RAPID PUBLICATION

Effect of Carbide Particle Morphology and Prior Austenite Grain Size on Barkhausen Noise in 0.4C-5Cr-Mo-V Hot-Work Tool Steel

By N. Nakai*[†], Y. Furuya* and M. Obata*

The effect of prior austenite grain size and carbide particle morphology (diameter and density) on Barkhausen noise (BHN) signals was studied as one of the basic research for non-destructive estimation of the quenching temperature in 0.4C-5Cr-Mo-V hot-work tool steel. Signals of BHN were detected on surfaces of plate specimens by a contact type sensor and analyzed by a digital spectrum analyser to determine the intensity of generated BHN signals. It became clear that total power voltage (V_p) of BHN signals depended strongly on mean values of diameter (dp) and density (N) of carbide particles.

(Received January 12, 1989)

Keywords: nondestructive evaluation, Barkhausen noise, tool steel, carbide precipitate, prior austenite grain size, contact type sensor

I. Introduction

It is important to non-destructively estimate the thermal history (quenching temperature, cooling rate etc.) of finished hot-work tools to guarantee their qualities and to keep them well during engineering use. The authors formerly reported that BHN method was applicable to estimation of cooling rate from austenitizing temperature of 0.4C-5Cr-Mo-V hot-work tool steel⁽¹⁾. The estimation of austenitizing temperature is the next subject in non-destructive estimation of the thermal history of the hot-work tool steel by the BHN method. The difference of austenitizing temperature causes the changes of prior austenite grain size as well as diameters of several kinds of carbide particles such as MC, M_7C_3 , M_6C , $M_{23}C_6$ at the same time⁽²⁾. Therefore, we should reveal how BHN signals change when prior austenite grain size and carbide particle morphology change at the same time for non-destructive application of BHN method to estimation of thermal

history in the hot-work tool steel. However, up to the present, there has not been existing the report discussing the responses of BHN signals to the simultaneous changes of these two factors⁽³⁾⁽⁴⁾. For this reason, this paper describes the investigation about the dependency of BHN signals on prior austenite grain size and carbide particles morphology (diameter and density) in a tool steel.

II. Experimental Procedures

Chemical composition and heat treatment conditions of the testing specimens are shown in Table 1 and Table 2, respectively. Prior austenite grain size ranged from 8 μm to 70 μm in diameter. In this study, carbide particles (MC, M_7C_3 , M_6C , $M_{23}C_6$) more than the size of 0.12 μm in diameter were measured by using an image analyser. Mean values of area ratio, diameter and density (existing number per unit

Table 1 Chemical composition of the tested specimen (mass%).

C	Si	Mn	Cr	Mo	V
0.38	0.92	0.41	5.25	1.07	0.51

* Department of Material Processing, Faculty of Engineering, Tohoku University, Sendai 980, Japan.

[†] On leave from Nippon Koshuha Steel Co., Ltd., Japan.

Table 2 Heat treatment and hardness of the tested specimens.

No.	Heat treatment		Hardness
	Quenching	Tempering	
1	1173 K, 1.8 ks→AC	853 K, 5.4 ks+1073 K, 7.2 ks	HRC15.0
2	1233 K, 1.8 ks→AC	853 K, 5.4 ks+1073 K, 7.2 ks	HRC15.7
3	1293 K, 1.8 ks→AC	853 K, 5.4 ks+1073 K, 7.2 ks	HRC21.4
4	1293 K, 1.8 ks→AC	853 K, 5.4 ks+ 973 K, 7.2 ks	HRC28.2
5	1353 K, 1.8 ks→AC	853 K, 5.4 ks+1073 K, 7.2 ks	HRC23.3
6	1133 K, 14.4 ks	$\xrightarrow{5.6 \text{ K/ks}}$ 873 K→AC	HRB88.5

Table 3 Conditions of magnetization by contact type sensor.

Magnetization frequency	1 Hz
Magnetization voltage wave	Triangular wave

area, N) of carbide particles were in the range of 4.7–8.7%, 0.15–0.39 μm and 560×10^3 – $2860 \times 10^3/\text{mm}^2$, respectively. The surface of the tested specimen plate (3 mm $\times$ 24 mm $\times$ 62 mm) was polished by the #320 sand paper after heat treatment procedure. Magnetizing condition is shown in Table 3. Magnetically induced voltage which was detected by pick-up coil (permalloy core) in the contact type sensor was amplified, filtered (low pass=10 kHz, high pass=700 Hz) and analyzed by a digital spectrum analyser to determine total power voltage of BHN signals (Vp). Other technical details are shown in the reference paper, (1) and (5).

III. Results and Discussion

Variations of mean value of carbide particle diameter (dp) and number of carbide particles per unit area (N) with total power voltage of BHN signals (Vp) are shown in Fig. 1 and Fig. 2 respectively. As shown in Fig. 1 and Fig. 2, the value of Vp depends strongly on dp and N . The value of Vp decreases with the decreases of dp and $1/N$. On the other hand, the relationship between prior austenite grain size (dg) and Vp shown in Fig. 3 is very weak in comparison to the results shown in Fig. 1 and Fig. 2. These results can be explained by the Sakamoto's theoretical model⁽³⁾ about BHN. According to

Fig. 1 Variation of total power voltage of Barkhausen noise signals (Vp) with the mean value of carbide particle diameter (dp). Fig. 2 Variation of total power voltage of Barkhausen noise signals (Vp) with the number of carbide particles per unit area (N).

Fig. 3 Variation of total power voltage of Barkhausen noise signals (V_p) with prior austenite grain size (d_g).

his model, the number of gaussian-pulse out-breaks (i.e. BHN pulses) at the movements of magnetic domain walls from the pinning of car-

bide particles increases with the decrease of dp and $1/N$ and these pulses come to overlap with each other. As a result, it is thought that this overlapping effect causes the decrease of power voltage of BHN signals (i.e. reduction of the voltage amplitude of BHN signals) as shown in Fig. 2. In conclusion, we can nondestructively get the informations on carbide particles morphology (diameter, density) from total power of BHN signals (V_p), but it is difficult to estimate prior austenite grain size only from a parameter of V_p in this tool steel.

REFERENCES

- (1) N. Nakai and M. Obata: to be published in Tetsu-to-Hagané.
- (2) T. Okuno: Tetsu-to-Hagané, **69** (1983), 655.
- (3) H. Sakamoto, M. Okada and M. Homma: IEEE Trans. Magnetics, Mag-**23** (1987), 2236.
- (4) R. Ranjan, D. C. Jiles, O. Buck and R. B. Thompson: J. Appl. Phys., **61** (1987), 3199.
- (5) Y. Furuya, H. Shimada and K. Arato: J. Japan Inst. Metals, **52** (1988), 267.