STRESS-RUPTURE OF Al-Ni EUTECTIC ALLOYS

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By

ENG. MOHAMED ADEL A. RIZK

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M.Sc. Thesis Submitted by

ENG. MOHAMED ADEL A. RIZK

Under the supervision of

PROF.DR. MOHAMED H. ABDEL LATIF

Examiners

PROF. DR. A. E. EL MEHERI ....

Faculty of Engineering-Cairo University.

PROF. DR. MOUSTAFA A. CHAABAN ....

Faculty of Engineering-Ain Shams University.

PROF. DR. MOHAMED H. ABDEL LATIF ....

Faculty of Engineering-Ain Shams University.

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SUMMARY

The mechanical properties of eutectic composites have received considerable attention during the past decade. This is because of their potential advantages in many applications, particularly at elevated temperatures. The present work was devoted to study the effect of the microstructure and micromorphology of the dispersed phase of the Al-Ni eutectic alloy on the stress-rupture properties.

The experimental work included the redesign and construction of an electric resistance furnace in which the as-cast Al-Ni eutectic alloys were prepared under controlled Argon atmosphere. Heat treatment was carried out on some of the as-cast rods to yield Al_3Ni in spherodized shape. Directional solidification was performed on other rods to produce rod-like and lamellar Al-Ni composites. This was accomplished on a directional solidification apparatus which was especially modified to satisfy the required conditions. The prepared Al-Ni eutectic alloys were metallographically examined. Stress-rupture tests were performed at 573°K on specimens representing the different alloy structures as well as the directionally solidified Aluminium representing the matrix of the composites. A stress-rupture testing machine was especially constructed for this purpose. The machine was equipped with a split electric resistance furnace, temperature control system, system for determination of the rupture time, and electric circuit for detecting the breakdown of the supply current. The stress-rupture tests were carried out at different stress levels and the elapsed times to rupture were

determined. Elongation of the fractured specimens was measured. Macro and micro examination of the fractured specimens were also carried out to study the fracture mechanism.

The experimental results revealed that;

(1) The nature and morphology of the dispersed phase, Al_3Ni, was different according to the preparation technique used in the production of the Al-Ni eutectic alloys in this work. The Al_3Ni phase exhibited a feather-like appearance in the as-cast alloys, globular shape in heat treated alloys, aligned rod-like in composites directionally solidified at high growth rates and lamellar at low growth rates.

(2) The prepared Al-Ni rod-like eutectic composites showed a colony structure. This was expected due to the commercial purity of the materials used. However, no colony structure was observed in the lamellar structure. This may be attributed to the low growth rate used leading to a higher G/R ratio that suppressed colony formation.

(3) Stress-rupture properties of the unidirectional solidified composites were superior to those of the conventional cast and globular alloys, as indicated by longer rupture times and lower percentage elongation at rupture/rupture time for the same stress. This is due to the more effective strengthening of the aligned dispersed phase in the composites

(4) The morphology of the dispersed phase influenced the stress-rupture properties of the prepared eutectic alloys. Rod-like composites exhibited long rupture times and higher% elongations than lamellar composites, and globular alloys exhibited higher % elongations and shorter rupture times compared to those attained by the as-cast alloys.

(5) A reasonable linear correlation between the stress and the rupture time was determined for the results of the as-cast and globular Al-Ni eutectic alloys as well as the directionally solidified Aluminium on a log-log scale. However, the results of the Al-Ni eutectic composites were found to be better represented by a broken line with a higher slope at high stress levels. This may be attributed to the increase in the number of fiber/or lamella fractures at high stresses which deteriorated the composite strength.

(6) Due to the effect of microstructure and micromorphology of the dispersed phase, the prepared alloys showed a pronounced diversity in their fracture mode. As-cast specimens fractured with a brittle mode. Heat treated specimens produced a ductile fracture accompanied with the formation of the familiar cup and cone fracture. Rod-like composite specimens developed a shear fracture. Lamellar composite specimens exhibited a brittle fracture.

(7) At high stress levels, the density of microvoids associated with whisker fractures was high for the composites. These microvoids rapidly coalesced

resulting in a smaller specimen cross sectional area supporting the stress eventually leading to failure of the specimen by tensile overload. At low stress levels, the density of microvoids associated with whisker fractures was low. Therefore, more time was needed for growth of the microvoids before their coalescence leading to higher rupture times.

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CONTENTS

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INTRODUCTION

Unidirectional solidification of eutectic alloys provided a technique which avoids many of the difficulties normally encountered in the fabrication of composites. The multiple requirements of optimum reinforcement including the perfection and alignment of the whiskers and strong interfacial bond are achieved simultaneously in a single metallurgical process. Growth of eutectics by this method has produced Aluminium, Magnesium, Nickel and Tantalum based binary eutectics which display in-situ strengthening of a metal matrix by a stiffer less ductile phase.

Previous work has shown that the creep and stress-rupture behaviour of eutectic composites is intimately related to both the quality and scale of the microstructures. Finer microstructures lead to significant improvment in creep properties, and the occurence of cellular structure was found to be detrimental. The studies also showed the important contribution the matrix makes to the creep response.

It is felt that the morphology of the reinforcing phase has an important effect on the stress-rupture behaviour of composite materials. In this work the effect of microstructure and intermetallic compound morphology of a binary eutectic composite Al-Ni alloy on the stress-rupture properties was studied. Specimens representing the different microstructures of the Al-Ni eutectic alloys namely as-cast, globular and directionally solidified composites with either rod-like or lamellar morphology were prepared from commercial purity materials and stress-ruptured. Fractographic examination of the fracture surface as well as metallographic examination of sections below the fracture surface was conducted to study the fracture behaviour of these composites.

CHAPTER I

LITERATURE SURVEY

1.1. Eutectic Classification

The particle size, shape and distribution of the dispersed phase are imoprtant parameters affecting the properties of a wide variety of two-phase eutectic materials. Thus, the intricate and varied patterns presented by eutectic microstructure have long been of interest to metallurgists.

The early work of Bradly and Portevin (quoted in 1) classified eutectics according to the morphology of the phase present. This system is still in use today, with the result that eutectics are termed either lamellar, globular, rod-like or slivery (needle-like). Hogan (2) reported that Scheil classified eutectic structures according to the mode of solidification to three types mamely,normal, anomalous and degenerate. He stated that , in normal eutectics the growth of the two phases must be simultaneous and a lamellar or rod structure is formed . In anomalous eutectic the two phases are still closely intermingled , but there is much less regularity. In degenerate eutectic, the association of the two phases has been reduced to minimum, as though two primary phases have been grown independently from the same melt.

Experiments by Weart and Mack (3) have done much to clarify the structures seen in eutectic alloys. These authors showed that, a normal eutectic has three definite structures: the grain structure, the colony structure, and the eutectic structure, each one contained by the one preceding it. The grain structure is analogous to the polycrystalline structure of a metal or single phase alloy, in that each grain grows from a single nucleus. The eutectic grain consists of two penetrating single crystals representing the two solid phases. A grain is taken to be the region in which the matrix phase is monocrystalline. The colony structure is a subgrain structure whose units contain several dozen phase particles arranged in a characteristic pattern. This pattern is a consequence of the cellular solid-liquid interface topography. The phase particles arrange in a tubular-like pattern, in which the axis of each tube representing one colony-laying roughly parallel to the growth direction. At colony center the phase particles are more or less parallel to colony axis but they tend to fan out and coarsen as they approach the colony boundary, Fig. 1. The colony structure is distinguished only by the phase particle arrangement and not by crystallographic orientation as in the case of grains. This structure is only obtained if the specimen is grown unidirectionally. The eutectic structure is smaller than either the grain or colony structures. The term "eutectic structure" refers to the actual shape of the phase particles such as plate-like, globular and so on. All of these structures arise of course, because of the partitioning of atoms in the liquid during its transformation to two solids.

1.2. Eutectic Composition.

A most important first point, which applies to all classes of eutectics, is that the pure eutectic structure, containing no primary crystals, does not necessarily occur at the eutectic point as given by the equilibrium diagram. Under suitable conditions of freezing it may be found at a composition deviating substantially from the equilibrium eutectic composition (2). The work by Flemings (5,6,7) has

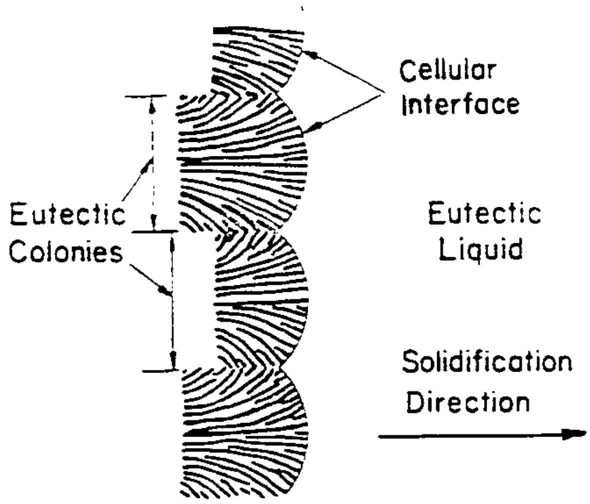

Fig. 1.Schematic drawing of eutetic colonies;(Ref. 4).

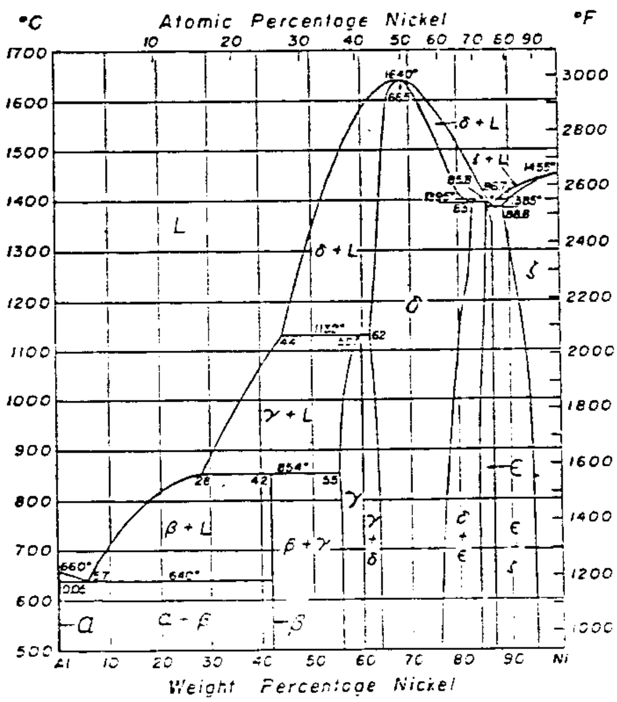

Fig. 2.Al-Ni phase diagram;(Ref. 8).