THE PROPAGATING FATIGUE CRACK LENGTH ESTIMATION BASED ON CRACK OPENING VALUE AT THE SPECIMEN EDGE MEASUREMENT RESULTS

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ABSTRACT

The crack length measuring method on flat specimen with single edge crack based on the crack opening value measured at the specimen's edge is presented in this paper. This method was applied in 18G2A steel specimen tests, loaded at constant amplitude and also at constant amplitude with onefold overloadings.

KEYWORDS

Low cycle fatigue, crack length, crack opening, overloads

INTRODUCTION

The crack length determination during flat specimen fatigue tests remains yet a crussial task especially at constant amplitude loadings. The crack length measurement method on a flat specimen with single edge crack (SEC) based upon crack opening value measuring results on the specimen's edge is presented in this paper. It was applied in tests of 18G2A steel specimens loaded at constant amplitude and also at constant amplitude with some onefold overloadings applied at equal time intervals repeatedly.

EXPERIMENTAL TECHNIQUES

A standard clip gauge with the base of 10 mm was used to measure the crack opening quantity. The standardisation and calibration of the gauge was assured by the testing machine itself at its corresponding measuring units. The appropriate fatigue tests were carried out after the initiation. They consist of two investigation sets. The first one - at constant amplitude loading at σ_{max} equal 160 MPa; the other one also at constant amplitude but interrupted every 10000 half cycles with almost static (at frequency of 0.01 Hz) overloadings at k_{ov} = 1.75 - overloading coefficient. For both sets an asymmetry cycle coefficient equal R = 0.3 was accepted. During the tests the fatigue cycle number N, loading force F and opening value of the fatigue crack were recorded. In this tests the INSTRON fatigue rig was used.

TEST RESULTS

The crack opening values versus fatigue cycle numbers for both cases are presented in Fig. 1 and Fig. 2 respectively.

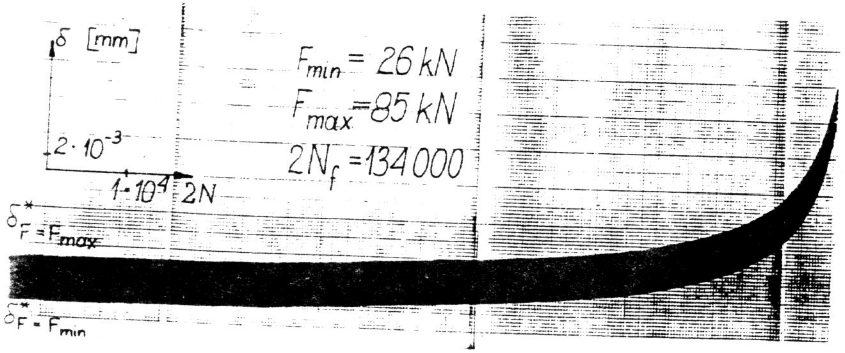

Fig. 1 The experimental record of the fatigue crack opening value versus the cycle numbers for specimen without overloadings

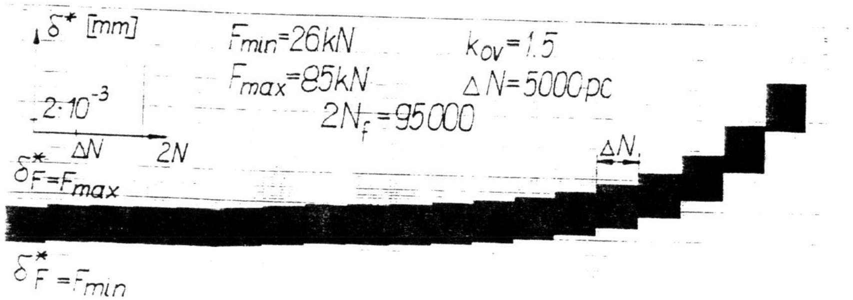

Fig. 2 The experimental record of the fatigue crack opening value versus the cycle numbers for overloaded specimen

In the case without overloadings (Fig. 1) a characteristic continuous rise of the crack opening value from the initial to the critical point was obtained. For the tests with overloadings (Fig. 2) the changes of the crack opening levels takes place only in the overloading events on the other hand and stayed approximately at constant levels between them also in the subcritical crack developement range. Characteristic pictures of fatigue fracture micrographs in both cases are presented in Fig. 3 and Fig. 4 respectively.

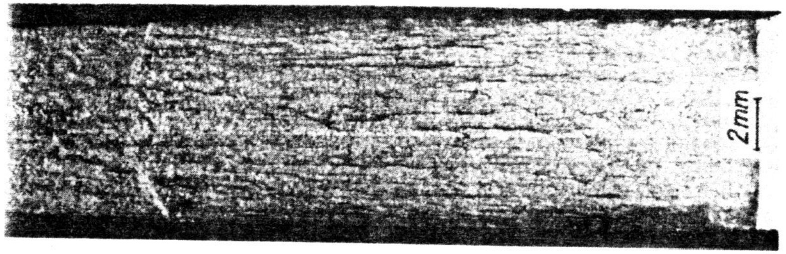

Fig. 3 Microfractograph of a SEC specimen tested without overloadings

In the first case - tests without overloadings - the fatigue fracture has a marked fatigue zone with different initiation part at the top of the crack and also a brittle crack zone (Fig. 3).

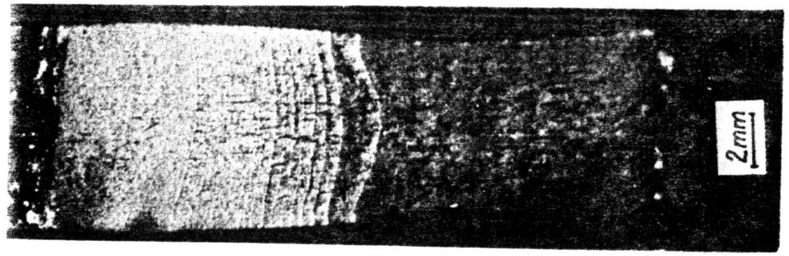

Fig. 4 Microfractograph of a SEC specimen tested with overloadings

In the second case - test with overloadings - the fatigue zone along the crack propagating path from the initial to the critical length is characterizied by overloading lines /Fig. 4/. The spaces between the overloading lines increases systematicaly in the fatigue fracture area with the rise of the crack length. Since the overloading lines number at the sample fatigue fracture surface equals the standed through ovelroading events - one can draw a simple relation a = f(N) using the distance measurement results of the specimen fatigue overloading lines. A microphotographic analysis of the specimen fatigue fracture areas with the use of electron- or scanning microscopes shows clearly that the fatigue crack developement takes place both in the overloading events and also between them - what can be seen in the form of fatigue striations located between the overloading lines. For the specimen without overloadings we can not expect the presence at the fatigue fracture area of the overloading lines, therefore we can not get the experimental relation for a = f(N) . For this case a method of the propagating crack length value estimation based upon the changes of crack opening values - a parameter which can be recorded in both cases of testing - is here presented. This method was first tested on specimens with overloadings by comparing the calculated and experimentaly measured crack length. The crack opening value changes recorded during the tests versus increasing force values applied at 0.01 Hz frequency in the overloading events were used. The records in half cycles of tension and reverse runs of the curves force - crack opening value for specified overloading cycles and corresponding crack length are shown in Fig. 5.

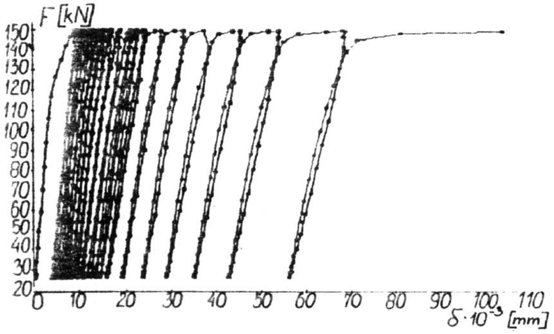

Fig. 5 Loading force versus crack opening value recorded from SEC specimen for succesive overloading cycles

The crack opening value after each overloading event has increased and remains only to the defined force level linear relation versus the loading force. The increase of the crack opening value in Fig. 2 is caused by permanent plastic deformation in the overloading events, this is shown by an increase of the extensometric signal value. After eliminating the permanent deformations from this crack opening values and estimating the zero value of the crack opening in each overloading

event the plot in Fig. 5 can be transformed to the form shown in Fig. 6. There are only the tension half cycles presented and the transformation is based on assuming a linear relation: force - crack opening value in the range of 0 to 50 kN.
The specified curves correspondes to the sequential overloading events and are equivalent in meaning assigned to the determined on base of fatigue fracture crack length measurements. The defection from the linear relation $\delta = f(F, a)$ [1] which markes the overcrossing the linear-elastic fracture mechanics area in the course of testing and also the essential drop of the plastic deformations in the tested material.
The runs of the first overloading events (which correspondes to the nondeformed material under overload of the range $k_{ov} = 1.75$) shows another character, which argues that in the linear-elastic range, the presented relation can bear a quite different character.

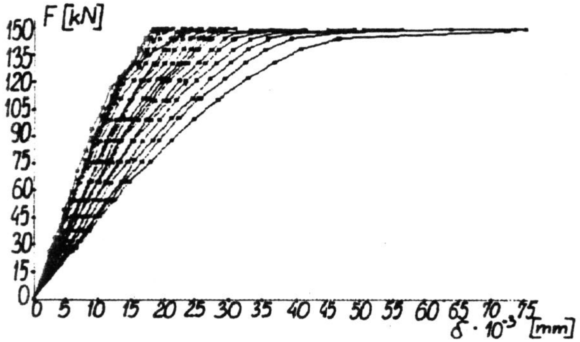

Fig. 6 Loading force versus crack opening value recorded from SEC specimen for succesive overloading cycles after elimination of permanent deformations

Using the plots of Fig. 6 one can at given force level F = constant express the crack length - crack opening value relation as the individual curves are univocal with the measured length connected. In Fig. 7 for F = constant e.g. 70; 85 and 149 kN respectively the curves crack length - crack opening value ($a = f(\delta)$) approximated by the curvelinear regression method are shown. We have got this relations respectively:

$$a_{70} = -2.451 + 231.484\delta - 370.062\delta^2$$

$$a_{85} = -2.148 + 201.482\delta - 296.304\delta^2$$

$$a_{149} = -0.308 + 97.477\delta - 127.924\delta^2 + 58.069\delta^3$$

The estimation of a crack length based on the recorded crack opening value gives good fitness in the central part of the relation range.

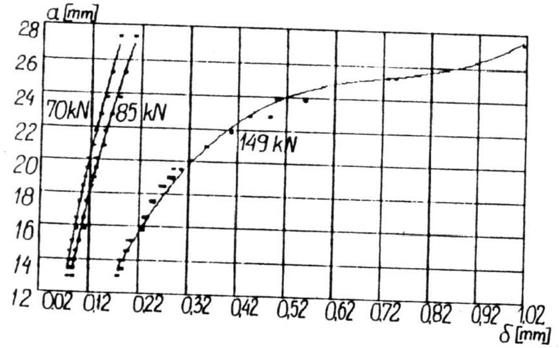

Fig. 7 The crack length change versus crack opening value for chosen load levels measured on a SEC specimen

The relations a = f(δ) at F = constant adequate for testing without overloads create the possibility to determine the fatigue crack length from the crack opening values measurement results also at specimens without overloadings.

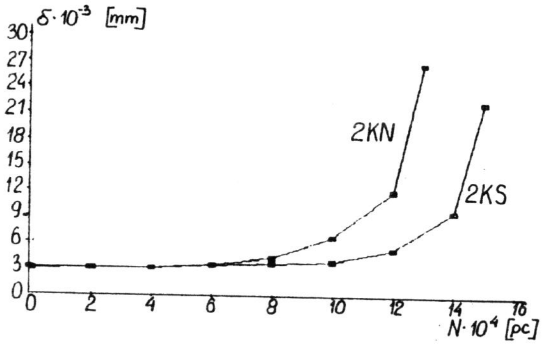

Fig. 8 The recorded crack opening values versus half cycle number runs on SEC specimen tested without overloadings

In Fig. 8 the measured in test runs without overloadings on 18G2A steel SEC specimens crack opening values versus the cycle numbers are presented. The tests were carried at F_{max} = 85 kN, on unwelded specimen - 2KN and on specimen with a welding joint - 2KS.
In Fig. 9 the corresponding plots of a = f(N) based on respectively relation a = f(δ) are ahown.

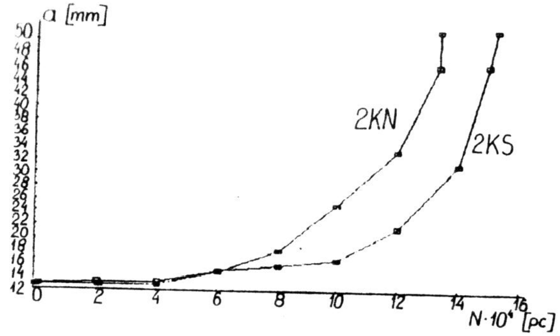

Fig. 9 Fatigue crack length estimation results based on the crack opening values for SEC specimen tested without overloadings

FINAL REMARKS

The fatigue crack length estimation method based on the crack opening values measuring results on flat specimens with a single edge crack presented here reflects good the crack propagating length values. It was in good agreement confirmed experimentaly. Using this method one can check the length of a propagating crack also in the case of permanent plastic deformation appearance.

REFERENCES

1. Y. Murakami 1987 "Stress Intensity Factors Handbook" Pergamon Press. New York.