DEVELOPMENT AND ANALYSIS OF DIRECT CURRENT LOW ENERGY MICRO-SHEET-FORMING MACHINE

CHANG TAI ANN

Master of Engineering(Mechanical)

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering in Mechanical

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(Supervisor's Signature)

Full Name : DR. AKHTAR RAZUL RAZALI

Position : Senior Lecturer

Date : 1/11/2016

STUDENT'S DECLARATION

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

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(Student's Signature)

Full Name : CHANG TAI ANN

ID Number : MMM14024

Date : 1/11/2016

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Ra	Average roughness
Ah	Charge
I	Current
Ω	Electrical resistance measured in Ohms
F	Force
Hz	Frequency measured in hertz
k	Kilo
L	Length
Rz	Mean roughness depth
μm	Micrometer
V_m	Min. Volts
N	Newton
A_p	Peak Amps
W_p	Peak Watts
P	Power rating
V_o	Tapped density
T	Thickness
t	Time consumed measured in seconds
V	Voltage measured in volts
W	Watt
Wh	Watt-hour

LIST OF ABBREVIATION

AC	Alternative current
AFM	Atomic force microscopy
CNC	Computer numerical control
CVD	Chemical vapour deposition
DAQ	Data acquisition
DC	Direct current
ECM	Electrochemical machining
EDM	Electrical discharge machining
EMF	Electro-magnetic filter
FEM	Finite element method
FFT	Fast fourier transform
FRF	Frequency response function
FSR	Force sensitive resistor
LIGA	Lithographie, Galvanoformung, Abformung
MEL	Mechanical engineering laboratory
MEMS	Micro-electro-mechanical systems
NSOM	Near-field scanning optical microscopy

SEM	Scanning electron microscopy
STM	Scanning tunnelling microscopy
PVD	Physical vapour deposition
PZT	Lead zirconate titanate
UTS	Ultimate tensile strength
TEM	Tunnelling electron microscopy

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ABSTRAK

Permintaan yang meningkat terhadap mikro-produk telah mendorong perkembangan pesat dalam teknologi pembuatan mikro bagi bahagian-bahagian individu dan sistem, yang merangkumi pembangunan baru proses pembuatan, peralatan dan jentera. Banyak usaha yang telah dilakukan hingga kini untuk meningkatkan kecekapan teknologi pembuatan miniatur/ mikro. Walau bagaimanapun, tidak banyak kajian yang dilakukan terhadap penjimatan tenaga semasa pemprosesan bahan. Pengurangan saiz bahan yang diproses dijangka akan turut mengurangkan penggunaan tenaga secara berkadaran dengan skala miniatur. Fokus kajian ini adalah untuk merekabentuk mesin penghasil kepingan mikro yang menggunakan tenaga dalam kuantiti yang rendah bagi tujuan aplikasi pembentukan kepingan logam yang nipis, dan membina mesin penghasil kepingan mikro yang menggunakan arus terus dengan kuasa yang rendah. Di samping itu, kajian ini bertujuan mengukur dan menganalisis keupayaan dan kualiti mesin yang dibina. Beberapa konsep telah dihasilkan dan dinilai dengan melakukan analisis Kaedah Unsur Terhingga (Finite Element Method) dan perbandingan bahan-bahan. Konsep optimum telah dipilih untuk membangunkan reka bentuk yang terperinci. Pembinaan dan pemasangan mesin dilakukan berdasarkan reka bentuk konsep yang telah dipilih. Satu prototaip yang mempunyai sistem penggunaan tenaga yang rendah bagi mesin penghasil kepingan mikro merangkumi elemen-elemen mekanikal dan elektronik telah dibangunkan. Prestasi mesin ini telah diuji dari segi frekuensi asli, daya tebukan, kelajuan dan keupayaan penebukan, penggunaan tenaga (tebukan tunggal dan berdasarkan kekerapan masa). Mesin ini didapati mampu melakukan proses penghasilan kepingan mikro dalam satu peringkat tunggal untuk membentuk bahagian-bahagian kepingan logam yang nipis dengan ketebalan kurang daripada 100 mikron. Selain itu, mesin ini juga berkeupayaan menghasilkan sehingga 600 lejang seminit, dengan kapasiti daya sebanyak 320 N. Sejumlah 0.0038 Wh tenaga telah digunakan oleh mesin ini untuk menghasilkan satu bahagian tunggal. Oleh yang demikian, dapatlah dirumuskan bahawa kajian ini telah berjaya membangunkan sebuah mesin penghasil kepingan mikro yang menggunakan tenaga yang rendah bagi aplikasi pembentukan kepingan logam yang nipis.

ABSTRACT

Increased demands for micro-products have led to rapid development of micro-manufacturing technologies in the manufacture of individual parts and systems, which includes development of new manufacturing processes, tools and machinery. Tremendous efforts have been made, to date, to improve the efficiency of miniature-/ micro-manufacturing technologies. However, there has been lack of research on energy saving during which materials are being processed. It is expected that with the miniaturization of materials being processed, energy consumption is also being 'miniaturized' proportionally. The focus of this study was to design a low energy micro-sheet-forming machine for thin sheet metal application and fabricate a low direct current powered micro-sheet-forming machine. In addition, the research aimed to quantify and analyze the capability and quality of the fabricated machine. Several concepts were generated and these were evaluated by performing Finite Element Method (FEM) analysis and materials comparison. An optimal concept was selected to develop a detailed design. Fabrication and assembly of the machine was made according to the selected conceptual design. A prototype of low energy system for a micro-sheet-forming machine that included mechanical and electronic elements was developed. The machine was tested for its performance in terms of natural frequency, punching forces, punching speed and capability, energy consumption (single punch and frequency-time based). The machine was capable of single stage of micro-sheet-forming processes for thin sheet metal parts with thickness of less than 100 μm. Furthermore, it was also capable of producing up to 600 strokes per minute, with force capacity of 320 N. The energy consumption for the machine to produce a single part was 0.0038 Wh. Thus, it can be concluded that this research has successfully resulted in the development of a low energy micro-sheet-forming machine for thin sheet metal forming application.

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