INVESTIGATION OF CRACK INITIATION AND PROPAGATION USING THE ELECTROINDUCTIVE METHOD

P.I. Barzakov,* M.S. Albrzawi **

It is proposed to use the electroinductive method for studying the crack initiation and propagation in specimens under static loading. On the obtained plots of the relationship between output signal and loading one can clearly observe the characteristic regions of changes in the material when loaded. The moments of macrocrack initiation and its unstable propagation are determined.

INTRODUCTION

The determination of material resistance characteristics in brittle fracture is standartized to a considerable extent but more efficient, rapid methods are still sought for characterizing the crack resistance of the material, by using fewer specimens or just one specimen (1),(2),(3). The authors of this report are also taking part in this search proposing the use of the electroinductive method for obtaining a sufficiently rapid, reliable and cheap result. Using this method it is possible to investigate the crack initiation and propagation not only in high-strength steels, but also in medium- and low-carbon steels.

* Department Strength of Materials, Technical University - Sofia, 1797 Sofia, Bulgaria.

** Mechanical and Electrical College, Damascus University, Damascus, Syria.

SPECIMEN, MATERIALS AND EXPERIMENTS

Specimens and materials. Two types of specimens are used, plates and cylinders (Fig.1). With the help of a cutter, a concentrators of width 1 mm, tip radius 0.1 mm and depth 5 mm, is made in the middle of one or two edges of the plates. A wedge-shaped circumferential concentrator is made on the cylindrical specimen too. The two types of specimens are tested without creating fatigue crack, as-delivered, without thermal treatment, and under normal laboratory conditions.

TABLE 1 - Chemical composition and mechanical properties

Mate-rial	C %	Mn %	P %	S %	Si %	Ni %	Cr %	σ_{ys} MPa	σ_{ts} MPa	E GPa
st-20	0.20	0.65	0.04	0.03	0.30	0.25	0.25	250	42	210
st-45	0.45	0.70	0.04	0.04	0.35	0.25	0.25	360	75	210
st-65G	0.65	1.1	0.04	0.04	0.03	0.25	0.25	440	100	210

Experimental technology. Two specimens are used. They are put separately into measuring coils in such a way that the coils are located over the stress concentrators. The measurement circuit is given in Fig.2. Only specimen 1 is loaded with force P, measured by load cell 2. The signal of load cell is applied, through the amplifier 3, to the input "X" of X-Y recorder 4. The measuring coil over specimen 1 and the coil over specimen 5, which is just compensating, are connected in an electrical semi-bridge. The semi-bridge output signal is applied, through a universal strain-gauge amplifier 6, to the input "Y" of the recorder. The tension loading of the specimen is performed by using a test machine of speed 0.5 to 1 mm/min.

Experimental results. The results of testing 12 specimens of each material are analyzed. The typical curve of the relationship between the output signal and the force for st-65G is shown in Fig.3. With load increase an increasing of the specimen's electromagnetic signal occurs (zone OA), and then a constant electrical signal is observed (zone AB). This can be explained by the theory of ferromagnetism. After point B the electrical signal begins to diminish at a higher rate. The metallographic investigations of the material around the concentrator tip show that a macrocrack has already occurred there, i.e. the force corresponding to that point can be assumed as a "force initiating crack opening", P_i. In the zone between points B and C the electrical signal decreases almost linearly, which corresponds to the stable crack opening. In zone CD the signal is changing without increasing the force. This force value is P_{max}, at which the unstable propagation of the crack occurs, and after point D the specimen is physically divided into two parts. After generalizing the results for the tested specimens of st-65G the value of P_{max} is 7880 $\pm$ 150 N. The same force, P_{max}, for this material obtained by the standard method for crack-tip opening displacement is 7600 N. St-65G and st-45 give similar curves, but st-20 curve (Fig.4) has larger zones due to material plasticity.

CONCLUSION

The use of the electroinductive method has shown that the internal structural changes in steels when cracks are initiated and propagated can be traced with sufficient sensitivity and selectivity, and that medium- and low-carbon steels may also be tested.

SYMBOLS USED

σ_{ys} = yield strength (MPa)
σ_{ts} = tensile strength (MPa)
E = Young's modulus (GPa)
P_i = load initiating crack opening (N)
P_{max} = maximum load (N)

REFERENCES

(1) Clarke G.A. et al, "Single Specimen Test for J. Determination", ASTM STP 590, Am. Soc. Testing mats. 1976, pp.27-42.

(2) Willoughby A., Garwood S., "On the Unloading Compliance Method of Deriving Single-Specimen R-curves in Three - Point Bending", ASTM STP 803, S.F.Shih, ed, Am.Soc.Test. Mat., pp. II- 372-397.

(3) "Standard Practice for R-curve Determination". ASTM-E 561-86.

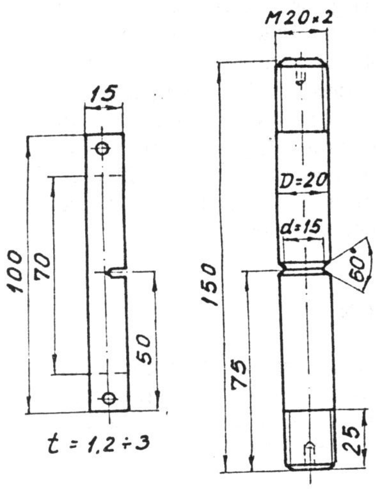

Fig.1. Specimens

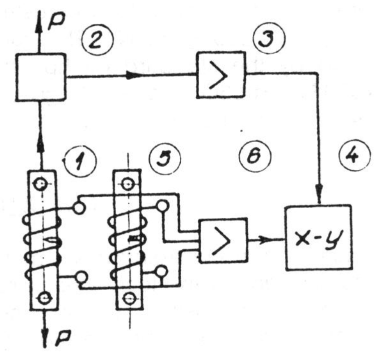

Fig. 2. Measurement scheme

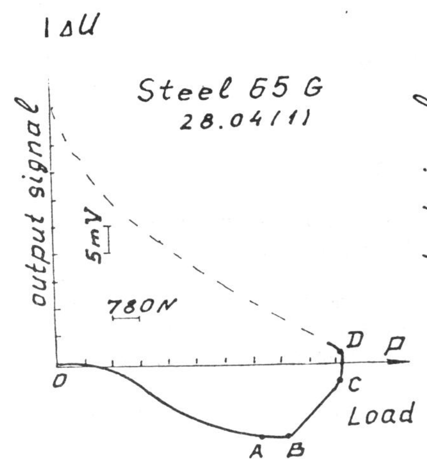

Fig.3. Experimental curve for st.65G

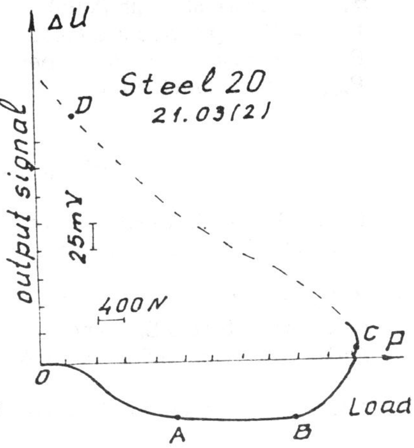

Fig.4. Experimental curve for st.20