An understanding of the flow and fracture behaviour of materials at elevated temperatures is of paramount importance both for making appropriate selections and for developing improved or new materials for high temperature applications. There are numerous metallurgical variables that influence the high temperature mechanical properties, of which grain size is known to be an important one. This thesis is concerned with the effect of grain size on the flow and fracture behaviour of AISI 316 stainless steel at elevated temperatures. Type 316 stainless steel is chosen for this investigation in view of its wide application in steam generating plants as piping and superheater tube material and in Liquid Metal Fast Breeder Reactors (LMFBRs) as cladding and structural material. The aim of the present investigation is to study the deformation and fracture characteristics of type 316 stainless steel in the temperature range generally encountered in fast breeder reactors (670-970K). In particular, a study of the influence of grain size on flow and fracture is considered useful since no systematic attempt has been made in this direction.

The deformation and fracture characteristics were studied with the help of tensile and creep tests. Tensile tests were carried out over a wide temperature range from 300K to 1223K with a view to achieving a better understanding of the flow and fracture behaviour of this material. The nominal strain rates employed were in the range $6 \times 10^{-6}$ to $1.2 \times 10^{-3} \text{sec}^{-1}$. Creep tests were performed at 873K and 973K over a wide range of stress (50-260 MPa). Different grain sizes in the range 0.025 to 0.650 mm were produced by suitable combination of deformation and annealing treatments. All the specimens were given a final solution treatment at 1323K for 30 min followed by a water quench in order to minimize differences that might arise due to
microstructural features like carbide precipitation, solute segregation etc. Microstructural investigations employed in this study included optical metallography, scanning electron microscopy on fractured specimens and some substructural observations using transmission electron microscopy.

A decrease in the grain size has caused an increase in the flow stress ($\sigma_e$) and the variation has been in accordance with the Hall-Petch relationship at temperatures up to 1023K:

$$\sigma_e = \sigma_0 + k_e d^{-\frac{1}{2}}$$

where $d$ is the average grain diameter and $\sigma_0$ and $k_e$ are constants. The Hall-Petch intercept, $\sigma_0$, has increased linearly with strain and decreased monotonically with increase in temperature. The variation of the slope, $k_e$, with temperature has shown a peak in the range 523 to 723K and this has been attributed to dynamic strain aging (DSA) occurring in grain boundary regions. The value of $k_e$ has also increased with strain and reached a maximum value at about 15% strain in the temperature range 523 to 823K. These results are found to be in good agreement with the modified pile-up theory of grain boundary strengthening. The relationship between ductility and temperature is marked by a minimum ductility at about half the absolute melting temperature where intergranular cracking has been observed. The temperature corresponding to the minimum in ductility has been found to increase with increase in grain size and in this temperature range the ductility has decreased with increase in grain size. It has been shown that the influence of grain size on the fracture mode and ductility is the result of the triple junctions restricting the crack growth along boundaries.
Serrated yielding has been observed in the temperature range 523-923K. The various other manifestations of dynamic strain aging like the flow stress plateaus and peaks, work hardening peaks and negative strain rate sensitivity have also been observed. These features are more pronounced in fine grained material. The type of serrations and the critical strain, $\varepsilon_c$, for the onset of serrations are influenced by grain size, strain rate and test temperature. A linear relationship between log $\varepsilon_c$ and log d has been obtained with an exponent of 0.6. The grain size dependence of critical strain arises from the grain size dependence of dislocation density. An apparent activation energy for serrated yielding $\approx 255$ kJ/mol has been obtained from the temperature dependence of $\varepsilon_c$, which supports a model based on diffusion of substitutional atoms.

The variation of steady state creep rate with grain size has been found to depend on applied stress and test temperature. Grain boundary strengthening has been observed at high stresses (180-260 MPa) at 873K. This strengthening does not correlate quantitatively with the available models which attempt to incorporate a Hall-Petch strengthening effect into high temperature strain rate equations. The creep rate has not been significantly influenced by grain size variations for stresses in the range 90-140 MPa at 973K. At an applied stress of 70 MPa at 973K, a definite minimum has been recorded in the creep rate - grain size curve. Also the weakening effect of grain boundaries is more pronounced at low stresses. These results are in good agreement with a model that considers the influence of grain boundaries in terms of grain boundary sliding. An understanding of the grain size effects is developed on the basis of dislocation substructures produced during creep.

Rupture life and rupture ductility have generally decreased with increase in grain size. However at 973K, a
peak in the variation of rupture life with grain size has been observed for 70 MPa corresponding to the minimum in creep rate. An understanding of these grain size effects is developed in terms of influence of grain size on the crack growth stage of creep fracture. The variation of rupture life with grain size is consistent with a model for intergranular creep fracture that considers growth of creep cavities as deformation controlled. Various creep fracture criteria are briefly considered and in general the results are in support of the Griffith-Orowan critical crack length criterion.

In Chapter I, introductory material on the flow and fracture characteristics of polycrystalline materials at elevated temperatures is presented. The influence of grain size on deformation and fracture and phenomenon of dynamic strain aging are reviewed with special reference to austenitic stainless steels. Precipitation behaviour of austenitic stainless steels is described. The experimental details are included in Chapter II and the results of current investigation are presented in Chapter III. Discussions on the results are presented in Chapter IV under the following sections: (i) Influence of grain size on tensile properties, (ii) Dynamic strain aging and (iii) Influence of grain size on creep properties. Chapter V gives the summary and conclusions of the present investigation.