DETERMINISTIC AND PROBABILISTIC LIFETIMES FROM KINETIC CRACK GROWTH – GENERALIZED FORMS

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1 Overview

The lifetime prediction methodology developed here is an addendum to and a generalization of that given earlier by Christensen and Miyano [1]. The previous results were not sufficiently general to model some of the results in the intermediate time ranges. The present results still retain the kinetic crack formalism but include more general forms that are in accordance with data. This new method admits both deterministic and probabilistic forms. Specific applications are given for creep rupture and constant strain rate programs. Possible applications are for any materials types whose very long term creep rupture behavior takes a power law form.

In previous work, Christensen and Miyano [1] developed a lifetime prediction methodology based upon kinetic crack growth in polymers. The general outline of the method is as follows. An initial flaw is idealized as a central crack under Mode I conditions. The far field loading activates the crack to grow in a quasi-static manner. The crack rate of growth is taken to have a power law dependence upon the stress intensity factor. The crack continues to grow until such time as it reaches the size which in relation to the far field loading causes the crack to become unstable, and thereby propagate in an uncontrolled manner. The corresponding time at which this occurs is taken to be the lifetime of the material. All of the developments follow rigorously from this kinetic form of fracture mechanics. The key condition in the kinetic aspect of the problem is the assumption of the power law form for the crack growth rate.

When the general lifetime forms are specialized to the case of creep rupture, involving constant stress, the resulting creep rupture analytical solution for the lifetime is quite simple. However, the comparison with creep rupture data is not good. The form obtained from kinetic crack growth shows a rather narrow transition region between the short time asymptote and the long time power law asymptote. The data show this transition region to be very broad and spread over many decades of time. Thus the previous kinetic forms do not model the data in a satisfactory manner, except in the long time, power law range. The problem could be with either of two basic assumptions in the previous work. These assumptions were those of using the stress intensity factor or those of using the power law form for the crack kinetics. At this point it is not known which of these two assumptions is likely to be too restrictive, but a more general form for the special case of creep rupture will be derived here. This new form will be carefully synthesized such that it will admit generalization to probabilistic conditions in the same highly useful manner as in the previous work.

The form to be derived and used in the following will still admit a power law description in the long time range. In a general sense then this implies retaining some type of power law form for the crack growth rate, and thus preserves the tie of this work to the kinetic crack formalisms having the crack rate of growth expressed as having a power law dependence upon the applied stress. This corresponds to the widely used “Paris law” and is in general accordance with the many approaches which employ crack kinetics in a life prediction formalism. Also the related case of constant strain rate rupture will be included. The resulting forms will be compared with data for the lifetime of polymeric composite materials. Finally probabilistic matters will be taken up. The full paper is to be found in Christensen and Miyano [2].

2 Results

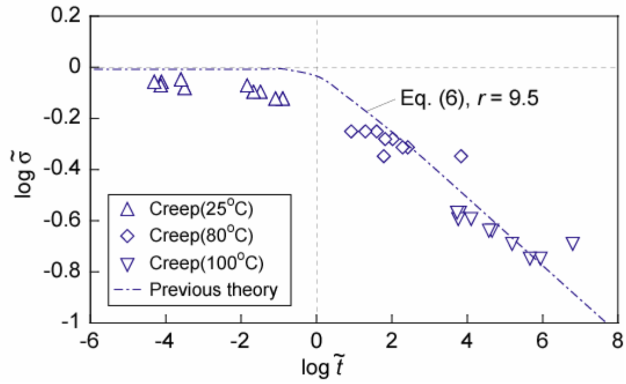

Fig. 1. Creep rupture, previous study

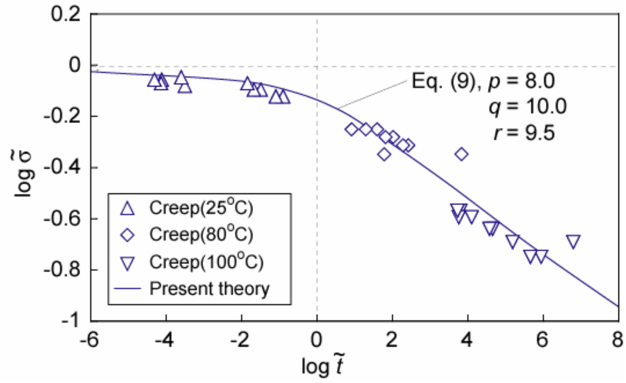

Fig.2. Creep rupture, present theory

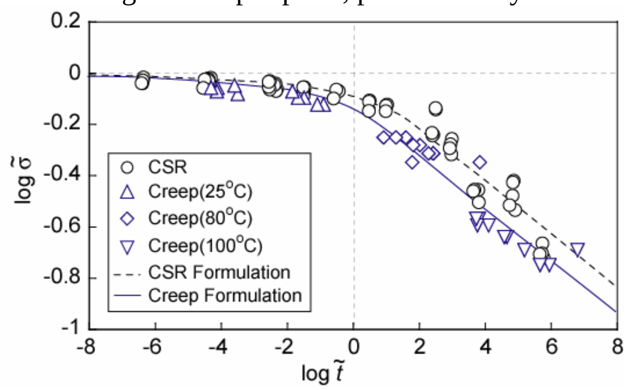

Fig.3. Creep rupture and constant strain rate

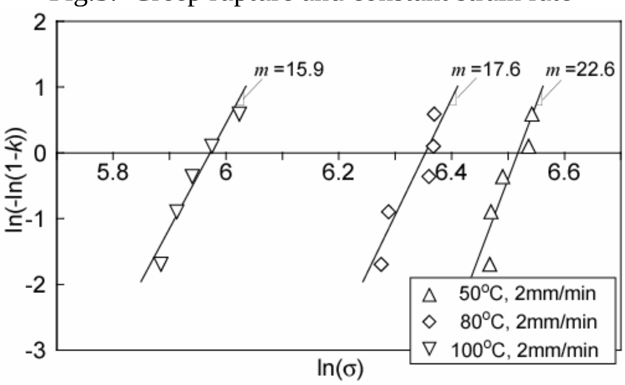

Fig.4. Weibull statistics, constant strain rate

References

[1] Christensen, R. M. and Miyano, Y., "Stress intensity controlled kinetic crack growth and stress history dependent life prediction with statistical variability", *International Journal of Fracture* Vol. 137, pp 77-87, 2006.

[2] Christensen, R. M. and Miyano, Y., "Deterministic and Probabilistic Lifetimes From Kinetic Crack Growth - Generalized Forms", *International Journal of Fracture* (in press).