شبكة المعلومات الجامعية

بسم الله الرحمن الرحيم

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

شبكة المعلومات الجامعية

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

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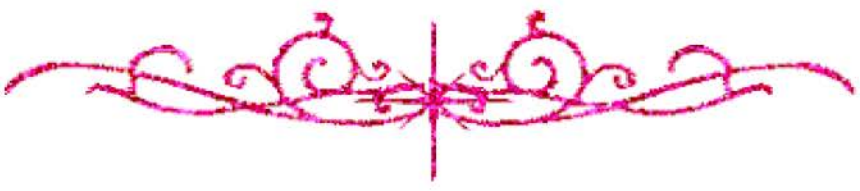

INFLUENCE OF AUTOFRETTAGE ON RESIDUAL STRESS INTENSITY FACTORS OF INTERNALLY OR EXTERNALLY CRACKED GUN BARRELS

BY

Wissam Moustafa Al-Hozwany

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for Degree of
DOCTOR OF PHILOSOPHY
in
MECHANICAL ENGINEERING

Under supervision of

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FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
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ABSTRACT

A traditional method of improving structural strength against cracking is through the existence of residual stresses. In the case of gun barrels, the beneficial residual stresses can be obtained by using the autofrettage process. This technique is carried out by applying an internal pressure sufficient to plastify a portion of the wall leaving the outer part elastic. Then this applied pressure is released leaving behind appreciable residual stresses. The estimation of these residual stresses requires an accurate knowledge of mechanical properties of gun barrels materials. In addition, the cyclic pressurization of gun barrels (firing and unfiring) tends to produce radial cracks at the bore. The presence of residual stresses in the cracked gun barrels can significantly influence their fatigue and fracture behavior. In order to predict the fatigue growth rates of such cracks, and hence the safe-life , a knowledge of the residual stress intensity factor , K_{res} , is very essential.

The first part of the present work is concerned with the chemical composition, heat treatment and microstructure of three types of high strength steels which are called gun steel. Also, impact toughness, tensile properties and reverse yielding in small plastic strain range are evaluated. In addition, fracture toughness and fatigue crack growth rates were estimated experimentally using compact tension specimens.

Charpy V-notch impact toughness is determined at the temperature range -70 °C to +70 °C . Tensile testing results showed that the monotonic plastic tensile behavior is almost linear. Tensile loading up to different values of plastic pre-strain (up to 2.5%) followed by reverse loading in the compression mode are determined and described by relevant equations for future modeling of the autofrettage process of gun barrels. The experiments illustrated that the elastic unloading range is much less than twice the initial yield strength of the material, which indicates a high degree of Bauschinger effect. Also, it is

found that the subsequent compressive stress- strain behavior is highly non-linear.

Plane-strain fracture toughness is determined according to ASTM E399-90 standard specification using compact tension specimen. The tests provided an invalid K_{IC} result. Therefore, and elasto-plastic J-integral was estimated according to ASTM E813-90 in a way of characterizing the fracture behavior. The validity requirements for calculating J_Q obtained from the J-R resistance curves, showed that the thickness and the ligament satisfy the requirements; both $B,\ (W,a) \geq 2.5 * J_Q / \sigma_o$. Finally, fatigue load with minimum to maximum load ratio of about 0.13. Threshold stress intensity factor K_{th} was found to be about 27 MPa$\sqrt{m}$.

The second part of the present work is concerned with investigating the residual stress distribution in autofrettage thick-walled tubes. Residual hoop stress distribution is predicted by means of simple Hill's approach assuming isotropic hardening and the more recent approach developed by Megahed-Abbas accounting for Bauschinger effect and non-linear reverse yielding. The effect of yield criteria on residual stresses is also investigated. the results showed that the residual stress distribution is sensitive to the particular model of material behavior and yield criterion employed. The calculations showed that both of Bauschinger effect and reverse yielding caused the residual compression at the bore to be overestimated.

Stress intensity factors induced by the residual stresses K_{res} in both internally or externally cracked gun barrels are analytically evaluated as a function of crack depth using two different techniques. The first technique employs the weight function method as proposed by other investigators. The second method relies on finite element technique where the residual stress field is simulated by means of artificial temperature gradient across the tube wall.

The results obtained from both methods yielded similar results. It is shown that K_{res} values associated with internal cracks in residual stress fields induced by the autofrettage are negative for almost the entire range of crack

length and thus beneficial. For external cracked tubes, K_{res} is always positive and therefore promotes failure at the tube outer surface. For both internally and externally cracked tubes, K_{res} solutions corresponding to residual stresses predicted by Tresca criterion yielded values that are approximately twice the magnitude of the corresponding values predicted by von-Mises yield criterion assuming equal autofrettage pressure. Possible reasons for these variations in estimating K_{res} are discussed.