

High Temperature Oxidation of a Work Roll Grade High-Chromium White Cast Iron

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Abstract: High-chromium white cast iron is a common material for the manufacture of the work rolls used in the finishing stands in hot strip mills. The high temperature oxidation behaviour of as-cast and heat-treated high-chromium white cast iron was studied by gravimetric means at 650 °C in atmospheres that included dry air and a mixture of dry air and water vapour. For both environmental and material conditions, the oxidation rate of the alloys was represented by parabolic trends and the oxidation phenomenon was more obvious when the samples were oxidised in water vapour. Water vapour also influenced the chemical composition of the oxides formed in the alloy and under this condition, the oxide scale formed on the alloy contained the oxides FeCr_2O_4 , $(\text{Fe,Cr})_3\text{O}_4$ and $(\text{Fe,Cr})_2\text{O}_3$. In contrast, the alloys exposed to dry air conditions only experienced the formation of FeCr_2O_4 and $(\text{Fe,Cr})_2\text{O}_3$. It was found that the presence of water vapour and the chromium content of the alloys increased the oxidation rate by a mechanism that involved chromium depletion of the oxide as a result of hydroxide formation. The differences observed in the oxidation behaviour of the alloy are discussed in terms of the composition of the oxidant atmosphere and the metallurgical condition of the specimens.

Key words: white cast iron; oxidation; water vapour; work roll

For many years, considerable efforts were directed to develop hot mill work roll materials with superior anti-thermal fatigue and abrasive wear properties for substituting white cast irons and high speed steels^[1–3]. Despite many metallurgical strategies developed to produce better work rolls, the surface oxidation of these elements remains an important problem in hot mills and leads to the development of surface defects in the strip and roll failure^[4–6]. Earlier investigations on work roll oxidation did not take into account the effect of water vapour on the oxidation characteristics of work rolls. However, recent investigations developed by H Kim et al^[7], M J Monteiro et al^[8] and N F Garza-Montes-de-Oca et al^[9] indicate that water vapour modifies the oxidation behaviour of high speed steel work rolls by increasing the rate of oxide formation and the phases presented in the oxide scale formed.

Similar investigations pointed out that water vapour, apart from controlling the chemical composition of the oxides formed on the surface of high

speed steel work rolls, also has an important impact on the wear performance of these tools^[9–11].

Unfortunately, the effect of water vapour on the high temperature oxidation properties of high-chromium white cast iron work rolls was barely studied. In this work, the effect of water vapour on the oxidation resistance of as-cast and heat treated high-chromium white cast iron specimens is presented. The aim of this investigation is to identify if the gases present in the atmosphere in which this phenomenon occurs influence the oxidation rate and the chemical composition of the oxides formed on the surface of the alloys.

1 Experimental Procedure

The alloy was produced in the laboratory of metallurgy and materials processing at the University of Sheffield for earlier work roll projects and its manufacture route can be described elsewhere^[12]. The chemical composition of the alloy is shown in Table 1. Samples with size of 15 mm × 15 mm × 5 mm were cut directly from the as-cast material using the spark erosion

Table 1 Alloying elements in master alloy
(mass percent, %)

C	Cr	Ni	V	Mo	Fe
2.70	17.70	1.30	0.15	1.5	Balance

technique. Once cut, some samples were heat treated by a procedure consisting of heating the specimens to 1050 °C and holding at this temperature for 30 min in a muffle furnace. After this stage, the samples were removed from the furnace and quenched in mineral oil. Immediately after this heat treatment, the samples were tempered by a procedure that consisted of heating them to 450 °C for 20 min and quenching in mineral oil once this time was reached.

Prior to the oxidation experiments, both as-cast and heat treated specimens were ground and polished following standard metallographic procedures. One face of each specimen was polished to a 1 μm surface finish to allow a better understanding of the oxidation phenomenon during analysis. The remaining faces of the specimens were ground to an 800 grit surface finish only.

The oxidation behaviour of the samples was studied by gravimetric means in an oxidation reactor. This installation was built for previous studies on the oxidation behaviour of high speed steel work rolls^[9]. For this investigation, the tests consisted of heating the samples to 650 °C under inert atmosphere conditions (argon gas), and once this temperature was reached (approximately 10 min), the oxidant gas was introduced into the reactor.

The oxidation kinetics of the specimens was studied in the time interval comprised between 60 to 360 min using a new sample for each test, by measuring the mass change of the samples before and after high temperature exposure with an electronic balance of 1×10^{-5} g in accuracy. This procedure was fol-

lowed to study the oxidation of the alloys using either dry air or the mixture of dry air and water vapour (produced at 85 °C) as oxidant gases. In either case, the oxidant mixture was introduced into the reactor at a rate of 150 cm³/s.

After the tests, the oxide phases formed on the surface of the specimens were identified by means of X-ray diffraction using an installation coupled with CuKα radiation source that was produced at 40 kV and 30 mA. High definition scans were performed at a rate of 0.20(°)/min in the 2θ interval ranging from 20° to 80°.

The surface morphology of the samples was characterised by using a field emission gun scanning electron microscope (FEGSEM). For this analysis, the samples were coated with a thin layer of gold to allow charge dissipation during the analysis. Alternatively, metallographic cross sections of the oxides were also prepared for inspection in the FEGSEM. Before cutting, the samples were coated with conductive silver dag aiming to preserve most of the features of the oxides formed. Once dried, the samples were sectioned in a high speed cutting rig by using a cubic boron nitride diamond disc. A large amount of water was applied during this process to avoid sample overheating. Finally, the specimens were mounted in conductive bakelite and then were ground and polished following standard metallographic procedures until a mirror finish surface was produced. To improve image quality, the specimens were also coated with a thin layer of gold and then were analysed in the FEGSEM at various acceleration voltages and working distances. Energy dispersive X-ray analyses were conducted on the samples when required.

2 Results

Fig. 1 shows the microstructural components of as-cast and tempered specimens. The microstructure

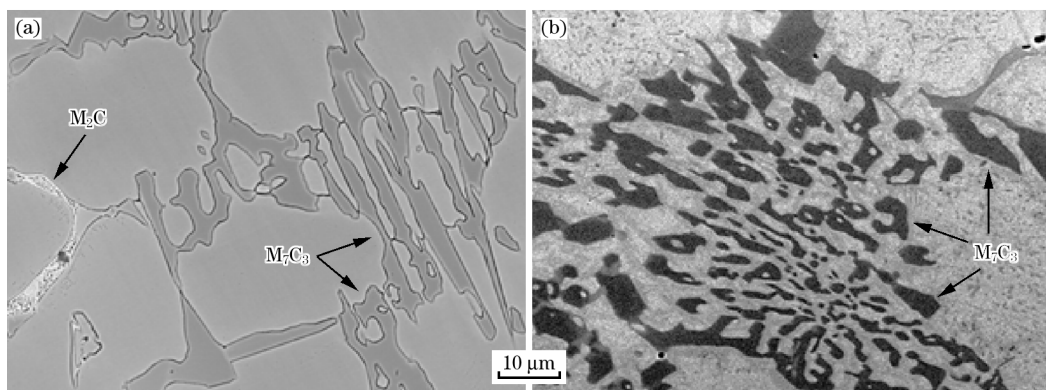


Fig. 1 Backscattered electron microscopy images showing microstructure of alloys in as-cast (a) and heat treated (b) conditions

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