HOLD-TIME EFFECTS IN HIGH-TEMPERATURE LOW-CYCLE FATIGUE

A LITERATURE SURVEY AND INTERPRETIVE REPORT

Prepared for
The Metal Properties Council
by E. Krempl and B. M. Wundt

STP 489

AMERICAN SOCIETY FOR TESTING AND MATERIALS

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FOREWORD

The Metal Properties Council Subcommittee on Fatigue sponsored preparation by B. M. Wundt of an extensive Bibliography on Low-Cycle Fatigue. Published by ASTM in 1968 as their Special Technical Publication No. 449, that survey listed over 800 references for the years 1957 through 1967.

Encouraged by a larger-than-anticipated demand for that Bibliography, the Subcommittee is now promoting the preparation and publication of surveys telling the general content of the literature pertaining to each of several major factors affecting low-cycle [high strain] fatigue behavior.

The present report surveys the influence of hold time on low-cycle fatigue failure at constant temperature. It covers most of the papers listed under Subject 3 of the 1968 Bibliography, together with some more-recent papers.

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E. Krempl[1] and B. M. Wundt[2]

ABSTRACT

A literature survey was made of the effect of hold time on the deformation and fracture behavior during low-cycle fatigue loading at elevated temperature. The need for such investigations is traced back to the operational conditions of power generation, chemical processing and flight propulsion plants.

Hold time is shown to have a significant influence on the cyclic strain hardening (softening) behavior and on cycles to failure. The effect depends on the nature of the surrounding atmosphere. Stress analysis and failure criteria have to be modified to account for these time dependent effects. The presently available design approaches are reviewed and recommendations for future research are given.

KEY WORDS: Fatigue (materials), high temperature tests, fractures (materials), life (durability), cyclic loads, stress cycle, plastic deformation, thermal stress, strains, crack propagation, damage, design, stress relaxation, creep properties, austenitic stainless steels, alloy steels, review, evaluation.

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NOMENCLATURE

$\Delta\epsilon_{pr}$ = plastic strain due to stress relaxation [in/in]

$\Delta\epsilon_{p}$ = plastic strain range [in/in]

$\Delta\epsilon_{t}$ = total strain range [in/in]

ϵ_{max} = maximum strain [in/in]

ϵ_{min} = minimum strain [in/in]

$\Delta\epsilon_{c}$ = creep strain accumulated during hold time in stress control [in/in]

$\dot{\epsilon}_{s}$ = secondary creep rate [1/time]

$\Delta\sigma$ = stress range [psi]

σ_{r} = stress at the end of the hold time [psi]

$\Delta\sigma_{r}$ = total stress relaxed during hold time [psi]

σ_{max} = maximum tensile stress [psi]

σ_{min} = minimum tensile stress [psi]

σ_{u} = ultimate tensile strength [psi]

E = modulus of elasticity [psi]

N_i = number of cycles to crack initiation

N_f = number of cycles to failure

α, β = constant

C, C_1, C_2, A = constants with appropriate dimensions

k, k_1 = constant with appropriate dimensions

t_f = time to failure

t_H = hold time

ν = frequency of testing [cycles/unit time]

T = time for one cycle = $1/\nu$

D = tensile ductility = $ln \frac{100}{100\text{-}RA}$

RA = reduction in area [percent]

t_r = time to rupture failure in a creep test [h]

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