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# Effects of component size, geometry, microstructure and aging on the embrittling behavior of creep crack growth correlated by the $Q^*$ parameter

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## Abstract

The driving force for creep crack growth is dominated by local elastic–plastic stress in the creep damage zone around a crack tip, temperature and microstructure. In previous work, $C^*$, $C_t$, load line displacement rate $d\delta/dt$ and $Q^*$ parameters have been proposed as formulations of creep crack growth rate (CCGR). Furthermore, using parameters mentioned above, the construction of the algorithm of predictive law for creep crack growth life is necessary for life assessment procedures. The aim of this paper is to identify the effects of component size, geometry, microstructure, aging and weldment on the embrittling behavior of creep crack growth and incorporate these effects in a predictive law, using the $Q^*$ parameter. It was found that for specimen size (width and thickness) and of material softening due to aging the values of the activation energy were the same whereas for grain size change and structural brittleness, which affected crack tip multi-axial stress state the values for the activation energy for CCGR differ.

*Keywords:* $C^*$ parameter; $C_t$ parameter; Load line displacement rate $d\delta/dt$; $Q^*$ concept; Weld component

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## 1. Introduction

The driving force for creep crack growth (CCG) is dominated by the local elastic–plastic stress in the creep damage zone around a crack tip. Temperature, geometry and microstructure play an important part in the stress state and hence the cracking behaviour in the creep range. In previous work, $C^*$ [1–4], $C_t$ [5], load line displacement rate $d\delta/dt$ [6–8] and $Q^*$ parameters [8–12] have been proposed as correlating parameters for creep crack growth rate (CCGR). These parameters incorporate implicitly or explicitly the factors of local elastic–plastic stress around a crack tip and temperature. Furthermore, using parameters mentioned above, the construction of the algorithm of predictive law for creep crack growth life is necessary for life assessment procedures.

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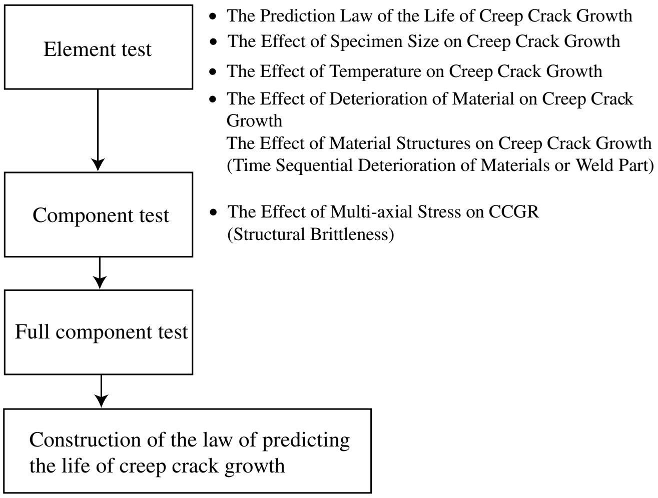

Fig. 1. Flow chart of mechanical tests for practical use.

Effects of specimen size and geometry influence the local stress around a crack tip, which in turn affects the growth rate of creep cracks [8,10,13]. Specimen size effects are closely related to the effect of plane stress or plane strain on CCGR of which the size of the creep damage symmetrically changes. Specimen geometry affects the CCGR via the effect of multi-axial stress, which is related to the stress field of component specimens, for example a round bar specimen with a circular notch. The effect of temperature on CCG rates is dominated by local-stress-dependent, thermally activated processes [8–12]. In addition, it has been observed that cracking is affected by the degradation of the material microstructure over time, as a result for example of the coarsening of carbides within the grains and on the grain boundaries [20].

To incorporate these effects (size, geometry, temperature, microstructural degradation) in a law capable of predicting the creep crack growth life, a number of factors need to be taken into account. The scale effect of the specimen size on CCG rate can be incorporated into the law as a proportional coefficient of this equation without changing the algebraic form of the equation. Hence the relationship can be useful to predict the life of CCGR for various sizes of specimens. In previous work, scaling effects have been noted on brittle fracture such as process region [15] and dislocation-free zone [16].

In the present paper, scaling effects of specimen size on CCG rate are investigated. Furthermore, the effects of multi-axial stress and material degradation on CCG rates are also investigated. The prediction of CCG life in industrial components is an important factor to determine appropriate intervals for structural maintenance and life extension. Therefore, a law for predicting the creep crack growth life, as obtained by element tests, can be modified by including the correction factors and formulas for the above-mentioned effects. The flow chart of this process is illustrated in Fig. 1.

## 2. Effect of specimen width and thickness on creep crack growth rate

### 2.1. $C^*$ parameter

The effect of specimen thickness $B$ on the creep crack growth rate (CCGR) as estimated using the $C^*$ parameter is shown in Fig. 2 for a Cr–Mo–V steel, which is a creep-ductile material [14]. As the specimen thickness increases, CCGR increases. The observed effect is not due to an increase in the CCGR properties of the material itself, but due to the transition from a state of plane stress to one of plane strain [14]. The load line displacement rate, included in $C^*$ parameter, is also sensitive to the effect of specimen thickness. Since the variation of CCGR with respect to $C^*$ parameter is dominated by the relationship between the CCGR and the load line displacement rate included in $C^*$ parameter [17].