EFFECT OF SIMILAR AND DISSIMILAR ALUMINUM ALLOY TAILOR WELDED BLANK TO TWIST SPRINGBACK

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UNIVERSITI SAINS MALAYSIA

2021

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July 2021

This dissertation is submitted to
Universiti Sains Malaysia
As partial of the requirement to graduate with honours degree in
BACHELOR OF ENGINEERING (MANUFACTURING ENGINEERING WITH MANAGEMENT)

UNIVERSITI SAINS MALAYSIA

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Engineering Campus,
Universiti Sains Malaysia

ACKNOWLEDGEMENT

I would like to express our gratitude to Allah SWT for giving me opportunity and eased the completion of this research work. I am extremely grateful to my supervisor, Assoc. Prof. Dr. Ahmad Baharuddin Abdullah for his invaluable advice, continuous support, and patience during my research study. His immense knowledge and plentiful experience have encouraged me in all the time of my academic research and daily life.

Special thanks to En. Safie for his guidance to me in making the simulation process on my study. Without his guidance in the Ansys software, I could not manage to get the simulation results on time.

I also would like to thank all the members and friends in the USM. It is their kind help and support that have made my study and life in the USM a wonderful time. Finally, I would like to express my gratitude to my parents for their encouragements and confidence in me to complete the study successfully. Without their tremendous understanding and encouragement in the past few years, it would be impossible for me to complete my study.

Iskandar Mirza bin Mohd Nasir

June 2021

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ABSTRAK

Dalam industri automotif, bahagian terjahit kimpalan berasaskan aluminium aloi merupakan bahan yang diperlukan untuk pelbagai komponen kerana ketumpatan rendah dan sifat mekaniknya yang baik, terutama apabila ia memberikan pengurangan berat khususnya dalam industri automotif. Lazimnya bahagian logam yang dihasilkan menggunakan mana-mana proses pembentukan mengalami bidas-balik, yang akan mengakibatkan komponen yang tidak mengikut toleransi produk yang diperlukan dan kilasan bidas-balik adalah antara yang paling sukar untuk diramalkan. Kebanyakan kajian yang lepas mengenai pengukuran dan ramalan kilasan bilas-balik tertumpu pada bahan asal, dan kajian mengenai bahagian terjahit kimpalan berasaskan aluminium daripada gred yang serupa mahupun berbeza masih kurang dan diperlukan. Dalam kajian ini, kesan momen yang digunakan dan jenis bahan terhadap kilasan bidas-balik akn disiasat pada beberapa jenis profil aluminium. Proses pembentukan kilasan dimodelkan dalam perisian FEA komersial, ANSYS Workbench, dengan menggunakan prosedur analisis struktur statik. Hasilnya menunjukkan bahawa aluminium yang berbeza akan mengurangkan kilasan bidas-balik, sementara aluminium yang serupa meningkatkan bidas-balik. Kesimpulannya, semua parameter yang dipilih mempunyai kesan yang signifikan terhadap tingkah laku bidas-balik. Perbandingan antara aluminium yang serupa dan berbeza telah menunjukkan perbezaan besar pada sudut putaran selepas memuatkan beban. Perbezaan ini dapat dikaitkan dengan kesan pengerasan regangan dalam pengeluaran profil aluminium yang serupa dan berbeza.

ABSTRACT

In an automotive industry, aluminium alloys-based tailor welded blanks are demanding materials for various components due to its low density and good mechanical properties, especially when it is offered weight reduction in the automotive industry However, stamped metal mostly experiences springback defects, which would result in components that do not conform to the required product tolerances and twist springback is among the most difficult to predict. Past studies on the measurement and prediction of twist springback have mostly focused on virgin material, and studies on similar and dissimilar grade aluminium-based tailor welded blanks are still lacking and demanding. In this study, the effect of moment applied and material type on several types of aluminium based tailor welded blanks on twist springback will be studied. The twist forming process was modelled in a commercial FEA software, ANSYS Workbench, using a static structural analysis procedure. The results have shown that dissimilar aluminium would decrease the twist springback, while a similar aluminium increases the twist springback. In conclusion, all the parameters chosen had significant effects on the springback behaviour. The comparison between similar and dissimilar aluminium have shown major difference on the twist angle after loading. This difference could be attributed to the strain hardening effect in the production of the similar and dissimilar aluminium profiles.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The automotive industry is a major user of sheet metal components, taking advantage of the benefits of tailor welded blanks. These benefits include weight, cost, and noise reductions while increasing durability, dimensional precision, and corrosion resistance.

Twist forming is a fundamental operation in a complex profile sheet metal forming process. Several variables such as twist angles, workpiece geometries including length, width and thickness and the material properties of the workpiece should be considered. The corresponding shaping process usually led to a twist springback.

Many components and products experience torsional stress during operation. A range of products, including shafts, switches, fixtures and auto steering columns, can be torsional stressed. Torsion testing allows manufacturers to simulate real-world conditions, assess product quality, check designs, and maintain proper production methods. Torsion tests can be used to determine the torsional properties of material. These properties include elasticity in shear, shear strength of yield, ultimate shear strength, shear break modulus and elasticity. [1].

Therefore, the aim of this research is to study the effect similar and dissimilar aluminium alloy grades tailor the welded blanks to twist springback. The study involves the simulation work using Ansys.

1.2 Problem Statement

Tailor welded blank is one the strategies in reducing automotive parts weight. It can fabricate using friction stir welding. Friction stir welding can combine a variety of materials, including several which are difficult to weld using traditional fusion processes. Twist springback is one of the defects discovered. However, limitation of literature focusing on the effect of twist springback for similar and dissimilar aluminum alloy tailor welded blanks.

1.3 Objectives

This research aims to:

- To simulate the springback in twist forming process of similar and dissimilar aluminum alloy tailor welded blank using Finite Element Method (FEA).
- To study the effect to twist springback of similar and dissimilar aluminium alloy grades tailor welded blank.

1.4 Scope of study

In this study, six aluminum alloys grade, i.e AA 6061-T6, AA 6061-OA, AA 5052, AA 7075, AA 5083, AA 1100 and five combinations of dissimilar aluminum grade, i.e AA 6061-T6-OA, AA 6061-5052, AA 6061-7075, AA 6061-5083, AA 6061-1100 are chosen to be modelled in ANSYS using static structural analysis. The material properties for each aluminum alloy such as the stress-strain curve was obtained from various sources. The parameters evaluated were twist angle, material type and moment applied only.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Metal forming is the process of directly modifying a workpiece's form, surface, and material properties while sustaining mass and strength. The plasticity of metals is used in forming operations to produce fabricated metal material and structural elements. Forming depends on the material structure's ability to sustain unit deformations along crystalline glide lines without effecting material cohesion and is based on the flexible moldability of many materials. It saves material because no waste is generated during the forming process. The goal is to achieve a fine surface finish to prevent excessive finishing. Metal forming processes are categorized according to the effective stresses used during the forming process:

(i) compressive,
(ii) combination of tensile and compressive,
(iii) tensile,
(iv) bending, and
(v) shearing conditions.

Important procedures include upsetting, wire drawing, deep drawing, extrusion, stretch shaping, bending, and forging. The process of forming affects the workpiece, tool, lubricant, environment, and machine. It can be determined by yield stress, deformation size, flow conditions, anisotropy, and the flow curve. Hot forming refers to the process of working with heated workpieces, whereas cold forming refers to working with workpieces at room temperature. Cold forming of metallic materials is often followed by work hardening, which is defined by that as deformation increases, yield strength and breaking strength increase while breaking elongation decreases [2].

The uniform shaping of plates, sheets, and tubes is the foundation for the description of forming processes. It consists of a homogenous and isotropic material with constant friction between the work piece and the equipment with constant yield stress. The process of forming a strip model is briefly described. A minimum width strip is evaluated between two parallel boundary surfaces between the upper and lower forming tools. The upper and lower limits are parallel to the surface of the tool. The tool's movement sense determines the strip height and angles described. It is assumed that the strip's adjoining cross-sectional areas remain parallel to each other. The remaining loads are only assumed to be ignored by compression stress that influence the cross section and boundary surfaces. By multiplying tensions by the suitable surfaces, the forces impacting these surfaces are determined. These are horizontal and vertical forces which represent loads on the boundary surfaces of the strip.

The formability of the material depends on a number of elements, including thickness, material properties and the complexity of the geometry of the component. Uncontrolled springback is the most common issue encountered while stamping sheet metal. Recent efforts have been made to improve the sheet metal manufacturing process and forming capability. However, not all processes can produce complex shape. To solve these problems, manufacturers are increasingly turning to semi-finished products or tailored blanks as favorite to manufacture. Tailored blanks can reduce weight by 20-34 percent. Tailored blank is a term used to describe semi-finished sheet goods that include small differences in thickness, sheet material, coating, and material properties [3].

2.2 Springback

Springback is a major geometrical variation challenge in metal forging. The inner and outer panels, for example, might have a significant impact on the final stamping quality. Springback is an inherent occurrence in sheet metal forming caused during the unloading process by elastic recovery and redistribution of the internal stress [4]. In this case, springback is the elastically generated shape changes that are occurred when the forming loads are released from the workpiece after a sheet formation process. This is often undesired, leading to issues such as higher tolerances and variability in later forming procedures as a final assembly. These factors frequently affect the appearance and quality of the products produced.

The springback consists of minor strains similar in size to other forms of elastic deformation of metals. In comparison to the large-scale deformation necessary for form, it was usually viewed as a reliable occurrence. However, understanding has proven useful in two areas for the complexity of the springback. For the large-strain plastic reaction, high accuracy is necessary, which immediately effects the stress in the body before external pressures are removed. In most cases, although the unloading is theoretically linear, it could differ greatly from an ideal linear law[2].

Springback predictions can generated using analytical methods using Finite Element Analysis (FEA). The approach of analysis involves simplified processes and material properties. Finite Elements Analysis (FEA) is a known tool for evaluating and forecasting strains of sheet forming for a large variety of materials and testing situations. FE is more sensitive than the forming of simulations to numerical tolerances and materials properties.

2.2.1 Basic Springback Theory

The fundamentals of springback and how it can be assessed are explained in this section. Elastic recovery typically results in springbacks because of limitations on the elastic modulus of the materials. When the load is removed, compression material attempts to expand, while tension material attempts to compress, which leads to a phenomena called springback [5].

2.3 Twist Springback

The twist springback definition is measured by the rotation between two separate cross sections along the axis[6]. The twist springback is created by torsional momentum in the cross-section of the component. Torsional displacement happens due to differential deformation of the elastic and residual stresses that generate a torsional moment that tends to spin one end of the part compared to the other (Figure 2.1). Residual strains in the plane of the flanges, horizontal walls or the two may cause torsion.

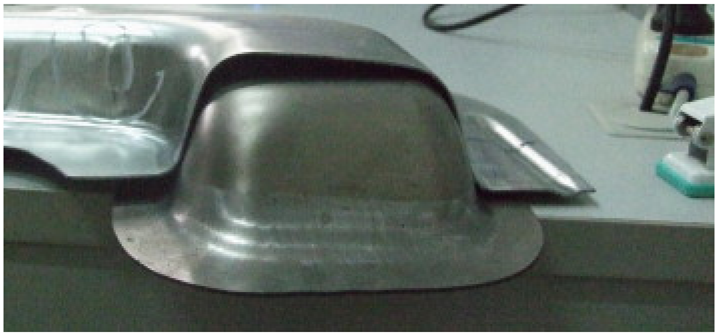


Figure 2.1: The twist springback of workpiece section plane.

Twist springback is described as a twisting component tends to return to its original form once a torsion stress has been removed [7]. If a workpiece twists above its elastic limit, the twist angle returns elastically when the stress is removed. This phenomenon is defined in mechanics because of torsional moments in the workpiece's cross-section. The bending angle changes, before and after unloading, can be used to describe the springback torsion value, as shown in Figure 2.2. In the case of twist springback, the angle of residual twist is defined by the position on the curve from which unloading begins as well as the shape of the elastic unloading line. Twist springback is a function of twist angle and elastic modulus of elasticity. [8].

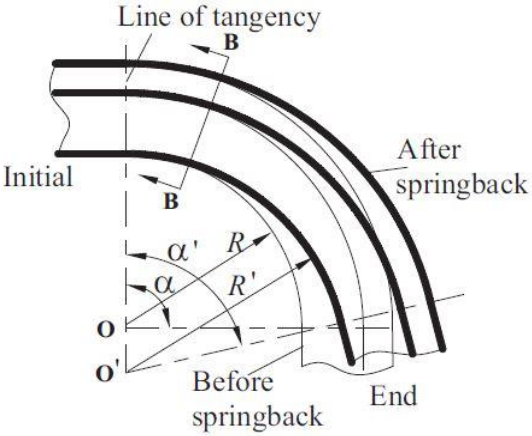


Figure 2.2. Definition of longitudinal twist springback angle[8]

2.4 Parameters Affecting Twist Springback Behavior

A range of technical factors affect springback, including material properties, thickness, lubrication variables, cutting tool, and process parameters. The challenge is that the behaviors and design concepts established in traditional mild steels may not be applicable to such high-strength steels, forcing a costly and time-consuming trial-and-error method to meet the design criteria. [6].

The twist springback factors can be investigated using two methods, experimental and simulation. Simulation is used to assess the manufacturability of sheet metal parts and can be an effective tool for determining springback. A typical forming condition, on the other hand, may involve several multifactor concerns that can be difficult to precisely simulate, resulting in a significant variance between experimental and simulated outcomes [9]. The existing approach of managing twist springback is still based on time-consuming and resource-intensive trial-and-error experiments. This would result in a longer development period and increased expenditures.

2.5 Material Properties

Different Different materials respond differently, resulting in a variety of springback behaviors. At equivalent torque, for example, springback is larger in aluminum than in mild steel [10]. This is since aluminum has a lower Young Modulus value than mild steel. Furthermore, the elastic modulus, thickness, and shape of a part can all influence its deformation [11]. The degree of springback is approximately proportional to the ratio of residual stress after unloading to elastic modulus of material. If steel sheets are deformed significantly in forming, the elastic modulus has a significant impact on twist springback behavior.

As the elastic stress increases, the springback also increases at high yield strength. After the parts are manufactured, materials having a low Young Modulus and a high yield strength have a large springback. Strain hardening improves the mechanical characteristics of cold-formed profiles, leading in larger yield stresses. When a result, as the yield strength of the material increases, so does the springback angle.

2.6 Geometries

Part geometries such as the thickness, width and length of the workpiece have been found to directly affect the twist springback behaviour. Thickness is one of the part geometries that contribute significant effect.

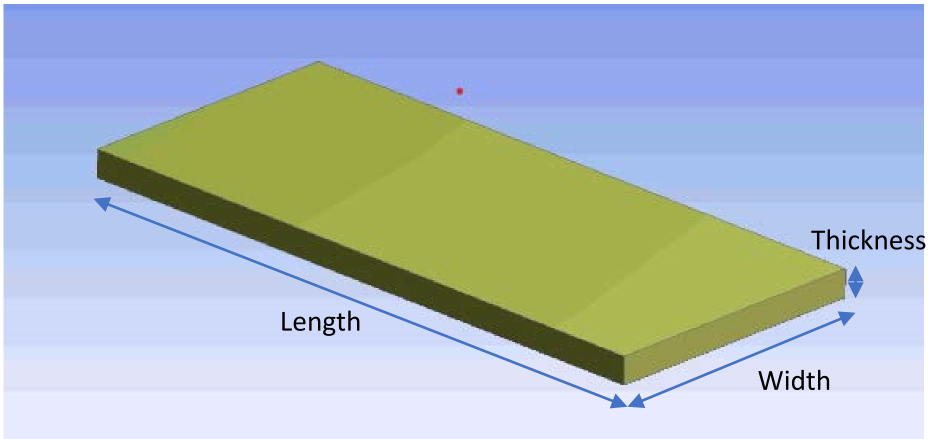


Figure 2.3 Illustration of the geometries (3D model strip)

Previous research has demonstrated that increasing the thickness of the workpiece reduces the springback angle. Similar trends were observed in the studies by Nazmi [12] on springback. Greater workpiece thickness causes increased surface stresses and substantial plastic deformation, reducing springback responsiveness. A thin sheet metal, on the other hand, has a lower plastic zone, which increases the springback angle. In terms of specimen length, there is no substantial effect on the angle of twist. According to previous research, in terms of specimen geometry, only the thickness of the specimen plays a major role, whilst the specimen length and width have no obvious effects on the twist springback behavior.

2.7 Material Characteristic

One of the important decisions you must make when working on an extrusion project is alloy selection. You may be considering 6061 aluminums, as it is one of the most extruded alloys. It’s an alloy with a long history. Developed in 1935, it was originally called “Alloy 61s.” Today, people also refer to it as “structural aluminum.” Its mechanical properties make it ideal for a wide range of applications. However, it is especially suitable for applications such as building products, electrical products, piping, and recreational products. It is a wrought alloy, as opposed to a casting alloy. So, it can be extruded, rolled, or forged into a variety of shapes[13].

In the "O" temper or annealed condition, alloy 6061 has good formability. In the T4 condition, severe forming can be done, whereas, in the T6 condition, properties may be obtained by artificial aging.

From research paper, the quasi-static and dynamic yield and flow behavior of Al-6061-T6 and Al-6061-OA are investigated under uniaxial tension loading at the test temperatures range from room temperature down to -1700C. At all strain rates, Al-6061-T6 showed high strength but lower ductility than Al-6061-OA. In the Split-Hopkinson Tension Bar (SHTB) experiments, both heat treatments showed slightly positive strain rate sensitivity and high work hardening after necking. As test temperature decreases, both materials show significant increased tensile strength. The necking strain increases as strain rate increases and test temperature decreases[14].

2.8 Summary

According to the literature, previous research has mostly concentrated on uniform thickness sections, with investigations of dissimilar material sections on the measurement and prediction of twist springback still insufficient. Type of material is one of the most critical factors influencing twist springback behavior. Therefore, the dissimilar material section may affect the observation and much difficult to predict the springback.

As a result, as described in the literature, parameters such as twist angle, material type, and thickness are important. Twist angle is the angle at which the workpiece is twisted to perform the twist forming process, which is important in predicting twist springback, and different material types with varying mechanical qualities produced different twist springback results. The deformation of a part can be impacted by the material's Young's modulus and yield strength. In order to estimate twist springback on dissimilar materials, previous research is used to create a theoretical analysis that was supported by experimental data. There are limited studies to measure the twist springback for similar and dissimilar aluminum.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The procedures and methods used in this investigation are explained in this chapter. The research is carried out through finite element (FE) simulation. The simulation's input parameters, such as the stress-strain curve for the chosen material, were collected from various of sources. Figure 3.1 shows the overall research flow chart for this study.

3.2 Finite Element Analysis

The specimen profile used in the simulation is shown in Figure 3.2, which illustrates a typical twist springback occurrence in a twist formed specimen profile. Because images from other directions are difficult to obtain in experimental evaluations, the twist springback would be measured in the elastic range.

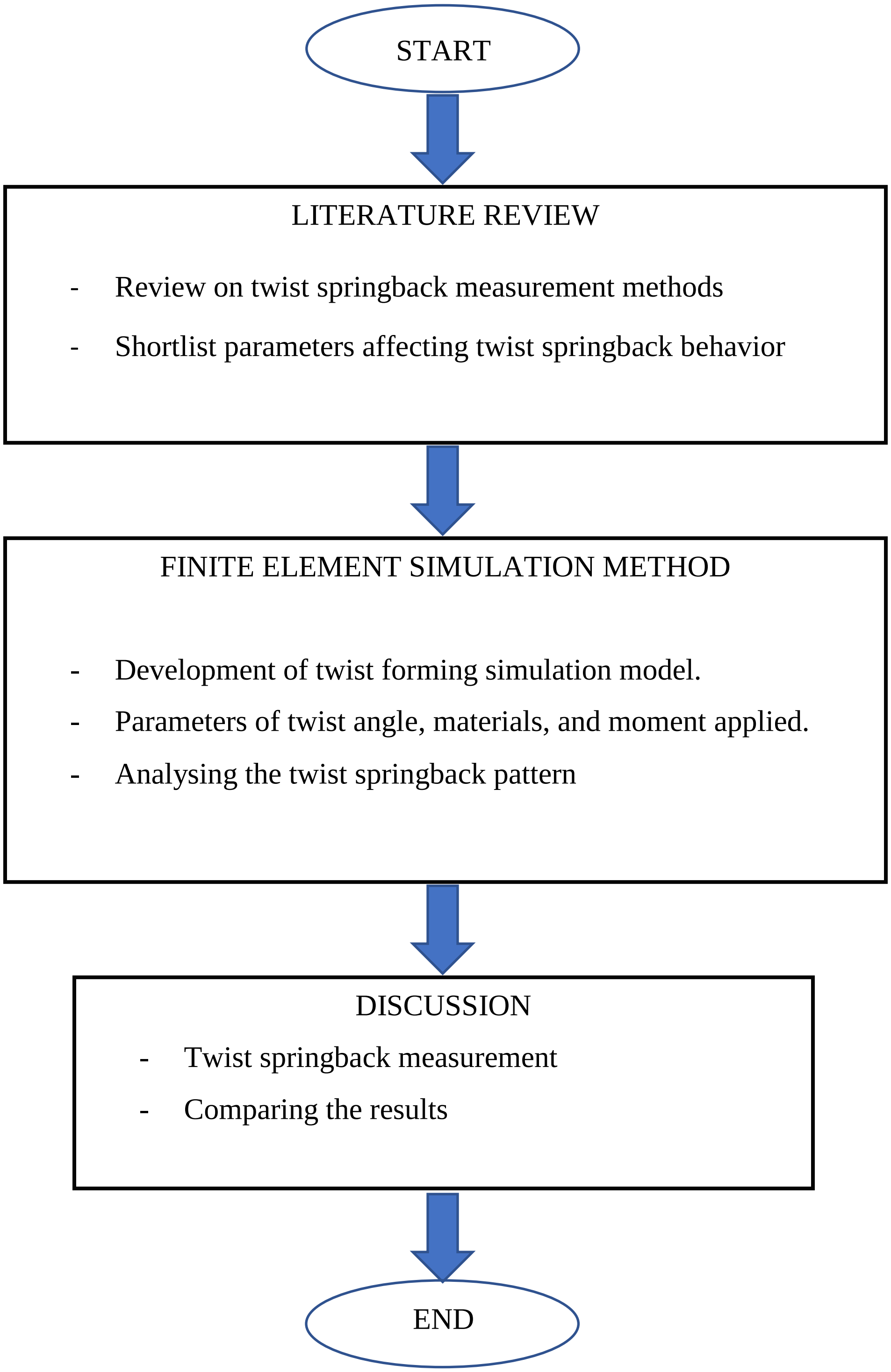


Figure 3.1. Flow chart of the research

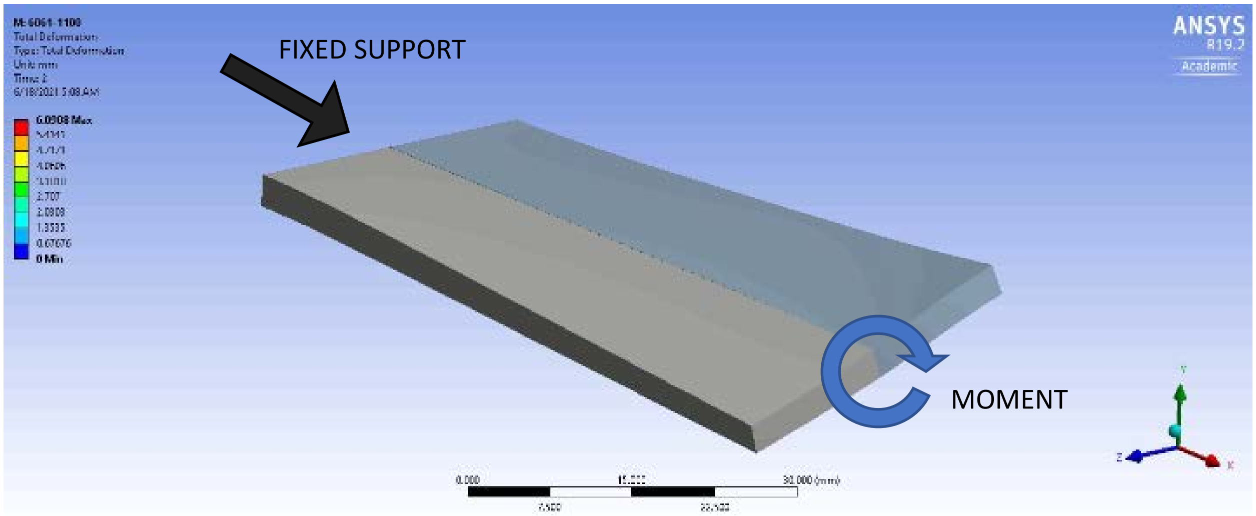


Figure 3.2. Illustration of the specimen model for simulation process

3.2.1 3D Modelling

For finite element simulation of the twist forming process, the specimen geometry was produced in the 3D CAD software SolidWorks and exported to ANSYS Workbench 16.0. The static structural analysis method was used, and isotropic hardening is considered as the material's plasticity to obtain the springback. The simulation is divided into two parts, loading, and unloading. To perform the twist forming operation, a range of 3000, 4000, and 5000 Nm of moment of force was applied during the loading step. The moment was quickly released during the unloading process to get the specimen profile where the twist springback would occur. After obtaining the deformed profile, if the simulation results in good agreement with the experimental results, the result is considered satisfied. If not, the simulation is repeated. Figure 3.3 shows the flow chart of the steps taken in the finite element simulation. There are several types of aluminium to choose from, but just six of the most used are compared. AA 6061-T6, 6061-OA, 5052, 7075, 5083, and 1100 were chosen.

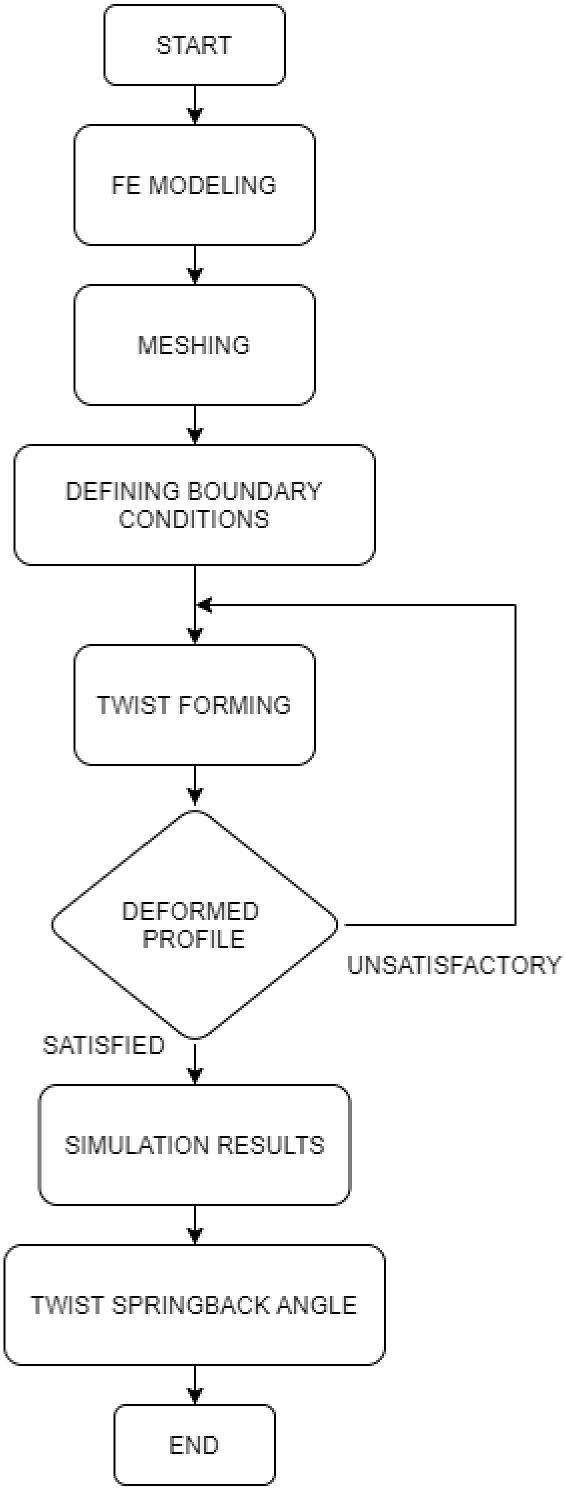
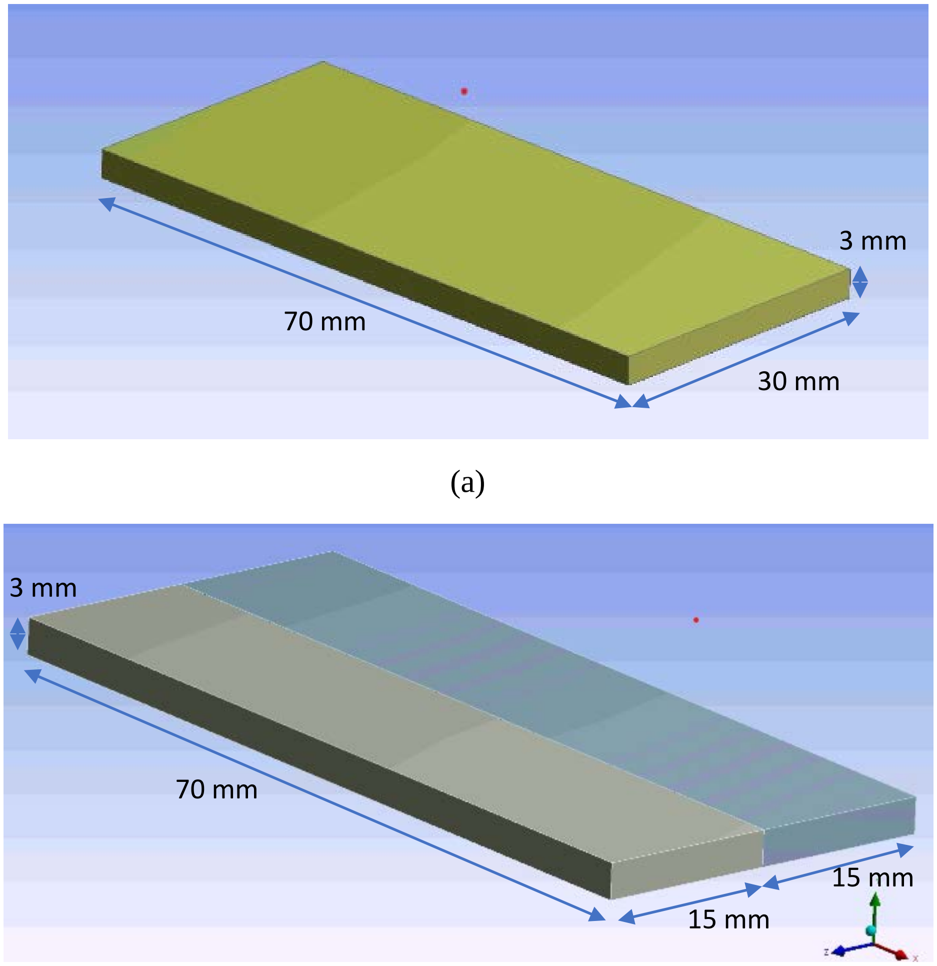


Figure 3.3. Flow chart of simulation

The twist springback behavior has been found to be directly affected by part geometries such as the thickness, width, and length of the workpiece. However, in this study the geometry is neglected. Figure 3.4 shows the geometry of the similar (a) and dissimilar (b) specimen that been used in the simulation.



(a)

(b)

Figure 3.4. The developed model of the profiles (a) similar aluminium, (b) dissimilar aluminium

3.2.2 Meshing and Boundary Conditions

To get a sufficient mesh density, a meshing operation was performed on the imported 3D model. Optimizing the mesh density would significantly reduce simulation time. The convergence tests indicated that increasing the number of elements beyond 7956 had just a little impact on the results. As a result, the meshing parameters were determined to be 7956 elements with an element size of 0.9 mm, as illustrated in Figure 3.5. To simulate the twist forming process, the moments and boundary conditions were defined on the surface area and applied to the deformed geometry. Figure 3.6 shows the locations of the fixed support (a) and moments (b) on opposing sides of the specimen, representing the real twist forming conditions.

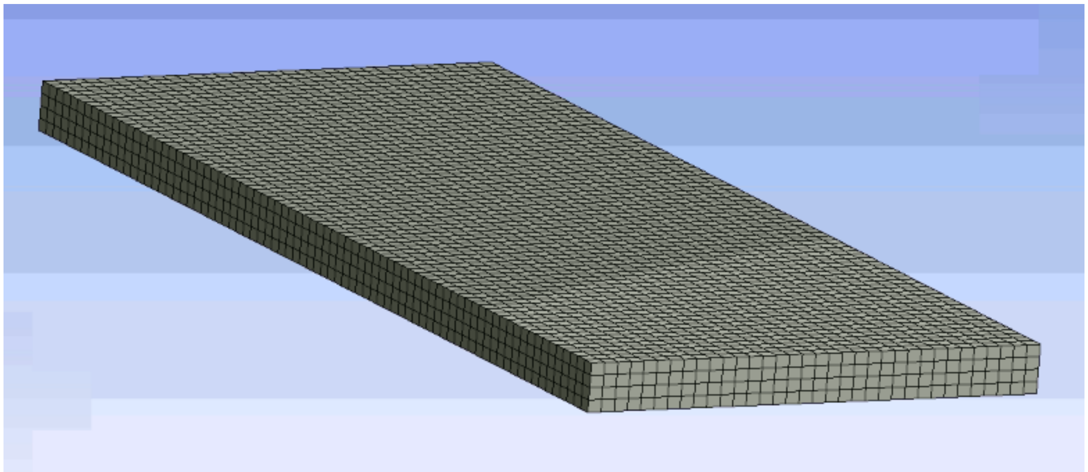


Figure 3.5. Specimen with suitable meshing (7956 elements. 0.9 mm element size)