PLASMA SPRAY OF NICRALY COATING ON LASER SURFACE MODIFIED H13 TOOL STEEL

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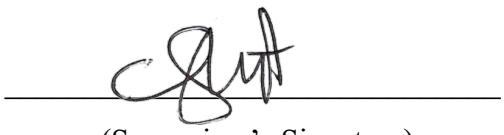
I hereby declare that I have checked this thesis and, in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.



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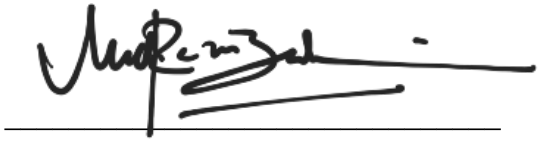

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ABSTRAK

Tesis ini membentangkan kajian eksperimen tentang penyalutan aloi berteraskan nikel, NiCrAlY ke atas permukaan keluli AISI H13 yang telah diubahsuaikan oleh laser dengan menggunakan semburan plasma bertekanan atmosfera. Keluli AISI H13 seringkali digunakan sebagai bahan die di dalam teknologi pembentukan logam, secara spesifiknya pemprosesan logam separa pepejal. Proses pengulangan yang melibatkan kemasukan logam separa pepejal bersuhu tinggi, pemejalan dan sepuh lindapan secara cepat menyebabkan kesan hakisan dan kakisan pada permukaan die. Hakisan yang disebabkan oleh geseran dan kakisan oleh tindakbalas kimia mengurangkan sifat prestasi dan ketahanan die. Maka, mengekalkan sifat die adalah penting bagi memperolehi pemprosesan logam separa pepejal yang optimum. Tujuan ujikaji ini adalah untuk mengubahsuai sifat mekanikal dan lekatan antara muka lapisan salut NiCrAlY. Sifat mekanikal permukaan kekuatan mikro keluli AISI H13 ditingkatkan daripada proses sepuh lindap oleh pengubahsuaian permukaan denyut laser. Manakala, lekatan pengikatan antara muka salut NiCrAlY ditingkatkan dengan penambahan peratusan resapan elemen kimia dan dan gerutu kekasaran permukaan untuk saling kunci mekanikal. Pengubahsuaian permukaan keluli AISI H13 dengan ditingkatkan sifat permukaannya telah dibangun menggunakan saiz bintik laser 90 µm dan 600 µm secara berasingan. Sifat mekanikal dan lekatan antara muka lapisan NiCrAlY ditingkatkan pada parameter laser berlainan. Julat parameter bagi laser bersaiz bintik 90 um yang digunakan adalah kuasa puncak; 0.76 kW dan 1.3 kW, frekuensi kadar denyutan (PRF); 2500 Hz dan 2800 Hz dan kelajuan imbasan rentasan; 2.0 mm/s dan 6.0 mm/s. Manakala julat parameter bagi jenis laser bersaiz bintik 600 um adalah kuasa puncak; 1.6 kW dan 2.0 kW, frekuensi kadar denyutan (PRF); 40 Hz dan 60 Hz dan kelajuan imbasan rentasan; 14.13 mm/s dan 20 mm/s. Sebelum proses salutan NiCrAlY dilakukan, sampel yang telah diubahsuai permukaannya oleh laser bersaiz bintik 600 um telah melalui proses bagas pasir. Profil permukaan iaitu gerutu, kedalaman lembah dan ketinggian puncak serta nilai purata kekasaran, R_a juga telah dianalisa. Kehadiran gerutu permukaan pada keseluruhan profil permukaan dengan lembah dan puncak yang bersaiz rendah meningkatkan kebolehbasahan partikel setrsunya meningkatkan kelekatan saduran NiCrAlY. Analisa komposisi elemen menunujukkan ikatan kimia berlaku akibat difusi elemen. Kehadiran fasa metastabil di permukaan yang telah diubahsuai oleh laser menggalakkan difusi atom berlaku yang memudahkan pelekatan salutan. Fasa metastabil ini mempunyai tenaga lebihan yang membantu penyerapan atom di antara permukaan yang telah diubahsuai oleh laser/saduran. Keputusan ujian lekuk antara muka Vickers menunjukkan kekuatan antara muka lapisan salut NiCrAlY dan permukaan yang telah diubahsuai oleh laser yang diperolehi adalah melangkaui keputusan sampel rujukan iaitu 2.08 MPa. Julat kekuatan antaramuka lapisan yang diperolehi adalah di antara 2.02 MPa dan 6.54 MPa. Sebagai kesimpulan, lekatan antara muka lapisan salut NiCrAlY dipertingkatkan berdasarkan daripada hipotesis penyelidikan. Saling kunci mekanikal memainkan peranan penting untuk lekatan antara muka lapisan salut NiCrAlY. Permukaan yang mempunyai gerutu pada keseluruhan profil permukaan, pengurangan ukuran dalaman dan puncak meningkatkan lekatan saduran. Saling kunci mekanikal memainkan peranan penting bagi kejayaan lekatan saduran NiCrAlY. Maka, saduran NiCrAlY ke atas permukaan logam H13 oleh laser yang bersaiz bintik 600 um memerlukan pasca pemprosesan menggunakan bagas pasir. Dapatan kajian ini penting untuk merekabentuk lapisan salutan prestasi yang berkerintangan haus pada suhu tinggi, ke arah kelestarian pembuatan.

ABSTRACT

This thesis presents experimental study of nickel-based alloy, NiCrAlY coating on laser modified AISI H13 steel using atmospheric plasma spray (APS). AISI H13 steel is often being used as die material in metal forming technology, specifically semi solid metal processing. Repetitive process of incoming high temperature, solidification and rapidly quenched semi solid metal through die, causes erosion and corrosion wear on the die cavity surface. Erosion which was causes by friction and corrosion by chemical reaction mitigate die performance and durability properties. Hence, retaining die properties were crucial to gain optimum semi solid metal processes. This study aims to modify AISI H13 steel substrate surface for enhanced mechanical properties and interfacial bonding with NiCrAlY coating. Mechanical properties of AISI H13 steel surface micro hardness was enhanced from rapid quenching process by pulse laser surface modification. While, interfacial bonding of NiCrAlY coating was enhanced by increasing the percentage of chemical elemental diffusion and the surface roughness asperities for mechanical interlocking. A modified layer of AISI H13 steel with enhanced surface properties was developed using two different laser spot size of 90 µm and 600 µm separately. The mechanical properties and interfacial bonding of NiCrAlY coating on laser surface modified AISI H13 steel substrate were enhanced at different laser parameters. Laser parameters of 90 um spot size used were laser peak power; 0.76 kW and 1.3 kW, pulse rate frequency (PRF); 2500 Hz and 2800 Hz and laser scanning speed; 2.0 mm/s and 6.0 mm/s. While, laser parameters of 600 um spot size used were laser peak power; 1.6 kW and 2.0 kW, pulse rate frequency (PRF); 40 Hz and 60 Hz and laser scanning speed; 14.13 mm/s and 20 mm/s. Prior to NiCrAlY coating, lasered samples being modified by 600 um laser spot size went on sandblasting process. Surface profile such as asperities, valleys depth and peak height and average roughness, R_a also had been analyzed. Asperities at the entire surface profile with low peaks and valleys size promotes wettability of coating particle splats during coating. Elemental analysis showed chemical bonding occurred in coating because of element diffusion. Metastable phase occurred on the laser modified surface inspired atomic diffusion that enhanced coating adhesion. Metastable phase consists of excited energy that promotes atomic diffusion between the laser modified/coating interlayer. Results for coating interfacial toughness obtained by Vickers interfacial indentation test (IIT) were obtained above reference sample toughness measurement which was 2.08 MPa. Interfacial toughness range between 2.02 to 6.54 MPa. For conclusion, interface bonding of NiCrAlY coating is enhanced based from the research objectives. Mechanical interlocking plays an important role for interface bonding of NiCrAlY coating. Surface that contains asperities at whole surface profile, decreasing depth and peaks measurement increased coating adhesion. For atomic bonding, metastable α-Fe phase occurs from laser surface modification assists atomic diffusion in the NiCrAlY coating interlayer. Mechanical interlocking plays major role in the succesful of the NiCrAlY coating adhesion. Hence, NiCrAlY coating on laser modified H13 steel by 600 um laser spot size requires surface post processing using sandblasting. This research findings were important to obtained achievement of coating layer with resistance to erosion and corrosion in the direction of manufacturing sustainability.

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