UNIVERSITI PUTRA MALAYSIA

RESIDUAL STRESS RELAXATION OF SHOT-PEENED 2024-T351 ALUMINIUM ALLOY

OMAR SULIMAN ZAROOG

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By
OMAR SULIMAN ZAROOG

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

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DEDICATION

To

My family members especially my beloved wife, my children and my ever -encouraging father for his love

Abstract of thesis presented to Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: Associate Prof. Aidy Ali, PhD

Faculty: Engineering

Near surface tensile residual stresses tend to accelerate the initiation and growth phases of the fatigue process while compressive residual stresses close to a surface may prolong fatigue life and consider as beneficial residual stresses. Shot peening process used to induce beneficial compressive residual stress in materials. However, the residual stresses may relax due to thermal, static mechanical load and cyclic load. Even with partial relaxation, there found a beneficial effect of compressive residual stress on fatigue life. The problem is how much is the relaxation? To answer this question a 2024 T351 aluminium alloy specimens were shot peened into three shot peening intensities 0.0054 A, 0.0067 A and 0.009 A. The cyclic test for the two loads magnitude, 15.5 kN and 30 kN, was performed for the 1, 2, 10, 1000 and 10000 cycles. The initial residual stress and residual stress as well as cold work after each cyclic load were measured for the three shot peening intensities and for the two magnitudes of loads using X-ray diffraction method. Initial and after microhardness of each cyclic load were measured for the three shot peening intensities.

The results showed that the most relaxation of the initial residual stress took place in the first cycle; the initial residual stress was relaxed by 46% after first cycle in the load 30 kN and shot peening intensity of 0.0054 A. Relaxation of residual stresses occurred within first loading cycles were increasing with increasing loading stress amplitude and due to quasi-static relaxation effects. The residual stress after the first cycle found to relax depends on the load amplitude. The maximum relaxation found is 54% of the initial residual stress in the shot peen intensity of 0.0054 A after 10000 cycles for the load of 30 kN. The changed in the relaxation percentages of all specimens from 10 cyclic load to 10000 cyclic load is in the range of 5-8% of the initial residual stress. Microhardnesses were found to decrease depending on the load amplitude. A load of 30 kN made microhardness in the specimens decrease more than the 15.5 kN load. The microhardness was reduced by 39%, given a shot peen intensity of 0.009 A after 10000 cycles under a load of 30 kN. From observations and results, empirical equations to estimate the residual stress relaxation were proposed. The equations incorporated the number of cycles and cold work to predict the amount of residual stress relaxation. Finally, the results of the estimation are in a good agreement with experimental data.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

RELAKSASl STRES SISA OF SHOT-PEENED 2024-T351 ALUMINIUM ALOI

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January 2011

Pengerusi: Profesor Madya Aidy Ali, PhD

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Tegasan-tegasan lebihan berdekatan permukaan cenderung untuk memacu fasa-fasa permulaan and pertumbuhan dalam proses fatig dan tegasan-tegasan lebihan mampatan berdekatan sesuatu permukaan mungkin akan memanjangkan jangkahayat fatig dan diandaikan sebagai tegasan-tegasan lebihan yang bermanafaat. Proses ‘shot peening’ telah digunakan untuk menghasilkan tegasan lebihan mampatan di dalam bahan tersebut. Walau bagaimana pun, tegasan-tegasan lebihan tersebut berkemungkinan akan berada di dalam keadaan rehat disebabkan oleh suhu, beban mekanikal statik, dan juga beban berputar. Walaupun dengan keadaan separa rehat, adalah didapati terdapat kesan yang bermanafaat hasil dari tegasan lebihan mampatan terhadap jangkahayat fatig. Persoalannya, berapa banyak jumlah keadaan rehat tersebut? Bagi menjawab persoalan ini, spesimen aluminum aloi 2024 T351 telah di kenakan proses ‘shot peening’ berintensiti 0.0054 A, 0067 A dan 0.009 A. Ujian putaran untuk bagi dua magnitud beban iaitu 15.5 dan 30 kN, telah dijalankan untuk 1, 2, 10, 1000 dan 10000 putaran. Tegasan lebihan permulaan dan juga tegasan kerja sejuk selepas setiap beban putaran telah diukur untuk tiga intensiti ‘shot peening’ dan untuk dua magnitud beban dengan menggunakan

kaedah ‘X-ray diffraction’. Bacaan mikro-kekerasan untuk setiap beban putaran telah diambil untuk tiga intensiti ‘shot peening’. Keputusan telah menunjukkan yang kebanyakkan keadaan rehat pada tegasan lebihan permulaan berada pada permulaan kitaran; tegasan lebihan permulaan telah direhatkan sebanyak 46% selepas putaran pertama pada beban 30 kN dan intensiti ‘shot peening’ 0.0054 A. Kerehatan tegasan lebihan telah berlaku dalam masa beban putaran pertama dan bertambah dengan pertambahan amplitud bebanan tegasan dan juga disebabkan oleh kesan-kesan kerehatan quasi-statik. Kerehatan tegasan lebihan selepas putaran pertama didapati bergantung kepada amplitud bebanan. Kerehatan maksima adalah 54% dari tegasan lebihan permulaan pada intensiti ‘shot peening’ 0.0054 A selepas 10000 beban putaran bagi bebanan sebanyak 30 kN. Perubahan di dalam peratusan kerehatan untuk semua spesimen daripada 10 ke 10000 beban putaran adalah di dalam julat 5 – 8% daripada tegasan lebihan awal. Mikro-kekerasan didapati telah mengurang, bergantung kepada amplitud bebanan. Beban sebanyak 30 kN telah menyebabkan bacaan mikro-kekerasan berkurangan sebanyak 15.5 kN bebanan. Bacaan mikro-kekerasan telah berkurangan sebanyak 39%, pada intensiti ‘shot peening’ 0.009 A selepas 10000 putaran pada beban 30 kN. Daripada pemerhatian dan hasil keputusan, persamaan-persamaan empirikal untuk menganggarkan kerehatan tegasan lebihan telah dicadangkan. Persamaan-persamaan tersebut mengambilkira jumlah putaran dan juga kerja sejuk bagi menganggarkan jumlah kerehatan tegasan lebihan tersebut. Adalah didapati, hasil keputusan anggaran tersebut menunjukkan persamaan dan di dalam julat yang boleh diterima jika dibandingkan dengan data-data dari ujikaji.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted in fulfilment of the requirements for the degree of Doctor of Philosophy. Members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the 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 and it not concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.

Omar Suliman Zaroog

Date: 25 January 2011

TABLE OF CONTENTS