# AN ANALYSIS ON THE EFFECT OF SURFACE MORPHOLOGY, MICROSTRUCTURE AND HARDNESS OF FRICTION STIR PROCESSED Mg AZ91

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**SUPERVISOR'S DECLARATION**

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 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 degree at Universiti Malaysia Pahang Al-Sultan Abdullah or any other institutions.

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# ABSTRAK

Ketumpatan rendah aloi berasaskan magnesium adalah merupakan salah satu potensi sebagai bahan struktur paling ringan untuk aplikasi automotif dan aeroangkasa kerana mempunyai kekuatan yang tinggi serta ringan. Walau bagaimanapun, kecacatan Mg yang lemah dan aloinya mengehadkan penggunaan kaedah mekanik haba. Mengawal suhu dan kadar ubah bentuk tidak mudah untuk dicapai. Antara proses mekanik haba, pemprosesan pusingan geseran (FSP) menawarkan cara mudah untuk mencapai kestabilan proses dan peningkatan sifat mekanikal dengan rawatan haba yang mengakibatkan penutupan keliangan dan memperhalus saiz butiran. Semasa proses ini, haba dihasilkan oleh putaran daripada alat proses FSP. Beberapa parameter iaitu kelajuan putaran dan perjalanan harus dikawal untuk menjadikan FSP kekal dalam keadaan pemprosesan yang ditentukan. Kajian tesis ini bertujuan untuk menyiasat pengukuhan sifat mekanikal pada Mg AZ91 menggunakan FSP. Pengubahsuaian permukaan telah dilakukan ke atas aloi Mg AZ91 dan dinamakan sebagai FSPed Mg AZ91 menggunakan alat keluli H13 dengan pin bersilinder lurus. Dalam penyelidikan ini, setiap FSP dilakukan pada satu pas menggunakan kelajuan putaran yang berbeza iaitu 1000, 1100, 1200, 1300 dan 1400 putaran seminit sementara kelajuan perjalanan pula bervariasi pada 25, 35, 45 dan 55 milimeter seminit. Pemerhatian mikrostruktur dilakukan menggunakan mikroskop optik untuk mendedahkan saiz butiran halus dalam spesimen yang telah diproses. Sifat mekanikal aloi Mg AZ91 iaitu kekerasan diuji dan dibandingkan. Mikrostruktur selepas FSP terdiri daripada butiran-butiran yang lebih kecil serta kekerasan yang dipertingkatkan sebanyak 22 - 65% jika dibandingkan dengan logam asas Mg AZ91. Apabila kelajuan putaran FSP meningkat, purata nilai kekerasan mikro didapati meningkat setelah saiz butiran mengecil. Hal ini disebabkan oleh penghalusan butiran Mg AZ91. Dengan melaksanakan modifikasi bahan dan prosedur langsung FSP, proses pengukuhan permukaan mekanikal terhadap kekerasan dan struktur butiran dapat diperkukuhkan. Akhirnya, parameter yang optimum bagi memproses Mg AZ91 adalah dengan menggunakan kelajuan putaran: 1400 putaran seminit dan kelajuan perjalanan: 45 milimeter seminit kerana ia mempunyai kecacatan minimum pada spesimen yang telah diproses, terdiri daripada saiz butiran yang terkecil iaitu 59.2 μm dengan kekerasan yang tertinggi iaitu 84.4 HV.

**ABSTRACT**

Low density of magnesium-based alloy is one potential as the lightest structural material for light weight-high strength applications for automotive and aerospace. However, the poor deformability of Mg and its alloys limits the application of the thermomechanical approach. Controlling over temperature and deformation rate is hard to achieve. Among the thermomechanical processes, friction stir processing (FSP) offers an easy way to achieve process stability and mechanical properties enhancement by heat treatment which results in the closure of porosity and refined grain size. During this process, heat is generated by the rotation of the FSP processing tool. Few process parameters as rotational and traverse speeds should be controlled to make FSP stay within the defined processing condition. This thesis study aims to investigate the mechanical properties strengthening on Mg AZ91 using FSP. The surface modification was done on Mg alloy, namely FSPed Mg AZ91 using H13 tool steel with a straight cylindrical pin tool. In this research, each FSP were performed at single pass using different rotational speeds which were 1000, 1100, 1200, 1300 and 1400 rpm while traverse speeds were varied at 25, 35, 45 and 55 mm/min. FSP was used as an approach to refine the microstructure and enhance the mechanical properties of Mg AZ91. Microstructure were observed using optical microscope to reveal the refined grain size within the FSPed specimens. The mechanical properties of Mg AZ91 particularly the hardness was tested and compared. The microstructure after FSP consists of smaller grains as well as the hardness were enhanced about 22 - 65% when compared to base metal Mg AZ91. When FSP rotational speed increases, the average microhardness value increases as the grain size reduces. This significance was due to grain refinement of Mg AZ91. By implementing the material modifications and direct procedure of FSP, the mechanical surface strengthening processes on hardness and microstructure can be boosted. As the result, the optimized parameter to process Mg AZ91 is by using rotational speed: 1400 rpm and traverse speed: 45 mm/min as it has minimum defects observed on the FSPed specimen, consisting the smallest grain of 59.2 μm and fine recrystallized equiaxed grains with highest hardness of 84.4 HV.

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