Sintered Duplex Stainless Steels Corrosion Properties

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Abstract

This work presents mechanical properties and corrosion resistance of duplex stainless steels obtained through powder metallurgy starting from austenitic, martensitic powders by controlled addition of alloying elements in the right quantity to obtain the chemical composition of the structure similar to biphasic one. In the mixes preparations the Schaffler's diagram was taken into consideration. Prepared mixes of powders have been sintered in a vacuum furnace with argon backfilling. After sintering rapid cooling was applied using nitrogen. Corrosion properties have been studied through electrochemical methods in 1M NaCl.

Keywords: duplex, stainless steel, sintered steels, pitting corrosion

1. Introduction

Duplex powders were subject to studies at different universities as well as in major companies producing powders. The application of powder metallurgy technology for producing biphasic duplex steels enables precise control of their chemical and phase composition of structure as well as elimination of number of technological difficulties that are present during the production of same kind of steels but using traditional methods. In order to reduce production costs of parts made from sintered duplex stainless steels, the heat treatment, so called „sinter-hardening" has been introduced, which relies on rapid convection cooling directly from sintering temperature. The application of this heat treatment method, in case of duplex stainless steels allows obtaining precipitate free structures that have influence on the increase of mechanical properties and corrosion resistance [1-5].

2. Experimental procedure

Different compositions have been tested, using austenitic X2CrNiMo17-12-2 (AISI 316L) and martensitic X6Cr13 (AISI 410L) as starting base water atomized powders of Hoganas. Austenitic base powder X2CrNiMo17-12-2 were mixed with addition of alloying elements powders such as Cr, Ni, Mo and Cu in the right quantity to obtain the chemical composition similar to biphasic one - mixtures A and B. Powder mixtures signed as C and D were produced starting from martensitic powder X6Cr13. Moreover, the ferritic stainless steel X6Cr17 (AISI 430L) powder has been mixed to austenitic stainless steel powder in the ratio of 1/1 in order to examine the structure derived after sintering (mixture E). In the preparation of powder mixtures, Schaffler's diagram was taken into consideration thus Cr_E and Ni_E equivalents were obtained introducing the wt. % quantity of the corresponding element into the formula which locates all the products in a well defined area, at least from a theoretical point of view. Chemical compositions of produced mixtures were placed in austenitic-ferritic area of the Schaffler's diagram. Powders were mixed with single elements using a laboratory turbula mixer. Acrawax was used as lubricant in a quantity of 0.65 wt.% in excess 100 for all compositions produced. Samples were obtained using a hydraulic press applying a pressure of 800 MPa with a floating die. The debinding process was done at 550°C for 60 minutes in a nitrogen atmosphere. Samples were then sintered in a vacuum furnace with argon backfilling at 1260°C for 1 h. After sintering rapid cooling with an average cooling rate of 245°C/min using nitrogen under pressure 0.6 MPa were applied.

3. Results

Density results, where evaluated using the water displacement method obtained in terms of green and sintered density show that for the martensitic based mixtures sintered densities were included in the range of 7,13 to 7,25 g/cm^3. For the austenitic based powders, lower values were obtained, even though starting with green values similar to the other compositions. It is remarkable to notice that, in case of mixture (B), an approximate dimensional stability was obtained. For this composition green and sintered density is in convergence. Mixture (E) obtained by mixing ferritic and austenitic powders in equal amounts shows good density after sintering cycle. Greater reactivity of martensitic grade powders when compared to austenitic grades results in higher shrinkage rate of the first one. Moreover, the addition of copper has resulted in the formation of a liquid phase during sintering and there through it influences on growth of sinterability caused by faster mass transport. This is evident for compositions containing copper with reason of higher sintered density when compared with sintered duplex stainless steels without copper addition.

Executed X-ray analyses confirm that the structure of the obtained sintered steels consists of austenite and ferrite phases. Composition (A) and (D) reaches the ferrite content about 75% while composition (B) 18%. For composition (C) the approximate balance of ferrite and austenite was archived. Steel marked as (E) reach ferrite content about 67%.

According to metallographic examinations of obtained materials the presence of a fine microstructure with no recollection of precipitates can be seen. The absence of precipitates shows that applied technology and the way of achieving mixtures result in the right microstructure. Austenite and ferrite are well mixed with an observed balancing between the two structures present throughout the sample.

The pitting corrosion behaviour was evaluated by analyzing of the polarization curves. The testing envelopment was a 1M NaCl at room temperature. During electrochemical tests the passivation of all analysed sintered duplex steels was not obtained and the usual active-passive transition maximum does not appear. After the passive range rapid increases of current density occur and passive layer destruction proceeds and transition to pitting corrosion region. The corrosion potential of sample prepared by mixing ferritic and austenitic powder in equal amounts (E) is more active and rest of the steels demonstrate lower current density in active region. In the case of composition (C) the lowest increase of current density in active region was found. Moreover the lowest corrosion current density value was found for (C) composition. It is remarkable to notice a limit current density of about $12mA/cm^2$ was measured for this composition while for composition (E) about $22mA/cm^2$.

According to achieved results, it was affirmed that applied sintering method as well as powder mixes preparation allows for manufacturing the sintered duplex steels with good corrosion properties which depends on austenite/ferrite ratio in the structure and elements partitioning between phases. Corrosion resistance of sintered stainless steels is strictly connected with the density and the pore morphology present in the microstructure too. The highest resistance to pitting corrosion in 1M NaCl solution was achieved for composition (C) with approximate balance of ferrite and austenite in the microstructure was archived.

4. References

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