MICROSCOPIC STUDY OF 5083-H321 ALUMINIUM ALLOY UNDER FRETTING FATIGUE CONDITION

By

SAEED ESLAMIAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

January 2005

DEDICATION

TO MY WIFE AND DAUGHTERS

Abstract of thesis to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Prithvi Raj Arora, Ph.D

Faculty : Engineering

In this investigation, fretting fatigue study is carried out using 5083-H321 aluminium alloy. The test rig was designed to apply the normal load on the thickness side of the surface of the specimen, which is presumed to be the active surface for the fretting process. Fretting fatigue experiments were designed with an emphasis to study the crack initiation behaviour in the fretted region using scanning electron microscope. In order to investigate the possible crack initiation mechanisms in fretting fatigue as well as for the associated fatigue two different types of tests were proposed along with fundamental pure plain fatigue tests. These tests are named as fretting fatigue test and interrupted fretting fatigue test. First, pure plain fatigue tests were carried out with three maximum stresses of 200 MPa, 220 MPa, and 230 MPa, and with a stress ratio R of 0.1 at a frequency of 20 Hz. At each stress level three specimens were tested. Further fretting fatigue tests were carried out for normal pressures of 15 MPa, 30 MPa, and 45MPa at each axial stress level of 200 MPa, 220 MPa, and 230 MPa, with a stress ratio, R of 0.1 at a frequency of 20 Hz

and. It has been found that the fatigue life reduces by a factor of 2.55, 3.48, and 3.54 for specimens tested with normal pressures of 15 MPa, 30 MPa, and 45 MPa using a maximum axial stress of 200 MPa respectively. The life reduces by factors of 3.16, 2.07, and 4.54 for specimens tested with normal pressures of 15 MPa, 30 MPa, and 45 MPa respectively using a maximum axial stress of 220 MPa. On the other hand the fatigue life reduces by a factor of 2.24, 2.37, and 2.81 for normal pressures of 15 MPa, 30 MPa, and 45 MPa respectively using maximum axial stress of 230 MPa. In general we can say that the fatigue life reduces by a factor of 2 to 3 for all specimens tested at fatigue stress levels and the normal pressures applied to the specimens as indicated above due to fretting fatigue in this investigation.

For the fretting fatigue specimen tested with maximum axial stress of 200MPa and a normal stress of 15 MPa the crack initiates from the locations along the pad edge boundary of the specimen with a mild river pattern and subsequently propagates to failure. For the fretting fatigue specimen tested with maximum axial stress of 200MPa and a normal stress of 30 MPa the crack appears to propagate in multi directions whereas for the case of maximum axial stress of 200MPa and a normal stress of 45 MPa the behaviour is somewhat similar to the cases of normal stress of 15 MPa and 30 MPa but the rate of crack propagation is relatively faster. The fracture surface of the specimens tested with normal stress of 15 MPa, 30 MPa, and 45MPa using maximum axial stresses of 220 MPa and 230 MPa indicate a similar pattern of cracking behaviour as indicated for maximum axial stress of 220. As far as the fracture morphology is concerned more tilt towards the fibrous nature along with increased crack propagation rate has been observed for specimens tested with more normal pressure/ stress as well as with increase in applied maximum axial stress. Also it is observed that the fretting fatigue failure often initiated at the boundary between the pad and specimen contact surface. As far as the damage is concerned the fretting damage increases with number of cycles and crack initiated after the specimens are tested to in the life range of 40% to 60% of life at maximum axial stress of 200MPa giving the damage threshold in basic fretting behaviour. But the crack initiation life is less for higher normal pressure/stress at the contact interface.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KAJIAN MIKROSKOPIK ALOI ALUMINIUM 5038 – H321 DI BAWAH KEADAAN RETAK LESU

Oleh

SAEED ESLAMIAN

Januari 2005

Pengerusi : Profesor Madya Prithvi Raj Arora ,Ph.D

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Dalam siasatan ini, satu ujian retakan dijalankan ke atas aloi aluminium 5038-H321. Pelantar ujian direaka untuk menggunakan beban normal atas permukaan paling tebal spesimen iaitu permukaan yang di anggap paling aktif dalam proses retakan. Eksperimen retak lesu direkja dengan mengutamakan kajian ke atas perlakuan permulaan rekahan pada kawasan retakan dengan menggunakan ‘Misroskop Imbasan Elerktron’. Untuk mengkaji mekanisme permulaan rekahan yang mungkin berlaku dalam retak lesu dan juga kelesuan yang berkaitan dua ujian berbeza dicadangkan bersama-sama dengan ujian kelesuan asas yang tulin. Ujian ini dinamakan ujian retak lesu dan ujian lesu terganggu. Pertama, ujian kelemahan tulen dijalankan pada tahap tekanan tiga paksi kitaran pada 200, 220 dan 230 MPa dengan nisbah tekanan R 0.1 pada frekuensi 20Hz. Pada setiap tahap tekanan, tiga spesimen diuji. Lebih banyak ujian retak lesu dijalankan pada tekanan

normal 15 MPa, 30 MPa dan 45 MPa pada tahap paksi tekanan 200, 220 dan 230 MPa, dengan nisbah tekanan R 0.1 pada frekuansi 20Hz. Di dapati bahawa Jangka hayat kelesuan berkurangan dengan faktor 2.55, 3.48 dan 3.54 untuk setiap spesimen yang diuji dengan tekanan normal 15, 30 dan 45 MPa menggunakan tekanan paksi maksima setiap satu. Jangka hayat berkurangan dengan faktor 3.16, 2.07 dan 4.54 masing-masing untuk tekanan normal 15, 30 dan 45 MPa pada tekanan paksi 220 MPa.

Sebaliknya jangkahayat kelesuan berkurangan dengan faktor 2.24, 2.37 dan 2.81 untuk tekanan normal 15 MPa, 30 MPa dan 45 MPa setiap satu menggunakan tekanan paksi maksima 230 MPa. Secara amnya boleh dikatakan bahawa jangka hayat kelesuan disebabkan retakan kelesuan berkurangan dengan faktor 2 hingga 3 untuk setiap tahap tekanan kelemahan yang diuji dan pada semua tekanan normal yang diberikan kepada spesimen dalam kajian ini. Sampel retak lesu yang diuji pada tahap tekanan paksi 200 MPa dan tekanan normal 15 MPa, rekahan bermula dan tersebar sepanjang sempadan spesimen dengan corak aliran sungai dan akhirnya menemui kegagalan. Sementara untuk kes tekanan paksi maksima 200 MPa dan tekanan normal 45 MPa, perlakuannya adalah sama seperti kes-kes tekanan normal 15 MPa dan 30 MPa tetapi kadar penyebaran retakan adalah lebih cepat.

Permukaan retakan spesimen yang diuji pada tekanan normal 15 MPa, 30 MPa dan 45 MPa menggunakan tekanan paksi 220 MPa dan 230 MPa memperlihatkan corak perlakuan retakan yang sama seperti terkanan paksi maksima 220 MPa. Untuk retakan pula, didapati bahawa terdapat lebih kecondongan berbentuk fiber serta pertambahan kadar penyebaran retakan bagi spesimen yang diuji pada tekanan normal dan penambahan tekanan paksi maksima. Dilihat juga kegagalan retak lesu kerap bermula pada sempadan antara permukaan pelapik dan spesimen. Bagi kerosakan retak pula bertambah dengan bilangan pusingan dan retakan yang dimulakan selepas spesimen-spesimen diuji dalam lingkungan hayat 40% - 60% pada jangka hayat tekanan paksi maksima 200 MPa memberikan ambang kerosakan dalam perlakuan retakan adalah lebih kurang untuk tekanan normal yang lebih tinggi di permukaan sentuh.

ACKNOWLEDGEMENTS

Thank thee O God for the opportunity given to me so I could receive my education.

I would like to thank Associate professor Dr. Prithvi Raj Arora for his enthusiastic and inspirational support and supervision throughout this project. His knowledge, constructive criticism and encouragement were vital to my learning. I am very grateful to my supervisory committee members, Associate professor Dr. Abdel Magid Hamuada and Dr. El-Sadiq Mahdi for their invaluable suggestions during the course of technical discussions.

I extend my gratitude to Mr. M.S Jacob and Mr. A. Saifol for their help and assistance when needed.

Finally, but not the least, I would like to express my sincere appreciation to my wife Maryam and my daughters Fahimeh and Fatemeh for their love, cheerful encouragement, warm support, patience and understanding throughout this work. I am also grateful to my parents for moral and additional financial support. None of this would have been possible without their love and encouragement throughout my life.

I certify that an Examination Committee met on 31st January 2005 to conduct the final examination of Saeed Eslamian on his Master of Science thesis entitled "Microscopic Study of 5083-H321 Aluminium Alloy Under Fretting Fatigue Condition" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as partial fulfilment of the requirement for the degree of Master Science. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

SAEED ESLAMIAN

Date: 31st January 2005

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