INFLUENCE OF TITANIUM SOLUTE ADDITIONS ON THE MICROSTRUCTURAL AND MECHANICAL BEHAVIOURS OF Ni-B ALLOYS

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Abstract

The study prepared seven ternary Ni-B-Ti alloys with varying compositions of titanium and one binary Ni-B alloy (control sample). It also determined the solidification path and phase formation of the alloys, their microstructures and their mechanical properties. This was with a view to determining the effect of varying amount of titanium on the microstructure and some mechanical properties of the Ni-B system.

The components of the alloys were pure Ni, binary Ni-B containing 18.3wt %B and pure Ti. The components of each alloy were accurately weighed and then melted using an electric furnace. The samples were quenched in air after melting. Differential Thermal Analyzer (DTA) was used to study the solidification path and phase formation of the alloys. The heating and cooling rates ranged from 10-20^{o}C/min. Scanning Electron Microscope (SEM) equipped with Energy Dispersive X-ray Analyzer (EDXA) and Optical Microscope (OM) were used to characterise the structures of the alloys. The sample for SEM and OM investigations were polished, then slightly etched with an etchant consisting of 5g $FeCl_3$+10ml HCl dissolved in 50ml H_2O. Instron machine was used to measure the compressive strength of the alloys while the hardness values of the alloys were measured with a micro-hardness tester on the Vickers and Rockwell-C scale.

Microscopic and thermal investigations of the alloys revealed the presence of two major primary phases [Ni(α), τ] and other binary and ternary eutectic structures. Microsegregation was not observed in the quenched alloys due to their very high solidification rates. Upon subjection to slow cooling, the microstructures of the alloys becomes complex due to solid-state reactions and large undercoolings in the alloys. The addition of titanium to the Ni-B system led to a shift in microstructure of the alloys from the hypoeutectic to the hypereutectic region during slow cooling. Solid state (eutectoid) transformation of the τ phase was observed in alloys with low titanium contents. But such transformation was not observed for alloys with high titanium contents. The hardness values and Stiffness values of the Ni-B-Ti matrix increased with increase in titanium contents.

The study concluded that Ni-B-Ti alloys which were suitable as coating materials to solve wear and abrasive problems in the engineering industries could also be applied to make the materials harder and stiffer.

Keywords: Titanium Solute / Microstructural /Mechanical behaviours / Ni-B Alloys / Engineering industries

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CHAPTER ONE

INTRODUCTION AND BACKGROUND TO THE STUDY

1.0 Introduction

Most pure metals when subjected to use are mostly unable to meet the need of engineers for the particular purpose they are used for. The inability of pure materials to meet the desired need of engineers has resulted in the doping of parent materials with other re-enforcing agents (materials) so as to get the desired properties needed for engineering purposes by engineers. This 'marriage' between materials increases or decreases certain properties of the material such as wear and corrosion resistance, ductility, hardness, compressive strength, tensile strength, low thermal expansion etc. This has led to the concept of "alloys".

The gradual deterioration of metallic components in industrial plants is observed due to corrosion and wear phenomena. The gradual deterioration of components results in loss of plant efficiency and sometimes it may cause a plant shutdown. The more alarming fact is that, if corrosion and wear phenomena are combined, these may cause much higher material loss that can be caused by each of them separately. Corrosion and wear often combine to cause aggressive damage in a number of industries such as mining, mineral processing, chemical processing, pulp and paper production, petrochemical, energy production, etc. (Shakoor *et al.*, 2014). In many applications the surface of the component is subjected to vigorous mechanical forces and solvent attack. Therefore, in such cases, modifying the surface properties has proven to be an efficient and economical way rather than improving the bulk properties (Shang *et al.*, 2008). The surface properties (hardness, wear, abrasion and corrosion) can be successfully improved by many techniques like carburizing, nitriding, carbonitriding, flame hardening, laser hardening, induction hardening, internal oxidation, chemical vapour deposition, physical vapour deposition, etc. It is known that oxygen plays a vital role in wear and corrosion and the role of moisture in wear and corrosion cannot be under-estimated (Ajao, 2009b).

One of the basic components of the Nickel-based hardfacing alloys according to Ajao (2010b) are the Ni-B hard phases. Ajao (2010b) went further to posit that the hardfacing alloys are specially developed to solve the problems of wear and corrosion in petrochemical, glass, automobile, aerospace, nuclear and other related industries. These alloys are usually used as coating materials which are deposited on engineering materials by different coating techniques. The hard alloys usually consist of nickel as a base metal while titanium, vanadium, chromium, tungsten and molybdenum are used as metallic additives and boron, silicon and carbon as non-metallic additives (Knotek *et al*., 1981 in Ajao, 2010b).

1.1 Concept of Alloys

Almost every material we could ever want is lurking somewhere in the planet beneath our feet. From the gold we wear as jewelry to the oil that powers our cars, Earth's storehouse of amazing materials can supply virtually every need. Chemical elements are the basic building blocks from which all the materials inside Earth are made. There are 90 or so naturally occurring elements and the majority of them are metals. But, useful though metals are, they are sometimes less than perfect for the jobs we need them to do. Take iron, for example. It is amazingly strong, but it can be quite brittle and it also rusts easily in damp air. Or what about aluminum. It is very light but, in its pure form, it is too soft and weak to be of much use. That is why most of the "metals" we use are not actually metals at all but alloys: metals combined with other elements to make them stronger,