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BROWN UNIV PROVIDENCE RI DIV OF ENGINEERING

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PREDICTION OF CREEP OF AL 2618 UNDER VARIABLE

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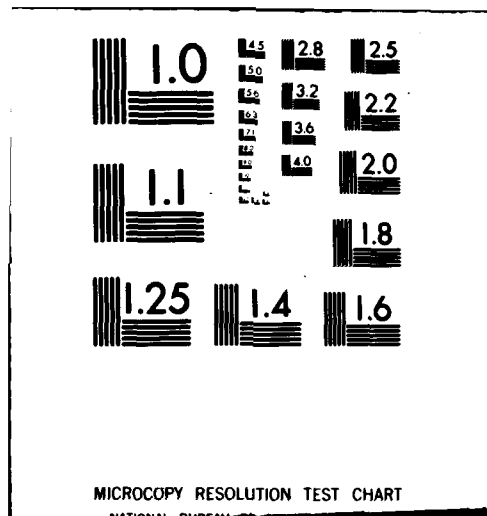
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Prediction of Creep of AL 2618 Under
Variable Multiaxial Stresses

Final Technical Report

William N. Findley

December 3, 1980

U.S. Army Research Office
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Brown University
Providence, R.I.

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Army Research Office
Final Technical Report
on
Prediction of Creep of AL 2618 under Variable Multiaxial Stresses
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Statement of the Problem

Information available for developing constitutive equations for use in design in critical applications involving creep under variable stress states is limited largely to uniaxial states of stress. This is insufficient information. Data are available from prior work in my laboratory on 2618 aluminum for tests at moderately high stresses under variable states of stress of the following types: step-up, step down, side-step, recovery followed by reloading, reverse stress, relaxation and simultaneous creep and stress relaxation. It was proposed to use the results of creep and creep-recovery at constant stress with suitable constitutive equations to predict behavior under the type of variable stress listed above and test the predictions against actual experimental results. It was proposed to test a viscous-viscoelastic model employed by the author and models proposed by others.

It was proposed also to perform new experiments especially at low stress levels and other experiments needed to explain certain features of observed behavior and to permit use of other theories.

Statement of Most Important Results

New Work:

1. Results of experiments on simultaneous creep in torsion and stress relaxation in tension were analyzed. These experiments included proportional and non-

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- proportional loading, unloading, and reloading. Predictions of these experimental results were made using the results of constant load creep and recovery experiments under combined tension and torsion only. In general the features of the material behavior were similar to those observed under combined tension and torsion creep. Results showed that a modified viscous-viscoelastic (MVV) theory predicted all the observed features and in general had the best prediction of creep rate and relaxation rate of the three theories considered.
2. Nine additional experiments have been performed at low stress levels. The stresses were chosen to lie along a Mises and a Tresca ellipse. The test programs included creep followed by recovery in each test. After these two periods other stress histories were as follows: a series of steps down followed by steps up; partial unloading followed by reloading; full stress reversal and partial stress reversal in torsion with and without simultaneous constant tension; pure tension followed by pure torsion; and proportional loading in one direction followed by the same magnitude but in a different direction. The lowest stress levels employed were 5 ksi tension and 2.5 ksi torsion. Aging tests were also included.
 3. A preliminary analysis of the experimental results suggests the following: above a transition stress level the response to stress is nonlinear and synergistic. Below this transition the behavior is reasonably linear and any synergistic effect is very small. This is in contrast to strong non-linearity and synergistic behavior at higher stresses. There is creep at stresses as low as 5 ksi tension and 2.5 ksi torsion and the creep is not fully recoverable even at such low stresses. There appears to be no true creep limit. A surface of constant creep rate for combined tension and torsion appears to lie between the Mises and Tresca ellipses.
 4. During a series of down steps in stress it was found that creep or recovery was essentially zero at some of the intermediate steps. The creep rate in torsion was remarkably increased when a tensile stress was added during torsion creep. During full stress reversal after 48 hrs. of creep at a low stress the time-dependent behavior was the same for both positive- and subsequent negative-stressing, and the prior strain was not wiped out upon stress reversal. In prior work we found reversal of high stress after 2 hrs. of creep also showed the same creep behavior on both first stressing

- and reversed stressing but the creep resulting from the first stressing was wiped out on stress reversal.
5. Constant tension with torsion reversing every 24 hrs. at a low stress level showed a continuous creep in tension - unlike that observed previously at high stress reversed every 2 hrs. Also there was no jog in the recovery of torsional when tension was removed after 24 hrs. These observations are consistent with a linear behavior at low stresses.
 6. The constants required for the viscous-viscoelastic model previously employed have been determined from the tests at low stress levels for both a linear and nonlinear representation. The latter has been found to reasonably represent the data at high stresses (above the apparent transition) and gives very good prediction for the material behavior under step stress changes (including pure tension, pure torsion and proportional loadings).

Prior Work:

Analysis of results of comparison of predictions of creep with experimental data for nonlinear creep of 2618 aluminum under combined tension and torsion stress states and under varying stress history showed that a strain hardening (SH) theory does not properly describe the behavior on unloading or reloading; but a viscous-viscoelastic (VV) theory with certain modifications (MVV theory) predicts most of the features of the observed creep behavior quite well.

Among the conclusions are the following:

1. The behavior may be represented by resolving the time-dependent strain into recoverable and nonrecoverable components having the same time dependence.
2. The material behaved as though there was a creep limit such that only very small creep occurred unless the stress was greater than a limiting value having fixed values σ^* , τ^* for tensile stress and shear stress components, respectively.
3. On partial unloading the material behaves as though the nonrecoverable strain component ϵ^V continued to creep in accordance with strain hardening unless the stress became less than the creep limit; whereas the recoverable strain component ϵ^{Ve} remained constant unless the decrease in stress exceeded the magnitude of the creep limit.

4. On reloading following an interval t_x of partial unloading involving no further change in ϵ^{ve} the component ϵ^{ve} resumed creep as though the interval t_x did not exist.
5. Very small reductions of stress are best represented by the viscous-viscoelastic (VV) theory, which is inconsistent with the behavior under small stress reductions.
6. Recovery on complete unloading following a history of step changes in stress is reasonably represented by the (VV) or (MVV) theories, but best represented by the (VV) theory.
7. An increase in tension under constant torsion was well represented by the theory but a subsequent increase in torsion at constant tension was not as well represented.
8. Reduction of one stress component while the other remained constant required treating the pure stress and mixed stress terms separately. The strains associated with the mixed stress terms remained constant, whereas the strain behavior associated with the pure stress remained unchanged.
9. Removal of one of two stress components during creep was observed to have no effect on creep associated with the other stress components. This was partially accounted for by considering that the ϵ^{ve} strain associated with the mixed stress terms remained constant until both stress components were zero.
10. On partial or complete reversal of stress the nonrecoverable strain component ϵ^v behaved as though the reverse stress was applied to a virgin material.
11. If the stress was partially reversed the prior residual strain resulting from ϵ^v remained. However, if the stress component was completely reversed the residual strain from the nonrecoverable strain component ϵ^v appeared to be completely recovered (wiped out).
12. The axial creep resulting from cycles of reversed torsion in the presence of constant tension consisted of: continuous recoverable creep; plus continuous nonrecoverable creep from the first application of positive torsion and also from the first application of negative torsion associated with pure tension terms only; plus new virgin creep associated with the mixed tension-torsion stress terms at each reversal of torsion.

Publications

1. *Findley, W. N. and Lai, J. S., "Creep and Recovery of 2618 Aluminum Alloy Under Combined Stress with a Representation by a Viscous-Viscoelastic Model," ASME Journal of Applied Mechanics, Vol. 45, 1979, p. 507.
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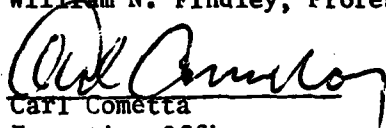
Technical Reports

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