from the material to be tested. After measuring their cross-section and marking a specified length, the specimens are placed between the jaws of a testing machine. The gradually increasing load and the elongation are accurately checked

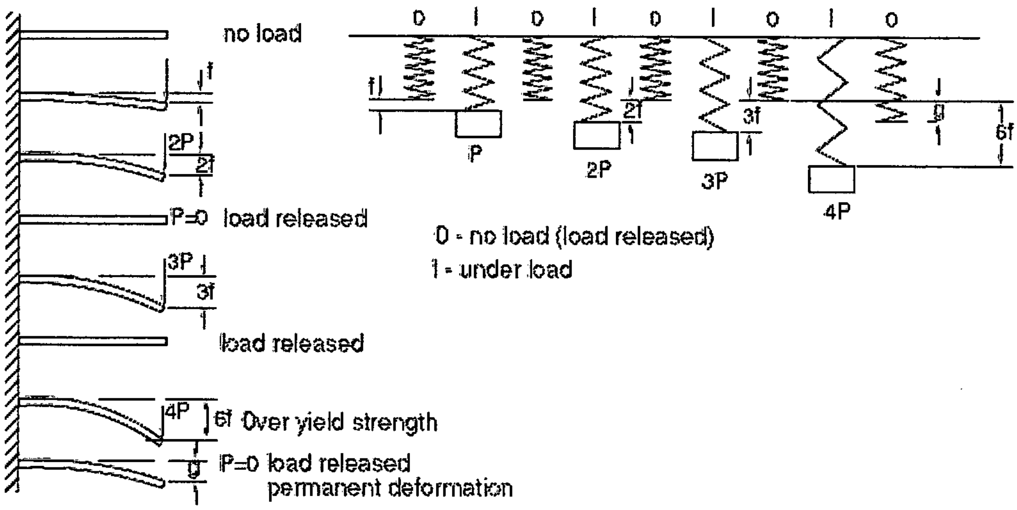

Figure 2.1: Loading and unloading beam and spring [2].

Under any load (stress), the test specimen will elongate (strain). Doubling the load (stress) will double the elongation (strain) — up to a certain load. If the load is released before the specimen starts to yield, then the specimen will return ("shrink back") to its original length. At a specific stress, the strain will increase without increasing the stress. In other words, the material will "yield" under the load. If the load is released after yielding, then the specimen will not regain its original length but will remain "permanently" longer. Where this yielding of material occurs, the stress is called the "yield stress" [2].

2.5 Forming Metal

Forming any metals, however, must be achieved with stresses above the yield stress. Material formed with a stress below yield would spring back to its original shape. The forming stress should not exceed the maximum tensile stress, otherwise the product will crack or tear during forming. A quick glance at the stress – strain diagrams reveals that the larger the difference between the yield and the ultimate tensile stresses, and the larger the elongation, the better the chance is to form the metal. It is more difficult (even impossible) to form metals with extremely high yield and tensile stresses and having a near zero elongation. These materials will crack at the sharp bend lines because the elongation in the outside fibers, created by the bending, would be larger than the maximum elongation of that material [2]. High-yield steels produce more elastic deformation for a given total bending compared to low-yield steels. As a result, high-yield steels have more springback than low-yield steels [6].

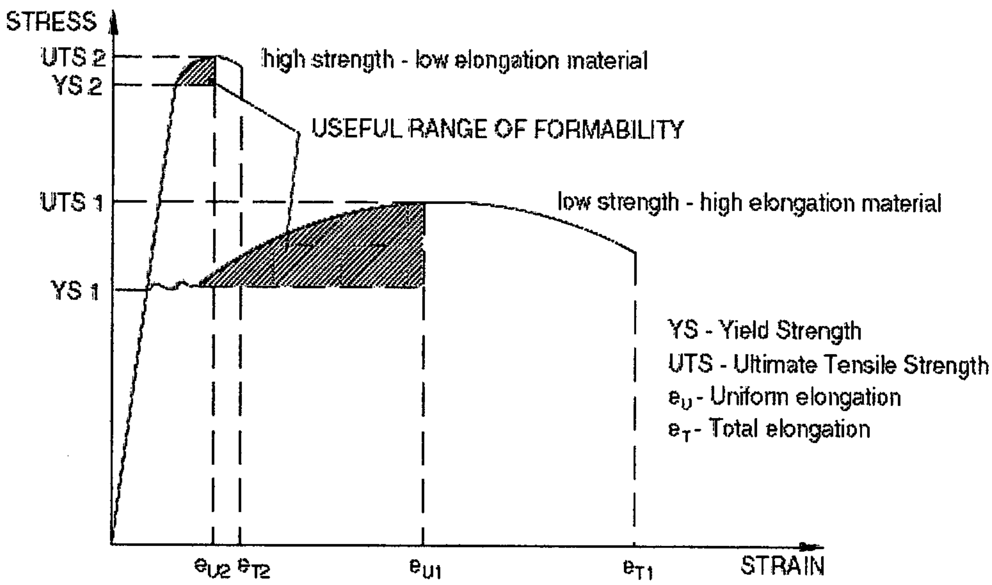

Figure 2.2: Assessing formability from stress-strain diagram [2].

2.6 Stress – Strain Relations

2.6.1 Strain

Strain is related to change in dimensions and shape of a material. The most elementary definition of strain is when the deformation is along one axis:

$$\text{Strain} = \frac{\text{Original length}}{\text{Change in length}}$$

When a material is stretched, the change in length and the strain are positive. When it is compressed, the change in length and strain are negative. This conforms with the signs of the stresses which would accompany these strains, tensile stresses being positive and compressive stresses negative. This definition refers to what are termed normal strains, which change the dimensions of a material but not its shape; in other words, angles do not change. In general, there are normal strains along three mutually perpendicular axes By contrast, strains which involve no length changes but which do change angles are known as shear strains. The measure of strain is the change in the angle. Normal and shear strains are illustrated below (Figure 2.3).

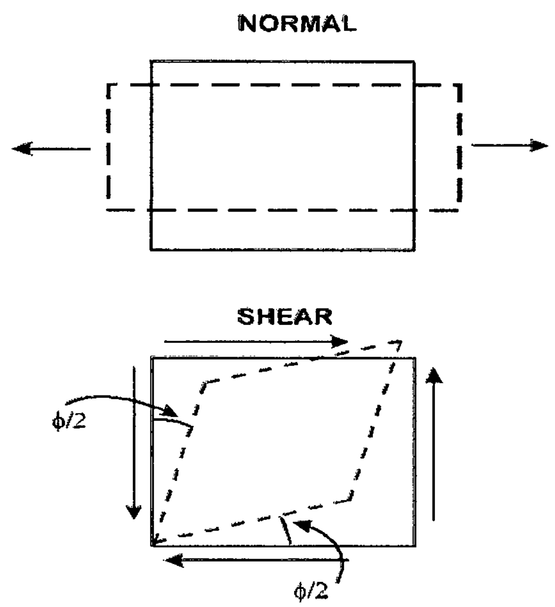

Figure 2.3: Illustration of normal and shear strain [2].

2.6.2 Engineering Shear Strain

Focus on the strain e_{xy} for a moment. The expression inside the parentheses can be rewritten as,

$$\gamma_{xy} = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}$$

where $\gamma_{xy} = \varepsilon_{xy} + \varepsilon_{yx} = 2\varepsilon_{xy}$. Called the engineering sheer strain, g_{xy} is a total measure of shear strain in the *x-y* plane. In constrast, the shear strain e_{xy} is the average of the shear strain on the *x* face along the *y* direction, and on the *y* face along the *x* direction.

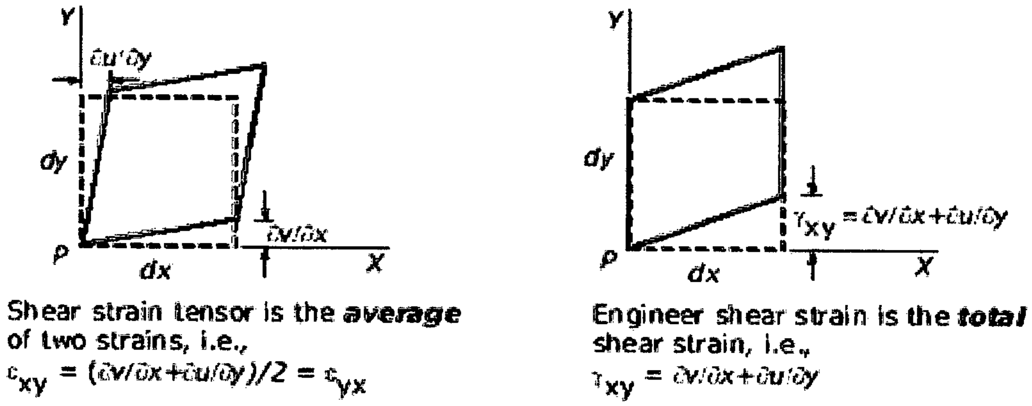

Figure 2.4: Different between shear and engineer shear strain

Engineering shear strain is commonly used in engineering reference books. However, please beware of the difference between shear strain and engineering shear strain, so as to avoid errors in mathematical manipulations.