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K O M U N I K A T Y

AN EXPERIMENTAL INVESTIGATION OF δ_r AND J_r RESISTANCE CURVES AND *COA* BY REPLICATION TECHNIQUE

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Silicone rubber replicas are used to investigate the crack growth problems in a stainless steel under various loading conditions. These replicas are analyzed by means of the optical and electron microscopy. Certain parameters describing the elastic-plastic fracture of a material are examined in greater detail.

1. Introduction

The problems of elastic-plastic fracture of low and medium strength steel of ductile nature are important in engineering. Robinson and Tetelman [1] suggested that a hardening silicone rubber can be used to make a replica of a crack while under load. The *COD* and δ_i for the middle section of the specimens under the loading condition are measured. In the work by Miller and Fields [2], several replicas were casted in a single specimen by means of the replication technique, the crack initiation point was determined and *COD* for the various loading states were measured. In a paper by one of the authors [3], the replication technique has been investigated by using silicone rubber made in China. The toughness parameter *COD* for the small specimens made of steel 1Cr13 was measured. In present paper eight or ten replicas are continuously casted and taken off from a single specimen under various loading states. The replicas of the crack are analyzed under optical and scanning electron microscopes. The resistance of the materials for the crack growth are carefully measured. Some of the parameters describing the elasto-plastic fracture of materials are examined.

2. Experimental details

2.1. Specimen

The three-point bend specimens ($10\times10\times55$ mm) are used with $a_0/w\approx0.5$. They are made of stainless steel 1Cr13. The mechanical properties of that material are $\sigma_{0.2}=56.1$ kg/mm^2, $\sigma_b=72.3$ kg/mm^2, $\delta=23.4\%$, $E=2.04\times10^4$ kg/mm^2, $n=0.06$.

2.2. Silicone rubber

The hardening silicone rubber at room temperature condition is made of the following components: silicone rubber 106 and 107, stuffing (quartz powder), thinner (toluene) join agent $(C_2H_5)_4$ SiO_4 and catalytic agent $(C_{32}H_{64}O_4Sn)$ etc.

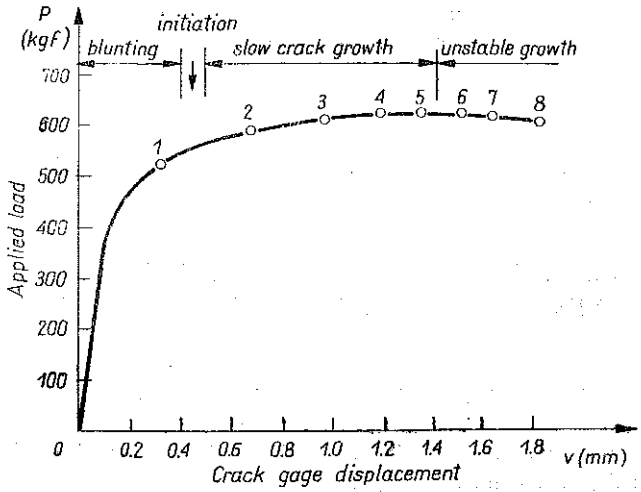

FIG. 1a. P vs. V curve (specimen No 1).

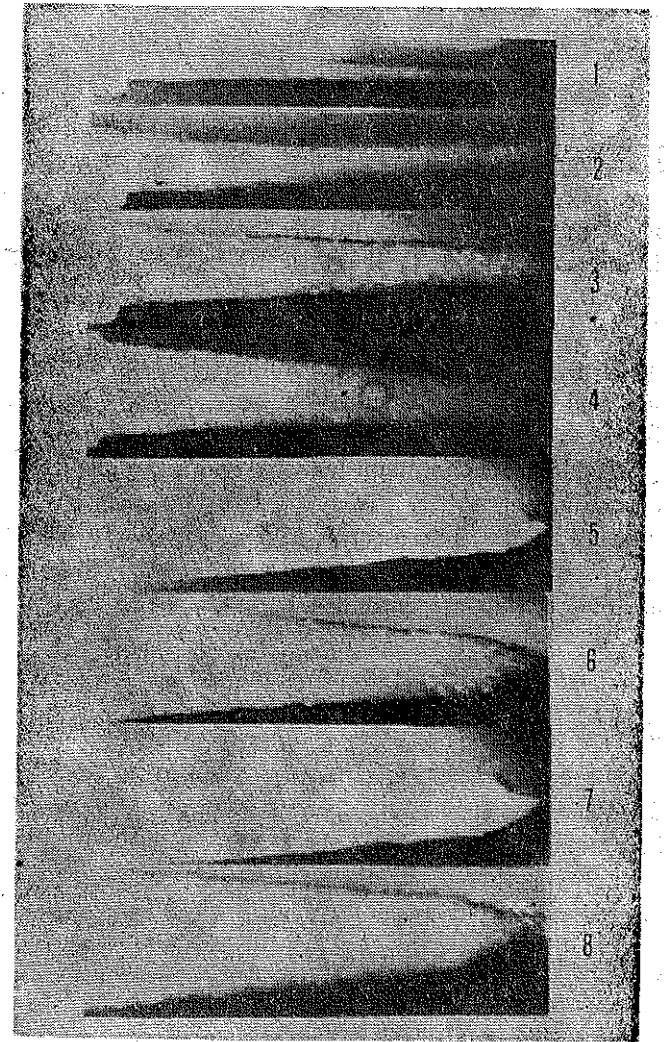

FIG. 1b. Middle section of crack replicas of specimen No. 1. (25×).

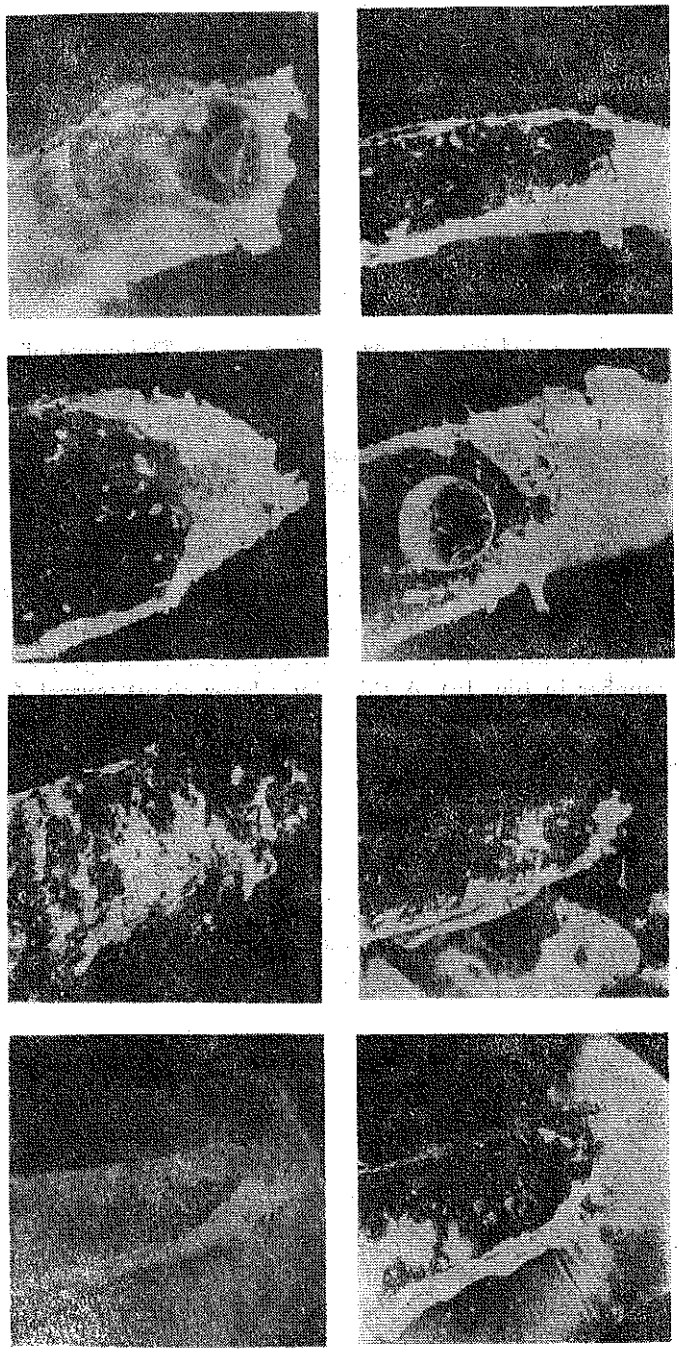

FIG. 1c. Scanning electron microscope plates of silicone rubber replicas crack for specimen No. 1 (vertical section).

It is provided with good fluidity and can be easily infiltrated into the crack tip solidification. Its elasticity and strength are quite good (σ_b=4.7 kg/cm^2, δ=50%) after solidification. The silicone rubber is found to shrink very slightly with time. The rate of shrinkage is less than 0.5% after 500 hours. Since all crack tip replicas were measured within 48 hours, shrinkage is negligible. The solidification time is about 40–60 minutes at room temperature. The experimental results show that the replicas can be easily taken off from the unbroken specimen when $COD>0.03$ mm.

2.3. *The procedure of the experiment*

The specimen is loaded by a screw loading setup. The curve of P versus V is recorded by a x–y recorder. When the load reaches a prescribed value, loading is stopped. The silicone rubber prepared according to the prescribed procedure is infiltrated into the crack of the specimen after the silicone rubber is solidified; loading is continued. At the next load point the solidified silicone rubber replicas are taken off from the specimen. This procedure is repeated until the specimen is broken. About 8 to 10 replicas can be obtained from one specimen. The curve of P vs. V recorded in the experiment for the No. 1 specimen is shown in Fig. 1a. The numbers 1, 2, ... marked on the curve indicate the measured points. The middle section of the replicas are shown in Fig. 1b (the number in the plate corresponds to the same number in Fig. 1a). A thin silver layer about several Å in thickness is plated on the silicone rubber replicas by means of vacuum coating. The crack profile of the replica are then observed and recorded by a scanning electron microscope (Fig. 1c).

3. Experimental results

1. *COD*, *SZW*, Δa (including SZW), da (real crack growth) etc. can be directly measured from the middle section of a silicone rubber replica, and δ_r and J_r curves can easily be obtained. The results of No. 1 specimen are shown in Figs. 2 and 3.

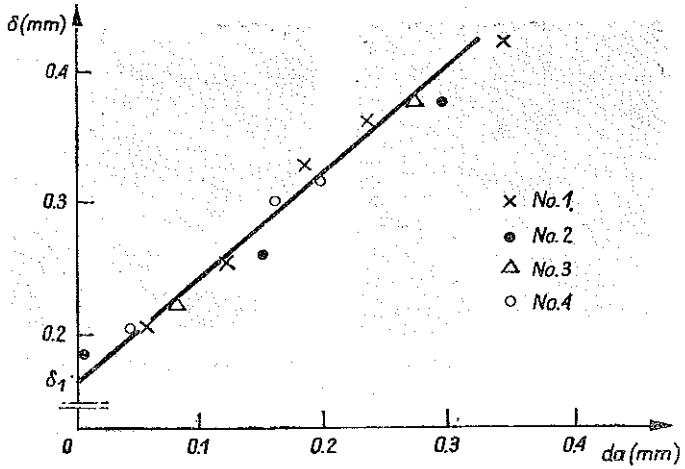

Fig. 2. Material 1 Cr 13, δ-resistance curve.

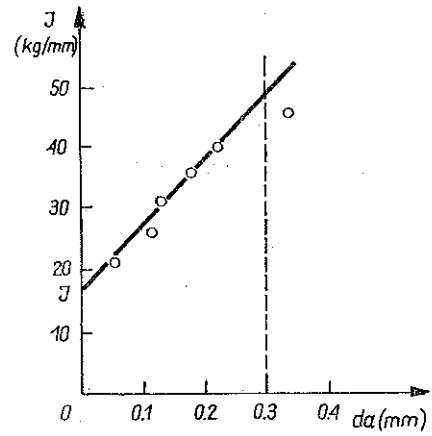

Fig. 3. *J*-resistance curve (specimen No. 1).

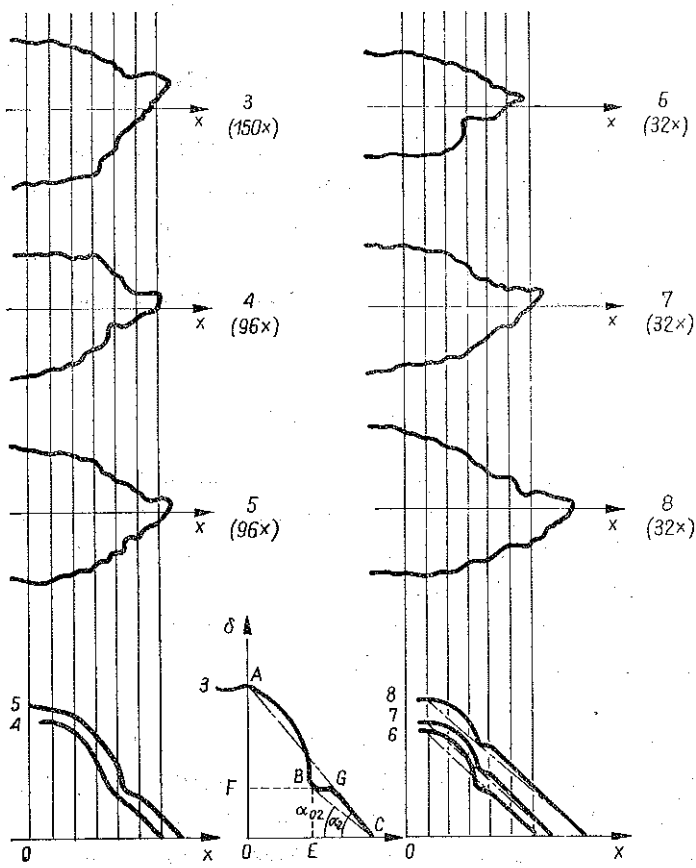

Fig. 4. Determination of *COA* (specimen No. 1).

From our experiments for steel 1Cr13 we determined that $\delta_i=0.161$ mm, $J_i=16.1$ kg/mm, $T_{\delta_r}=263$, $T_{J_r}=517$, while according to the crack profile method suggested by ROBINSON [1] δ_i is equal to 0.164 mm.

2. For the irregular front of crack we may determine *COA* by the method shown in Fig. 4. Figure 5 shows the measured *COA-da* curve for specimen No. 1 where α_i is the local *COA* [4]. α_{01} corresponds to $<AOC$ and α_{02} corresponds to $<BCO$ (Fig. 4). For specimen No. 1 $\alpha_i\approx 45°$.

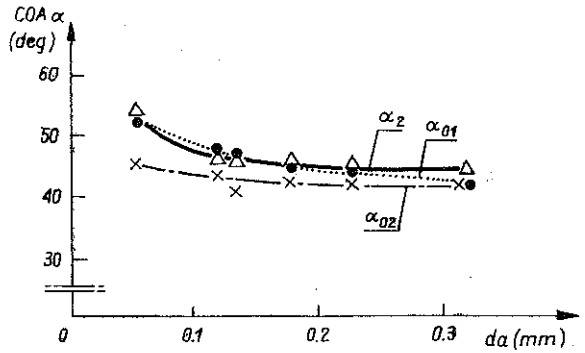

Fig. 5. *COA* vs. *da* curve (specimen No. 1).

3. We may divide the profile of crack tip into four zones. Those are: 1) fatigue zone, where the surface is rather rough and with the feature of typical fatigue surface; 2) deformed fatigue zone, which was produced by deformation of initial fatigue zone; 3) stretched zone, where the surface is relatively smooth and with the marks of slip deformation; 4) crack growth zone, where the surface is fracture surface of static fracture.

4. CONCLUDING REMARKS

1. By using the silicone rubber replication technique we can measure elastic-plastic parameters directly and we can get the characteristic resistance curve of crack growth. This experimental method is economic and simple.

2. The measured data of steel 1Cr13 show that for stable crack growth of such ductile materials tearing moduli T_J and T_δ or *COA* may be chosen as crack parameters. But to describe the behaviour of materials T_δ and *COA* may be more relevant and deserve more attention.

3. From the analysis of silicone rubber replicas in scanning an electron microscope plate, can we measure not only the macroscopic mechanical parameters of materials, but can we also observe the complete picture of crack profile and the deformations of crack tip. Therefore it provides a hopeful way to study crack problems using a combined method of macroscopic and microscopic observations.

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