Ain Shams University

Faculty of Engineering

BEHAVIOUR OF METALS UNDER " HOT WORKING CONDITIONS "

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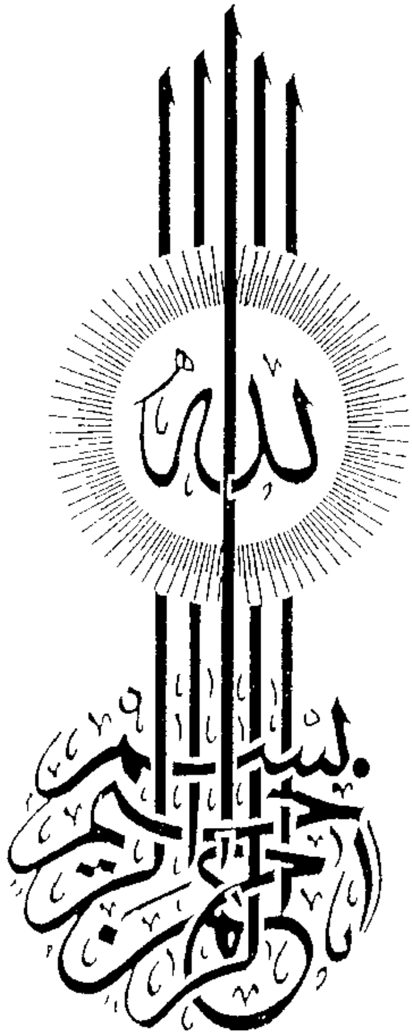
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SUMMARY

This investigation was carried cut to study the behaviour of commercial purity Al - Ni eutectic alloys under plastic working conditions. The material was tested in both the as cast and extruded conditions.

The literature related to this topic was critically reviewed and for the experimental work a variable speed hot tension machine was designed and constructed.

The tension tests were carried out over a temperature range of R.T. to 450°C and strain rates of 0.022 to 0.334/sec.

The experimental results and discussions of the present work indicated that the strength of both the as cast and extruded materials increased with increasing the strain rate and decreased with the increased of temperature. The hot strength results best fitted to the sinh relationship given by :

$$Z = \dot{\varepsilon} \exp. (Q/RT) = A'' (\sinh (\alpha \delta))^{n'}$$

where "Z" is a temperature compensated strain rate parameter, "δ" is the true stress, "Q" the activation energy, "R" the universal gas constant, "T" the absolute temperature, "$\dot{\varepsilon}$" the true strain rate, A", α, and n' are constants depending on the material.

This correlation is of a special practical import-

tance since it can predict the true deformation stress for a certain combination of temperature and strain rate .

The activation energy for the eutectic composition of aluminium nickel alloy was found to be 27 k cal/mole which is less than that of the activation energy of pure aluminium . This was attributed to the existence of the second phase particles of Al_3 Ni intermetallic compound which caused stress concentrations in the vicinity of the matrix .

The extruded alloys lost their superiority in strength over the as cast materials at temperatures above 200 ° C, this was attributed to the instability of the Al_3 Ni fibres produced by extrusion .

The results also showed that the ductility increased with the increase of temperature, that the behaviour of the extruded material was similar to that of pure alumi - nium , while the as cast material was less ductile .

The ductility was not very sensitive to the strain rate variation and the results best fitted to the sinh relationship given by :

$$Z = T_r \exp . (- Q/RT) = + B'' (\sinh (\alpha \delta))^{-n'}$$

where "Z" is a temperature compensated failure time parameter , T_r is the time to failure , B" , α , n' are constants depending on the material .

Contents

INTRODUCTION

The term "Two - Phase Materials " embraces an extremely broad spectrum which includes many naturally occuring minerals and rocks , materials of organic origin and man made aggregates of metallic , ceramic, glassy and polymeric materials . In this Investigation we shall be concerned with a system in which the second phase component is in the form of dispersed particles. The particle size has a lower limit of one micron to avoid discussion of precipitation hardening .

Commercial two phase metallic systems usually consist of a hard phase distributed throughout a soft tough matrix . These second phase particles are often added for strengthening purposes but frequently they exist in the form of inclusions that are a legacy of the starting materials .

The base material , i.e. the matrix in this study is aluminium , in which the intermetallic compound Al_3 Ni is in the form of a hard second phase embedded in the soft matrix .

The mechanical properties of the eutectic composite Aluminium - Nickel alloy have been studied under hot working conditions . The work in the eutectic systems recently begun at the Research Laboratories of the

United Aircraft Corporation in 1963 , and has been directed towards gaining an understanding of the process involved in the deformation of unidirectionally aligned eutectic alloys . The aim of this project was to obtain fundamental informations on the role played by the fibres in the deformation and fracture of the two phase systems.

The main feature of hot working is that extremely large strains are applied to materials at high rates of temperature above 0.5 T_m, where T_m is the melting tem - perature in degrees Kelvin . Strength and ductility under these conditions are markedly dependent on both temperature and rate of straining . Ductility is inti - mately related to the deformation processes that govern plastic flow . These large strains can be achieved with little or no-strain hardening , indicating that dynamic softening processes can operate sufficiently rapidly to balance the strain hardening processes .

In this situation the structural changes involved can be used to obtain information on the mechanism of deformation . However , care must be taken in the inter-pretation of such hot-worked structures since signifi-cant structural changes can occur on holding at the temperature of deformation or on cooling to room tempe-rature . For economic reasons, hot working is normally carried out at high rates of strain , although with difficult materials it may be necessary to use low rates to prevent cracking . The true strain rates are usually in the range from 0.5 to 500 / sec . At such rates adiabatic heating occurs and can lead to some problems in the interpretation of the structure as well to ductility problems in practice .

In view of the importance of hot working considerable attention has been paid to the development of hot workability tests to give information on the optimum processing of materials .

Various tests have been advocated depending on the dominant stress system operating in the deformation process e.g. compression for rolling or forging , torsion for tube piercing . In general , the stress systems in practice are complex and the laboratory tests tends to simplify the situation for hot workability. Basic research on the mechanisms of deformation and fracture during hot working requires data over ranges of working conditions that are not utilised in practice and hence development of this field has been slow .

One of the most important and widely used method for testing materials in laboratory is the tension test . The basic data on the mechanical properties of a material is obtained from this test in which a suitably designed specimen is sujected to increasing axial load until it fractures , however some disadvantages appear to limit its application specially for high strain rates where marked adiabatic heating occurs in a small volume leading to marked temperature rise .

In this investigation a comparison was made between the as cast structure and the extruded rods of the eutectic composition of the aluminium - nickel alloy under various temperatures , and various strain rates . For this purpose a hot tension machine giving a large range of strains was constructed and the application of heat during the tests was possible by using a specially designed electrical split furnace giving the required range of temperatures .

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CHAPTER I

Mechanical Behaviour of Metals under Hot Working Conditions

1.1 Introduction

In this chapter the mechanical behaviour of metals under hot working conditions will be analysed using the results of the published literature . Particular attention will be paid to the behaviour of the eutectic composition of Aluminium-Nickel specially the effect of the second phase particles of Al_3 - Ni on the mechanical properties .

It is a general experience that as the deformation temperature increases the strength of the metal decreases , while the ductility increases . This is thought to be due to the dynamic recovery process superimposed on the basic mechanism of strain hardening. Since the dynamic recovery process is thermally activated , the rate of deformation will be expected to play an important role in the resistance to deformation at high temperatures .

The results of several investigations in this field given in the literature will be classified under five main sections :-

(1) Effect of temperature on mechanical properties

(2) Effect of strain rate on mechanical properties

(3) Combined effect of strain rate and temperature

(4) Plastic deformation of the two phase materials

(5) The stability of the eutectic compositions at elevated temperatures .

1.2 Effect of temperature :-

It was found that the minimum temperature for hot working was about 0.5 T_m . Beyond this temperature recovery starts to operate . The role of temperature is to allow for recovery and recrystallisation to occur and eliminate the strain hardening as much as possible . The general feature of hot working is reducing the level of the stress strain curve and fracture occurs with increased ductility as shown in fig. (1) .

1.2.1 Strain Hardening

This term denotes that the resolved shear stress needed for slip to occur should increase in order to obtain further slip in the plastically deformed metal and so the metal appears to become harder as it is further strained .

Strain hardening is caused by dislocations interacting with each other and with barriers which impede their motion through the crystal lattice, those barriers could be :

1- Intersection of dislocations .

2- Dislocation pile - ups .

3- Dissociation of dislocations : stacking faults .

4- Sessile dislocations .

1.2.2 Annealing , Recovery and Recrystallisation :

The cold worked state is a condition of higher internal energy than the undeformed metal . With increasing temperature there is a tendency for strain-hardened metal to revert to the strain - free condition and restoring the ductility of the metal.The over all process by which this occurs is known as annealing.[1] This over all process can be divided into three fairly distinct processes, recovery, recrystallisation and grain growth . Fig.(3) distinguishes between these processes . Recovery is defined as the restoration of the physical properties of the cold worked metal with-out change in microstructure .

It is evidenced by a decrease in hardeness or strength and increase in ductility . With further increase in temperature grain growth will occur , it is inhibited considerably by the presence of a fine