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FABRICATION AND PROPERTIES OF T42 SINTERED PART USING SPARK PLASMA SINTERING

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Abstract. High speed steels T42 were used as cutting tools and wear parts, due to their high strength, wear resistance, hardness together with appreciable toughness and fatigue resistance. The spark plasma sintering (SPS), which is a pressure assisted pulsed direct current sintering technique, is employed to consolidate powders of very different natures. T42 HSS powders were sintered by Spark Plasma Sintering at various temperatures and holding times. In the case of sintering, optimum specimen was obtained by sintered at 1000 °C for 25 min, heated at vacuum at 1210 °C, and then oil-quenched. The oil-quenched specimen was tempered at 560 °C, which has homogeneous carbides distribution and carbides precipitation. Also, the highest hardness of 760 Hv can be obtained in this study.

1. INTRODUCTION

Recently, high speed steels (HSS, T42) have been used as high performance cutting and rolling tools. Tools structural application is a combination of high strength, wear resistance, high hardness together with toughness, fatigue resistance and thermal resistance [1,2]. Recent research on extending tools life and improving structural performance are being carried out through manufacturing process, heat-treatment, surfacing process and alloying elements.

SPS technique has the merits of faster heating rates, shorter sintering times and high density [3]. During SPS process, alloy powders in a graphite die are pressed uniaxially a D.C. pulse voltage is applied and the heating is accomplished by electric discharge between particles. However, the research for the T42 using SPS was not carried out generally.

In order to enhance the carbide precipitation hardening, sintered specimens should be heat-treated between from 1100 and 1200 °C. Meanwhile, considerable efforts have been focused on the microstructural changes during the tempering process. It is well known that after tempering at 500-600 °C, the so-called secondary precipitation of HSS is responsible for the increment of hardness values. As the times of tempering repeat, precipitation of carbides will become greater than one time of tempering [4-6].

In the present study, T42 sintered parts manufactured using spark plasma sintering. Meanwhile, the oil-quenched and multi-tempered microcstucture of the T42 HSS was analyzed to understand the microstructural changes and carbides behaviors.

2. EXPERIMENTAL PROCEDURE

2.1. SPS processing

The composition of the material is given in Table 1. The water atomized powder grade was supplied by

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(EPSON ATMIX CORPOPATON - Japan) and the mean particle size of T42 powders is about 10 mm. Spark plasma sintering (Eletec Inc. – Korea) was carried out in the SPS machine under 50 MPa to 5x10^{-3} torr in vacuum. Also in order to prevent adhesion between sample and graphite mold, the BN spray and carbon sheet were used. And the specimens were pre-heated up at 800 °C for 30 mins. Sintered specimens were fabricated at 900, 1000, and 1100° and kept at each sintering temperatures for 10 mins. Sintered specimens were held at 1000 °C for 15, 20, 25, and 30 min, respectively.

2.2. Heat treatment processing

High speed steels must own high strength, hardness and toughness to resist cracking. And the heat-treatment process was conducted in vacuum to prevent the oxidation of the specimens. After sintering process, the specimen sintered at 1000 °C for 25 min was heated-up at vacuum from 1190, 1210, 1230, and 1250 °C, then oil-quenched respectively. In detail, the heating rate was 10 °C/min and pre-heated-up to 800 °C for 30 min.

The tempering temperatures have been varied from 540 to 600 °C and the heating rate was 10 °C/min.

Tempering was processed at the Image-furnace (Ulvac Riko – Japan) under nitrogen atmosphere of 150 cc/min flow rate.

2.3. Analysis

Densities were measured by the Archimedes' principle. Cross sections were mechanically polished, etched with 2% nital and observed by Field Emission Scanning Electron Microscope (Philips XL30 S FEG – Netherland). The hardness test was performed with a Vickers hardness tester (Akshi corporation –Japan). The mean grain size and carbide mean size were measured by Image analysis program. X-ray diffraction (Rigaku corporation - Japan) with Cu K_a radiation was carried out for phase analysis of specimens. The precipitated carbides percentages were measured by point-analysis.

3. RESULT AND DISCUSSIONS

Fig. 1 shows hardness and relative density of sintered parts at various sintering temperatures. Clearly with the increasing of the temperature, the hardness and relative density greatly increased due to the decrement of the original pores existed in the specimens. Meanwhile the full-density and higher hardness of 568 HV can be obtained at 1100 °C.

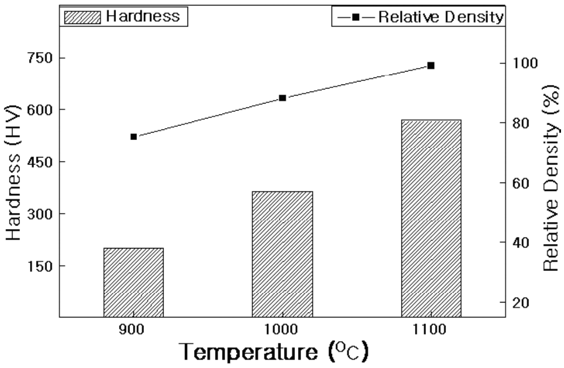

Fig. 1. Density and hardness of T42 sintered by spark plasma sintering at 900, 1000, and 1100 °C.

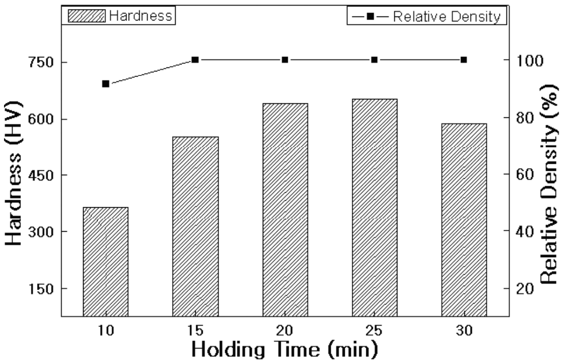

Fig. 2. Density and hardness of T42 sintered by spark plasma sintering process at 1000 °C for various holding times.

Fig. 2 shows hardness and relative density of sintered parts at 1000 °C for various holding times. In the case of sintering at 1000 °C from 15 to 30 min, the relative full densities were obtained. And the similar values of hardness can also be reached by sintering for 25 min due to its smaller grain size and carbides size. Therefore, it can be considered that the increment of hardness is proportion to the increment of its densification.

The FE-SEM micrographs of oil-quenched specimens at 1190, 1210, 1230, and 1250 °C are shown in Fig. 3, respectively. Clearly, we can get the conclusion that the grain size and the carbides size can be gradually increased with the increment of the temperature during the whole oil-quenching process. However, the percentage of carbides just increased at the heat treating temperature from 1190 to 1210 °C, and then decreased greatly for the formation of the large carbides in the specimen.

Fig. 4 shows the percentage of carbide, grain size and hardness at various quenching temperatures. The specimen oil-quenched at 1210 °C showed the highest hardness of 727 HV due to the highest percentage of carbides and the lowest grain

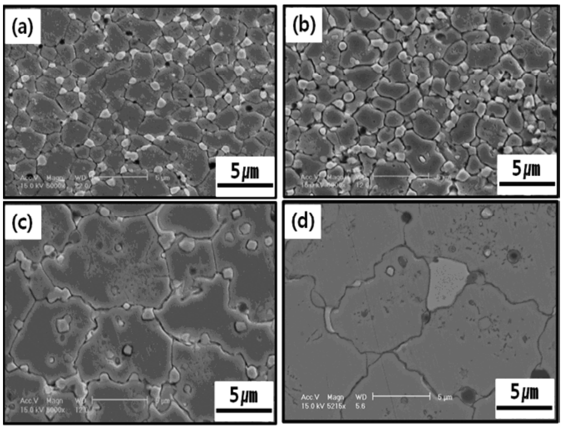

Fig. 3. FE-SEM images of oil-quenched : (a) 1190 °C, (b)1210 °C, (c)1230 °C, (d)1250 °C.

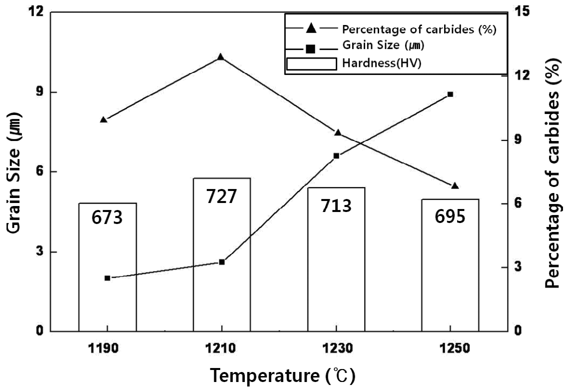

Fig. 4. Hardness, grain size and percentage of carbides at the various quenching temperature.

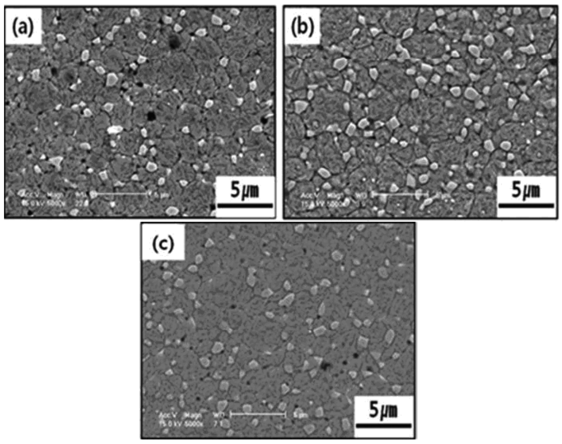

Fig. 5. FE-SEM image of tempered : (a) 540 °C, (b) 560 °C, (c) 600 °C.

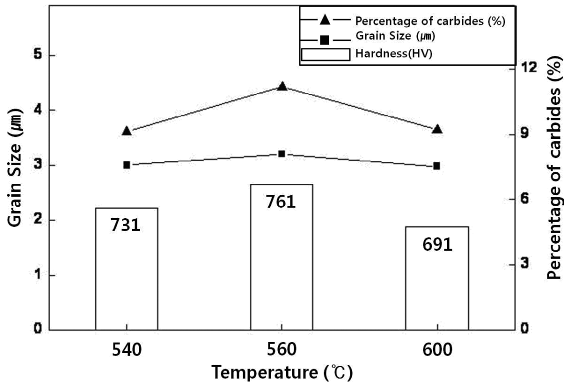

Fig. 6. Hardness, grain size and percentage of carbides at the each tempering temperature.

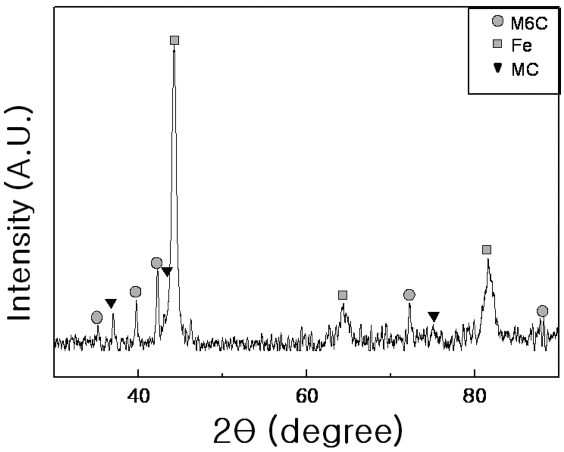

Fig. 7. XRD pattern of T42 tempered at 560 °C.

growth rate, which can be decided to be the optimum of quenching condition. It is considered that the matrix was changed to martensite matrix after quenching and the carbides were precipitated at the grain boundary.

Fig. 5 shows the tempered microstructure at different temperatures. It is considered that the martensite matrix was changed to tempered-matensite matrix to from extra carbide precipitation at the grain boundary.

The hardness, percentage of carbides and grain size at each temperature is shown in Fig. 6. Generally matrix of tempered parts, are soft but matrix hardening could be obtained by secondary precipitation in case of HSS. No grain growth was occured

Table 1. Chemical composition of the as-received T42 HSS powder.

Elements	C	Cr	Mo	Co	V	W	Fe
wt.%	1.27	4.18	3.50	9.50	3.36	9.59	Bal.

at all tempered specimen. The hardness of tempered at 560 °C has higher than others due to high percentage of carbides. The specimen has regular homogenous carbides (MC and M_6C) distribution and huge amounts of carbides.

Fig. 7 shows XRD pattern of T42 tempered specimens. Two types of carbides were precipitated at the grain boundary and in the grain. One is the W and Mo rich M6C carbide and the other is V rich MC carbide.

4. CONCLUSION

In the case of sintering at 1000 °C from 15 to 30 min, the relative full density can be obtained. But in the case of sintered for 25 min, the hardness was 653 H_V. However, the highest hardness of 727 H_V could be obtained by oil-quenching at 1210 °C due to the more quantities of carbides formation. The tempered martensite matrix and secondary hardening was obtained by tempering.

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