Improvement in the MIM Sintering Properties of 440C Stainless Steel

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Abstract

More and more applications or demands for machine parts etc are expected for AISI 440C (hereinafter referred to as "440C") Stainless Steel because of its characteristic features, i.e. high-strength as well as high-corrosion resistance. This research has enabled us to obtain sintered products with good quality even under a wide range of temperature by utilizing the pinning effect of NbC, improving the relevant sintering feature of 440C Stainless Steel in the MIM method.

Keywords: MHT440C-Nb, NbC, pinning effect

1. Introduction

However, 440C depends on MIM method in manufacturing for small or complex shape machining parts. (Sintering) temperature needs to be maintained within a relatively narrow range for the 440C Stainless Steel Powder to be sintered, which means that the small downward deviation from the appropriate temperature range could cause distortion or low strength due to insufficient sintering. Conversely, when it is sintered at the temperature a little higher than the said range (upward deviation), the strength could deteriorate as a result of deformation or formation of network-carbides associated with excessive sintering.

Additionally, the use of the newly developed Nb additional steel powder MHT440C-Nb has allowed us stable manufacturing of 440C parts which are as strong as the wrought products.

2. Purpose

This research has been conducted with a focus on the influence of Nb, which is strongly combined with C and has low diffusion speed in order to improve the sintering feature of 440C Stainless Steel. In this research, the effect of additional Nb that could impact themachining characteristics, has been confirmed, by measuring the hardness and bending strength of 440C and 440C-Nb at respective sintering temperatures. The effect of Nb carbide was also examined by using X-ray analysis as well as EPMA in this research.

The chemical composition and the powder characteristics of shown in Table1.

Table 1. Chemical composition of MHT440C, MHT440C-Nb powder

Steel	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cr (%)	Nb (%)	O (ppm)
MHT440C	0.96	0.91	0.18	0.018	0.012	17.12	–	2700
MHT440C-Nb	0.96	0.87	0.21	0.029	0.016	17.12	2.99	3400

3. Sintering Feature Examination:

① Carbon Adjustment（$\Delta C\%/\Delta O\% = 0.75$）

Generally, while sintering, all oxygen contained in alloyed powder reacts with carbon, and CO and CO2 gas are generated. The amount of carbon, which is approximately 75% of the oxygen, needs to be consumed in this reaction.Graphite powder was added to MHT440C so that the carbon contents of MHT440C after sintering were 0.80%, 1.00% and 1.20%.

Similarly, graphite powder was added to MHT440C-Nb in order that carbon contents of MHT440C-Nb after sintering were 1.10%, 1.30% and 1.50% and by increasing the amount of C, considering the combined with C due to producing NbC.

②Sintering Examination

Graphite powder for carbon adjustment and stearic acid (5.0 wt %) as a lubricant was added to test materials. Then these test materials were uniformly heated and kneaded at the temperature of 80 ℃, then cooled to the room temperature and crushed to pellets. These pellets were compacted using a pressure of 0.6 Ton/cm2. Compact sizes are Width 10mm×Length 25mm ×Thick 8mm for the bending test, Diameter 25 mm×Heigh 8 mm for corrosion test. Sintering examination has been conducted by using 3 test pieces per condition.

The temperature was given at every 10℃ within a range of 1240℃ to 1300℃ when sintering under vacuum atmosphere. Fan cooling with an argon gas was utilized down from 1050 ℃ to room temperature. Sintering process is shown below:

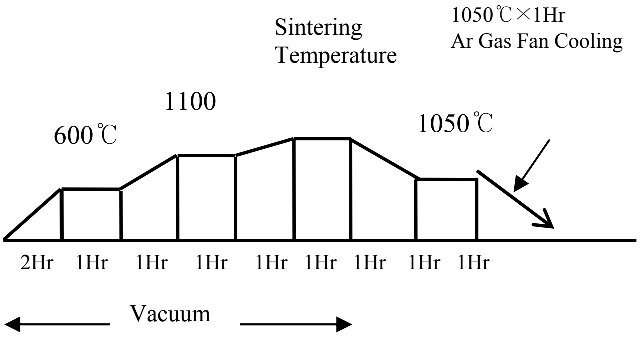

Fig. 1. Sintering Process

Sintered test samples were evaluated using X ray analysis, EPMA, bending strength test, Vickers hardness test and corrosion test.

4. Examination Result

Fig 2 and 3 below describe the test results of our examination showing the relationship between sintering temperature and bending strength, sintering density of MHT440C(C=1.00%) and MHT440C-Nb(C=1.30%).

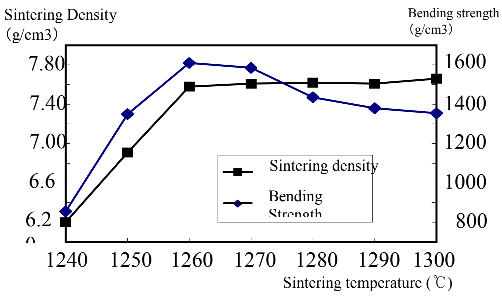

Fig. 2. Relationship between Sintering temperature and Bending strength, Sintering density of MHT440C

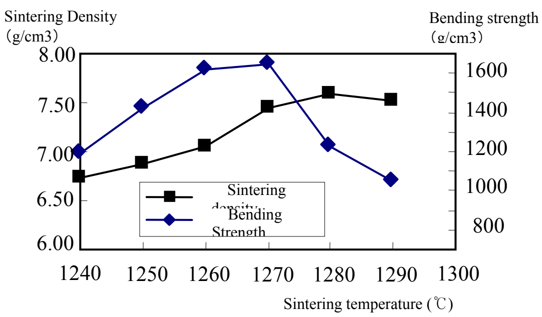

Fig. 3. Relationship between Sintering temperature and Bending strength, Sintering density of MHT440C-Nb

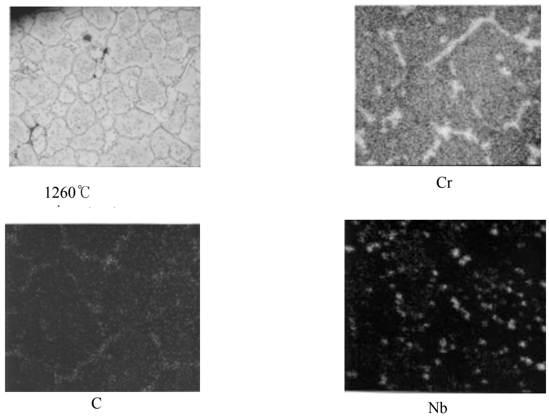

Photo1. EPMA result

1) As shown in Fig 2 which refers to MHT440C, sintering density is 7.4g/cm^3 while bending strength shows significant decline at the temperature of 1270℃.

The target range of sintered temperature is relatively limited since the bending strength starts to decline substantially about the same time sintering has completed. Also, melting deformation was observed at the sintering temperature of 1300℃.

2) Fig 3 referring to MHT440C-Nb indicates that sintering density is 7.5g/cm^3 at 1260℃ and the density remains almost constant up to 1300℃. Unlike MHT440C, bending strength remains steady or slightly declines, even though the sintering temperature rises. In light of these outcomes, broadening of an appropriate range of sintering temperature is realized with MHT440C-Nb by the addition of Nb.

3) Photo 1 shows, while the sintering, Niobium with low speed diffusion combines with Carbon and NbC precipitate minutely and homogeneously. This is attributed to the fact that the coarsening by Cr with high speed diffusion is inhibited by the pinning effect of NbC.

4) With regard to the hardness, a similar trend in bending strength was observed. It was confirmed that the decline of hardness resulting from a rise in temperature is smaller in MHT440C-Nb than in MHT440C.

5. Conclusion

Niobium's binding force with carbon is stronger than Chromium's binding force and this NbC with slow speed diffusion precipitates minutely and homogeneously. CrC with high speed diffusion precipitates from the surrounding NbC.

With the addition of Nb, it is quite unlikely that CrC will become coarse since they are restricted by NbC. Also, the grain size in the austenitic structure keeps comparatively fine by the pinning effect of NbC.This study confirmed that there was no deterioration of machining features associated with increased sintering density.