MICROSTRUCTURAL CHARACTERIZATION OF NI-Cr-Al-C-(Nb) ALLOYS

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Abstract

The microstructures of two nickel based alloys Ni-Cr-Al-C-(Nb) containing chromium and chromium plus niobium carbides were investigated. These alloys unlike commercially available nickel based superalloys contain a high volume fraction of carbides to obtain high wear resistance. Moreover aluminum addition enables precipitation hardening of the nickel based matrix. Scanning electron microscopy (SEM) including energy-dispersive X-ray spectroscopy (EDX) and X-ray diffraction (XRD) studies were carried out with particular attention to phase composition of materials.

Keywords: Nickel based alloys, carbides, cast alloy, SEM

1. INTRODUCTION

Development of new alloys plays an important role in the modern industry. Materials such as nickel based alloys are used in severe mechanical, chemical and high temperature conditions such as jet engines. Most of modern alloys are strengthened by intermetallic phases and/or by carbides. Introduction of carbides into microstructure of steels, cast irons and cobalt based alloys is a very effective method for increasing of wear resistance and increasing of in-service temperature. Carbides in steels are crucial constituents of the microstructure, during heat treatment some of carbides may be dissolved and precipitated in form of fine particles within the matrix and on the grain boundaries [1 - 5]. Types of carbides, their size and morphology determine further properties of steels [6, 7]. That knowledge has been utilized in industrial practice but even recent studies indicate that improper heat treatment of tool steels is the most likely cause of part failure [8, 9]. Nickel and cobalt matrices, in comparison to iron, poses much lower carbon solubility in solid solution and those elements do not form carbides. Much research on nickel based alloys with high volume fraction of carbides has been performed by Berthod [10, 11], Bala [12 - 14] and authors of the present paper [15]. As reported by Bala [12, 16] precipitation hardening of nickel based alloys with high volume fraction of carbides is possible. However, previous studies do not take into account niobium carbides and $Ni_3(Al,Nb)$ precipitation hardened matrix. Based on the approach presented by Bala [14], the purpose of this paper is to reveal influence of niobium on the microstructure of nickel based alloy with high carbon content.

2. MATERIALS AND METHODS

Two alloys with designed chemical composition shown in **Table 1** were melted in Balzers vacuum furnace and casted into metal chills.

Microstructure and phase composition has been investigated using FEI Versa 3D SEM and PANALYTICAL Empyrean X-Ray diffractometer using CuKα1 radiation. Hardness tests were performed using Tukon 2500 hardness tester by Willson Hardness applying Vickers diamond pyramid method and load of 9.8 N.

Table 1 Designed chemical composition of experimental alloys (wt.%)

Alloy No.	C	Cr	Al	Nb	Ni
1	0.85	20	4	-	Bal.
2	0.85	20	4	6	Bal.

3. RESULTS

Microstructures of investigated Ni-Cr-Al-C and Ni-Cr-Al-C-Nb alloys are given in **Fig. 1a)** and **b)** respectively.

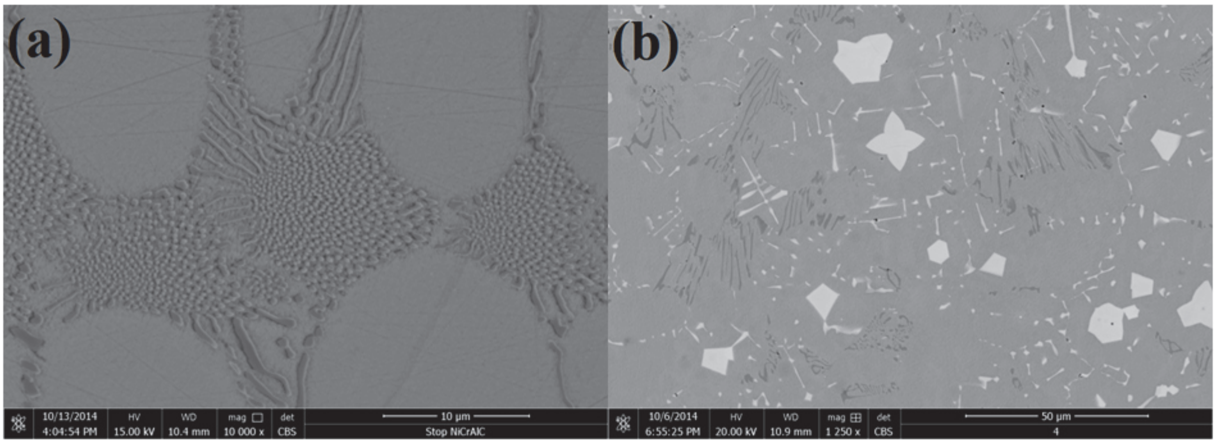
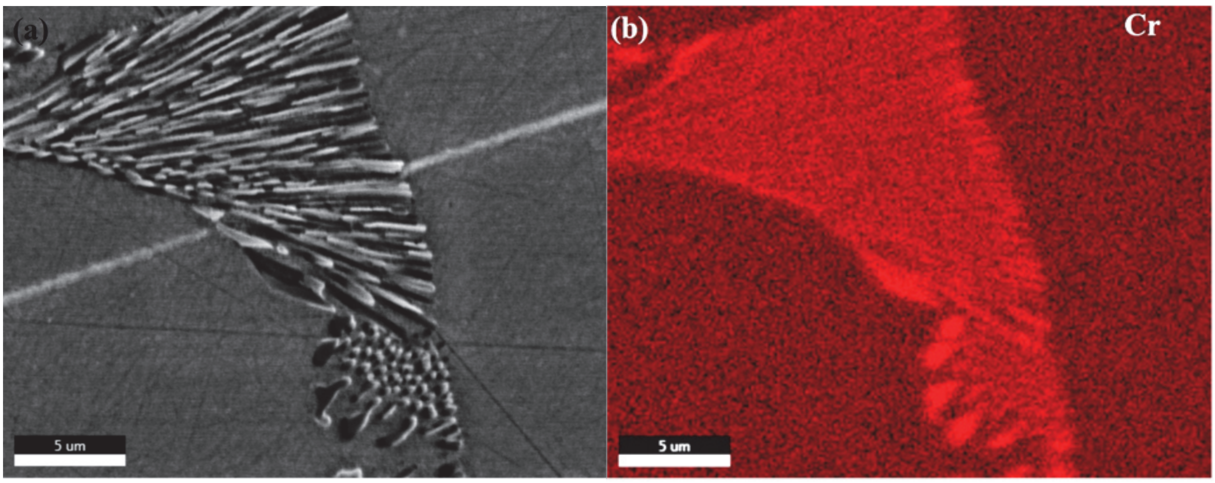


Fig. 1 Microstructures of Ni-Cr-Al-C (a) and Ni-Cr-Al-C-Nb (b) alloys, SEM-BSE

EDS maps of chromium and chromium and niobium are shown in **Fig. 2**.

Fig. 3 presents XRD patterns of investigated alloys, Cr_7C_3 chromium carbides were fitted for Ni-Cr-Al-C spectrum. However, in the case of Ni-Cr-Al-C-Nb alloy XRD spectrum does not give certain information about the type of chromium carbides.

Hardness of investigated alloys was 364 ± 10 HV_{10} and 428 ± 11 HV_{10} for Ni-Cr-Al-C and Ni-Cr-Al-C-Nb alloys, respectively.



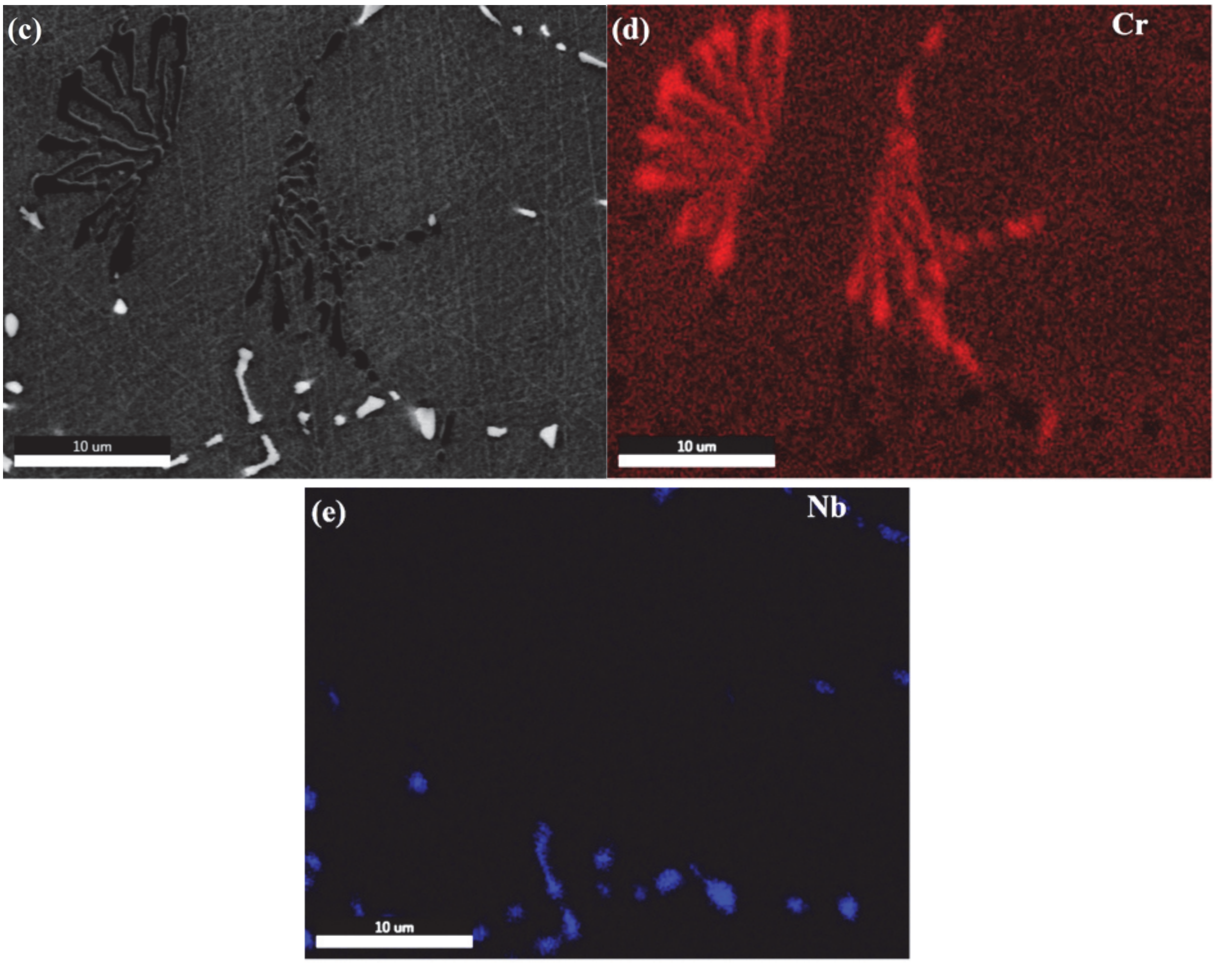


Fig. 2 SEM-BSE images a), c) and EDS maps of elements for Ni-Cr-Al-C alloy: chromium map b) and for Ni-Cr-Al-C-Nb alloy chromium and niobium map d) and e) respectively

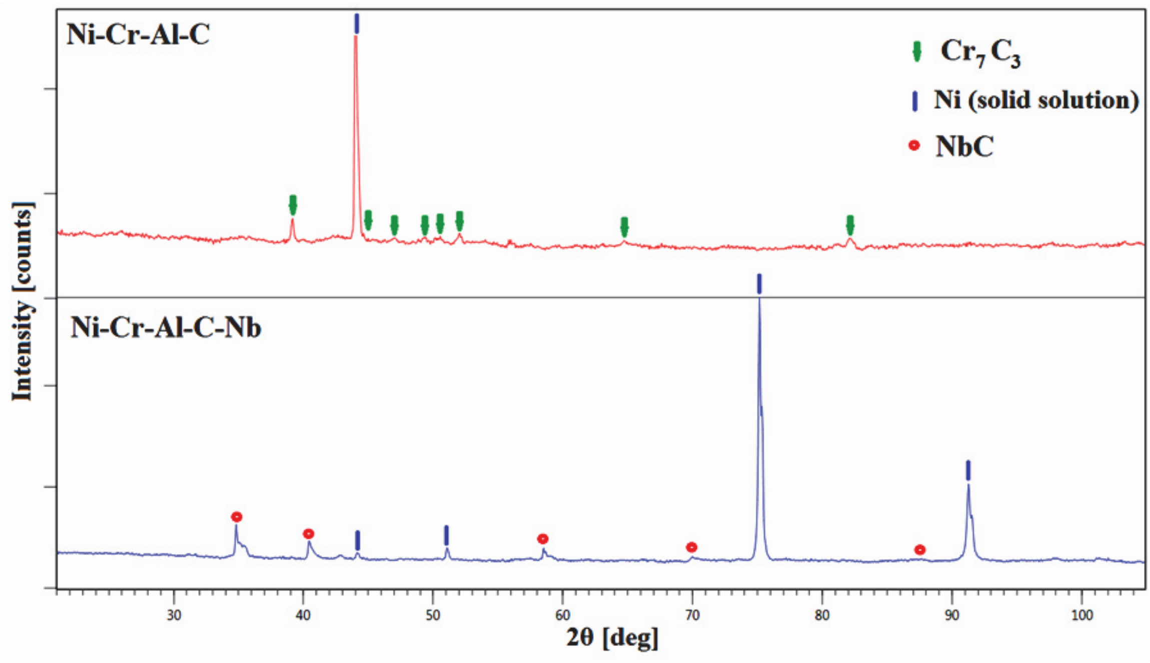


Fig. 3 XRD patterns of investigated alloys

4. DISCUSSION

The main purpose of this paper was to study an influence of niobium on the microstructure and properties of nickel based alloys with relatively high chromium and carbon contents. Addition of niobium caused partitioning of carbon during solidification process into chromium and niobium carbides. Microstructure of Ni-Cr-Al-C alloy consists of dendrites and eutectic made of fine carbides and nickel based solid solution. On the other hand addition of niobium led to precipitation of large NbC and chromium carbides in interdendritic zones. Precipitation of NbC carbides results in an increase in hardness of approx. 60 HV_{10}. Two different morphologies of NbC carbides reveal dual nature of their precipitation. First type, observed as blocky carbides precipitated probably right after formation of dendrites when liquid is rich in chromium, carbon and niobium the second type, observed as so called “Chinese Script” NbC carbides precipitated as eutectic with nickel based solid solution, when liquid alloy reached eutectic chemical composition. The XRD study revealed Cr_7C_3 carbides in Ni-Cr-Al-C alloy, but did not bring certain proof for chromium carbides type in Ni-Cr-Al-C-Nb. The alloy system after addition of niobium is depleted in carbon content due to formation of NbC carbides before eutectic solidification. In addition, this situation causes uncertainty of chromium carbides characterization. Moreover, volume fraction of chromium carbides decreases what makes X-Ray diffraction peaks less pronounced as well.

5. CONCLUSIONS

Based on the results presented herein, it is possible to conclude that high volume fraction of niobium and chromium carbides is possible to obtain in nickel based matrix. Niobium carbides at certain solidification conditions precipitated in two morphologies (blocky and so called “Chinese Script”). Higher hardness of niobium carbides in comparison to chromium carbides causes significant increase in hardness of investigated alloy. Determination of chromium carbides type in Ni-Cr-Al-C-Nb needs further studies.

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