DEVELOPMENT AND ANALYSIS OF ETHYLENE GLYCOL/ NANOCELLULOSE BASED NANOFLUID COOLANT FOR MACHINING SUS 304 STAINLESS STEEL

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree Master of Science.

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STUDENT'S DECLARATION

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

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ABSTRACT

In the manufacturing industry nowadays, machining plays a significant role. When the machining operation is carried out, the temperature rises with the speed and the tool strength decreases, leading to faster wear and tool failure. Thus, it is essential to cool down the heat generated at the tool and work piece interface for a better tool life via effective cooling system. This thesis discusses the effectiveness of Ethylene Glycol/Nanocellulose based Nanofluid Coolant (EGN-NFC) in term of its thermo-physical properties such as thermal conductivity and viscosity. Besides that, its' effectiveness is evaluated and analysed in term of machining performances such as surface roughness, temperature distribution, tool wear, chip formation and tool life during turning machining operation of SUS304 stainless steel through the Box Behnken design of experiment using cemented tungsten-cobalt (WC-Co) coated carbide grade with Ti (C,N) + Al_2O_3 insert. The effectiveness of the EGN-NFC is compared with the conventional machining coolant which is metal working fluid (MWF). The mathematical model equation for surface roughness was developed using response surface methodology (RSM). The cutting variables are cutting speed, feed rate, and depth of cut. The developed model equations for the surface roughness shows that the most significant input parameter is the feed rate, followed by depth of cut and cutting speed. The turning operation by using EGN-NFC obtains lower surface roughness, achieved greater total length of cut prior to reach the ISO 3865:1977 wear criterion, low temperature distribution and produce discontinuous chip compared with turning operation by using MWF. The cutting tool in turning operation using EGN-NFC take longer time to wear when compare with the one using MWF as the coolant. According to ISO 3865:1977 the wear criteria for turning using MWF reached the maximum total length of cut of 500 mm but the maximum total length of cut for turning using EGN-NFC reached the wear criteria at the cutting distance of 750 mm. The SEM and EDX spectrum shows there are an interfacial layer of nanocellulose from the EGN-NFC embedded and fills the holes in the insert and for a layer which act as an additional protective layer and thermal bridge for the cutting insert. Build-up-edge (BUE), diffusion and adhesion at the cutting edge were the main tool wear mechanism present during turning operation using EGN-NFC. The usage of EGN-NFC in turning operation also helps to reduce the effect of cutting and friction forces during machining operation through discontinuous chip formation results from low cutting temperature. For optimum turning machining performances using EGN-NFC with minimum surface roughness and maximum total length of cut with tool life to be achieved, the parameters been optimized using Minitab to be cutting speed equals to 140 m/min, feed rate equals to 0.05 mm/rev and depth of cut equals to 0.5 mm.

ABSTRAK

Dalam industri pembuatan, pemesinan memainkan peranan yang penting. Semasa menjalankan pemesinan, penghasilan haba terus meningkat bersama dengan kadar kelajuan dan juga mengakibatkan kurangnya keberkesanan alat pemotong. Maka pentingnya mengurangkan haba yang terhasil di antara alat pemotong dan besi yang dipotong melalui adanya sistem penyejuk yang berhasil. Tesis ini membincangkan keberkesanan EGN-NFC dari segi sifat termofizikal seperti kekonduksian haba dan kelikatan. Selain itu, keberkesanan cecair peyejuk dari segi prestasi pemesinan SUS304 keluli tahan karat seperti kekasaran permukaan, pengedaran haba, kegagalan alat pemetongan dan pembentukkan cip semasa menggunakan alat pemotongan tungsten kobalt (WC-Co) yang disalut dengan Ti (C,N) + Al_2O_3 juga dinilai menerusi modal Box Behnken. Keberkesanan EGN-NFC dibandingkan dengan cecair penyejuk yang sedia ada di pasaran. Satu persamaan matematik untuk kekasaran permukaan direka mengunakan RSM. Kelajuan pemotongan, kadar kelajuan dan kedalaman memotongan merupakan pembolehubah dalam ekspriment ini. Persamaan matematik tersebut menujukkan kadar kelajuan mempunyai impak yang tinggi, diikuti dengan kedalaman pemotongan dan kadar kelajuan. Operasi pemesinan mengunakan EGN-NFC mencatakkan kekasaran permukaan yang rendah, pengedaran haba yang rendah, kegagalan alat pemotongan yang lambat sebelum mencapai ISO 3865:1977 taraf kegagalan, membentuk cip yang tidak berterusan berbanding dengan pemesinan dengan cecair penyejuk yang sedia ada. Alat pemotongan mengambil masa yang lama untuk rosak semasa menggunakan EGN-NFC berbanding dengan pemesinan dengan cecair penyejuk yang sedia ada. Berdasarkan taraf kegagalan ISO 3865:1977, pemesinan menggunakan cecair penyejuk yang sedia ada mencapai jumlah jarak pemotongan semaksimum 500 mm, malah jumlah jarak pemotongan semaksimum dengan menggunakan EGN-NFC sebelum mencapai ISO 3865:1977 ialah 750 mm. SEM dan EDX spektrum adanya zarah-zarah nanocellulose membentuk lapisan di atas permukaan alat pemotongan dan berfungsi sebagai lapisan tambahan da juga sebagai jambatan haba. BUE, penyebaran dan lekatan atas permukaan alat pemotongan adalah contoh kegagalan berlaku semasa menggunakan EGN-NFC. Penggunaan EGN-NFC ini menyebabkan pembentukkan cip yang tidak berterusan yang membantu untuk mengurangkan tekanan dan penggesaran berlaku semasa proses pemesinan dijalanakan. Pengoptimuman parameter untuk hasil pemesinan yang terbaik iaitu kadar kasaran permukaan yang rendah dan jumlah panjang pemotongan serta jangka hajat alat pemotong yang maximum, telah dilaksanakan menggunakan Minitab dimana kadar kelajuan ditetapkan pada 140 m/min, kadar pemotongan pada 0.05 mm/rev manakala kedalaman pemotongan pula ditetapkan pada 0.5 mm.

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LIST OF SYMBOLS

F_m	Feed Rate in mm/min
TL	Total Length to Reach Flank Wear Criterion 0.3 mm
R_a	Roughness Average
R_p	Roughness Smoothening Depth
R_t	Roughness Maximum Peak-to-Valley Height
k	Thermal Conductivity
K	Kelvin
^{o}C	Degree Celsius
γ	Tool Rake Angle
l_c	Tool-Chip Contact Distance
l_s	Shear Plane Length
a_c	Undeformed Chip Thickness
a_o	Deformed Chip Thickness
ϕ	Shear Angle
α	Clearance Angle
ω	Weight Percentage
φ	Volume Percentage
ρ	Density
μ	Dynamic Viscosity
ε	Emissivity

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
Al_2O_3	Aluminium Oxide
ASHRAE	American Society of Heating, Refrigerating and Air- Conditioning Engineers
BBD	Box-Behnken Design
BUE	Build-Up-Edge
BUL	Build-Up-Layer
CCD	Central Composite Design
CNF	Cellulose Nanofibers
Co	Cobalt
CrN	Chromium Nitride
CVD	Chemical Vapor Deposition
DOE	Design of Experiment
DSLR	Digital Single Lens Reflex
EDX	Energy Dispersive X-ray
EG	Ethylene Glycol
EGN-NFC	Ethylene Glycol/ Nanocellulose–Nanofluid Coolant
HRC	Hardness Rockwell C
ILMA	Independent Lubricant Manufacturers Association
IR	Infrared
ISO	International Organization for Standardization
MFC	Micro-Fibrillated Cellulose
MQL	Minimum Quantity Lubrication
MWF	Metal Working Fluid
NCC	Nano-Crystalline Cellulose
PVP	Poly Vinyl Pyrrolidone
RSM	Response Surface Method
SEM	Scanning Electron Microscope
SiO_2	Silicon Oxide
SUS	Steel Use Stainless
TEM	Transmission Electron Microscope

TiCN	Titanium Carbo-Nitrate
TiN	Titanium Nitrite
TiO_2	Titanium Oxide
VB	Flank Wear
W	Water
WC	Tungsten
ZnO	Zinc Oxide

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