DEVELOPMENT OF TRI-HYBRID NANOFLUIDS AS CUTTING FLUIDS TO ENHANCE PERFORMANCE OF END MILLING PROCESS OF ALUMINIUM ALLOY 6061-T6

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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 of Doctor of Philosophy.

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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 degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Pemesinan aluminium aloi kompleks disebabkan oleh kecenderungannya untuk melekat pada mata alat. Semasa pemesinan, kehausan mata alat berlaku disebabkan oleh kelekatan dan bahan terbina disisi, menjejaskan kualiti permukaan. Beberapa kajian dijalankan untuk menghalang penjaan haba semasa pemesinan. Diantara pelbagai alternatif, bendalir pemotong kekal sebagai pilihan. Oleh itu, pelbagai teknik diterokai untuk menggantikan bendalir pemotong. Kini, aplikasi teknologi nano dalam sains dan industri telah menambahbaik keputusan. Justeru, operasi pemesinan telah menggunakan bendalir nano dan mata alat berlapis. Namun, penggunaannya masih diperingkat awal dan memerlukan perhatian. Bendalir hybrid nano berpotensi meningkatkan prestasi pemindahan haba dan sifat thermo-fizikal melebihi satu jenis bendalir nano. Proses pemesinan menggunakan bendalir hybrid nano memerlukan kajian lanjut untuk memahami mekanisme kehausan mata alat dan perkara asas yang belum diterokai. Kajian ini bertujuan untuk membangunkan tri-hybrid bendalir nano sebagai bendalir pemotong untuk meningkatkan prestasi pemotongan AA6061-T6. Tri-hybrid nanopartikel dilarutkan dalam cecair, yang terdiri daripada 60:40 vol.% cecair tanpa ion kepada etylene glycol, dan kepekatan 0.08 dan 0.12 wt.% dicampur dengan agen penstabil CTAB pada kadar 1:3. Selepas 2 minggu pemerhatian dan ujian UV-Vis spectral, didapati tri-hybrid bendalir nano adalah stabil. Keupayaan zeta melebihi 30 mV, menunjukkan kelarutan yang baik. Mata alat tungsten karbida; tanpa kalis dan berkalis, digunakan semasa eksperimen dijalankan. Kajian telah dijalankan dengan menggunakan kelajuan, kadar suapan, kedalaman, kadar aliran dan kepekatan dan pemesinan diukur ialah kekasaran permukaan, suhu, daya, haus tepi. Kaedah permukaan bertindak dengan pendekatan rekabentuk berpusing komposit pusat digunakan dan data eksperimen telah disahkan secara statistik. SEM grafmikro dan corak EDX digunakan untuk menilai mata alat. Pada 0.1 wt.% dan 70°C, tri-hybrid bendalir nano menunjukkan peningkatan konduksi termal diantara 41.1, 10.5 dan 20.3% berbanding dengan bendalir asas, SiO_2-Al_2O_3 dan SiO_2-ZrO_2. Tri-hybrid bendalir nano lebih 50.5% likat pada kepekatan dan suhu yang lebih rendah. Semasa kadar pemesinan yang tinggi, pemotong tanpa kalis menghasilkan permukaan kekasaran yang rendah kesan dari keberkesanan tri-hybrid bendalir nano. Suhu pemotongan direkodkan dibawah 38°C semasa proses pemotongan, penambahbaikan 84% dibandingkan dengan teknik konvensional. Daya pemotong yang diukur adalah di bawah 30 N peningkatan 35% bagi proses prestasi. Mata alat berlapis menunjukkan daya yang lebih tinggi kerana kekerasan permukaan dan mekanisme kegagalan mata alat. Kelekatan, geseran, lapisan tercabut dan keretakan sisi antara kegagalan mata alat. Kehilangan bahan terbina disisi ialah kesan pengurangan bahan yang terlekat pada kadar alir dan kepekatan yang tinggi. Haus sisi lebih teruk pada mata alat berlapis berbanding yang tidak dilapis kerana fenomena lapisan yang tercabut dari permukaan. Namun, mata alat yang tidak dilapis lebih dominan dengan mekanisme kehausan jenis geseran. Pemotongan optimum untuk karbida tungsten tidak berlapis adalah 8440 rpm, 50.1 mm/min, 0.336 mm, 1.8 mL/min and 0.112 wt.% menggunakan kaedah pelbagai kriteria pembuat keputusan. Penggunaan tri-hybrid bendalir nano merupakan percubaan pertama untuk meningkatkan sifat terma-fizikal termasuk proses prestasi pemesinan dibawah kelajuan tinggi. Adalah dicadangkan untuk menggunakan tri-hybrid bendalir nano dengan teknik MQL dalam pelbagai proses pemesinan industri.

ABSTRACT

Machining of aluminium alloys is extensively complex due to the adherence tendency of aluminium to the tool surface. During machining, the tool wear is mainly affected by forming an adhesive layer and built-up-edge, significantly affecting the machined surface's quality. Several studies are carried out to restrict the heat generated in machining. Among the various alternatives available, the cutting fluids remain to be the choice. Therefore, different techniques are explored to replace the use of cutting fluids. Nowadays, using nanotechnology in science and industry improves the yield of different processes. Hence, machining operations are used as nanofluid and coated cutting tools with nanoparticles. However, their usage in machining is a comparatively primary stage and deserves much attention. The hybrid nanofluids are potential fluids to offer better heat transfer performance and thermophysical properties than single nanofluids. The machining process using hybrid nanofluids requires further research to better understand the mechanism of tool wear and the fundamental aspects are not yet ventured. This study aims to develop tri-hybrid nanofluids as cutting fluids to enhance the performance of the end milling process of AA6061-T6. The tri-hybrid SiO_2-Al_2O_3-ZrO_2 nanoparticles were dispersed in 60:40 vol.% of deionized water to ethylene glycol, and concentrations 0.08 and 0.12 wt.% were selected to mix with dispersing agent CTAB at a 1:3 weight ratio. After two weeks of daily visual and UV-Vis spectral examination, the tri-hybrid nanofluids were stable. The zeta potential is higher than 30 mV, suggesting well-dispersed nanoparticles. The uncoated tungsten carbide, single-layered CVD TiCN-Al_2O_3 and dual-layered PVD TiAlTaN tungsten carbide inserts were used. The study was conducted using cutting speed, feed rate, depth of cut, MQL flow rate and concentration and machining responses of surface roughness, cutting temperature, cutting force, flank wear. Response surface methodology with central composite rotatable design approach is used, and experimental data were validated statistically. SEM micrographs and EDX patterns characterized tool damage. At 0.1 wt.% and 70°C, tri-hybrid nanofluids were 41.1, 10.5 and 20.3 % better thermal conductivity than base fluid, SiO_2-Al_2O_3 and SiO_2-ZrO_2, respectively. The tri-hybrid nanofluids exhibited 50.5% viscosity enhancement at higher concentrations and lower temperatures. At a higher feed rate, uncoated demonstrated lower surface roughness of AA6061-T6, reflecting the effectiveness of tri-hybrid nanofluids. The cutting temperature below 38 °C improved 84% over the conventional technique. The cutting force was below 30 N, indicating a 35% improvement in process performance. Coated tool exhibited higher cutting force due to coated hardness and various tool failures mechanism. Adhesion, attrition and edge fracture were among of tool failures observed. The absence of BUE is attributed to reduced chip adhesion with higher MQL flow rates and concentrations. Due to coating delamination, coated inserts had worse flank wear than uncoated inserts. However, uncoated tool dominated attrition wear. The optimal end milling parameters were established. The optimum uncoated tungsten carbide cutting conditions were 8440 rpm, 50.1 mm/min feed rate, 0.336 mm cut depth, 1.8 mL/min MQL flow rate, and 0.112 wt% concentration using multi-criteria decision making on parallel coordinates. The application of tri-hybrid nanofluids is the first attempt to enhance single and dual-hybrid thermal-physical properties as well as end milling process performance under high-speed machining. It is strongly recommended to use a newly created tri-hybrid nanofluid with MQL technique in various applications of machining industries.

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