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DEVELOPMENT OF NICKEL BORON ALLOYS FOR BRAZING MATERIALS

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Abstract

Nickel-base filler materials are generally used in applications where resistance to corrosion and heat resistance required. Their description as high-temperature brazing filler materials is amply justified. In this study, nickel boron (NiB) alloys is produced via carbothermic reduction starting from boric acid (H_3BO_3) together with high purity nickel (NiO), charcoal and sawdust by using DC arc furnace which the boron-containing composition of the basic metal is tapped at the bottom. In the arc furnace experiments, different starting mixtures were carried out, and optimum starting composition for producing 15-20 wt. % B containing NiB alloys were investigated. Alloy compositions, metal recoveries, graphite electrode and energy consumptions were performed. The obtained products were characterized by using wet chemical analysis (AAS/ICP), XRD and SEM/EDS techniques.

Introduction

The development of the technologies has showed us for the different materials being worked together. For a long time, lots of methods have been developed to connect the same or different materials. Brazing can be described such a connecting two or more metallic materials by melting another material whose melting temperature is lower than those of connected materials [1]. Brazing with filler metal, which has been widely range of used such a cost effective appliance in high technology industries, has been showed to be able to manufacture high performance links with ideal strength and well corrosion resistance. There is an essential situation after the strong metallurgical process and the base metal in order to prevent the precipitation of brittle intermetallic phases like silicides, borides and phosphides from the relatively high contents of respective metalloids in brazing alloy [2]. Also if the dissolution process was not well controlled, there exits some problem that the over-dissolution of base metal could be have unwanted corrosion pits being brazed [3]. The invention of carbothermal method of producing nickel-boron composition by the reduction of boron-containing raw material, e.g. an oxide of the base materials and the carbon material applying and electrical furnace and boron comprise material of the basic metal is tapped at the bottom [4].

Our work aims to developed a scientific and engineering background in the production of Nickel boron alloys (NiB) which can be used as a brazing material, wear-corrosion-oxidation resistive applications via carbothermic reduction that is the effective and attractive process technique regarding high mass of production for industry such as brazing, automotive, electronics, aircrafts, coatings etc.

Experimental Procedure

In this study, nickel-boron alloy was produced from a mixture of boric acid, nickel oxide, charcoal and wood charcoal. The purity of granular boric acid was 99.5%, and nickel oxide has a 99.0% purity, respectively. Chemical analysis of charcoal and wood charcoal are given in Table I.

Table I. Chemical Analysis of Charcoal and Wood Charcoal (wt. %).

Reductant	C_{fix}	Ash	Volatiles
Charcoal	65.18	9.52	25.30
Wood Charcoal	10.16	0.35	89.49

The laboratory type 270 kVA DC arc furnace used in this work was graphite lined and 250 kg charge capacity. The diameter of the furnace was 36 cm and 90 cm depth. The voltage and current readings were measured by manually. During the taping of the alloy, temperature measurements were done by using of an optical pyrometer.

Charcoal, wood charcoal and selected ratios of H_3BO_3 and NiO were mixed and 60 kg of these mixtures were fed to the open arc heated furnace. H_3BO_3/NiO ratio was selected as 1.11 for the experiments, and the amount of charcoal addition was selected between 12.80 – 17.80 % of charge by weight. After 1 hour of the experimental run, the liquid metal was tapped and the arc stopped. The furnace was left to cool for checkup. After cooling, the samples were taken from sinter sectors in the furnace with the range of 20 cm. These samples were analyzed with XRD (Rigaku, CuKα) technique.

Results and Discussions

Chemical analysis of the alloys obtained by addition of the different ratios of the charcoal to the initial mixtures were given in Table II. As H_3BO_3/NiO ratio of 1.11 fixed, boron contents in the final alloy was increased with increasing in ratio of fixed C to the total initial mixtures. Alloy weights were measured as 5.4 kg in first experiment and as 3.9 kg in second experiment, respectively. Alloy weight was decreased with increasing in ratio of fixed C to the total initial mixtures. The casting temperatures were measured as 1182°C in the first experiment and as 1145°C in the second experiment, respectively.

Table II. Chemical Analysis of Alloys (wt. %).

Exp. No	Charcoal / Total Mixture Ratio, %	Compositions, wt. %						
		Ni	B	Al	S	Si	Fe	C
1	12.80	90.06	9.13	0.007	0.006	0.35	0.26	0.07
2	17.80	85.25	13.76	0.280	0.003	0.23	0.33	0.06

After the cooling of arc furnace, at the bottom of the arc furnace there was a formation of alloy and slag with weight of 12.1 kg. Chemical analysis showed that, alloy had a composition of 75.05 % Ni, 18.40 % B, 0.35 % Al, 0.007 % S, 0.68 % Si, 0.23 % Fe, 1.62 % C by weight, respectively. Alloy weights and energy consumption values were given in Table III. At optimum metal production conditions, total energy consumption was measured 200 kW and electric energy was consumed 11.62 kWh/kg product.

Table III. Weights of Alloys and Energy Consumptions of the Experiments.

Alloy	Weight, g	Total Energy Consumption, kWh/kg	Total Electrode Consumption, gr/kg product	Total Electrode Consumption, cm/hour	Duration of Casting, min.
1	5.4	11.62	52.57	3.77	64
2	3.9				79
Tailed alloy in the furnace	7.9				-

In order to understand possible mechanism of nickel-born formation, samples from different sectors of the charge have been taken out. These samples have been carefully examined by XRD techniques. The comparative XRD graphs of the samples was given in Figure 1, and compounds list formed at different sectors in furnace was given in Table IV. The stoichiometry of the reactions and the corroding of the upper electrode tip have proven that reduction reactions take place at the upper electrode tip.

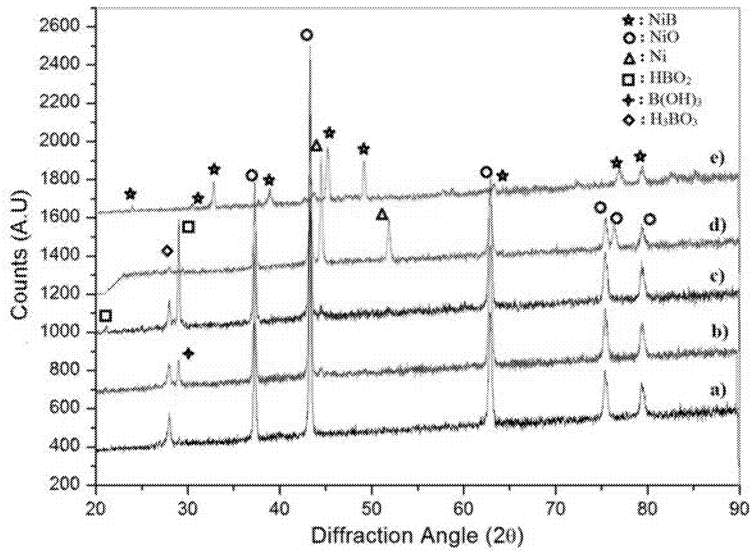

Figure 1. Comparative XRD graphs of the samples taken from a) 20 cm depth, b) 40 cm depth, c) 60 cm depth, d) 80 cm depth, e) at the bottom of the furnace.

Table IV. Weights of Alloys and Energy Consumptions of the Experiments.

Compounds	Sectors				
	20 cm depth	40 cm depth	60 cm depth	80 cm depth	At the bottom of EAF
NiB					X
NiO	X	X	X	X	X
Ni				X	
HBO_2			X		
$B(OH)_3$		X			
H_3BO_3	X	X	X		

Conclusions

In the production of nickel-boron alloy in an electric arc furnace, as the charge containing boric acid, nickel oxide, charcoal and wood charcoal dehydrate during the feeding into the furnace and while boron oxide melts, the charge is sintered but forms the porosity needed, by using carbonized charcoal. This permits the maintenance of the reduction reaction. With the help of high temperature, boron and nickel are reduced together from a glassy slag to produce 15-20 % B containing nickel-boron alloys.

It's an ongoing study, further studies have been carried out with using different initial mixture ratios (NiO/H_3BO_3, etc.), with using different ratios of fixed C to initial mixtures. Also the micro-structural studies will be realized by using SEM/EDS technique.

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