WEAR RESISTANCE PERFORMANCE OF ZIRCONIA TOUGHENED ALUMINA (ZTA) CUTTING TOOL ADDED WITH MgO AND CeO_2

AFIFAH BINTI MOHD. ALI

UNIVERSITI SAINS MALAYSIA
2016

WEAR RESISTANCE PERFORMANCE OF ZIRCONIA TOUGHENED ALUMINA (ZTA) CUTTING TOOL ADDED WITH MgO AND CeO_2

by

AFIFAH BINTI MOHD. ALI

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

July 2016

Dedication

To my late father, my source of inspiration,

my mother, my greatest supporter

my husband and daughter,

my strength and hope.

ACKNOWLEDGEMENT

Bismillahhirahmanirrohim. Alhamdulillah, with the granted from Allah S.W.T, this thesis can finally be completed.

Firstly, I would like to express my sincere gratitude to my supervisor Prof. Dr. Hj. Zainal Arifin bin Ahmad for the continuous support of my PhD research and personal life for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my PhD study. Besides my supervisor, I would like to thank my co-supervisor: Prof. Dr. Mani Maran Ratnam and Dr. Norazharuddin Shah bin Abdullah for their continuous support through their suggestions and guidance in the research and myself developments.

My special thanks to Dean, Prof. Dr. Zuhailawati binti Hussain, deputy deans, lecturers and all staffs of School of Materials and Mineral Resources, Universiti Sains Malaysia (USM) for their kind assistance and support. I am specifically grateful for the technical support from Mr. Shahrul Ami bin Zainal Abidin, Mr. Mokhtar bin Mohamad, Mr. Rashid bin Selamat, Mr. Khairi Bin Khalid, Mr. Mohamad Zaini bin Saari, Mr. Mohamad Shafiq bin Mustapa Sukri and Mrs. Hasnah binti Awang. My thanks also for Mr. Baharom bin Awang, Mr. Mohd Syahril bin Mohd Yusof and Mr. Mohd Shawal Faizal bin Ismail from School of Mechanical for their experimental and technical support.

I gratefully acknowledge the Ministry of Education, Malaysia and International Islamic University Malaysia (IIUM) for their sponsorship throughout my study under the SLAB/SLAI Scholarship Scheme.

My sincere thanks also goes to Dr. Hazman bin Seli, Dr. Ahmad Zahirani bin Ahmad Azhar, Dr. Nik Akmar bin Rejab, and Dr. Wan Fahmin Faiz bin Wan Ali, who help me throughout this research with their knowledge and expertise. Without their precious support, it would not be possible to conduct this research.

I would love to thank my fellow lab mates, Dr. Abdul Rashid bin Jamaludin, Mr. Muhammad Johari bin Abu, Mr. Hamdan bin Yahya, Mr. Mohd. Fariz bin Abdul Rahman, Mr. Ko Chun Min, Ms. Rosyaini binti Afindi Zaman, Ms. Nor Fatin Khairah binti Bahanurddin, Ms. Suhaida binti Shahabuddin, Ms. Saniah binti Abdul Karim and Ms. Maliha Siddiqui for the stimulating discussions, for the time we were working together and supporting each other and for all the fun we have had in the last three years.

I am also would like to thanks my friends, Ms. Norshahida binti Sarifuddin, Ms. Suhaily binti Mokhtar, Ms. Siti Norbahiyah binti Mohamad Badari, Ms. Farah Diana binti Mohd. Daud, Ms. Nur Farahiyah binti Mohammad, Ms. Siti Shuhadah binti Md. Saleh, Ms. Shazeela binti Ahmad, Ms. Roslina binti Ishak, Ms. Dalila Syairah binti Mohamad Zubir and Ms. Nazarulniza binti Kamarul Ariffin who were with me through thick and thin throughout my journey in finding knowledge. May Allah reward them for all of their help and sacrifices.

Last but not the least, I am grateful to my late father, Mohd. Ali bin Din who always inspire me to pursue my study and to do what I love. I would like to thanks my mother, Fatimah binti Othman, my greatest supporter emotionally and financially, my husband Mohd. Suhaili bin Sukami and my daughter Anis Safia binti Mohd. Suhaili who always be there and believe in me. Not to forget my eldest sister, my life counsellor and brothers for supporting me spiritually throughout my study and my life in general.

TABLES OF CONTENTS

Pages

CHAPTER THREE - MATERIALS AND METHODOLOGY

CHAPTER FOUR - RESULTS AND DISCUSSIONS

CHAPTER FIVE - CONCLUSION AND FUTURE RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Al_2O_3	Alumina
ASM	American Society for Metals International
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
CeO_2	Cerium Oxide
CNC	Computer Numerical Control
DPH	Diamond Pyramid Hardness
EDAX	Energy Dispersive Spectroscopy
FESEM	Field Emission Scanning Electron Microscope
GPa	Giga Pascal
HV	Vickers Hardness
ICCD	International Centre for Diffraction Data
ISO	International Standards Organization
MgO	Magnesium Oxide
MPa	Mega Pascal
NL	Number of grains intercept
Pt	Platinum
PSZ	Partially Stabilised Zirconia
Ra	Average Roughness
SEM	Scanning Electron Microscope
USA	United State of America

XRD	X-Ray Diffractometer
YSZ	Yttria Stabilised Zirconia
ZMM	ZTA added with micro particle MgO
ZMN	ZTA added with nano particle MgO
ZNC	ZTA added with nano particle MgO and CeO_2
ZrO	Zirconium Oxide
ZTA	Zirconia Toughened Alumina

LIST OF SYMBOLS

n	Integer
λ	Wavelength
θ	Angle
d	Distance between planes in Angstrom unit
Å	Angstrom unit
L_0, L_1	Length
F	Force
A	Area
K_{IC}	Fracture Toughness
H	Vickers hardness
E	Modulus of Elasticity
A	Half distance of indent length
c	Crack length
Im	Intensity monoclinic phase
It	Intensity tetragonal phase
f	weight fraction of the reinforce materials
E_r	Modulus of elasticity of the reinforce or additive materials
E_m	Modulus of elasticity of the matrix
W_d	Dry weight of the samples
W_s	Soaked weight of the samples

W_a	Suspended weight of the samples
ρ_{water}	Density of water (1 g/cm^3)
ρ	Bulk density (g/cm^3)
v	Volume fraction
N	Number of atom per unit cell
V	Unit cell volume (cm^3)
MW	Molecular weight (g)
N_a	Avogadro number

PRESTASI RINTANGAN HAUS MATA PEMOTONG ALUMINA DIPERKUAT ZIRKONIA DENGAN TAMBAHAN MgO DAN CeO_2

ABSTRAK

Prestasi rintangan haus alumina diperkuat zirkonia (ZTA) dengan bahan tambah MgO dan CeO_2 diselidik. Komposisi optimum bahan tambahan telah digunakan dalam alumina / zirkonia terstabil yttria (YSZ). Tiga jenis komposisi adalah ZTA + 0.7 wt.% MgO (ZMM, partikel mikro), ZTA + 1.1 wt.% MgO (ZMN, partikel nano) dan ZTA + 0.7 wt.% MgO (partikel zarah) + 5.0 wt.% CeO_2 (ZNC). Komposisi-komposisi ini dicampur, ditekan dalam satu arah ke dalam acuan berbentuk mata pemotong rombus 80º dengan 0.8 mm jejari muncung dan disinter pada suhu 1600 ºC selama 4 jam dibawah keadaan tanpa tekanan. Analisa pemotongan dilakukan ke atas rod keluli tahan karat kormesial 316L dengan diameter 50 mm sebagai bahan kerja. Bahan kerja ini telah dipotong pada 1500, 1750 dan 2000 rpm. Kadar suapan dibezakan pada 0.1, 0.3 dan 0.5 mm/putaran manakala kedalaman potongan dikekalkan pada 0.2 mm. Faktor - faktor yang memberi kesan kepada prestasi alat memotong ZTA iaitu parameter pemesinan, serpihan pemotongan dan transformasi fasa yang disebabkan oleh proses pemesinan telah dikaji. Rintangan haus dan kekasaran permukaan bahan kerja diukur. Empat jenis kelakuan rintangan haus dapat dilihat iaitu haus rusuk, haus kawah, haus hidung dan sumbing. Kelajuan putaran dan kenaikan kadar suapan menyebabkan semua jenis haus meningkat terutamanya haus rusuk dan haus hidung. Haus kawah sangat dipengaruhi oleh pembentukan serpihan semasa proses pemotongan. Pembentukan serpihan sebaliknya sangat dipengaruhi oleh kenaikan kadar suapan kerana beban berlebihan pada mata pemotong. Kebanyakan sumbing diperhatikan apabila kadar suapan berada pada 0.5 mm/putaran. Kekasaran permukaan sebaliknya menurun dengan kenaikan kelajuan putaran dan meningkat dengan kenaikan kadar suapan. ZMM sangat terkesan dengan haus rusuk dan haus kawah kerana kekerasannya yang rendah. ZMN sebaliknya terkesan oleh serpihan di mana luas sumbing alat pemotong ZMN adalah lebih besar berbanding dengan ZMM dan ZNC. Selain itu, ZNC memberikan nilai tertinggi haus hidung. Mata pemotong ZMM memberikan nilai kekasaran permukaan yang terbaik dengan kekasaran paling rendah di mana-mana parameter manakala ZMN memberikan nilai kekasaran permukaan yang paling tinggi. Panjang dan bentuk serpihan juga memberi kesan kepada kemajuan haus kawah. Serpihan yang panjang menyebabkan haus kawah menjadi teruk. Serpihan berbentuk tiub panjang yang paling teruk menjejaskan alat memotong seramik. Ini dapat dilihat daripada corak haus kawah di mana kawasan haus kawah tertinggi dapat diperhatikan apabila serpihan berbentuk tiub panjang terhasil semasa proses pemesinan. Disebabkan transformasi fasa dalam alat pemotongan berlaku semasa proses pemesinan, kekerasan meningkat manakala keliatan patah menurun bagi semua jenis alat memotong (ZMM, ZMN dan ZNC). ZMM menunjukkan kadar tertinggi kenaikan kekerasan (22.0%) dan susutan keliatan patah (21.1%) diikuti oleh ZNC dengan masing-masing 11.8% dan 9.4%. ZMN mempunyai kenaikan terkecil kekerasan sebanyak 2.6% dan pengurangan keliatan patah sebanyak 8.4%. Kesimpulannya, ZMN menunjukkan prestasi yang terbaik sebagai alat memotong berbanding ZMM dan ZNC.