MULTI OBJECTIVES PERFORMANCE OPTIMISATION OF ULTRASONIC ASSISTED DRILLING PARAMETER FOR GORILLA GLASS: PARAMETERS INVESTIGATION

Submitted in accordance with the requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

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ABSTRAK

Pada masa kini, kaca yang diperkuatkan secara kimia mempunyai permintaan yang tinggi dalam pelbagai industri kerana kaca ini mempunyai sifat-sifat yang sangat baik. Permintaan untuk mikromachining kaca berkembang pada masa sekarang untuk pembuatan alat-alat mikro. Walau bagaimanapun, micromachining kaca adalah satu cabaran besar kerana sifat kekerasannya yang tinggi dan sifat kelemahlembutannya. Ciri-ciri ini membawa kepada beberapa masalah semasa pemesinan seperti menghasilkan banyak burr, mengurangkan hayat alat, kekasaran permukaan dan ketepatan pemesinan. Untuk menangani cabaran ini, satu teknik penggerudian yang baru diperkenalkan, teknik ini melibatkan getaran ultrasonik bergabung dengan alat penggerudian putar untuk meningkatkan prestasi penggerudian. Teknik ini menggunakan mekanisme gerakan terputus-putus untuk memotong bahan. Mekanisme ini boleh menghasilkan proses pemotongan yang lancar dan meningkatkan proses penghapusan cip. Matlamat utama penyelidikan ini adalah untuk mencari parameter-parameter input yang optimum untuk penggerudian kaca yang diperkuatkan secara kimia. Untuk mengoptimumkan proses penggerudian ini, hubungan antara parameter-parameter seperti frekuensi, amplitud, kelajuan pemotongan dan kadar suapan pada prestasi penggerudian telah disiasat dalam kajian ini. Tindak balas proses utama yang diambil kira adalah kekuatan permotongan, keluasan penyingkiran di permukaan kemasukan dan pengeluran mata gerudi. Hasil kajian yang dijangkakan adalah menghasilkan keluasan penyingkiran di permukaan kemasukan dan pengeluran mata gerudi yang kecil, kekuatan pemotongan yang rendah dan juga permukaan yang baik tanpa pembentukan burr mengelilingi lubang dengan menggunakan teknik penggerudian ini.

ABSTRACT

Nowadays, chemically strengthened glasses are highly demanded in various industries due to their superior properties. The demands for micromachining of glass are growing for the manufacture of micro devices. Nevertheless, micromachining of glass is a big challenge due to the properties of high hardness and brittleness of the glass. These properties lead to some problems during machining such as generate large amount of burr, reduce tool life, surface roughness and accuracy of machining. To tackle this challenge, a new drilling technique ultrasonic assisted vibration combine with rotary drilling tool was introduced aim to increase the drilling performance. This technique uses intermittent motion mechanism for removing material which produces a smooth cutting process and improves the chip evacuation process. The main objective of this research is to investigate the optimal input parameters for drilling of chemically strengthened glass. In order to optimize the drilling process, the correlation between the combined parameters namely the frequency, amplitude, cutting speed and feed rate on drilling performances were investigated in this research. The main process responses that have be taken into account are cutting force, delamination area at entry and exit. The expected results of this study is to produce small delamination area at entry and exit, low value of cutting force and also a good surface finish without formation of burr surround the machined hole by using ultrasonic assisted drilling.

DEDICATION

Only

my beloved father, Heng Peng Pong

my appreciated mother, Lim Phaik Kiang

my adored brother, Heng Wei Han

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

PC	-	Personal Computer
EDM	-	Electrical Discharge Machining
GTAT	-	GT Advanced Technologies
KNO_3	-	Alkaline Potassium
Na+	-	Sodium Ions
AJM	-	Abrasive Jet Machining
Al_2O_3	-	Alumina
AWJM	-	Abrasive Water Jet Machining
ASJM	-	Abrasive Slurry Jet Micro Machining
ECDM	-	Electro Chemical Discharge Machining
MEMS	-	Micro-Electromechanical Systems
UAD	-	Ultrasonic Assisted Drilling
MRR	-	Material Removal Rate
MOEMS	-	Micro-Optical-Electro-Mechanical-Systems
μTAS	-	Miniaturized Total Analysis Systems
CD	-	Conventional Drilling
BUE	-	Build-Up Edge
CNC	-	Computer Numerical Control
DOE	-	Design of Experiment
RSM	-	Response Surface Methodology
ANOVA	-	Analysis of Variance

LIST OF SYMBOLS

MPa	-	Mega Pascal
GPa	-	Giga Pascal
°C	-	Degree Celsius
mm	-	Millimeter
K_{IC}	-	Fracture Toughness
k	-	Dielectric Constant
n	-	Refractive Index
f	-	Feed Rate
Fz	-	Average Value of Thrust Forces
N	-	Spindle Speed
rpm	-	Revolutions Per Minute
E	-	Young's Modulus
ν	-	Poisson's Ratio
HV	-	Vickers Hardness
D_i	-	Inner Diameter
D_o	-	Outer Diameter
C_a	-	Abrasive Concentration
S_a	-	Abrasive Size
N_a	-	Number of Abrasive Particles
A	-	Amplitude
f	-	Frequency
hp	-	Horsepower
L	-	Liter
ipm	-	Inches Per Minute
Rz	-	Roughness Depth
Ra	-	Mean Roughness Value
µm	-	Micrometer

CHAPTER 1
INTRODUCTION

This chapter explains about the background of study, problem statement, objectives, scope of project, significant of study, organization of the thesis and summary of this project.

1.1 Background of Study

Corning Incorporated is one of the world's driving trend-setters in materials science. The company had invented a new glass technology named Gorilla Glass which has brought them instant acknowledgement in the world. Gorilla Glass is a chemically strengthened glass designed to be thin, light and damage-resistant. This chemically strengthened glass is widely used in portable mobile devices because of its superior properties such as good scratch-resistant and high surface strength. With the expanded use of portable mobile devices, Corning saw that the hard and durable protection glass is highly needed in consumer electronics industry.

Figure 1.1: The company logo of Corning Incorporated.

In fewer than ten years, Corning Gorilla Glass is presently an industry standard with remarkable brand awareness. Gorilla Glass is the favored material for portable electronic panel display devices application such as smartphone, laptop and tablet PCs

screen, camera lenses and optical component because it is around five times stronger and scratches resistance compared to the normal tempering glass that already existed in the market. There are a lot of major brands in electronic industry such as Samsung, Nokia, Sony, Motorola, LG and Asus have employed the chemically strengthened glass developed by Corning Incorporated on their products. In the current market, the smartphones with Gorilla Glass is more attractive than the smartphones without Gorilla Glass during customers make a purchase decision.

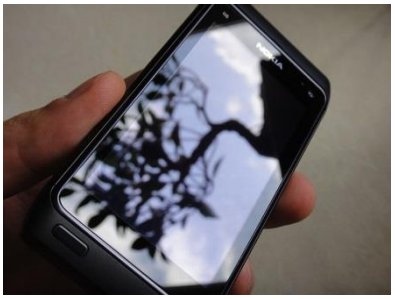

Figure 1.2: Corning's Gorilla Glass is used on the Nokia smartphone's screen.

Besides that, the application of Corning's Gorilla Glass is also existed in automotive industry. When the chemically strengthened glass is used as car window, it will reduce the weight of car window due to its properties of lightweight. The reduction of weight of a car can improve the car's acceleration and improve its braking performance. In addition, the lightweight vehicles can also enhance the fuel efficiency and reduce the emissions of carbon dioxide.

In such aforesaid applications, precise and effective micro holes drilling are requisite as to aid for the certain purposes, for example, camera lenses, speakers and proximity sensors. Nevertheless, employ conventional drilling methods to drill into chemically strengthened glass is a big challenge due to the properties of chemically strengthened glass. Conventional drilling process tends to produce high tensile stress due to the thrust forces that results in poor holes quality and cracks propagation.

In industry practices today, drilling of micro holes for chemically strengthened glass can be accomplished using numerous methods such as mechanical methods (mechanical drilling, powder blasting and ultrasonic drilling), thermal methods (laser drilling, ultra-short pulse laser, and focused electrical discharge), chemical methods (wet etching and deep reactive ion etching) and hybrid methods (vibration-assisted

micromachining, laser-assisted micro-cutting/milling, chemical-assisted micromachining, electrical discharge machining (EDM)).

Among all of the glass drilling approaches, ultrasonic assisted drilling has shown high potential in drilling chemically strengthened glass due to the intermittent motion mechanism of UAD. Hence, this project will study the characteristics of ultrasonic assisted drilling process and investigate the most suitable drilling parameters to drill chemically strengthened glass for this drilling process.

1.2 Problem Statement

There are a lot of problems occur during employing conventional drilling method to drill chemically strengthened glass. One of the problem is large amount of cutting force will be generated in conventional drilling. Optimization of the cutting force is very important for the drilling process due to it can influence other cutting output parameters. Another problem is the chemically strengthened glass will crack when undergo conventional drilling process due to the inherent properties of chemically strengthened glass in which stronger under compressive stress and weak under tension. Besides, machining of chemically strengthened glass is very challenging due to their hard and brittle properties which induced defects and severe tool wear.

Figure 1.3: Chemically strengthened glass cracks when undergo conventional drilling process.

Other than that, by not controlling the drilling parameters may cause the issue of holes precision of the glass, which implies that the penetration of drill bit to the glass is not accurate. Other problem that tends to occur during conventional drilling process is a lot of burr is produced during the process. The problems stated above are highly potential caused by utilizing inappropriate drilling parameters such as speed and feed rate of drill bit when undergo the conventional drilling process.

According to the research study on glass drilling, ultrasonic assisted drilling has shown high potential in drilling chemically strengthened glass. There are two additional parameters exist in ultrasonic assisted drilling which are amplitude and frequency of ultrasonic vibration. Based on the research, the thrust force will be lowered by employing the ultrasonic vibration frequency on the rotating diamond tool. Besides that, the ultrasonic vibration frequency can also improve the diamond wear and reduce the chip generation.

1.3 Objectives

There are three objectives that had been achieved in this project:

- To propose ultrasonic assisted drilling for drilling on chemically strengthened glass.
- To investigate the optimal ultrasonic drilling parameters such as amplitude, frequency of ultrasonic vibration, speed and feed rate for drilling of chemically strengthened glass.
- To validate the effectiveness of the optimal ultrasonic drilling parameters.

1.4 Scope

Scope of project is the work had been accomplished to deliver a project. The scope of this project is to optimize the drilling parameters for the drilling process on chemically strengthened glass. Those parameters are amplitude, frequency of ultrasonic vibration, feed rate and speed. In this project, the study or research was focused on one drilling process only which is ultrasonic assisted drilling. Besides that, the type of chemically strengthened glass was used in this project is Gorilla Glass. Other than that, the output responses were focused on this project are cutting force, delamination area at entry and exit.

1.5 Significant of Study

The findings of this project will provide the basis for advancing the technology related to micro machining of chemically strengthened glass. This study is very important for the industry today, as the current conventional drilling process lead to the problems like poor holes quality and cracks propagation on the surface of the chemically strengthened glass.

Besides that, this study will provide deeper information about the ultrasonic assisted drilling process and chemically strengthened glass to the industry. This information is very useful to investigate the optimal drilling parameters for the drilling process.

1.6 Organization of the Thesis

The organization of the thesis is as follows:

The first chapter of this report is the introduction about this study. This chapter includes the background of the research, problem statement, objectives of the study, limitation of the study and the significant of this study.

Chapter two covers the basic theories related to the research topic and review the literatures from books, journals, articles and internet resources that used in this study. The introduction of glass, glass structure, properties of glass and types of glass are illustrated. Besides that, the comparison between Sapphire Glass and chemically strengthened glass is shown. Other than that**,** the manufacturing process of glass and the comparison between chemical tempering process and conventional thermal tempering process are stated. The machining of glass such as mechanical drilling and ultrasonic assisted drilling, and the comparison between ultrasonic assisted drilling and conventional drilling is also be discussed in this chapter. Moreover, this chapter also describes the machining parameters of ultrasonic assisted drilling and their effect on the output variables.

Chapter three states the methodology of this project and the overview of the project. The overview of this research is plotted in a flow chart to visualize it. In this chapter, the materials and equipment were used in this project also have be stated. Besides that, it is also provides the information about the data collection and the way to analyze the data.

1.7 Summary

This study is mainly focus on provide the basis for advancing the technology related to micro holes machining on chemically strengthened glass. A lot of problems will arise when employing conventional drilling process on chemically strengthened glass such as poor holes quality and cracks propagation. According to the research study on glass drilling, ultrasonic assisted drilling has shown high potential in drilling chemically strengthened glass due to the present of two other parameters: amplitude and frequency of ultrasonic vibration. These two parameters can enhance the grinding process and chip evacuation during micro machining. Therefore, this project focused on study the characteristics of ultrasonic assisted drilling process and the properties of chemically strengthened glass. Lastly, the optimal ultrasonic drilling parameters for the micro holes machining on chemically strengthened glass were investigated.