DETERMINATION OF CREEP CRACK GROWTH IN THE LONG-TERM RANGE

K.H. Kloos, J. Granacher and R. Tscheuschner*

INTRODUCTION

For design and supervision of high temperature components for power plants the knowledge of the initiation and growth of creep cracks is important. For a description of the creep crack behaviour independent of geometry and load several parameters have been proposed (1) (2). Of special interest are low creep crack growth rates as observed in practice. For that interrupted constant load tests were started with planned test durations up to 30 000 h at 550 °C on a 1Cr-0.9Mo-0.7Ni-0.3V-turbine rotor steel (3). The steel was tested in three heat treatment conditions AGA, AGB, AGC representing different notch sensitivity under creep rupture conditions.

INTERRUPTED CONSTANT LOAD TESTS

The creep crack growth is measured on series of specimens in the interrupted constant load test (Fig. 1). The specimens of a single series are tested under the same conditions up to predetermined proportions of the "notch rupture time" t_{rn} expected for that series. After unloading, the specimens are ruptured at room temperature and the creep fracture surfaces A_{cr} are examined fractographically to determine the creep crack lengths $a-a_o$. The interrupted constant load test can be conducted in multispecimen machines with limited effort. The tests are carried out on round and flat specimens of different geometry (Fig. 1).

As an example the 550 °C-creep crack curve of low loaded CT 1/2-specimens with test durations up to about 9 000 h is shown (Fig. 2). The load is expressed by the initial nominal stress σ_{no} with the crack length a_o at test start. The nominal stress of CT-specimens is composed of tension stress and bending stress

$$\sigma_n = \frac{F}{B(W-a)} \cdot \left(1 + 3\,\frac{W+a}{W-a}\right) \tag{1}$$

From the creep crack growth curves covering now test durations up to 25 000 h with crack lengths of 0.3 to 2 mm, the creep crack initiation time t_i (for a given crack length) and the creep crack growth rate $\dot{a}$ (for all test interruptions) can be determined. On CT-specimens also the load line displacement v (Fig. 1) can be measured (Fig. 2).

CHARACTERIZATION OF THE CREEP CRACK GROWTH RATE

A main interest is the description of the creep crack growth rate independent of geometry and load. As assumed, stress concepts were not applicable. A simple description is given by the linear elastic stress intensity factor K_I. For CT-specimens this parameter is

$$K_I = (F \,/\, (B \cdot \sqrt{W})) \cdot f(a/W) \tag{2}$$

*) Institut für Werkstoffkunde, Technische Hochschule Darmstadt, FRG

with load F, specimen thickness B or B_n, crack length a (Fig. 1) and geometry function f(a/W) according to ASTM E 399-81. K_I-evaluation (Fig. 3) leads to a relatively wide scatter band with a factor of about 5 if single materials as AGB or AGC are regarded. Within the scatter bands the smaller specimens and the lower initial nominal stress values systematically show higher creep crack growth rates. Nevertheless, due to its relatively simple derivation from elastic stress analysis, the parameter K_I is of some practical interest. By introducing the Arrhenius equation, a temperature dependent upper limit of the creep crack growth rate can be formulated if the not represented 600 °C-results are included.

The C*-parameter is proposed for the case of prevailing creep strain in the ligament (2). For CT-specimens the C*-parameter can be calculated by

$$C^* = a \cdot \sigma_{net}^{n+1} \cdot A \cdot g\,(a/W,\ n) \qquad (3)$$

with the net stress

$$\sigma_{net} = F\ /\ (B \cdot (W-a)) \qquad (4)$$

and the Norton creep law

$$\dot{\varepsilon}_p = A \cdot \sigma^n \quad . \qquad (5)$$

The geometry function g(a/W, n) can be taken from (4). As compared with the parameter K_I, the C*-parameter (Fig. 4) describes the creep crack growth rate for the single test materials in considerably smaller scatter bands. Again, the highest creep crack growth rates were found at the heat treatment condition AGC presenting a high notch sensitivity. Including 600 °C-results not represented and neglecting some extreme results from the material AGC, an upper limit of the $\dot{a}$-C*-correlation can be defined.

SUMMARY

The initiation and growth of creep cracks was investigated on a 1Cr-0.9Mo-0.7Ni-0.3V-turbine rotor steel in interrupted constant load tests reaching up to 25 000 h at 550 °C. The creep crack growth rate can be described by the C*-parameter, and with a greater scatter band by the stress intensity factor K_I.

REFERENCES

1. Landes, J.D., J.A. Begley, ASTM STP 590 (1976) pp. 128-148.
2. Riedel, H., "Fracture at High Temperatures", Springer-Verlag Berlin, Heidelberg (1987).
3. Granacher, J., R. Tscheuschner, Adv. in mat. tech. for fossil power plants, Proc. Int. Conf., Chicago (1987) pp. 113-118, publ. by ASM.
4. Kumar, V., M.D. German, C.F. Shih, EPRI, NP-1931, Project 1237-1 (1981).

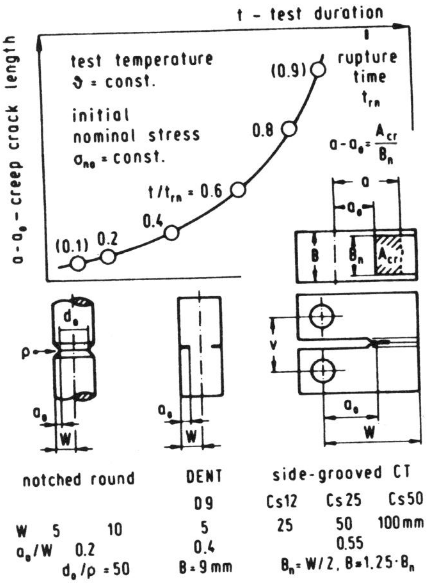

Fig. 1 Interrupted constant load test and specimen geometry

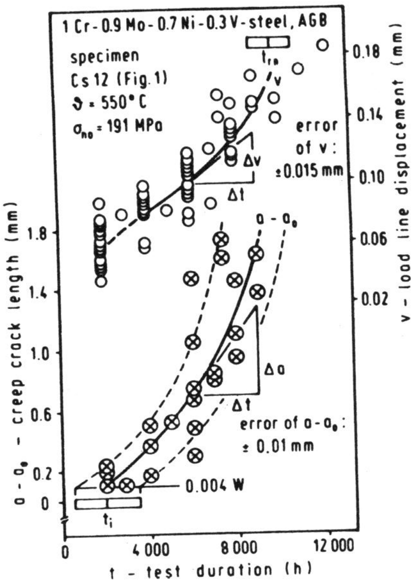

Fig. 2 Displacement curve and creep crack growth curve

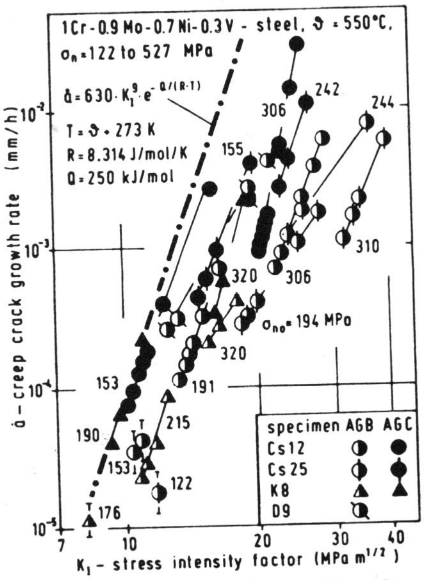

Fig. 3 Creep crack growth rate described by the parameter K_I

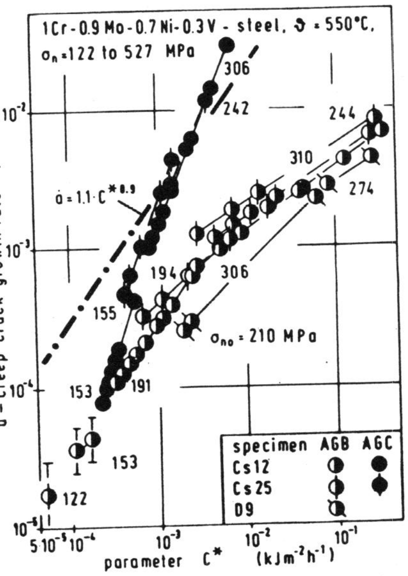

Fig. 4 Creep crack growth rate described by the parameter C*