OPTIMISATION DEEP DRAWING PROCESS PARAMETERS USING FE SIMULATION

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ABSTRACT

This paper presents the modeling simulation and experimental validation of cylindrical cup deep drawing. Prediction of the deep drawing results which includes determination of the optimum Blank Holder Force (BHF) and the thickness distribution of the sheet metal (blank) will decrease the production cost and time. Before performing the Finite Element (FE) analysis, it is required to understand the sheet metal (blank) properties and material model. In this FE analysis, the effect of fixed BHF on the cylindrical cup wall thickness distribution is examined. According to the experimental study, the optimum and maximum values of fixed BHF was at 1 kN and 11 kN respectively. These values are determined without the blank exceeding the tearing limits. Comparison of simulation and experimental study indicates that the FE model is considered valid, which can be seen from the similar thickness profile of simulation and experimental results.

ABSTRAK

Kajian tesis ini berkaitan simulasi permodelan dan pengesahan eksperimen terhadap cawan silinder penarikan dalam. Jangkaan keputusan penarikan dalam yang mencakupi penentuan nilai optimum daya pemegang contoh-kosong (*BHF*) dan agihan ketebalan kepingan logam (*blank*) akan mengurangkan kos dan masa proses pengeluaran. Sebelum melakukan analisa Unsur Terhingga, ia memerlukan pemahaman berkaitan sifat-sifat kepingan logam dan pemodelan bahan. Di dalam analisa Unsur Terhingga, kesan daya tetap *BHF* terhadap agihan ketebalan dinding cawan silinder dikaji. Melalui kajian eksperimen, nilai optimum dan maksimum *BHF* ialah 1 kN dan 11 kN masing-masing. Nilai ini ditentukan tanpa *blank* melebihi tahap kegagalan koyak. Perbandingan di antara kajian simulasi dan eksperimen menunjukkan model Unsur Terhingga boleh digunakan, ia diperhatikan daripada keputusan bentuk ketebalan di antara simulasi dan eksperimen yang menunjukkan kesamaan.

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LIST OF SYMBOLS

S_u - ultimate tensile strength
S_0 - initial sheet thickness
r - normal anisotropy
$\bar{r}$ - average normal anisotropy
c - constant value lies between 2 and 3
h_c - height of the cup
d_0 - initial diameter of
V^T - nodal point velocities
Δr - planar anisotropy
A - current section area
A_0 - initial cross sectional area
F - load on the specimen
f - the residual of the nodal point force vector.
$\mathbf{K}$ - stiffness matrix
K - strength coefficient
L - current length
L_0 - initial length
ΔL - displacement

Greek symbols

β - drawing ratio
μ - coefficient of friction
ε_{true} - true strain
σ_{true} - true stress
v - punch speed
ε_0 - initial strain
ε^P - plastic strain

Superscripts

n - strain hardening coefficient
T - transposition

LIST OF ABBREVIATION

BHF	-	Blank Holder Force
FE	-	Finite Element
FLD	-	Forming Limit Diagram
LDR	-	Limiting Drawing Ratio
*P*BH	-	Blank Holder Pressure

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CHAPTER I

INTRODUCTION

1.1 Introduction

The main strategy of automotive industry to reduce fuel consumption is to increase the percentage of light materials in car, mainly outer body. The main reason of this direction is because by reducing the weight of the car means increasing mileage per liter of fuel. The benefits of this are not only to reduce fuel consumption but also to protect our environment. The need to improve fuel economy and reduce emissions is an opportunity to expand the applications of light materials, particularly in body structures.

Energy use and the CO2 emissions caused by transport have increased significantly. This increase has been caused by the rapid growth in the size of the world's vehicle fleet. The manufacturers of vehicles and their suppliers are seeking ways to reduce the environmental impacts caused by transport. Different life cycle assessments have shown that reducing 1kg of a car body saves about 20 kg of greenhouse gas emissions (in CO2 equivalents).

Aluminum alloy can be categorized as a relatively light metal compared to metals such as steel, nickel, brass, and copper with a specific gravity of 2.7. It is a silverish white metal that has a strong resistance to corrosion which is a result of an oxide skin formed as a result of reactions with the atmosphere. This corrosive skin protects aluminum from most chemicals, weathering conditions, and even many acids. However alkaline substances are known to be able to penetrate the protective skin and corrode the metal.

Aluminum alloy is easy to machine and can have a wide variety of surface finishes. It is a very versatile metal and can be casted in any form. It can be rolled, stamped, drawn, spun, roll-formed, hammered and forged. The metal can be extruded into a variety of shapes, and can be turned, milled, and bored in the machining process. Aluminum can be riveted, welded, brazed, or resin bonded. For most applications, aluminum needs no protective coating as it can be finished to look good, however it is often anodized to improve color and strength

Deep drawing is one of the most important processes for sheet metal forming which is also widely used to fabricate automotive components such as Panel Floor Reinforcement and Support Grille Assembly. Deep drawing is a process in which a blank or work piece usually controlled by a pressure plate is forced into and/ or through a die by means of a punch to form a hollow component. The thickness is substantially the same as that of the original material. It is a complex forming process which is governed by many different parameters.

FE simulation is a method which can be applied to determine the optimum process parameters in deep drawing. It is a computer simulation technique used in engineering analysis. It uses a numerical technique called finite element method. The basic concept of the finite element method is discretization. A number of finite points are identified in the domain of the function. The values of the function and its derivatives when appropriate are specified at these points. The points are called nodal points. The domain of the function is represented approximately by a finite collection of subdomains called finite elements.

The main advantages of the finite-element method are the capability of obtaining detailed solutions of the mechanics in a deforming body, namely velocities, shapes, strains, stresses, temperatures or contact pressure distributions.

1.2 Problem Statement

Aluminum alloy or AA 5182 is a wrought aluminum in 5000 series. This AA 5182 has a limiting formability, therefore, it is important to determine the material limitation. Blank holder force (BHF) is one of the important parameters to control the wrinkle and tears of product. Each material with geometry product should have BHF limits where lower BHF cause the possible of wrinkle while higher BHF cause the possible of tears.

Finite element method (FEM) is a very effective method to simulate the forming processes with accurate prediction of the deformation behaviors. FEM can be used not only in the analysis but also in the design to estimate the optimum conditions of the forming processes. This can be done before carrying out the actual experiments for an economical and successful application to industrial components.

Trial and error is a common method that used in industry to determine blank holder force (BHF) which is takes a lot of time and very costly. Numerical simulation is a method to get fast result and inexpensive to determine optimum BHF. However, to perform numerical simulation the followings must be comprehended:

a. Material properties of the blank (Aluminum sheet metal).
b. Representative material constitutive equation.
c. Understanding the interaction between part geometry during process.

1.3 Objectives

The main objectives of this work are:

1. Determine the material properties of aluminum alloy 5182 in order to obtain valid input of material parameters in material model.
2. Select the material model for aluminum alloy 5182.
3. Conduct FE simulation using FE software with applicable non-linear transient dynamic analysis to determine optimum BHF value respect to friction coefficient (μ) and punch speed (v).

1.4 Scope

1. Material: Aluminum 5182.
2. Geometry Product: Cylindrical Cup.
3. Modeling and Simulation: Using FE software (ABAQUS CAE) to perform finite element analysis.
4. Experimental: Using Erichsen Test Machine and Universal Tensile Test.
5. Parameters: Fix the friction coefficient (μ) and punch speed (v).

1.5 Research Methodology

The details of the methodologies are explained in Chapter III and IV. Below are the summary of this research methodology.

1. Material Testing
   Perform tensile test on Aluminum 5182 sheet metal according to ASTM E8.
2. Material Model
   Select the modeling material behavior in deep drawing process for Aluminum 5182.
3. FE simulation
   Using FE software (ABAQUS CAE) to simulate optimum blank holder force (BHF) which respect to friction coefficient (μ) and punch speed (v).
4. Experimental
   Using selected BHF to determine percent of error between simulation and experimental result based on the thickness distribution.

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