CHAPTER - I

INTRODUCTION

1.1 General :

The phenomenon of superplasticity in which metals and alloys deform extensively at elavated temperature under small stress without risk of rupture has been well documented in past decades (1). Creation of the superplastic state, therefore may be a useful means of introducing sufficient extra ductility to enable current methods of working to be extended and for innovation as an advanced manufacturing technology, particularly in respect of the difficult-to-form materials. The understanding of the rate controlling mechanisms for superplastic deformation process in terms of stress, temperature, strain-rate and grain size is important not only for its intrinsic scientific value but also because of its significance in optimizing the processing parameters for forming operations. A sound understanding of the dependence of the superplastic strain-rate on flow stress, grain size and temperature will be of significant use in optimization of these variables so that the material can be deformed at the highest possible forming rates and still benifit from the exceptionally large neckfree ductility associated with superplasticity. However major breakthrough has yet unraveled the substructural details of the mechanism to reveal a complete satisfactory co-relation between mechanical and microstructural behaviour of superplastic alloys in general.

1.2 Origin of Superplastic behaviour :

Superplastic deformation behaviour, the stable flow orginates either by special environmental conditions or from special structural condition as follows.

1.2.1 Special environmental condition :

In certain environmental condition i.e. by application of stress, certain polycrystalline material became spontaneously plastic by generating intergranular stresses independent of any applied stress in some circumstances which leads to a shape change (2,3) due to increase in internal stress. To create high internal stress two common methods are used (a) temperature cycling of a material through a phase change which is known as transformation superplasticity (4,5) and (b) temperature cycling on a thermally anisotropic material (6). In case of transformation of ferrite to austenite, the plasticity was due to creep enhanced by an abundance of point defects (vacancies on heating, interstitials on cooling) created during the volume change (7) and also some physical models are suggested (7,8).

1.2.2 Structural superplasticity :

The superplastic behaviour of this group of materials, is closely associated with the singular properties of aggregates of small (of the order of 1-10μm) equiaxed grains at temperatures above half their melting temperature. The deformation usually takes place at constant temperature and the microstructure remains unaltered. The materials may be single-phase, but those exhibiting increased stability and more elongations are usually multiphased. Therefore many superplastic alloys are based on eutectic or eutectoid systems (1) between phases having similar melting temperatures.

1.3 Characterisation of Superplastic Flow :

The flow stress of structural superplastic materials is a sensitive function of strain-rate temperature and grain size and their behaviour is quite different from that of conventional materials. Characterisation of stress-strain-rate behaviour is usually made by a step strain-rate test (9) in which the strain-rate is increased in successive steps and the corresponding steady state flow stress is measured. But a constant flow stress is a negative loading rate which would occur at a point somewhat beyond the load maxima. Various arguments have been made in the literature (10) with respect to the proper selection of flow stress from the transient loading response in strain-rate change tests. Since plastic strain-rate, changes rapidly during this portion of the load curve, selection of data at the elastic limit from the rapidly rising part of the load curve is thought to be inappropriate (13). The step strain-rate test is believed to be a logical test method for use in superplastic forming applications provided the data are obtained with very little strain accumulation (of the order 0.2 - 0.5). The stress vs strain-rate data plotted on the basis of such small strain accumulation serves as the initial behaviour of the superplastic characterisation. Though the grain size effect is very strong in controlling flow stress in superplastic range, hence to characterise flow stress free from grain growth effects, stress must be selected soon after the elastic portion.

Above 0.5 Tm where equilibrium between recovery and strain hardening exhists (11), the important parameter strain-rate sensitivity, replaces the strain hardening index which is the controlling factor at low temperatures. The magnitude of strain-rate-sensitivity (0.3 - 0.8) is of considerable importance in superplastic deformation which has been demonstrated analytically by Rossard (12) and experimentally by Backofen et al. (23).

1.3.1 The Stress-strain rate relationship :

1.3.1.I Dependence of strain rate on stress and grain size :

All superplastic materials exhibit large tensile strains when pulled at high temperature at strain rate in the vicinity of about 10^{-3}sec^{-1} (13). However, there is a corresponding reduction in maximum elongation and thus a diminuation in the superplastic effect, when the strain-rate is either increased or decreased significantly. It is now conventional to describe stress strain behaviour by means of log σ - log $\dot{\varepsilon}$ curve where σ and $\dot{\varepsilon}$ corresponds to true stress and strain rate respectively (14,15,16).