RUPTURE STRENGTH OF METALS SUBJECTED TO AN ACCELERATED APPLICATION OF STRESS

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SUMMARY

In many cases the prediction of the rupture life of metals under variable stress is a major problem in the design of nuclear reactor components. Usually stress-rupture test data is obtained in tests at constant temperature and stress. For cases involving accelerated temperature or stress application, the life can be estimated by assuming that during any small time interval, the specimen loses some fraction of its life which is independent of the stress and temperature history. Rupture occurs when the sum of these fractions is equal to unity. Based upon this concept, the paper discusses the development of an equation which is useful for predicting the life of metals, such as Hastelloy X and 316 stainless steel, which are subjected to a constant accelerated rate of nominal stress application with time, at constant temperature. The stress versus rupture time \( r \) for such metals is assumed to be expressed analytically by the equation \( r = (C/\sigma)^n \), where \( C \) and \( n \) represent empirical constants.
1. Introduction

The ability to predict the rupture life of metallic nuclear reactor components is of major concern for design, especially when these components are subjected to an increasing stress, as in the case of loading which can arise as a result of gas generation due to nuclear radiation. Stress rupture data for a material can be attained from tests at constant stress and temperature. When the material is subjected to a variable temperature and stress, the life can be estimated by assuming that during a small time interval Δt, the material loses a fraction of its life which is independent of the stress and temperature history [1]. Consequently, available data of constant stress versus rupture time can be used to evaluate the portion of life expended during each interval. Failure occurs when the sum of these fractions of time Δt versus rupture time equals unity.

2. Methods of Analysis

If the material is subjected to a constant accelerating application of nominal stress, two methods of solution are possible. The stress versus time curve can be approximated by a finite number of constant steps, Fig. 1, in which case, as stated in the introduction, failure occurs when

\[ \Sigma(\Delta t/r) = 1 \]  

(1)

If the stress rate is increasing at a constant rate, that is, the stress is applied with constant acceleration, \( \dot{\sigma}_C \), then a closed form solution is possible. For example, if the stress rate \( \dot{\sigma} \) are initially zero, then

\[ \sigma = \frac{1}{2} \dot{\sigma}_C t^2 \]  

(2)

Furthermore, the fraction of life considered during each time interval Δt+dt, is then integrated, which yields the sum

\[ \int_0^{t_R} (dt/r) = 1 \]  

(3)

where \( t_R \) is the time to rupture. Metals such as Hastelloy X and 316 stainless steel are often used in reactor components and can be subjected to accelerated application of stress. The stress versus rupture time for such metals can be expressed analytically by the equation

\[ r = (C/o)^n \]  

(4)

where C and n represent empirical constants. Hence, if Eqs. (2)-(4) are combined, it can be shown that the rupture time is

\[ t_R = \left[ (2n+1) \left( \frac{2C}{3} \right)^n \right]^{1/(2n+1)} \]  

(5)
3. **Discussion**

To date, the validity of the above equation has not been experimentally tested, although applications of this method of analysis has been applied to the case of stress increasing at a constant rate [2]. There, it has been found that the accuracy of life prediction has been within five percent of its true value.

**References**


![Fig. 1 Application of Stress versus Time](image-url)