JOURNAL OF MATERIALS SCIENCE 39 (2004) 1121 – 1123

Effect of electromagnetic process on the microstructure and wear resistance of austenite medium Mn steel with granular $\gamma + (Fe,Mn)_3C$ eutectics

GAO-FEI LIANG, ZHEN-MING XU*, JIAN-GUO LI
School of Materials Science and Technology, Shanghai Jiao Tong University, Shanghai 200030, People's Republic of China
E-mail: Zmxu@sjtu.edu.cn

QI-CHUAN JIANG
School of Materials Science, Jilin University, Changchun 130025, People's Republic of China

Austenite medium Mn steel is developed mainly because the austenite structure has attractive strain-hardening ability [1–3]. The wear resistance of austenite steel increases with the increment of C content, but the toughness decreases greatly because of network and needle-like carbides appear in the austenite matrix [2]. In the previous investigation [4], the network and needle-like carbides have been changed into granular $\gamma + (Fe,Mn)_3C$ eutectics in the as-cast state by employing a Ca-Si agent modifier. The modified austenite medium Mn steel with granular eutectics (abbreviated EAMC) displays attractive integrated mechanical properties and wear resistance [5, 6]. However, the volume fraction of the granular eutectics is less than 10% in some samples. Over the last three decades, the influence of electromagnetic processing on the solidification of metals and alloys has been studied with various objectives [7–10]. The aim of this investigation is to elucidate, very probably for the first time, the effect of electromagnetic processing on the microstructure and wear resistance of EAMC.

The electromagnetic process was carried out with a high vacuum induction furnace under the argon atmosphere. Detailed descriptions of the preparation of preprocessed EAMC samples were given elsewhere [4]. After being placed in the induction coil, the samples were re-melted and superheated over 100 K with the alternating electric power of 10.8/kW. The alloy was solidified in under 10 min in the alternating electromagnetic when the output power of the electric was reduced to 6.2/kW. The preprocessed and processed samples were cut longitudinally, polished, and etched to reveal the metallurgical structure with a video and image digital analysis system (VIDAS). The preferred crystal growth orientation and lattice constant of γ in EAMC were determined by X-ray diffraction (XRD). Wear tests were performed on MPX-2000 pin-on-disc dry wear tester [5].

The microstructure of preprocessed EAMC reveals that $\gamma + (Fe,Mn)_3C$ granular eutectic particles are well distributed in the austenite matrix. A representative metallurgical structure is shown in Fig. 1a. The photomicrograph of EAMC processed with electromagnetic process is presented in Fig. 1b. VIDAS analyses indicate that the application of electromagnetic process results in an increase in the volume fraction from 5% to 18% for the granular eutectic in EAMC.

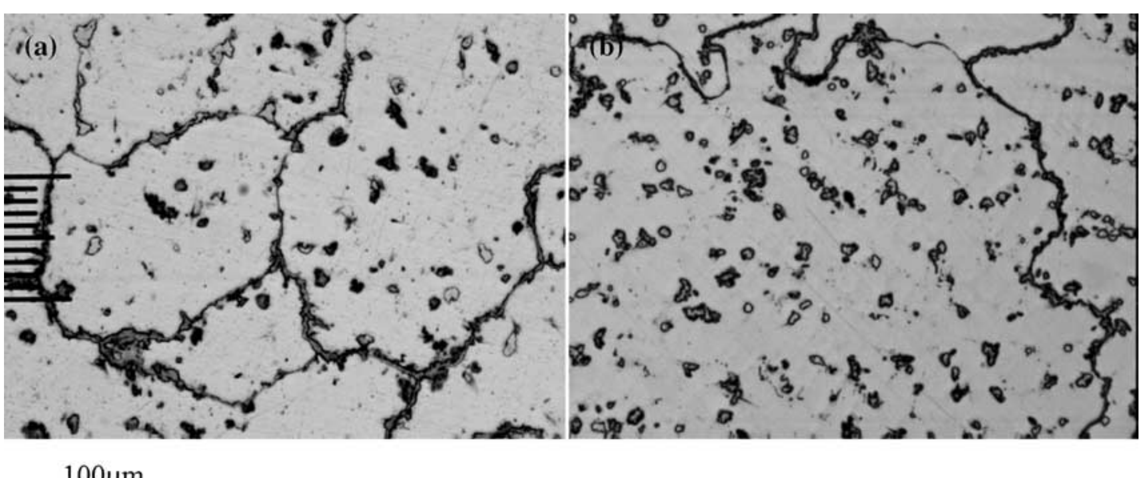

Figure 1 Effect of electromagnetic process on microstructure of EAMC: (a) preprocessed sample and (b) processed sample.

*Author to whom all correspondence should be addressed.

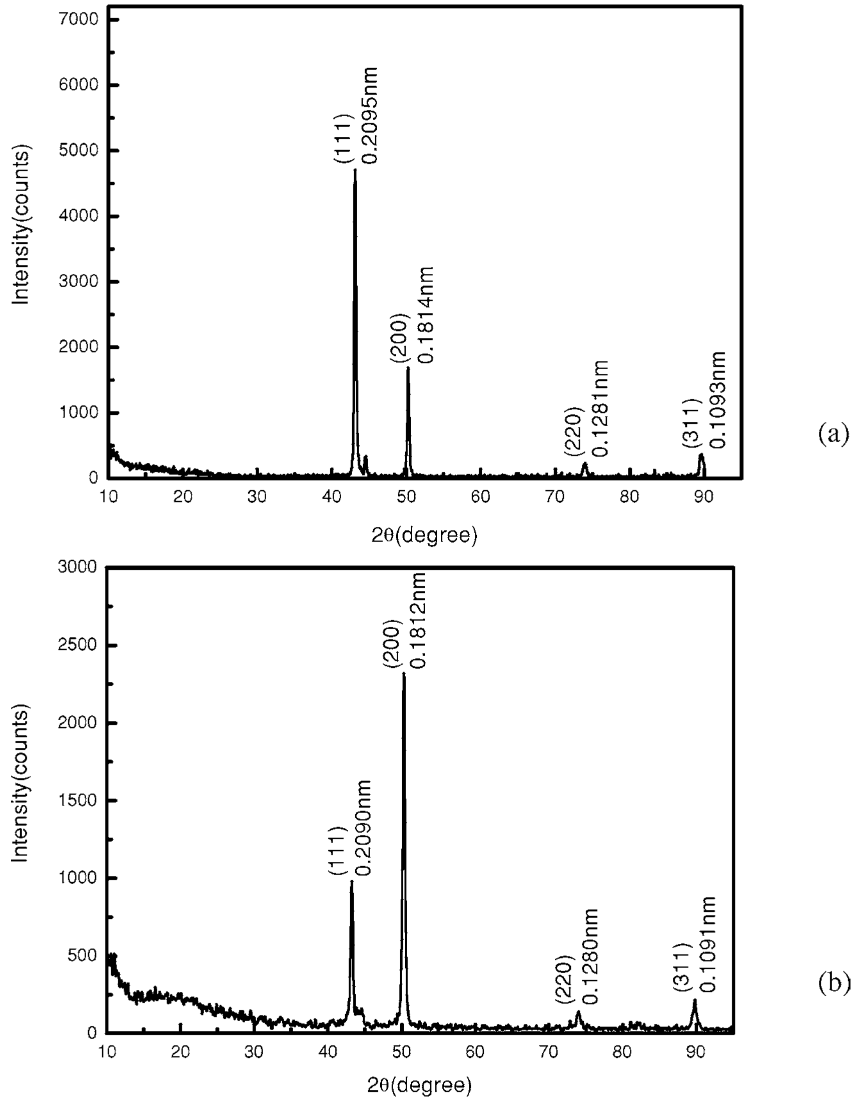

Figure 2 XRD spectrum (Cu K_α radiation) of the EAMC: (a) preprocessed sample and (b) processed sample.

Fig. 2 shows the X-ray diffraction spectra. The C content of austenite matrix ($\varpi(C)$) was calculated according to the following expressions:

$$a_\gamma = 3.5750 + 0.0451(\varpi(C) - 0.44) \text{ [11]} \quad (1)$$

and

$$a_\gamma = \sqrt{3}d_{(111)} \quad (2)$$

where a_γ is the lattice content of the austenite, $d_{(111)}$ the space between (111) crystal planes. Combining Equations 1 and 2, $\varpi(C)$ was calculated to be 1.63% and 1.43% for the preprocessed and processed EAMC samples, respectively. It is clear that $\varpi(C)$ decreases with electromagnetic processing. It indicates that the segregation of C element is enhanced by the process, which results in the increment of the volume fraction of granular eutectic in EAMC because the eutectic reaction occurs when the C-rich liquid in the small liquid pockets among the primary austenite dendrites enters into the inter-growth zone for $\gamma + (Fe,Mn)_3C$ eutectic in the Fe-C-Mn system [4].

It can be clearly noticed from Fig. 2 that the preferred crystal growth orientation changed from (111) to (100) for the austenite matrix in EAMC when subjected to the electromagnetic processing. This may be due to the fluid flow associated with the electromagnetic stirring and/or the induction heat.

Fig. 3 shows the wear rates of preprocessed and processed EAMC for normal loads ranging from 30 N to 250 N at a fixed sliding velocity of 0.67 m/s. Sliding distance was held at 804 m. 0.01 mm^3m^{-1} is regarded

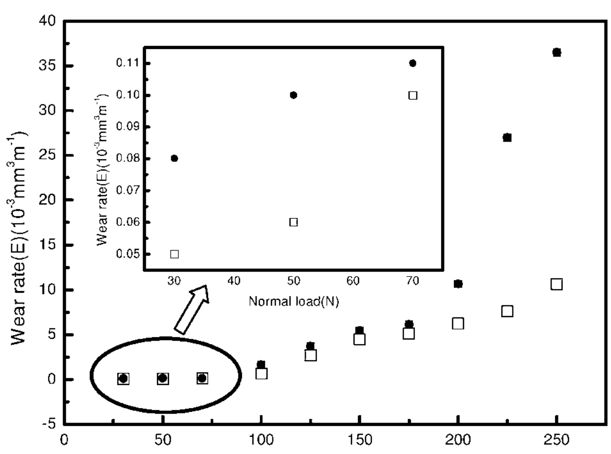

Figure 3 Wear rate of EAMC as a function of the normal load for (●) preprocessed sample and (□) processed sample.

as the threshold wear rate for the transition to severe wear [6]. It can be seen that the wear rate of processed EAMC is much lower than that of preprocessed one for identical wear conditions. Moreover, the transition normal load to severe wear for the processed EAMC is 250 N, which is higher than that of the preprocessed one (200 N). Therefore, the wear resistance of processed EAMC is superior to that of the preprocessed one.

Acknowledgment

The authors acknowledge financial support from the National Natural Science Foundations of China (Grant No. 50001008 and No. 50271042).

References

1. HE ZHENMING, JIANG QICHAN and XIE JINGPEI, *Wear.* **120** (1987) 305.
2. J. QICHUAN, H. ZHENMING and C. DONGHUAN, *J. Mater. Sci. Lett.* **9** (1990) 616.
3. Z. M. XU, T. X. LI and J. G. LI, *Acta Metall. Sin.* (*ENGLISH LETTERS*). **14**(2) (2001) 79.
4. GAOFEI LIANG, ZHENMING XU, QICHUAN JIANG and JIANGUO LI, *J. Mater. Sci. Lett.* **22** (2003) 549.
5. LIANG GAOFEI, XU ZHENMING, JIANG QICHUAN and LI JIANGUO, *Acta Metall. Sin.* **39**(5) (2003) 550 (in Chinese).
6. *Idem.*, *Trib.* **23**(2) (2003) 112 (in Chinese).
7. CH. VIVES, *Mater. Sci. Eng.* A **173** (1993) 169.
8. ALIREZA RADJAI, KENJI MIWA and TOSHIYUKI NISHIO, *Metal. Mater. Trans.* A **29** (1998) 1477.
9. S. ASAI, *ISIJ Int.* **29** (1989) 981.
10. H. C. LEE, J. W. EVANS and C. VIVES, *Metal. Mater. Trans.* **15B** (1984) 734.
11. Z. L. LIU, "Electron Principal and Composition Design" (in Chinese) (Jinlin Science Technology Press, Jinlin, 1993) p. 22.

Received 25 March
and accepted 7 August 2003