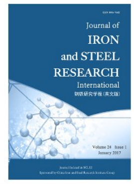
Journal of Iron and Steel Research, International 24 (2017) 43—49

Contents lists available at ScienceDirect

Journal of Iron and Steel Research, International

journal homepage: www.chinamet.cn



Morphology, microstructure and decomposition behavior of M_2C carbides in high speed steel

Xue-feng Zhou[1,*], Di Liu[1], Wang-long Zhu[2], Feng Fang[1], Yi-you Tu[1], Jian-qing Jiang[3]

[1] Jiangsu Key Laboratory of Advanced Metallic Materials, School of Materials Science and Engineering, Southeast University, Nanjing 211189, Jiangsu, China

[2] Jiangsu Engineering Research Center of Tool and Die Steel, Danyang 212312, Jiangsu, China

[3] Nanjing University of Information Science and Technology, Nanjing 210044, Jiangsu, China

ARTICLE INFO

Key words:
High speed steel
Carbide
M_2C
Morphology
Substructure
Decomposition

ABSTRACT

The morphology, microstructure and decomposition behavior of M_2C carbides in high speed steels with different chemical compositions have been investigated by scanning electron microscopy, transmission electron microscopy, electron backscatter diffraction and X-ray diffraction. The results show that the morphology and substructure of M_2C carbides are very sensitive to chemical compositions of high speed steels. M_2C carbides present the plate-like shape in tungsten-molybdenum steel and present the polycrystal orientation in the eutectic cell. In contrast, they show the fibrous shape in molybdenum-base steel and exhibit the monocrystal orientation. Plate-like and fibrous M_2C carbides are both metastable and decompose into M_6C together with MC at high temperatures. MC nucleates inside the plate-like M_2C while it is formed at the fibrous M_2C/matrix interface during the decomposition process. Such differences are expected to arise from different compositions of plate-like and fibrous M_2C carbides.

1. Introduction

High speed steels are ferrous-based alloys of Fe-C-X multi-component system where X represents different alloying elements, such as Mo, W, V, and Cr. They are characterized by high hardness and wear resistance both at room and elevated temperatures, and widely used in high-temperature applications. Their excellent properties are associated with the characteristic microstructure, namely martensite strengthened by a great quantity of alloying carbides.

It is well known that the mechanical properties of high speed steel strongly depend on the carbide type, shape, size and distribution, which are closely related to the as-cast structure of ingots, especially those eutectic carbides[1-4]. Different types of eutectic carbides can be created through the eutectic reaction in high speed steel. The major eutectic carbides are M_2C, M_6C and MC, depending on the alloy composition and cooling rate[5,6]. Among them, M_2C type is the most predominant one and exists in almost all high speed steels.

Previous studies have shown that the morphologies of M_2C eutectic carbides can be classified into the plate-like type and the fibrous one, depending on alloy compositions[7]. Plate-like M_2C carbides are mostly created in tungsten-molybdenum steels (e.g., M2) and promoted by increasing contents of carbon or aluminum[8-10]. They are metastable at high temperatures and decompose into a mixture of M_6C and MC carbides after annealing above 1000 ℃[11-14]. Fredriksson et al.[14] have reported that the matrix is involved in the decomposition reaction and the decomposition process can be classified as a quasi-peritectoid reaction, $M_2C + \gamma\text{-austenite} \rightarrow M_6C + MC$. In contrast, fibrous M_2C carbides are generally formed in molybdenum-base steels (e.g., M42) and favored by higher nitrogen or lower vanadium contents[15,16]. They also decompose into M_6C and MC at elevated temperatures[17]. However, little has been known about the differences between plate-like and fibrous M_2C carbides except for morphologies.

The present article is designed to investigate the influence of chemical compositions on the microstructure and decomposition behaviors of M_2C eutectic carbides in high speed steels. Emphasis has

* Corresponding author. Assoc. Prof., Ph.D.
E-mail address: *xuefengzhou@seu.edu.cn*.

Received 23 August 2016; Received in revised form 20 September 2016; Accepted 23 September 2016
Available online 15 January 2017

been placed on clarifying different characteristics of plate-like M_2C in M2 steel and fibrous M_2C in M42 steel during the solidification and subsequent heating process to provide more insights into microstructure transformaion in such a complex system.

2. Material and Methods

Materials used were AISI M2 and M42, which are typical grades of tungsten-molybdenum and molybdenum-base high speed steels, respectively. The compositions of M2 and M42 are listed in Table 1. The steel was remelted and then cast in sand moulds, the dimensions of which were ϕ60 mm×150 mm.

The morphologies of carbides were observed by optical microscopy using Murakami etchant, in which M_2C (black) carbides are selectively etched but not the matrix and MC carbides[18]. The matrix was deeply etched to observe three-dimensional morphologies of carbides by scanning electron microscopy (SEM, FEI Sirion-400). The carbide compositions were measured by Genesis 60S energy dispersive spectroscopy (EDS).

Table 1

Chemical compositions of M2 and M42 steels used in this work (mass%)

Steel	C	Si	Mn	W	Mo	Cr	V	Co	Fe
M2	0.89	0.35	0.24	5.93	4.82	3.95	2.08	—	Balance
M42	1.05	0.54	0.38	1.60	9.45	3.90	1.15	8.30	Balance

The microstructure of eutectic carbides was investigated by X-ray diffraction (XRD), electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM). Carbide powders were extracted from the ingots and then examined by using a Bruker D8 X-ray diffractometer. The samples for EBSD were prepared by mechanically polishing and electropolishing. The EBSD measurements were carried out using the EDAX diffraction system. The specimens for TEM were thin foils, prepared by mechanical polishing and twin-jet electropolishing. Then, they were examined by Tecnai G^2 TEM.

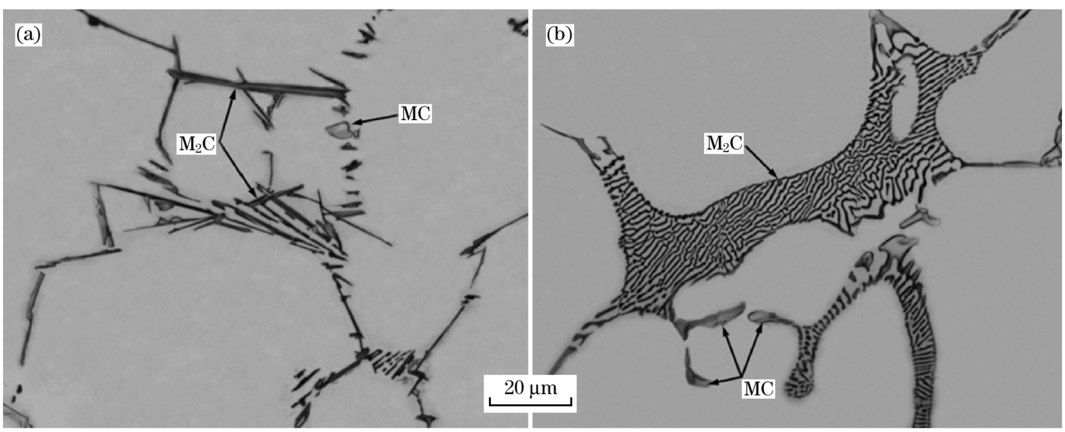
Samples sliced from ingots were heated at 1100 ℃ for 60, 180 and 360 min, respectively. The transformaion of carbides during heating was investigated by SEM and TEM. Carbide powders were extracted from specimens heated for 60 min, and then examined by XRD. The composition measurement was conducted on carbides in specimens after heating for 180 min.

3. Results and Discussion

3.1. Morphology of M_2C carbides

Fig. 1 illustrates the representative as-cast structure of high speed steel, consisting of the matrix and networks of eutectic carbides distributed in the interdendritic regions. Those eutectic carbides can be divided into two different types, M_2C and MC, distinguished by the Murakami etchant[18]. Among them, M_2C carbides are the predominant type. The morphologies of M_2C are very sensitive to chemical compositions of high speed steel. They assume a plate-like or needle-like shape in M2 whereas they appear in a fibrous shape in M42.

Fig. 2 further shows the three-dimensional morphologies of plate-like and fibrous M_2C carbides. It can be seen that M_2C carbides have quite different morphological characteristics in different high speed steels. They exhibit a lamellar structure with flat plates in M2, suggesting that plate-like carbides grow anisotropically and much faster in directions parallel to surfaces of plates. In contrast, they develop into a fibrous structure with round outlines in M42.



(a) Plate-like M_2C carbide in M2; (b) Fibrous M_2C carbide in M42.

Fig. 1. Typical morphologies of M_2C carbides after selectively etching with Murakami etchant.