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Kinetics of borided 31CrMoV9 and 34CrAlNi7 steels

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ABSTRACT

In this study, kinetics of borides formed on the surface of 31CrMoV9 and 34CrAlNi7 steels borided in solid medium consisting of Ekabor II at 850–900–950 °C for 2, 4, 6 and 8 h were investigated. Scanning electron microscopy and optical microscopy examinations showed that borides formed on the surface of borided steels have columnar morphology. The borides formed in the coating layer confirmed by X-ray diffraction analysis are FeB, Fe_2B, CrB, and Cr_2B. The hardnesses of boride layers are much higher than that of matrix. It was found that depending on process temperature and time the fracture toughness of boride layers ranged from 3.93 to 4.48 MPa $m^{1/2}$ for 31CrMoV9 and from 3.87 to 4.40 MPa $m^{1/2}$ for 34CrAlNi7 steel. Activation energy, growth rate and growth acceleration of boride layer calculated according to these kinetic studies revealed that lower activation energy results in the fast growth rate and high growth acceleration.

1. Introduction

As an effective thermochemical surface hardening technique, boriding can offer a superior alternative to conventional surface hardening processes, such as carburizing, nitriding or carbonitriding [1]. In boriding process, boron atoms diffuse into the surface of the workpiece to produce hard boride layers without requiring high technology [2–4]. Boriding surface hardening process can be applied to a wide variety of materials e.g. ferrous, nonferrous, and cermet materials [5,6]. Process involves heating well-cleaned materials in the range of 700 to 1000 °C, preferably for 1 to 12 h, in contact with a boronaceous solid powder, paste, liquid or gaseous medium [7,8]. Since surface hardening process with boriding has superior characteristic than the other thermochemical techniques it has been widely used in industrial applications where the control of friction and wear is important [3,7,9]. In general, depending on process temperature, time and boron potential of medium single-phase Fe_2B or two phases (FeB, Fe_2B) are obtained by diffusing of boron atoms into the surface of metallic materials [6,7,10]. The single-phase Fe_2B layer is preferred to the two phases layer because FeB, which is slightly harder than Fe_2B, is also much more brittle and has a coefficient of thermal expansion that is almost three times less than that of Fe_2B [6,12]. This significant difference between the coefficients of thermal expansion of the two layers, coupled with the brittleness of FeB, can cause cracks to form between the two layers [11]. These cracks often lead to flaking and spalling when a mechanical load is applied. By controlling the boriding process parameters, especially by limiting the boron potential of the boriding media, the Fe_2B phase can be consistently achieved during pack boriding [12,13] or formed FeB phase can

Table 1 – The chemical composition of test materials (wt.%)

Steels	C	Cr	Ni	Al	Cu	Mo	Mn	V	Si
31CrMoV9	0.32	2.6	0.2	0.01	0.06	0.2	0.6	0.2	0.25
34CrAlNi7	0.33	1.7	1.0	0.7	0.1	0.2	0.5	0.03	0.22

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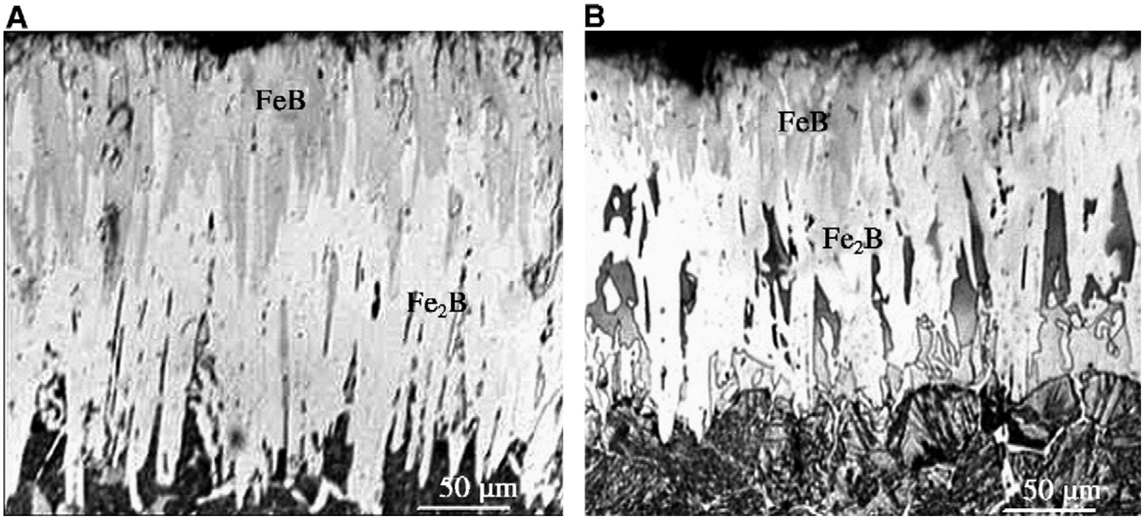

Fig. 1 – Microstructure of (A) 31CrMoV9 and (B) 34CrAlNi7 steels borided at 950 °C for 6 h.

transform into Fe_2B phase through heat treatment at high temperatures (950–1100 °C) [12].

In this study, 31CrMoV9 and 34CrAlNi7 steels were borided in solid medium, kinetics parameters of borides formed on the surface of test materials were investigated and how the growing rate and growth acceleration of borides change depending on test parameters such as process time, temperature and chemical composition were determined.

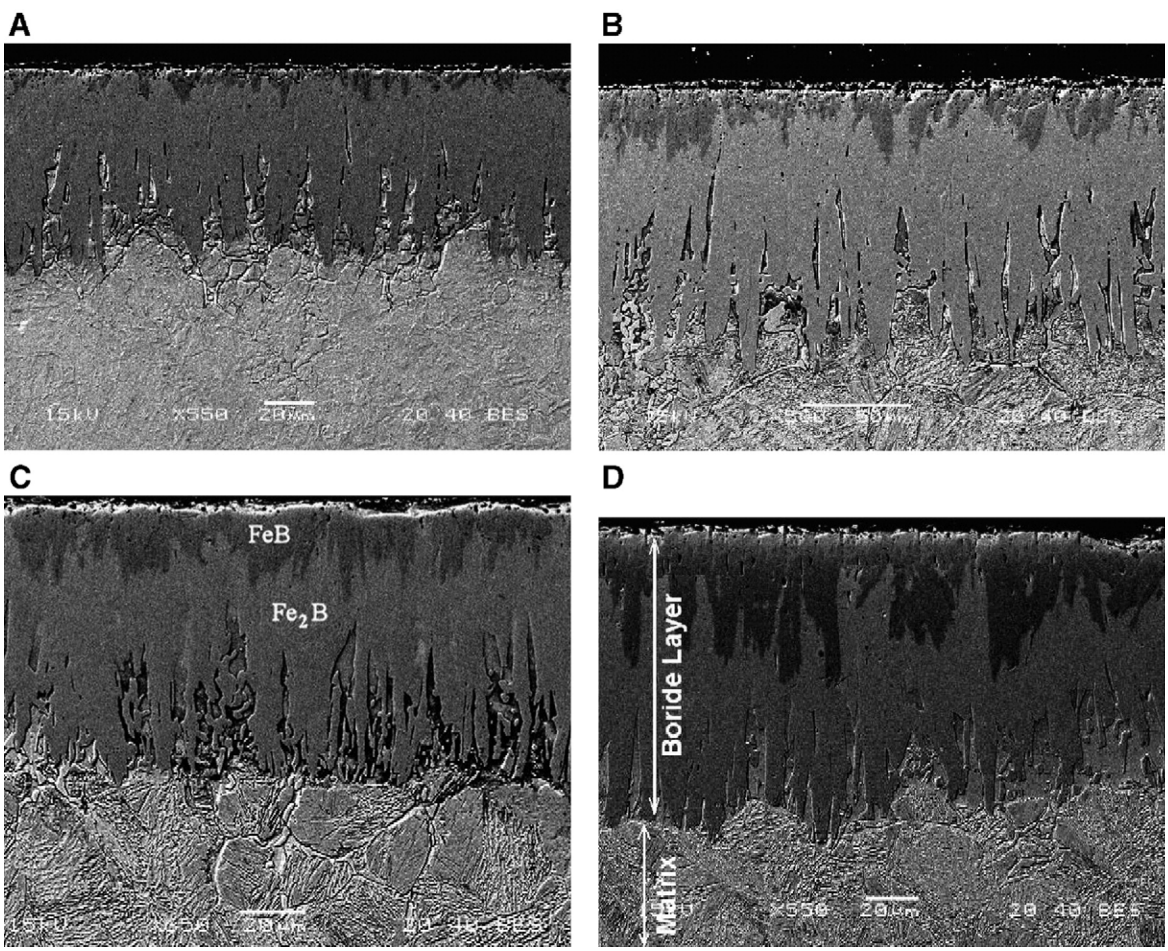

Fig. 2 – SEM micrographs of (A) 31CrMoV9 steel borided at 850 °C for 8 h, (B) 31CrMoV9 steel borided at 900 °C for 8 h, (C) 34CrAlNi7 steel borided at 850 °C for 8 h and (D) 34CrAlNi7 steel borided at 950 °C for 4 h.