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Fatigue behaviour of sintered duplex stainless steel

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Abstract

The stainless steel despite of tradition of use over the 100 years are steel interesting in terms of metallurgical improvement and development of new products. Stainless steel products undergo intensive development, especially for duplex stainless steel grades manufacture be conventional casting method and metal forming processes, thus, influences an increase in the interest of those materials by alternative technologies of metal forming, which is powder metallurgy. The powder metallurgy and manufacturing processes of metal powders and sintered components production undergoing rapid development. This trend applies also for sintered duplex stainless steels. The paper investigates fatigue behaviours of vacuum sintered duplex stainless steel produced by mixing in appropriate proportions powders of ferritic and austenitic stainless steel and elemental alloying powders and then sinter hardening in a vacuum. The mechanical properties of studied steel were evaluated in terms of tensile strength, hardness, toughness, plasticity. Fatigue tests were carried out in symmetric plane bending at stress ratio R= – 1 with frequency of about 24Hz. Fatigue crack propagation micromechanisms were investigated by means of a scanning electron microscope fracture surface analysis.

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1. Introduction

Duplex stainless steels are called as duplex because they have a two-phase microstructure consisting of ferritic and austenitic grains. When duplex stainless steel is melted it solidifies from the liquid phase to a completely ferritic structure and as the material cools to the room temperature the transformation of about half of the ferritic grain to austenitic grains take place, thus resulting in the microstructure of roughly equal amounts of austenite and ferrite. The duplex microstructure gives this family of stainless steels a combination of attractive properties. Duplex stainless steels are about twice as strong as regular austenitic or ferritic stainless steels. Duplex stainless steels have significantly better toughness and ductility than ferritic grades. Regarding the corrosion resistance of stainless steels for chloride pitting and crevice corrosion resistance, their chromium, molybdenum and nitrogen content are most important. Duplex stainless steel grades have a range of corrosion resistance, similar or higher to the range of austenitic stainless steels. Duplex stainless steels show very good stress corrosion cracking resistance, a property they have inherited from the ferritic stainless steels. Regarding costs, the duplex stainless steels have lower nickel and molybdenum contents than their austenitic counterparts of similar corrosion resistance. Due to the lower alloying content, duplex stainless steels can be lower in cost, especially in times of high alloy surcharges [1-4].

The demand for lower production costs, especially in the automotive industries, resulted in increased use of sintered components even for highly stressed fatigue loaded components, like parking gears, camshafts, etc. The main sintered materials for automotive components is low alloyed steel, but the sintered stainless steels plays an important role for demanding corrosion applications like exhaust flanges and HEGO boss applications. The sintered duplex stainless steels give a unique opportunity to join corrosion resistance, high toughness, high plastic properties and mechanical resistance in one material, thus are such interesting material for huge amount of possible automotive sintered applications [19, 29, 23]. Sintered duplex stainless steels may be obtained within a single sintering cycle through the controlled addition of alloying elements promoting formation of austenite or ferrite to single-phase powders, both ferritic and austenitic trying to predict the final structure on the bases of Schaffler's diagram [5]. Alloying element may be added in the form of single elements or in combined form and the sintering cycle is done in vacuum at argon backfilling and nitrogen is under pressure is used to obtain rapid cooling rate directly from sintering temperature. Sintered stainless steel, in order to achieve high mechanical properties must be must be sintered at high temperatures applying inert atmosphere [17, 18, 21, 22]. Depending on chemical composition sintered duplex stainless steels must be cooled form sintering temperature with controlled cooling rate due to the possibility of precipitations of brittle intermetallic sigma phase which highly negative influence on stainless steel properties. The presence of this brittle phase reduces the ductility and produce chromium depleted areas leading to decrease of the corrosion resistance and toughness. Sinter-hardening method mainly applied to steels undergoing a martensitic transformation during cooling, thanks to rapid cooling from sintering temperature can be applied to sintering duplex stainless steels thus creates the possibility of producing complex dual-phase microstructure with controlled mechanical properties and corrosion resistance in one sintering cycle with no need of the additional heat treatments [6-10].

The main purpose of this paper is the investigation on the basic mechanical properties and microstructures of different duplex stainless steels compositions manufactured from base powder of prealloyed single phase stainless steel and the addition of alloying elements powders. The mechanical properties of studying steels were evaluated in terms of tensile strength, hardness, toughness, plasticity with correlation to presented porosity and its morphology. Fatigue tests were carried out in symmetric plane bending at stress ratio $R = -1$ with frequency of about 24Hz.

2. Experimental procedure

To produce sintered duplex stainless steel different compositions have been tested, using alloyed ferritic AISI 410L (0.14%Ni, 12.2%Cr, 0.88%Si, 0.09%Mn, 0.04%C) base water atomized powder of Hoganas Corporation (table 1) as a starting powder. Stainless steel base powders were mixed with the addition of alloying elements powders such as Cr (as Fe-Cr powder) and Ni, Mo and Cu as elemental powders in the right quantity to obtain sintered steel with chemical composition corresponding to duplex one. Chemical compositions of producing mixture were placed in austenitic-ferritic area of the Schaeffler's diagram. During premix preparation and prediction of the final structure based on Schaffler's diagram, thus Cr_E and Ni_E (Cr_E= %Cr + %Mo + 1,5 x %Si + 0,5 x %Nb; Ni_E= %Ni + 30 x %C + 0,5 x %Mn) equivalents are obtained introducing the wt. % quantity of the corresponding element