Faculty of Manufacturing Engineering

EFFECT OF CARBON ADDITIVES AND SURFACTANT ON ELECTRICAL DISCHARGE MACHINING (EDM) OF REACTION-BONDED SILICON CARBIDE (RB-SiC)

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DECLARATION

I declare that this thesis entitled “Effect of Carbon Additives and Surfactant on Electrical Discharge Machining (EDM) of Reaction-Bonded Silicon Carbide (RB-SiC)” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature : .....

Supervisor Name : .....

Date : .....

DEDICATION

I dedicated this thesis to my beloved family.

Abdul Razak Bin Ahmad

Aisah Binti Biran

Nurul Suhaidah Binti Abdul Razak (sister)

and

to all my friends

ABSTRACT

Reaction-bonded silicon carbide (RB-SiC) is an important material in the manufacturing industry due to its excellent material properties. However, due to its high hardness, there are difficulties in machining this material to a good surface finish and with a high level of accuracy. To overcome these problems during the machining of ceramic materials, electrical discharge machining (EDM) is employed. Thus, the primary aim of this research is to conduct a comparative study of EDM on this material using different types of surfactant, concentrations of surfactant and carbon additive. The dielectric fluid, kerosene was mixed with different surfactants, namely Span 20 and Span 80. In order to investigate the effects of the surfactants, different concentrations of surfactant, namely 0 wt.%, 0.4 wt.%, 0.6 wt.% and 0.8 wt.%, were used. Carbon nanofiber (CNF), carbon nano powder (CNP) and carbon powder (CP) were used as an additives in this experiment. These powders are different in terms of size and shape. The responses of the machining, such as the stability of mixtures, material removal rate (MRR), electrode wear ratio (EWR), surface roughness, spark gap and surface topography, were also investigated. The results show that the surfactant and additives added to the dielectric fluid not only improved MRR and spark gap, but also reduced EWR, especially for the surfactant Span 80. The addition of a surfactant can prevent the agglomeration of powders and cause the powders to disperse well within the dielectric fluid. Therefore, the electro discharge frequency is increased, leading to a higher MRR and spark gap. The optimum weight percentage of surfactant concentration for obtaining smoother surface was at 0.4 wt.%. In terms of additives, CNF showed significant changes for MRR and EWR compared to CNP and CP. For comparison, the combination of surfactant Span 80 with 0.6 wt.% concentration of surfactant and CNF as additive is more significant in improving the machining efficiency of RB-SiC using conventional EDM compared to other surfactants, concentrations and additive powders.

ABSTRAK

Tindak balas terikat silikon karbida (RB-SiC) adalah bahan yang penting di dalam industri pembuatan disebabkan oleh sifat bahannya yang baik. Bagaimanapun, disebabkan mempunyai kekerasan yang tinggi, bahan ini sukar dimesin bagi menghasilkan kemasan permukaan yang baik dan berketepatan tinggi. Bagi mengatasi masalah permesinan bahan seramik, mesin penyahcas elektrik (EDM) telah digunakan.Oleh itu, tujuan utama kajian ini adalah untuk mengkaji perbandingan prestasi EDM bagi bahan ini dengan menggunakan jenis surfaktan, kepekatan surfaktan dan serbuk aditif yang berbeza. Cecair dielektrik jenis kerosin digunakan dalam eksperimen ini dicampur dengan surfaktan yang berbeza iaitu Span 20 dan Span 80. Bagi mengkaji kesan surfaktan, peratusan berat surfaktan yang berbeza digunakan iaitu 0 wt%, 0.4 wt%, 0.6 wt% dan 0.8 wt%.Karbon aditif yang digunakan bagi membantu keberkesanan permesinan adalah fiber nano karbon (CNF), serbuk nano karbon (CNP) dan serbuk karbon (CP). Perbezaan diantara ketiga-tiga serbuk ini adalah dari segi saiz dan bentuk. Respon pemesinan yang dikaji adalah seperti kestabilan campuran, kadar pembuangan bahan (MRR), nisbah kehausan elektrod (EWR), kekasaran permukaan, jurang percikan dan permukaan topografi. Keputusan menunjukkan bahawa surfaktan dan serbuk aditif yang dicampurkan ke dalam cecair dielektrik bukan sahaja meningkatkan nilai MRR dan jurang percikan malah mengurangkan nilai EWR terutama sekali surfaktan Span 80. Penambahan surfaktan dapat menghalang serbuk daripada bergumpal, dan menyebabkan serbuk aditif berserakan dengan baik di dalam cecair dielektrik. Maka, kekerapan perlepasan elektro dapat ditingkatkan dan menyebabkan MRR dan jurang percikan tinggi. Peratusan berat optimum surfaktan yang menghasilkan kemasan permukaan yang baik adalah pada 0.4wt.%. Dari segi aditif, CNF menunjukkan perubahan yang ketara untuk MRR dan EWR berbanding CNP dan CP. Untuk perbandingan, kombinasi surfaktan Span 80 dengan kepekatan surfaktan 0.6wt% dan CNF sebagai aditif menunjukkan perubahan ketara bagi meningkatkan kecekapan permesinan untuk RB-SiC menggunakan konvensional EDM berbanding surfaktan yang lain, kepekatan dan juga serbuk aditif yang lain.

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LIST OF ABBREVIATIONS

Al	-	Aluminium
Al_2O_3	-	Aluminium Oxide
B_4C	-	Boron carbide
BMI	-	Brain Machine Interface
CNF	-	Carbon Nanofiber
CNP	-	Carbon Nanopowder
CNT	-	Carbon Nanotube
CP	-	Carbon Powder
CTAB	-	Cetyltrimethylammonium bromide
DESSEDG	-	Double Electrode Synchronous Servo Electrical Discharge Grinding
DTAB	-	Dodecyltrimethylammonium bromide
EDM	-	Electrical Discharge Machining
EWR	-	Electrode Wear Ratio
FE-SEM	-	Field Emission Scanning Electron Microscopy
GA	-	Gum Arabic
HLB	-	Hydrophilic–Lipophilic Balance
RB-SiC	-	Reaction Bonded Silicon Carbide
SEM	-	Scanning Electron Microscopy

MRR	-	Material Removal Rate
NaDDBS	-	Dodecyl Benzene Sodium Sulfonate
PMEDM	-	Powder Mixed EDM
SDBS	-	Sodium Dodecyl Benzene Sulfonate
SDS	-	Sodium Dodecyl Sulphate
MMC	-	Metal Matrix Composites
α-SiC	-	Alpha Silicon Carbide
β-SiC	-	Cubic Silicon Carbide
SiC	-	Silicon Carbide
SiSiC	-	Silicon Infiltrated Silicon Carbide
TEM	-	Transmission Electron Microscopy
Ti-6Al-4V	-	Titanium Alloy
Triton X-100	-	Octyl Phenol Ethoxylate
WC–Co	-	Cobalt-Bonded Tungsten Carbide
WEDM	-	Wire Electrical Discharge Machining
ZrO_2	-	Zirconium Dioxide
3D	-	Three Dimensional

LIST OF SYMBOLS

A	-	ampere
MPa	-	megapascal
GPa	-	gigapascal
Hz	-	hertz
kHz	-	kilohertz
HV	-	vickers pyramid number
g	-	gram
g/lit	-	gram per liter
g/cm³	-	gram per cubic centimeter
nm	-	nanometer
µm	-	micrometer
µs	-	microsecond
mm^3/min	-	cubic milimeter per minute
mm^3	-	cubic milimeter
mm^2/s	-	square milimeter per second
mg/min	-	miligram per minutes
mm/s	-	milimeter per second
mm	-	milimeter
ml	-	mililiter

min	-	minute
mg KOH/g	-	milligrams of potassium hydroxide per gram
kg/m^3	-	kilogram per cubic meter
kPa	-	kilopaskal
K^{-1}	-	per kelvin
R_a	-	roughness average
R_q	-	RMS Roughness
R_z	-	average maximum peak
V	-	voltage
mV	-	milivolts
W/mK	-	watts per meter kelvin
wt.%	-	weight percentage
%	-	percent
°F	-	degree fahrenheit
°C	-	degree celsius
Ω.cm	-	ohm centimeter
μΩ.cm	-	microhm centimeter

LIST OF PUBLICATIONS

Award

1. **Abdul Razak, M.R.,** Liew, P.J., Hussein, N.I.S., and Ahsan, Q., 2016. Effect of Surfactants and Additives on Electrical Discharge Machining of Reaction Bonded Silicon Carbide. *International Conference on Engineering and ICT (ICEI 2016),*Hatten Hotel, Melaka, Malaysia, 4 -6 April 2016 **. (Best Paper Award)**

Journal

1. **Abdul Razak, M.R.,** Liew, P.J., Hussein, N.I.S., and Ahsan, Q., 2016. Effect of Surfactant on EDM of Low Conductivity Reaction-Bonded Silicon Carbide. *Key Engineering Materials, Vol. 701*, pp.107-111 (Scopus)(Accepted).
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