THERMAL RESPONSE OF SILICON DURING VIRTUAL LASER MICROMACHINING

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Thesis submitted in fulfilment of the requirements for the award of the degree of Bachelor of Mechanical Engineering

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NOVEMBER 2009

SUPERVISOR’S DECLARATION

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

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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LIST OF ABBREVIATIONS

CAE	Computer Aided Engineering
FE	Finite Element
FEM	Finite Element Model
HAZ	Heat Affected Zone
MEMS	Micro Electro Mechanical System
Si	Silicon

NOMENCLATURE

k	Thermal Conductivity
ρ	Mass Density
Cp	Specific Heat
T	Temperature
Ta	Ambient Temperature
A	Area
E	Modulus Elasticity
αt	Thermal Diffusivity
τp	Pulse Width
°C	Degree Celsius
W	Watt
GW	Gigawatt
mm	Millimetre
cm	Centimetre
s	Second
ns	Nanosecond
ps	Picosecond
fs	Femtosecond
J	Joule
v	Velocity
N	Newton
t	Thickness

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Laser micromachining of silicon material for Micro Electro Mechanical System (MEMS) component was analyzed to decrease the defection of material. Laser machining also have problems in thermally induced cracks and laser debris, for sure need specific research and development. It has been an emerging technology in processing of silicon material for MEMS. The processing options of silicon material for development of MEMS are still relatively limited. In other side, MEMS fabrication has increasing demands for new requirement in production technology. In terms of high reproducibility and positioning with low production cost, the packaging and assembly were required high accuracy. In parts of forming metal sheets have been used long pulse and continuous lasers for macroscopic mechanical applications. Even thought, for MEMS manufacturing, the applicability of various laser types is limited by long relaxation time of the thermal fields responsible for forming phenomenon. For example, laser thermal forming, as usual is laser forming that is a flexible rapid prototyping and low volume manufacturing process. It has many advantages in technological compared to the conventional forming technologies such as forming of thick plates, design flexibility, possibility of rapid prototyping and production of complex shapes, in directly this laser thermal can applied in thermal response of silicon after it were analyze in FEM.

Process application of laser machining in real world is very difficult to control and waste a large amount of heat. Important of virtual work is easily conducted without produce amount of waste and save an energy and money. From this project, virtual work can find out an errors occur when implement laser cutting process. In simulation, prospective to define and to visualize the machining zone is being able and easily to control a process by considering parameters involve. Simulation works also give exposure to user to find an accuracy data and most important is it save money, time and energy. Parameter to be control easily detected from simulation work.

In terms of thermal, it will consider about heat propagation and effect on material selected that is silicon. Response of heat affect will show the temperature distribute when laser micromachining has been perform. Investigation of material response to thermal applied goes through with ALGOR software. Thermal transient for heat transfer can analyze to simulate the virtual laser micromachining with different geometry.

1.2 PROBLEM STATEMENT

Laser micromachining has been proposed for silicon processing particularly in micro electro mechanical system, electronic and optical industries. However, there are a lot of uncertainties in laser machining of silicon due to being unable to visualize the machining zone and difficult to control the real process, which frequently leads to producing large amount of waste.

1.3 PROJECT OBJECTIVES

i. To develop a predictable model for virtual laser machining of silicon

ii. To simulate laser machining of silicon varying machining parameters

iii. To obtain a relationship between temperature distribution in silicon and process parameters

1.4 PROJECT SCOPES

i. The predictable model will be developed using ALGOR

ii. Machining parameters considered are pulse duration and laser power

iii. The model geometry will focus on 2D linear and circular geometries

iv. Material model will be isotropic phase change model

v. Simulation will be carried out in ALGOR package to obtain temperature distribution and machining parameters will be established in EXCEL

1.5 ORGANIZATION OF THESIS

This thesis consists of five chapters.

Chapter 1: Introduction of project

Chapter 2: Literature review

Chapter 3: Methodology

Chapter 4: Result and discussion

Chapter 5: Conclusion and recommendation

ABSTRACT

This project presents thermal response of silicon during virtual laser micromachining based on finite element method. Predictable models were developed using ALGOR FE code to simulate laser micromachining and to predict temperature distribution in silicon due to laser material interaction. Two FE models, linear and circular cutting were developed. Thermal properties of silicon were taken from literature. Time dependent heat flux was defined at each node along cutting line, laser velocity was designed by model distance and time interval. Transient heat transfer analysis was used to simulate laser micromachining. Process parameters considered were laser power, velocity and plasma gas effect. Total of 28 simulations were done. The FE model was validated from published report. Results qualitatively were found to be agreeable. Crucial factors are found to be pulse energy and moving velocity in reducing thermal cracks and thermal debris. This virtual work can significantly reduce the cost and time for process development in industry, and improve product reliability.

ABSTRAK

Projek ini membentangkan tindak balas haba terhadap bahan silika ketika perlaksanaan pemesinan mikro laser berasaskan cara unsur terhingga. Model – model ramalan telah dibangunkan menggunakan kod ALGOR FE untuk mensimulasikan pemesinan mikro laser dan meramalkan penyebaran suhu di dalam silika merujuk kepada interaksi bahan laser. Dua model FE, pemotongan garisan lurus dan bulatan telah pun dibangunkan. Sifat – sifat haba silika diambil dari penulisan – penulisan lepas. Aliran haba dan pergantungan masa ditentukan pada setiap not sepanjang garisan pemotongan, halaju laser yang direka oleh jarak model dan jarak masa. Analisis pemindahan ketidaktetapan haba digunakan untuk simulasi pemesinan mikro laser. Parameter – parameter proses yang dipertimbangkan adalah kuasa laser, halaju dan kesan plasma gas. Jumlah 28 simulasi telah pun dibangunkan. Model FE disahkan daripada laporan yang pernah diterbitkan. Kualiti keputusan – keputusan didapati bersesuaian dengan laporan yang telah pun diterbitkan. Faktor kritikal di temui di dalam tenaga detik dan halaju pergerakan di dalam mengurangkan keretakan haba ke atas bahan. Keputusan ini berupaya menurunkan kos dan masa untuk proses pembangunan dalam industri dan memperbaiki kepercayaan produk.

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