

Microstructure and Properties of High Nitrogen Sintered Stainless Steel

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Abstract

The use of the nickel free, high nitrogen stainless steel powder and nitriding during sintering of iron based materials have been shown as an alternative way to the conventional PM stainless steels containing nickel. Nitrogen as an alloying element for iron improves in an effective way the properties of sintered alloyed steels. The powder metallurgy route is a suitable way to introduce nitrogen into these alloys and, in particular, to produce high nitrogen (close to the solubility limit) stainless steels. The paper presents and discusses the nitriding behavior of nickel-free stainless steels produced by powder metallurgy method. Alloyed melt was atomized by nitrogen and in this way nitrogen was introduced into the powder. Further nitriding occurred during sintering in a nitrogen atmosphere. For comparison, compacts having the same composition as an alloyed powder were produced from elemental powders mixture. Sintering-nitriding behaviour of investigated materials has been controlled by dilatometry, chemical and X-Ray phase analysis and metallography. Mechanical properties of sintered compacts were also measured.

Keywords : high nitrogen steel, dilatometry, sintered stainless steel

1. Introduction

Powder metallurgy has become recently an effective route for high nitrogen steel production [1-4]. The main problem is to achieve a proper nitrogen level in the sintered compacts after pressureless nitriding process, which occurs during sintering [1-5]. There are few different ways to produce high nitrogen sintered stainless steels, i.e.:

- nitrogen can be introduced into the powder:
 1. by addition of high nitrogen ferroalloys into the melted stainless steel and its atomization by nitrogen [6],
 2. by nitriding the commercial stainless steel powder [7],
 3. by addition of nitrides, like CrN or MnN, into the commercial iron base powder [8],
- nitrogen can be introduced during sintering:
 4. by nitriding the compacts made of commercial iron base powder during their sintering in a nitrogen atmosphere,
- nitrogen can be introduced into the sintered compacts:
 5. by alloying sintered stainless steel compacts by nitrogen during their chemical heat treatment.

The main aim of this study was to show the sintering behaviour of nitrogen containing alloyed stainless steel powder on one hand, and the nitriding behaviour of the compacts made of powder mixture during sintering on the other hand.

2. Experimental and Results

The following starting materials were used:

- nitrogen atomized, nickeless stainless steel powder containing 0,44wt.-% nitrogen produced by the Institute of Metals Science, Bulgarian Academy of Sciences,
- sponge plain iron NC 100.24 grade Höganäs powder,
- milled elemental chromium powder, delivered by Merck,
- electrolytic elemental manganese powder, delivered by SAS Kosice,
- Kenolube Höganäs powder as lubricant.

Powder mixture containing 14.2wt.-% Cr and 15.08wt.-% Mn (which correlates with the alloyed powder composition) was prepared by tumbling. Rectangular (15 x 4 x 4 mm³) green compacts suitable for dilatometry investigations were produced by uniaxial cold pressing at 600 MPa. Sintering process was performed in a horizontal NETZSCH 402E dilatometer in a high purity flowing nitrogen atmosphere. Dimensional changes were monitored during the whole chosen temperature-time program: heat at 10°C/min. to 600°C, hold at 600°C for 15 min to remove lubricant, heat at 10°C/min to 1250°C, which was an isothermal sintering temperature, hold for 1 or 3 hours, and cooling at 20°C/min. to the RT. The nitrogen content in sintered specimens was analysed by LECO apparatus. ISO 2740 test specimens were produced by pressing at 800 MPa and sintering at 1250°C (60 and 180 min) in CARBOLITTE horizontal tube laboratory furnace. The results of sintering-nitriding behaviour are shown in Table 1 and in Figures 1. The chromium and manganese mass fractions were set high enough to ensure pressureless nitriding and to avoid denitriding, which was the case for low alloyed iron based compositions investigated earlier [9]. The final nitrogen content depends on the isothermal sintering time and on the type of powder used. According to the microstructural and

X-Ray analysis, stable nitride phases like Cr₂N or MnN were not detected, which suggests that nitrogen went into solution.

Table 1. Dimensional changes and nitriding during sintering.

Powder / Powder mixture	Isotherm. sintering time, min	Green density, g/cm ³	Sintered density, g/cm ³	Dimens. change, %	N ₂ , wt.-%
Atomized powder with nitrogen	60	4.95	5.71	− 8.89	0.56
	180	4.97	5.74	− 13.41	0.87
Mixture based on NC 100.24	60	6.18	5.57	+ 2.70	0.23
	180	6.12	5.87	+ 0.37	0.85

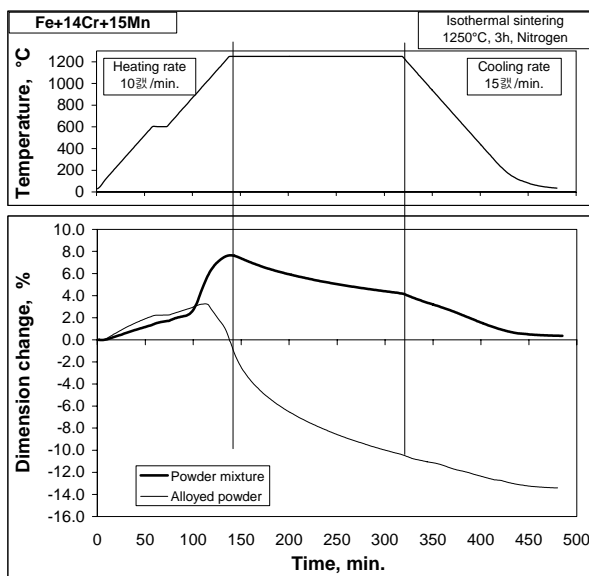


Fig.1. Dimensional behaviour during sintering.

In fact, nitrogen level of 0.95wt.-%, which is a lower limit for stable nitrides formation in comparable materials [2,3,5], was not exceeded. As it is known from literature, nitrogen soluble in the stainless steel stabilizes austenite and ensures high strength. That was corroborated by mechanical properties of sintered compacts (Table 2).

Table 2. Mechanical properties of sintered steels.

Powder / Powder mixture	Isotherm. sintering time, min	Sintered density, g/cm ³	Tensile strength MPa	Elongation, %
Atomized powder with nitrogen	60	5.71	451	3.6
	180	5.74	587	1.9
Mixture based on NC 100.24	60	5.57	492	4.6
	180	5.87	517	4.9

3. Summary

Powder metallurgy technique seems to be a useful approach for high nitrogen stainless steels production because nitrogen alloying takes place during the sintering process. Both the nitrogen containing atomized alloyed powder and the nitrogen-free elemental powder mixture can be used to produce sintered compacts with enhanced nitrogen content after sintering in a pure nitrogen atmosphere. High chromium and manganese contents in the investigated materials and a proper permeability of green compacts ensure pressureless nitriding. The nitriding behaviour depends on compact type in terms of the powder used, i.e. compacts made of alloyed austenitic powder solve more nitrogen than those made of powder mixture. Although the latter compacts tend to expand and the former ones to shrink extensively, the final sintered density of both materials is similar, which is a consequence of a large difference in the compactibility of both powders.

4. Acknowledgements

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5. References

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