STUDY ON THE APPLICATION OF IONIC LIQUIDS IN BIO-BASED LUBRICANT FOR A SUSTAINABLE MACHINING PROCESS

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ABSTRACT

Many factors tend to influence the increased demand in recent years, including state-of-the-art of effective and environmentally friendly metalworking fluids (MWFs). Bio-based lubricants from vegetable oils are highly biodegradable, non-toxic, pose good lubricating properties and low production costs. They have been widely perceived as a potential to reduce or replace the high dependency on the applications of petroleum-based MWFs. However, the inconsistent chemical composition and low thermal and oxidative stabilities of the natural oils leaves significant uncertainties about the overall sustainability performance of the bio-based MWFs. In this study, with the objective of achieving machining sustainability, a novel chemically modified Jatropha-based trimethylolpropane ester (MJO) was refined by mixing it with ionic liquids (ILs) additives. Two biocompatible and oil-miscible ILs; $[P_{6,6,6,14}][(^{i}C_8)_2PO_2]$ (PIL) and $[N_{1,8,8,8}][NTf_2]$ (AIL) were mixed in the MJO at 1, 5, and 10 % weight concentrations. The newly refined mixtures are validated for their physicochemical and tribological properties as well as when being applied for minimum quantity lubrication (MQL) machining (orthogonal and oblique) of AISI 1045 steel. Results showed that, the lubrication performance of MJO+AIL10% and MJO+PIL1% outperformed the other lubricant samples used herein. With improved physicochemical and tribological performances, e.g. corrosion inhibition, friction and wear reduction, smooth surface finish and high machining efficiency, they recorded improvement in machining forces up to 12 %, cutting temperature up to 10 %, surface roughness by 7% and increased cutting tool life up to 50 % compared to the commercial synthetic ester-based MWF. A machining sustainability index evaluation was applied to the MQL machining scenario and based on results, MJO+PIL1% obtained the highest score for minimum lubricant's cost, minimal energy consumption, or the best sustainability performance (4.08/5) and seconded by MJO+AIL10% (4.06). These novel bio-based MWFs provide another alternative to the world dominating mineral oil-based lubricants for "greener" and more sustainable working environment.

ABSTRAK

Dewasa ini penggunaan bendalir kerja logam (MWFs) yang terkini, canggih dan mesra alam adalah semakin meningkat disebabkan pelbagai faktor. Bendalir kerja logam berasaskan minyak tumbuhan adalah terbiodegradasi, tidak toksik, bersifat pelincir yang baik dan tidak menelan kos pembuatan tinggi. Ianya telah diterima secara meluas sebagai suatu potensi untuk mengurangkan atau menggantikan kebergantungan tinggi terhadap penggunaan MWFs berasaskan petroleum. Namun, minyak berasaskan tumbuhan mempunyai sifat komposisi kimia yang tidak konsisten dan kestabilan terma-oksidatif yang rendah menyebabkan prestasi keseluruhan mereka terencat untuk mencapai kelestarian dalam proses pemesinan. Dalam kajian ini, dengan objektif mencapai kelestarian dalam proses pemesinan, ester trimetilolpropana berasas minyak jarak dan diubahsuai secara kimia (MJO) telah disempurnakan dengan bahan tambah cecair ionik (ILs). Kedua-dua ILs; $[P_{6,6,6,14}][(^{i}C_8)_2PO_2]$ (PIL) dan $[N_{1,8,8,8}][NTf_2]$ (AIL), adalah bio-serasi dan larut minyak. Sampel campuran dengan ILs pada kepekatan berbeza 1, 5, dan 10 % berat daripada MJO telah ditentusahkan melalui sifat fizikokimia, tribologi serta pelinciran kuantiti minimum (MQL) ketika proses pelarikan (ortogonal dan oblik) logam AISI 1045. MJO+AIL10% dan MJO+PIL1% menunjukkan keputusan yang meyakinkan untuk mengatasi prestasi pelincir-pelincir lain yang diuji. Keduanya menunjukkan sifat-sifat fizikokimia dan ujian kelakuan tribologi yang cemerlang seperti perencatan kakisan, pengurangan geseran dan kehausan, penghasilan kualiti kekasaran permukaan yang tinggi serta mencatatkan pengurangan dalam daya pemesinan sehingga 12%, suhu pemotongan sehingga 10%, kekasaran permukaan sebanyak 7% dan peningkatan jangka hayat mata alat sehingga 50% berbanding dengan ester sintetik komersil. Penilaian indeks kelestarian semasa proses pemesinan MQL menunjukkan MJO+PIL1% (4.08) mengatasi MJO+AIL10% (4.06) dalam memperoleh skor tertinggi untuk kos pelincir dan penggunaan tenaga minimum atau prestasi kelestarian terbaik. Suatu sumber alternatif yang lebih mampan telah berjaya dihasilkan untuk membentuk persekitaran kerja yang lebih lestari.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percent, efficiency
a	-	Radius of wear scar diameter
AES	-	Auger Electron Spectrometer
AFM		Atomic force microscopy
AIL	-	methyltrioctylammonium bis(trifluoromethylsulfonyl)imide; $[N_{1,8,8,8}][NTf_2]$
AISI	-	American Iron and Steel Institute
Al		Aluminium
AOCS	-	American Oil Chemists' Society
ASTM	-	American Society for Testing and Materials
AW	-	Antiwear additive
BF_4	-	Tetrafluoroborate
BL	-	Boundary lubrication
BUE	-	Built up edge
C	-	Carbon, carbide
C_3H_8O	-	Isopropyl alcohol
CEC	-	Coordinating European Council
CH_4O	-	Methanol
CJO	-	Crude jatropha oil
CNC		Computer numerical control
COF	-	Coefficient of friction
CrN	-	Chromium nitride
d	-	Depth of cut
DAQ	-	Data acquisition system
DIN	-	Deutsches Institut für Normung (German national oganization for standardization)

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