UNIVERSITI PUTRA MALAYSIA

FINITE ELEMENT ANALYSIS OF SPRING BACK PHENOMENON IN V-BENDING OF SHEET METAL

RAMADAN MUFTAH IMHEMED ELWIRFALLI.

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By

RAMADAN MUFTAH IMHEMED ELWIRFALLI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Partial Requirements for the Degree of Master of Science

June 2004

Dedicated to my Parents

And to my wife and kids Muftah, Elmoatasem Belah, Ryan

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the partial requirements for the degree of Maser of Science

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RAMADAN MUFTAH IMHEMED

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Chairman: Associate Professor Abdel Magid S. Hamouda, Ph.D.

Faculty: Engineering

The objective of this study is to determine numerically, the effect of different parameters on springback phenomenon during sheet metal forming process. Nonlinear numerical simulation was performed using a finite element commercial MSC MARC software. Numerical results were verified with available experimental data obtained from the literature.

Four parameters namely, the effect of material type, sheet thickness, friction and punch radius were evaluated in springbak phenomena.

In evaluating the effect of material types on springback phenomenon, high tensile steel (HTS), mild steel (MS), deep drawing steel (DDS) and commercially pure aluminium (CA) were used. The computational results showed that the value of springback is influenced by type of material.

Deep drawing steel displayed the highest value of springback (3.48°), while the lowest springback value was recorded for mild steel (2.06°).

The effect of friction coefficient on springback phenomenon was determined using different friction coefficient ranging between 0.1 and 0.5 with increment of 0.1. Friction coefficient 0.5 displayed the highest value of springback (3.8°) and the lowest value of springbak (2.4°) was recorded for friction coefficient 0.1 which means that springback increases as friction coefficient increases.

Sheets have thickness of (3mm, 5mm, 8.3mm, 10mm and 12.8mm were evaluated for springback phenomenon. The results showed that the springback values decreases as sheet thickness increases. 3 mm sheet computed to have the highest value of springback (7.65°), 12.8 mm sheet had the lowest springback value (2.88°).

Finally, (3mm, 5mm, 8mm, 10mm and 12mm) punch radius were also evaluate to study their effect on developed springback,. The results showed that as the punch radius increases the springback values increases. The punch with 12mm radius exhibited the highest value of springback (5.84°) and the lowest springback value of 1° was computed for punch with radius of 3mm.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

ANALISIS UNSUR TERHINGGA TERHADAP FENOMENA MEMBIDAS BAGI BENGKOKAN –V TERHADAP KEPINGAN LOGAM

Oleh

RAMADAN MUFTAH IMHEMED

June 2004

Pengerusi: Professor Madya. Abdel Magid S. Hamouda, Ph.D.

Fakulti: Kejuruteraan

Tumpuan kerja ini adalah bagi mengkaji secara berangka kesan parameter yang berbeza ke atas fenomena membidas semasa proses pembentukan kepingan logam. Simulasi berangka tak lelurus telah dijalankan menggunakan perisian komersial MSC MARC. Keputusan berangka telah disahkan dengan data eksperimen yang sedia ada dari literature. Empat parameter telah diambilkira dalam kajian ini iaitu, kesan terhadap jenis bahan, kesan ketebalan kepingan, kesan geseran dan kesan jejari penebuk.

Untuk kesan jenis bahan terhadap fenomena membidas, empat jenis bahan telah diambilkira iaitu keluli tegangan tinggi (HTS), keluli lembut (MS), keluli penarikan dalam (DDS) dan aluminium tulen komersial (CA). Keputusan berkomputer sangat sensitive kepada jenis bahan. Mengikut urutan, keluli penarikan dalam mempamirkan nilai membidas tenaga tertinggi (3.48°), manakala nilai membidas terendah telah direkod oleh keluli lembut (2.06°).

Sebaliknya kesan angkali geseran ke atas fenomena membidas, angkali geseran yang berbeza telah diubah diantara 0.1 dan 0.5 dengan tokokan 0.1. Angkali geseran (0.5) telah menghasilkan nilai membidas (3.8°) tertinggi dan nilai membidas terendah telah direkod oleh angkali geseran 0.1. Ini bermakna membidas bertambah dengan pertambahan angkali geseran.

Lima nilai ketebalan logam telah dikenalpasti bagi mengkaji kesan ke atas fenomena membidas. Untuk tujuan ini, kepingan dengan ketebalan berbeza telah dikenalpasti (3mm, 5mm, 8.3mm, 10mm dan 12.8mm). Keputusan menunjukkan nilai membidas berkurangan dengan pertambahan ketebalan kepingan. Mengikut urutan, logam dengan ketebalan 3mm menghasilkan nilai membidas yang tertinggi (7.65°), manakala nilai membidas yang terendah telah direkod oleh ketebalan logam 12.8mm.

Akhir sekali, lima nilai jejari penebuk (3mm, 5mm, 8mm, 10mm dan 12mm) telah di ambilkira untuk mengaji kesannya ke atas membidas. Keputusan menunjukkan yang nilai membidas bertambah dengan penambahan jejari penebuk. Penebuk dengan jejari 12mm menunjukkan nilai membidas tertinggi (5.84°) dan nilai membidas terendah sebanyak (1°) telah menghasilkan untuk penebuk berjejari 3mm.

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I certify that an Examination Committee met on 2nd June 2004 to conduct the final examination of Ramadan Muftah Imhemed on his Master of Science thesis entitled "Finite Element Analysis of Spring Back Phenomenon in V-Bending of Sheet Metals" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Jamaloddin Noorzaei, Ph.D.
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Barkawi bin Sahari, Ph.D.
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Yousif A. Khalid, Ph.D.
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Ahmad Kamal Ariffin Mohd Ihsan, Ph.D.
Associate Professor
Faculty of Engineering
Universiti Kebangsaan Malaysia
(Independent Examiner)

GULAM RUSUL RAHMAT ALI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 26 AUG 2004

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Abdel Magid S. Hamouda, Ph.D.

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Megat Mohamad Hamdan,Ph.D.

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Elsadiq M. A. Saad, Ph.D.

Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

AINI IDERIS,Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 10 SEP 2004

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

RAMADAN MUFTAH IMHEMED

Date: 25/08/04

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NOMENCLATURE

Symbol

E	Young's Modulus (GN/m^2)
K	Numerical Constant
L_b	Bend Allowance
n	Strain Hardening Exponent
MBR	Minimum Bend Radius
R	Bend Radius
UTS	Ultimate Tensile Strength
T	Sheet Thickness
W	Width of Die Opening in Span of Beam
α	Bend Angle (in radian)
ε	Strain
ν	Poisson's Ratio
σ	Stress (N/m^2)
σ_y	Uniaxial Yield Strength
K_s	Strength Coefficient
$\Delta\theta_{EXP}$	Experimental Springback Angle
$\Delta\theta_{FEM}$	Predicted Springback Angle
u	Nodal Displacement Vector
K_t	Current Tangent Stiffness Matrix
F	External Load Vector
I	Internal Force Vector
B_k	Stress-Displacement Matrix for the k_{th} Element
v_k	Element Volume
σ_n	Normal Stress (N/m^2)
σ_t	Tangential Friction Stress (N/m^2)
μ	Friction Coefficient
t	Tangential Vector in the direction of the Relative Velocity
v_r	Relative Sliding Velocity

r	Tensile reduction of area
P	Bending Force
L	Length of the bend
A	Cross-Sectional Area $(mm)^2$
α_1	Bend angle under load
α_2	Bend angle after load
σ_0	Yield stress in a simple tension test (N/m^2)
τ_0	Yield stress in a simple shear test (N/m^2)
k_1, k_2	Material constants
N08904	Stainless steel material type

CHAPTER 1

INTRODUCTION

Sheet metal parts are produced in large quantities using special tooling and high-volume production techniques. The processes are predominantly tensile in nature and the amount of deformation that can be achieved in a single stage may be limited by the onset of tensile instability, necking and tearing. On the other hand, the sheet is usually thin so the buckling or wrinkling may take place in regions where one of the membrane stresses is compressive. The art and science of sheet metal forming is to devise processes in which the required shapes can be achieve without tearing or wrinkling and, furthermore, that the margin of safety in the operation is sufficient to tolerate variation in material properties and tooling conditions that will inevitably occur in a production system. Many sheet parts are of low cost and sold in a highly competitive market. The material cost may be a large fraction of the overall value and the part must be formed from the smallest possible piece of sheet or "blank".

As automotive industry is growing rapidly the demand for precise and accurate information concerning parts design and formability of metal sheet becomes essential. Aluminium sheet becomes favourable compared to steel with regards to some improvement at aerodynamic designs, increased engine efficiency and fuel economy.

Wide range of aluminium automotive product included doors, fenders, bumpers face bars, seat frames and backs, heat shields and roof panels have been produced.

Proper design of part geometries, forming tools and processes, and effective lubrication can effectively produce high quality fracture-free aluminium component. Strong understanding of forming process is critical to produce high quality and cost effective products. New equipment and control capabilities may lead to improve the forming process of complex shapes.

1.1 Importance of Study

Sheet metal forming is a technologically important process in manufacturing industries that allows economical production of parts with complex shapes from flat sheet stock. In industry, a great deal of time and money is consumed in finding appropriate tool geometries and manufacturing parameters by trial and error, whereby physical experiments must be performed and tools are repeatedly modified in response to the experimental results. The design of the required tooling and the process specifications represent critical issues that affect the cost and schedule associated with the production of sheet metal parts.

The aim of most current sheet metal forming research is to minimize the time and cost for process development and production while minimizing scrap and optimizing the quality of the parts produced. Finite element analysis is recognized by both researchers as well as industrial practitioners to be the key enabling technology for achieving these goals. Finite element simulations, can be used for predicting key outcomes of the forming process such as the final shape of the part, flow of material, possibility of failure based on necking, wrinkling, and/or forming limit diagrams and amount of spring back. Finite element analysis can be advantageously used to minimize die tryout and in addition provide the insights needed to guide the determination of optimum process parameters to minimize the cost of production. Finite element techniques are probably the only practical tool or analysis of realistic sheet metal forming operations with complex 3-D geometries, multiple forming steps and complex material models.

1.2 Problem Statement

Sheet Metal Forming is a very old process. Sheet forming dates back to 5000 B.C, when household utensils and jewellery were made by hammering and stamping gold, silver and copper. Currently sheet is produce by sheet mills and machines carry out forming process. Because of low cost and generally good strength and formability characteristics, low-carbon steel is the most commonly commercial material used for sheet metal. Where as in automobile, aircraft and aerospace applications common sheet materials are aluminium and titanium. Nowadays the use of aluminium is increasing especially in automobile industries.

Sheet metal forming consists of three basic processes: -

- Cutting to form a shape (blank).
- Forming by bending and stretching.
- Finishing.

In sheet metal forming operations, the final shape of metal sheet greatly depends on the rate of springback after the removal of the applied loads from the deformed sheet.