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Effect of extreme pressure agents on the anti-scratch behaviour of high-speed steel material

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ABSTRACT

Extreme pressure (EP) additives form reasonable hard films by reacting with metal surfaces and are a good alternative to protect the surface of metals exposed to various types of wear. In this paper, the chemical reactions between high-speed steel (HSS) roll material and various EP agents, such as those containing sulfur, chlorine and zinc dialkyl dithio phosphate (ZDDP), were investigated by dropping EP solutions on the heated HSS samples. The research results show that the sulfur element from the sulfur EP solutions was found in the substrate and the carbides. However, the chromium element could not be detected in the sample, and the decomposition products of the ZDDP covered the sample. The scratch tests were carried out to demonstrate that the ZDDP is more resistant to scratching than other EP agents.

1. Introduction

High-speed steel (HSS) materials have been widely used for the manufacture of work rolls in the hot rolling process, because of their mechanical properties including high hardness, strong wear resistance and high temperature properties which are greater than those of high-chromium steels [1,2]. The use of these high-speed steels is increasing, because wear of rolls is considerably reduced, which allows more products to be processed in these installations. In addition, they have the potential for improving surfaces of the rolls and decreasing roll consumption and roll grinding [3]. The outer part of the roll is made from HSS to retain good mechanical properties at high temperatures, while forged steel with its high toughness is used for the core part in order to avoid breakage in the case of high bending loads [4]. In the actual hot rolling process, the lubricant is sprayed on the roll surface to reduce the rolling force and improve the surface quality of the rolled strip. Since the quality of the rolled products is closely linked to the surface condition of the rolls, many researchers [5–10] have investigated the oxidation behaviour of HSS materials, whereas little research has been done into the influence of lubricants. Most commercial lubricants contain more than one additive, especially extreme pressure (EP) agents [11]. It is thought believed that EP agents react with the roll surface to form a solid film which can act as a boundary lubricant. 'Sticking' is the phenomenon occurring in the hot rolling process whereby fragments of a rolled material are detached and stick to the work roll surface, deteriorating the surfaces of both the roller and the rolled material [12]. This is a serious problem especially in the production of ferritic stainless steels, because a thin oxidation layer on stainless steel fails to prevent the strip substrate from direct contact with the work rolls. EP agents in lubricants form extremely durable protective films by thermo-chemically reacting with the metal surfaces. This film can withstand mechanical pressures and minimize direct contact between the surfaces, thereby protecting them from scoring and seizing [13].

EP additives are one of the most important constituents of lubricants [14]. The main objective of this paper is to determine which is the most effective EP agent to improve surface quality in the hot rolling of stainless steel. Various EP solutions have been tested on heated HSS samples and scratch tests have been conducted to examine the scratch behaviour of the films which formed on the samples. The solutions include water, sulfur-type EP, chlorine-type EP and zinc dialkyl dithio phosphate (ZDDP).

2. Experimental

The high-speed steel for this study was obtained directly from work rolls, and its chemical composition is given in Table 1. The

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Table 1
Chemical composition of the high-speed steel (in weight percent, wt%).

Fe	C	V	Mo	Cr	Si	Mn	W
Balance	2.1	6.6	5.9	4.2	0.7	0.4	0.07

specimens were cut into cubes with the dimensions of $10 \times 10 \times 5\ mm^3$. Given these dimensions, only one of the broad faces of each sample was ground and polished up to 1 μm diamond suspension, and the remaining faces were ground using 1200 grit sand paper. The samples were ultrasonically cleaned in acetone and alcohol prior to the tests [15].

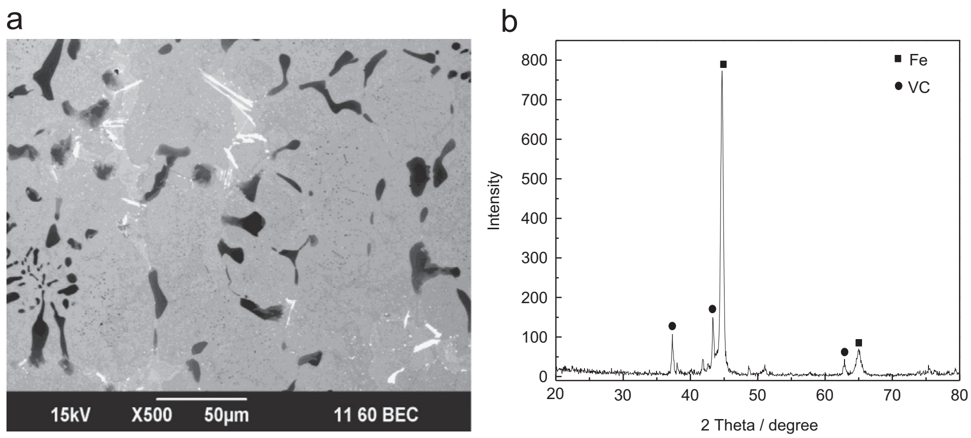

Fig. 1. (a) BSE microstructure and (b) XRD pattern of the HSS sample before the experiment.

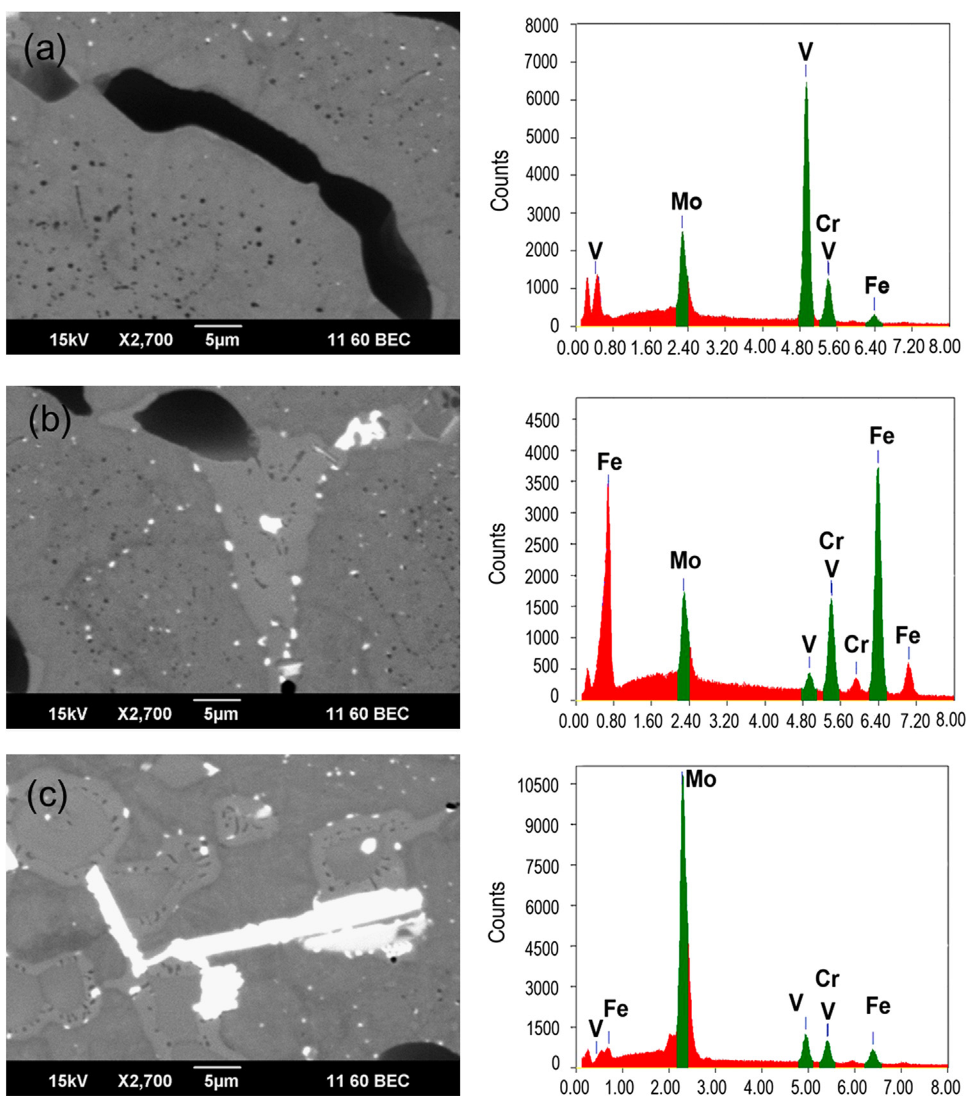

Fig. 2. BSE images and EDS spectra of carbides. (a) V-rich MC type carbides, (b) iron and chromium-rich M_7C_3 type carbides, (c) Mo-rich M_6C type carbides.