UNCLASSIFIED

X-822

OAK RIDGE NATIONAL LABORATORY

Operated By
UNION CARBIDE NUCLEAR COMPANY

UIC

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

ORNL
CENTRAL FILES NUMBER

CF. 56-10-76

"External Transmittal Authorized"

COPY NO. 24

DATE: October 15, 1956

SUBJECT: CORRELATION OF CREEP AND RELAXATION
TESTS ON INCONEL

TO: Listed Distribution

FROM: F. A. Field

LEGAL NOTICE

This report was prepared in the course of Government sponsored work. Neither the United States nor the Government nor any person acting on behalf of the Government makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information disclosed herein would not infringe upon privately owned rights, or that the Government may take action with respect to the use of, or for damages resulting from the use of, any information disclosed or provided hereunder in this report. It is the policy of the Government to make available to the public the results of research and development which are not classified as secret, confidential, or otherwise restricted, in the interest of the progress of science and technology. The Government assumes no responsibility for the use of, or for damages resulting from the use of, any information disclosed or provided hereunder in this report.

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

UNCLASSIFIED

588-1

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CORRELATION OF CREEP AND RELAXATION TESTS ON INCONEL

P. A. Field

It has been proposed that plastic strain is the criterion for failure of a material subjected to thermal or strain cycling. In order to establish the amount of plastic strain induced by thermal loading one must know the relaxation characteristics of the material cycled. Detailed relaxation data are also of value in determining the basic parameters of a thermal cycling test program and in interpreting the results of such a program. Since creep data is so readily available it is of some practical importance to be able to describe the relaxation of a material from its creep properties. Several techniques for doing this have been developed,^{1,2,3} and the purpose here is to describe briefly one of these methods and compare its results with experimental data.

The general relation describing relaxation is

$$\epsilon_p + \epsilon = \epsilon^* = \text{Const},$$

where

ϵ_p = plastic strain,

ϵ = elastic strain,

ϵ^* = total or initial strain.

But if σ = elastic stress and E = modulus of elasticity, then

$$\epsilon = \frac{\sigma}{E},$$

and

$$\epsilon_p + \frac{\sigma}{E} = \epsilon^* = \text{Const.} \quad (1)$$

Differentiating with respect to time

$$\frac{d\epsilon_p}{dt} = \frac{1}{E} \frac{d\sigma}{dt}. \quad (2)$$

For Inconel in the temperature range of interest, creep can be described by the standard exponential relation

$$\epsilon_p = K (e^{\sigma/s} - 1) t^m. \quad (3)$$

In this equation K , s , and m are material constants and t is time. The creep characteristics described by Eq. (3) are the results of an integration of some unknown differential creep law and, therefore, Eq. (3) may be differentiated in a variety of ways to establish a creep rate relation. Two primary methods which have been suggested for doing this are (1) which assumes creep rate to be a function of stress and time, and (2) which requires creep rate to be a function of stress and strain. The data published so far indicates that the latter or "strain hardening" technique gives very good agreement and has therefore been used in the present correlation. Taking the m^{th} root of both sides of Eq. (3) and differentiating gives a creep rate relation which satisfies the strain hardening assumption that creep rate is a function of stress and strain,

$$\frac{d \epsilon_p}{dt} = \frac{m [K (e^{\sigma/s} - 1)]^{1/m}}{\epsilon_p^{1/m} - 1}.$$

Combining this with Eqs. (1) and (2) gives

$$\frac{-1}{E} \frac{d\sigma}{dt} = \frac{m [K (e^{\sigma/s} - 1)]^{1/m}}{(\sigma^* - \sigma)^{1/m} - 1}.$$

Rearranging and integrating

$$t = \int_{\sigma^*}^{\sigma} \frac{1}{m (EK)^{1/m}} \frac{(\sigma^* - \sigma)^{1/m} - 1}{(e^{\sigma/s} - 1)^{1/m}} d\sigma.$$

This equation has been integrated numerically for several cases and the results are shown in the following figures. The experimental curves are from tests conducted by Oak Ridge National Laboratory Metallurgy Division and

by the University of Michigan. The creep data used were from tests reported by Oak Ridge National Laboratory Metallurgy Division.

PAF:HW

References

1. Irving Roberts, Prediction of Relaxation of Metals from Creep Data, Proc. ASTM, 51, pp. 811-825 (1951).
2. E. P. Popov, Correlation of Tension Creep Tests with Relaxation Tests, J. Applied Mech. 14, pp. A-135-A-142 (1947).
3. H. R. Vorrhees and J. W. Freeman, Notch Sensitivity of Heat-Resistant Alloys at Elevated Temperatures, WADC-TR-54-175 (May 1954).

588 5

6

INCONEL RELAXATION

1500° F

UNCLASSIFIED

ORNL-IR-DWG.-16613

-6-

7-886

7

INCONEL RELAXATION

1500° F

UNCLASSIFIED

ORNL-JR-DME-1661A

-7-

2-88-6

1-7