ABSTRACT

This thesis presents the results of influence of environment and prior coldwork on creep properties of AISI 304 stainless steel with an emphasis placed on the analysis of first order kinetic approach for creep. The results of constant load creep tests in air and static argon environment at 973 K and at stresses ranging from 80 to 200 MPa revealed that rupture lives are longer in air than those in argon at lower stresses up to 120 MPa, with the trend reversing at higher stresses. The strengthening in air observed at lower stresses is attributed to blunted surface cracks as against sharper surface cracks observed in argon. At higher stresses, the weakening observed in air is considered to arise through the occurrence of numerous wedge cracks and the mechanism involving interaction of vacancies produced during oxidation with dislocations in the deforming metal. The results also showed a two stress exponent behaviour with $n = 5.5$ and 8.9 for low and high stress regimes respectively. The results of constant load creep tests for varying levels of prior coldwork (0 to 20%) at 873 and 973 K in the stress range of 120-300 MPa revealed that prior coldwork is beneficial to creep-rupture properties and that the pseudo-tertiary creep behaviour is noticed only for prior coldworked specimens at 973 K.

The analysis of transient and tertiary creep as a first order kinetic process was carried out on the results obtained in air and argon at 973 K, as well as those obtained in air at 873 K for solution annealed and 5% prior coldworked conditions. The results obeyed first order kinetics for transient creep with different values of transient creep parameters $\dot{\varepsilon}_T$ and K as well as separate master creep curves for the respective stress regimes. A new relation between steady-state creep rate $\dot{\varepsilon}_s$, time for onset of steady-state creep $t_{os}$ and limiting transient creep $\dot{\varepsilon}_T$ is proposed as $(\dot{\varepsilon}_s^\alpha, t_{os})/\dot{\varepsilon}_T = \text{constant}$; the value of $\alpha$ is found to be unity. Based on the analogy between this relation and the Monkman-Grant relation (MGR), it is postulated that the validity of MGR is a consequence of first order kinetics.

The analysis of tertiary creep revealed that the results obeyed first order kinetics for tertiary creep with distinct master creep curves at 873 and 973 K and with a separate set of constant values of $K'$, $\varepsilon_t$, $\beta'$ and $C_{MG}$. A relationship between $\dot{\varepsilon}_s$,
time spent in tertiary creep \( t_t \) and limiting tertiary creep strain \( \varepsilon_t \) is formulated as
\[
(\dot{\varepsilon}_s t_t) / \varepsilon_t \text{ = constant}
\]
and this relation is found to be identical to the modified Monkman-Grant relationship (MMGR) for conditions satisfying \( f = 1/\lambda \); where \( f \) is the ratio of time for onset of tertiary creep to rupture life and \( \lambda \) is the damage tolerance factor. It is postulated that the validity of MMGR is also a consequence of first order kinetics. This investigation also presents an important relationship between creep rate and rupture life in terms of strain at the onset of tertiary creep \( \varepsilon_{23} \) and strain at failure \( \varepsilon_f \) as
\[
\dot{\varepsilon}_s t_t = (\varepsilon_{23} \varepsilon_f)^{1/2}
\]
for conditions satisfying \( f = 1/\lambda \). This relation is compared with the relation \( \dot{\varepsilon}_s t_t = (\varepsilon_{23}^2 \varepsilon_f)^{1/3} \) proposed by Radhakrishnan following the \( \beta \)-envelope method and it is shown that the Radhakrishnan relation becomes applicable for \( f \neq 1/\lambda \) condition.

A generalised and empirical relationship between creep rate and rupture life is obtained as
\[
\dot{\varepsilon}_{\min} t_r = (\varepsilon_{23}^{\eta-1} \varepsilon_f)^{1/\eta}
\]
applicable for cases obeying \( f^{\eta-1} \lambda = 1 \), where \( \eta \) is the slope of the enveloping straight line describing the tertiary creep data on a log(strain) vs log(time) plot. The implication of the empirical relationship \( f^{\eta-1} \lambda = 1 \) is extended to Robinson’s life fraction rule. It is suggested that the validity of life fraction rule could possibly imply the validity of \( f = 1/\lambda \) and the first order kinetics for tertiary creep.

**Key words:** AISI 304 Stainless Steel, Creep Properties, Environment, Prior Coldwork, First Order Kinetics, Transient Creep, Steady-State Creep, Tertiary Creep, Monkman-Grant and Modified Monkman-Grant Relationships, Life Fraction Rule.