Size effects on flow stress and springback behaviour in micro metal forming

A thesis submitted in partial fulfilment of the requirements
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From

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Certificate of original authorship

I, [Mandeep Singh], declare that this thesis is submitted in fulfilment of the requirements for the award of Master of Engineering (Research) in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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List of Publications

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http://www.testmagzine.biz/index.php/testmagzine/article/view/2878

2. Singh, M., Hossian, A. & Wei, D. 2019 "A Hybrid Model for Studying the Size Effects on Flow Stress in Micro-Forming with the Consideration of Grain Hardening", *Key Engineering Materials*, Vol. 794, pp. 97-104.
https://doi.org/10.4028/www.scientific.net/KEM.794.97

3. Singh, M. & Wei, D. 2018 "Size effects in Micro Forming: A review", *International Review of Mechanical Engineering* (IREME) ISSN 1970-8734, Special issue (print form). https://www.scribd.com/document/385504833/Mandeep2018-Dongbin

4. Singh, M., Sharma, S & Sharma, S. 2017 "Criticality of Micro-Forming Process - A Review", *International Journal of Emerging Trends in Engineering and Development*. 7(4), pp.191-198. RS publication.

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List of Abbreviations and symbols

1. Abbreviations

LVDT	-	Linear variable differential transformers
DCE	-	Double cup extrusion
ASTM	-	American society for testing and materials
MEMS	-	Micro-electromechanical systems
FEA	-	Finite element analysis
CAE	-	Computer aided engineering
AGI	-	Average grain intercept
SSD	-	Statistically stored dislocations
GND	-	Geometrically necessary dislocations
UTM	-	Universal testing machine
3D	-	Three-dimensional

2. Symbols

T	-	Thickness
D	-	Grain size
E	-	Young's modulus
ε	-	Plastic strain
ʎ	-	Scaling factor
V	-	Punch velocity
Ɛ	-	Logarithmic strain
σ_c	-	Flow stress in the cell interior
σ_w	-	Flow stress in the cell wall
ρ	-	Density

l	-	Material intrinsic length
l_m	-	Modified material intrinsic length
P	-	Conventional effective plastic strain
ŕ	-	Nye factor
Z	-	Taylor factor
M_P	-	Plastic bending moment
M_E	-	Elastic bending moment
θ_s	-	Springback angle
$\nabla\varepsilon$	-	Strain gradient effect
R_a	-	Arithmetic average of the roughness profile
V	-	Voltage

Abstract

The continuing trend of micro metallic devices and product miniaturization has motivated studies on micro metal forming technologies. A better understanding of material deformation behaviours with size effects is important for the design and operations of micro metal forming processes. In this dissertation, uniaxial micro tensile testing was conducted on copper specimens with characteristic dimensions to micro scales. The experimental results disclose the existence of size effects and reveal the inadequacies of the existing material models. Micro tensile experiments were carried out on copper specimens with varying grain sizes. The size effects on plastic deformation were demonstrated and were further elucidated by comparison between experimental results and the output of finite element simulations. The surface roughness assessment on tensile tested copper specimen showed the significant influences of size effects in micro metal forming process. Micro V-bending was conducted on copper foils with varying thicknesses and grain sizes. The material intrinsic length was observed and modified according to the average number of grains along the characteristic scale direction of specimen. The analytical model of springback with modified material intrinsic length was established and evaluated by employing MATLAB. This study also presents a research work aiming at the design and manufacturing of a compact UTM compatible with a 3D laser-confocal microscope for observing the deformation behaviour of materials in real-time.