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ScienceDirect

Physics Procedia 50 (2013) 124 – 130

Physics Procedia

International Federation for Heat Treatment and Surface Engineering 20th Congress
Beijing, China, 23-25 October 2012

Effects of Boronizing Treatment on Corrosion Resistance of 65Mn Steel in two Acid Mediums

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Abstract

To explore the soil workability of rotary blade suitable for large tilling depth (over 20cm) manufactured through boronizing treatment, this work focuses on the corrosion behavior of 65Mn steel after boronizing treatment in two acid mediums, i.e. the strong acidic medium that hydrochloric solution and the weak acidic that fertilizer-containing soil, and the comparison with existing technology of general rotary blade (lonnealing after overall quenching). The result shows that the corrosion resistance in the two acid mediums of 65Mn steel after boronizing treatment is remarkably improved. After 168 hours' corrosion in the hydrochloric acid solution, the weight loss of boronizing-status sample is only 27.9% of that of lonnealing-status sample. Moreover, there is no obvious weight loss in boronizing-status sample after 168 hours' corrosion in the fertilizer-containing soil, while the weight of lonnealing-status sample is lighter than the original weight after about 150 hours' corrosion. The improvement of the corrosion resistance lies in the significant reduction of the anodization speed in strong acid medium and the effective prevention of phosphorization reaction in weak acidic medium.

Selection and peer-review under responsibility of the Chinese Heat Treatment Society

Keywords: boronizing treatment; 65Mn steel; corrosion resistance; acid medium; rotary blade for large tilling depth

1. Introduction

Rotary tillage machinery for large tilling depth (over 20cm) is the basic equipment to implement "cultivation by returning straws completely to fields", a policy for sustainable agricultural development, and the key lies in corresponding rotary blade (Wu et al., 2009). 65Mn steel, featured with favorable comprehensive mechanical

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1875-3892 © 2013 The Authors. Published by Elsevier B.V.
Selection and peer-review under responsibility of the Chinese Heat Treatment Society
doi:10.1016/j.phpro.2013.11.021

properties, is listed in the national standard as a specified material for rotary blade by GB/T 5669-2008. However, the existing manufacturing technology of general rotary blade (lonnealing after overall quenching) can not meet the hard-surface and tenacious-core performance requirements of 65Mn steel rotary blade suitable for large tilling depth rotary tillage. Therefore, the manufacturing technology applicable to 65Mn steel deep-tillage rotary blade is one of the urgent key problem in modern agricultural machinery manufacturing.

Boronizing treatment, as a surface chemical heat treatment technology with excellent engineering adaptability, has been widely applied to modification on wear and corrosion resistance of tools, dies, parts and components. Nevertheless, those treated by boronizing mostly are the mild or medium carbon steels such as Q235A steel and 45 steel, while high carbon steels are rarely subject to surface modification through boronizing treatment (Uslu et al., 2007), (Kayali and Yalçin, 2011), (Mathew and Rajendrakumar, 2011), (Su et al., 2009). Wang et al. (2011), aiming at meeting the hard-surface and tenacious-core performance requirements of deep-tillage rotary blade, introduce boronizing treatment into rotary blade manufacturing to replace the original heat treatment technology of lonnealing after overall quenching, to have the surface covered with highly-hard boronizing layer to meet its wear resistance. At the same time, the core is still provided with pearlite microstructure with the favorable comprehensive mechanical property to satisfy requirement of bending strength, which may solve the aforesaid technical problem with deep-tillage rotary blade manufacturing effectively. It is well known that the essence of efficacy losing of rotary blade in operation process is the corrosion wear. Although there have been already a great number of researches on boronizing treatment, they mainly focus on the improvement of wear resistance while corrosion resistance of the surface boronizing layer of boronized 65Mn steel in acid mediums are rarely studied and researches on its corrosion resistance in fertilizer-containing soil (a weak acidic medium) have not been reported at home and abroad so far (Kiratli and Findik, 2011), (Mu et al., 2011), (Guo et al., 2011).

This work focuses on the corrosion behavior of boronized 65Mn steel in two acid mediums and the comparison with the existing technology to ascertain the soil workability of deep-tillage rotary blade made through boronizing treatment.

2. Materials and methods

The 65Mn steel used in the work was manufactured by New Fushun Steel Co., Ltd. of China. The boronizing agent was the powder boronizing agent manufactured by Shandong Jiuxing Heat Treatment Materials Co., Ltd. of China, for which ferroboron and boron carbide were adopted as the boron source and potassium fluoborate as the activator. Size of samples used for the test was 10 mm×10 mm×6 mm. The boronizing temperature was 850 °C and the soaking time was 6 hours. The boronized sample was cleaned for corrosion test.

The corrodent mediums were a strong acidic medium that the hydrochloric solution with 10% mole fraction and a weak acidic medium the fertilizer-containing soil. The soil was from a farmland in Dantu, Zhenjiang, China, being naturally dried in the air, and the fertilizer was 55.9% total nutrient NPK compound fertilizer (N-P_2O_5-K_2O: 11-44-0.09) solution with a 10% mass fraction. The total time of corrosion was 168 hours. During corrosion test, the sample was taken out every other day and weighed with a 1:10,000 electronic balance after being cleaned to calculate the weight variation rate. The weighed sample was put in the changed medium for the next round of test. To obtain uniform corrosion, the sample was put in a nylon string bag and hung in the corrodent. A JSM-7001F field emission scanning electron microscope equipped with an IE-350 energy dispersive spectrometer (EDS) and a LEICA DM2500M optical microscope were employed to observe the surface morphologies and the cross-sectional morphologies of corroded samples.

For the purpose of contrast, the corrosion test was concurrently conducted on 65Mn sample going through 850 °C×0.5h oil quenching plus 210 °C×2h lonnealing.

3. Results and discussion

3.1 Corrosion behaviors in hydrochloric solution

Figure 1 is the corrosion kinetics curves of two samples in the hydrochloric solution, from which it can be observed that the two samples are both in weightless state in the hydrochloric solution, but the weightless speed of