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Short communication

Characterization of wear and metallurgical properties for development of agricultural grade steel suitable in specific soil conditions

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Abstract

Pre-requisite of any agricultural implement is the desired combination of hardness and wear resistance properties. The implements conventionally manufactured from high carbon (∼0.70 C) steel is unsuitable for harsher applications (desert areas and harder soil condition) as after heat treatment it can produce hardness of HRC 38–45 only against a requirement of 50–60 HRC. Therefore, medium carbon (∼0.30 C) steels with microalloy additions of boron/chromium are being selected to achieve higher hardness and better wear resistance in the steel. The increase in hardness is due to faster cooling rate (water quenching) and increased hardenability is attributed to microalloy additions of boron/chromium in the steel. Because of low cost of heat treatment, the demand of such grade exists in many advanced countries. So, it was felt necessary to characterize both the high carbon (∼0.70 C) and medium carbon (∼0.30 C) low alloy steels for their possible application in agricultural implements such as tillage discs, soil and plant engaging components etc. The heat treatment parameters were optimized to achieve the desired mechanical properties, which largely depend upon its chemistry, quenching temperature and cooling rate.

Extensive wear tests were carried out to establish the grades for their end applications in specific soil conditions. The wear pattern, as measured from weight loss, clearly established the superior performance of boron/chromium steel. In fact, compared to mild steel, high carbon, boron steel and chromium steel were 2.28, 2.50 and 2.53 times more wear resistant, respectively. The wear characterization gives a concrete direction to customers about the required quality, properties and grade of steel for agricultural tillage discs in their specific soil condition, which is cheaper and durable. The correlation of phase transformation, hardness and hardenability with wear resistance properties rendered the three composition of steel suitable for use in specific soil condition.

Keywords: Abrasive wear; High carbon steel; Medium carbon steel; Hardness; Hardenability; Agricultural implements

1. Introduction

The life cycle of agricultural implements fully depends on the wear and abrasion characteristics of the material due to the problems associated with surface–soil interaction. Basic requirements of a finished agricultural implement for normal soil are high hardness (38–45 HRC) and high abrasion resistance. The candidate steel, usually having carbon content (∼0.70 C) after oil quenching achieved desired hardness level with a martensitic structure. However, higher hardness (50–60 HRC) is required in desert areas and harder soil condition. Achieving this level of hardness in conventional high carbon grades and yet having adequate toughness is not possible. Therefore, medium carbon (∼0.30 C) steels with microadditions of chromium or boron singly or in combination has been chosen for detailed characterization. The additions of chromium and boron in small quantity leads to an increase in hardness by shifting the bainitic bay to the right even if faster cooling rate by quenching in water is carried out. The increase in hardenability is an additional premium and since this has direct bearing on wear, better property combination might be predicted. This development envisages a savings of oil during heat treatment, thus becomes cost effective. Mild steel is taken as a guideline for comparison of wear properties.

Detailed investigations were carried out for high carbon (∼0.70 C) grade steel with oil quenching and tempering used presently for normal soil alongwith three selected medium carbon (∼0.30 C) steel grades with additions of boron and

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chromium singly or in combination by optimizing the chemistry and heat treatment parameters. The latter steel was water quenched in order to increase hardness for better wear resistance and is found suitable for application in agricultural implements used for harder soil condition.

2. Experiment

Laboratory heats with microadditions of boron and chromium in medium carbon (∼0.30 C) steel were made in induction furnace and cast into ingots weighing 25 kg each. The ingots were hot rolled and the test samples were prepared for detailed investigations. The steels were water quenched and the hardening and tempering temperature were optimized to achieve aimed mechanical properties. In case of chromium containing steels, three compositions were selected to optimize the chemistry and associated heat treatment cycles. Chromium contents of this steel were 0.16%, 0.26% and 0.43%. The most appropriate hardness range (50–60 HRC) was achieved in steel with 0.43% chromium when water quenched from 875 °C to 900 °C. Similarly for boron containing steels, three compositions were chosen where the percentage boron in the steel was 15 ppm, 23 ppm and a combination of 11 ppm with chromium 0.18%. The desired hardness range is achieved in the steel with 23-ppm boron and 11-ppm boron with chromium 0.18% by water quenching from the same range of temperature. The volume fractions of different phases

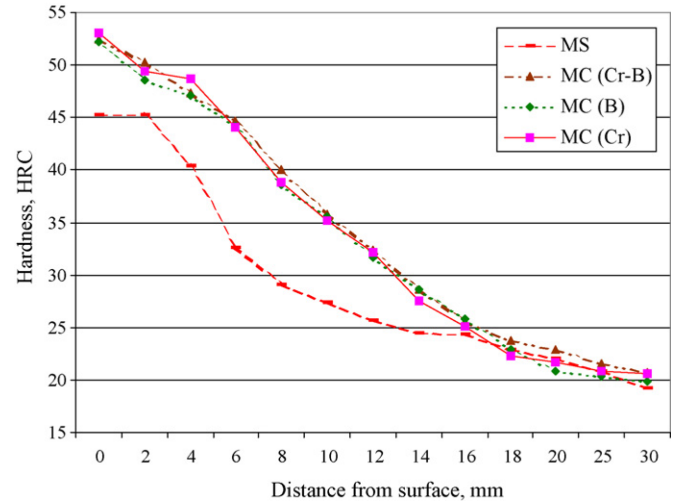

Fig. 1. Jominy hardenability curves for experimental steels.

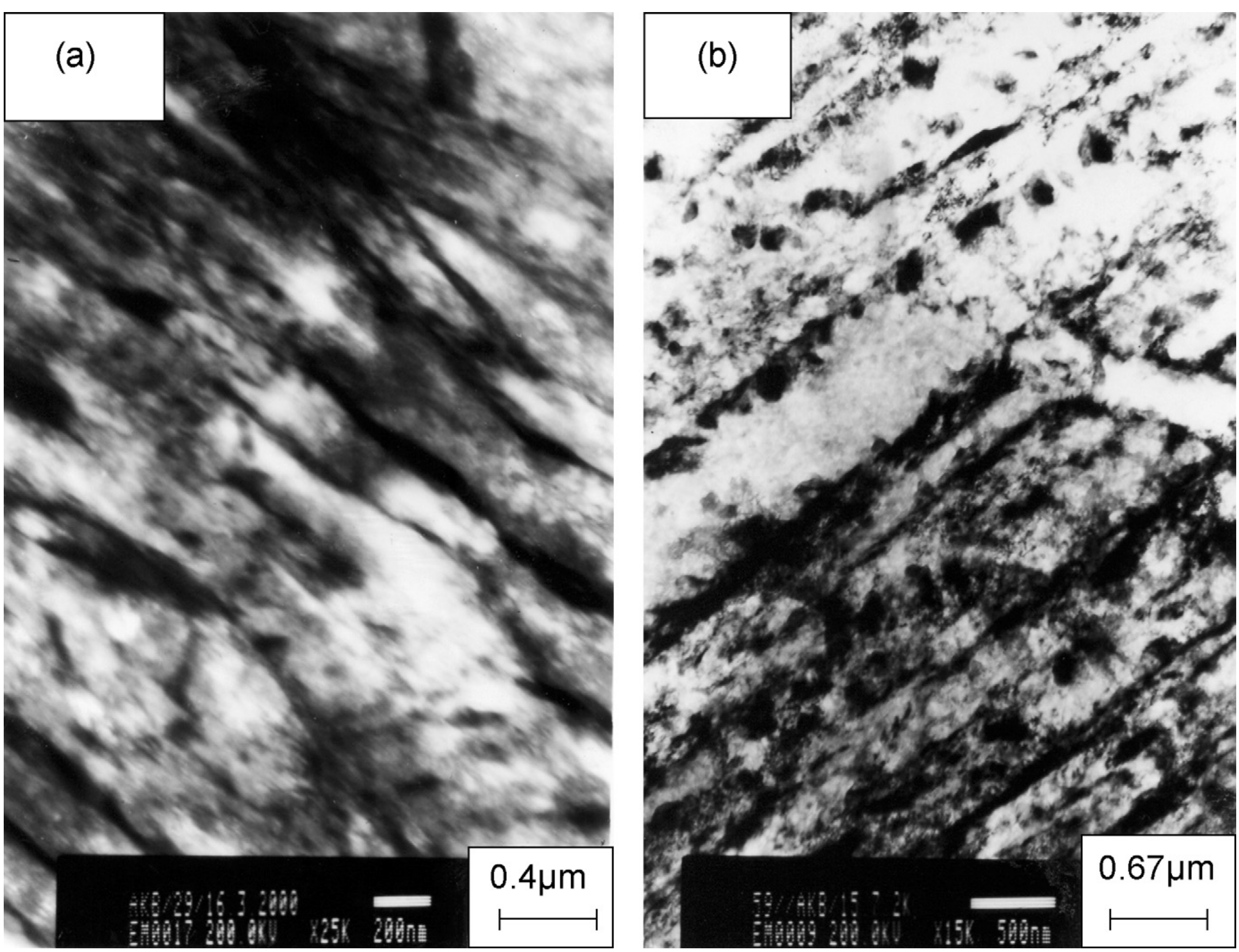

Fig. 2. Transmission electron micrographs: (a) bright field image of MC (Cr) steel at a magnification of 25k showing presence of thicker interlath cementite along interface of martensite laths and (b) bright field image of MC (B) steel at a magnification of 15k showing decomposed martensite with finer globular carbide phases.