ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING 17 (2017) 935–942

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/acme

Original Research Article

Analytical investigation of grain size dependence of microhardness in high nickel-containing reheated weld metal

Gaojun Mao [a,b], *Rui Cao* [a,b,*], *Jianhong Chen* [a,b,*], *Xili Guo* [c], *Yong Jiang* [c]

[a] *Department of Materials Science and Engineering, Lanzhou University of Technology, Lanzhou 730050, China*
[b] *State Key Laboratory of Advanced Processing and Recycling of Non-ferrous Metals, Lanzhou University of Technology, Lanzhou 730050, China*
[c] *Atlantic China Welding Concumables, Inc., Zigong 643000, China*

ARTICLE INFO

Article history:
Received 26 December 2016
Accepted 9 April 2017
Available online

Keywords:
Prior austenite grain
Subgrain
In situ observation
Microstructure
Microhardness

ABSTRACT

Grain size dependence of microhardness has been addressed in the bainitic reheated weld metals by in situ observation of morphological evolution and characterization of microstructural development. A higher cooling rate promotes the boundary of smaller prior austenite grains to provide more effective sites for primary bainitic ferrite nucleation, yet a lower cooling rate is increasingly beneficial to sympathetic nucleation as well as impingement of secondary bainitic ferrite. The microstructures, obtained by cooling at a higher rate and composed of abundant lath bainite, are closer to the microstructures in the raw weld metal than those cooled at a lower rate, including lath bainite, acicular ferrite and intercritical ferrite. Microhardness is decisive by prior austenite grain size mainly, as well as microstructures. Smaller grains contribute notably to microhardness, and it is worth stressing that the sizes of smaller grains lie on prior austenite grain boundaries rather than the subboundaries generated by intragranular acicular ferrite and intercritical ferrite.
© 2017 Politechnika Wrocławska. Published by Elsevier Sp. z o.o. All rights reserved.

1. Introduction

Low carbon bainitic weld metals have been widely utilized in many industries, e.g. automobile, shipbuilding, architecture, etc., owning to their excellent combination of high strength and high toughness [1]. Nickel is usually added in appropriate amounts to obtain finer microstructures during continuous cooling in industry [2].

Lath bainite (LB) and acicular ferrite (AF) are common microstructures of many weld metals. Therefore, it is known that both have substantially varying morphologies and features with specific impact on mechanical properties, such as strength and toughness. LB is composed of sheaves of parallel ferrite laths (or sub-units) with largely mutual orientations separated by low angle boundaries, where cementite precipitates may exist on the lath boundaries. Yet AF is characterized by a chaotic arrangement of fine-grained

* *Corresponding authors at*: Department of Materials Science and Engineering, Lanzhou University of Technology, Lanzhou 730050, China.
E-mail addresses: caorui@lut.cn (R. Cao), zchen@lut.cn (J. Chen).
http://dx.doi.org/10.1016/j.acme.2017.04.001
1644-9665/© 2017 Politechnika Wrocławska. Published by Elsevier Sp. z o.o. All rights reserved.

ferrite plates with different orientations that are separated by high angle grain boundaries [3]. It has been illustrated that both strength [4] and toughness [5] could be significantly improved by increasing AF. The increases in strength and toughness were largely associated with the small grain size and the high density of high angle grain boundaries, respectively [6]. On one hand, larger austenite grains finally lead to longer bainitic sheaves while smaller austenite grains bring about more grain boundaries, which impose more restrictions on the growth of bainitic sheaves. Once impinging the grain boundary, the growing bainitic sheaves are restrained because the bainitic sheaves could not traverse grain boundary [7]. On the other hand, intragranular transformation prefers to occur in the large grains, so larger grains give rise to easier AF generation. AF is able to divide the large prior austenite grains into small subgrains and ferrite sheaves are also capable of acting as new-subboundaries, providing a grain boundary strengthening effect [8]. It seems that decreasing the grain size is an attainable method to increasing strength. It is acknowledged that microhardness keeps the direct proportional linear correlation with yield strength (YS) [9]. In the case of the Hall–Petch effect, decreasing the grain size can impede dislocation movement and increase YS [10]. However, low carbon bainitic weld metal with smaller subgrain size shows a weakening of hardness in this study. It means that grain boundary, causing grain refinement, should be certainly reconfirmed during bainite transformation.

Grain size is decisive by grain boundary, so it is of considerable importance how to define the specific grain boundary correctly. The final grain boundary can only be detected after transformation for a certain time through conventional metallographic investigations, where the study of formation and growth process of grain boundary cannot be realized. However, in situ observing grain formation and growth process of bainite transformation can be conducted continuously, which has more advantages over conventional methods by utilizing laser scanning confocal microscopy (LSCM). And the machine was introduced elaborately in Ref. [11]. In addition, LSCM has been gradually used recent years, for instance, Liu et al. studied the austenite growth in Fe–C–Mn–Si super bainitic steel [12], Kolmskog et al. directly observed bainite formation below the martensite start temperature (Ms) by LSCM [13] and Terasaki et al. poured attention into morphology and crystallography of bainite transformation in a single prior-austenite grain of low carbon steel with the aid of LSCM [14], and so on. In a word, the LSCM will play as accurate a role to verify the effective grain boundary.

More specifically, it is still controversial whether prior austenite grain size or subsequently-formed grain size affects microhardness dominatedly. This paper aims to fill this gap by conducting a series of micro-mechanical tests.

2. Experimental procedure

The test materials were low carbon bainitic weld metals, which were obtained by employing a kind of metal power flux-cored wire with the diameter of 1.6 mm (Wire grade is CHT120CK4, and its type is GB/T17493E83C-K4) as filler metals on the base metal with the dimensions of 450 mm × 250 mm × 28 mm. Fig. 1(a) depicts the Y-type joint by multi-pass welding and the specimens for LSCM that were machined to a cylinder of 6 mm diameter and 2 mm height. It needs to be stressed that the top and bottom surfaces of LSCM specimens should be polished conventionally to keep a level measurement face. Besides, the compositions of weld metals are presented in Table 1. LSCM (VL2000DX SVF17SP) for high-temperature applications are shown in Fig. 1(b). Pure aluminum [melting point: 933 K (660 °C)] was used to calibrate the LSCM. LSCM test procedure is shown in Fig. 1(c). The specimens were heated to 200 °C at the rate of 0.8 °C/s, then heated

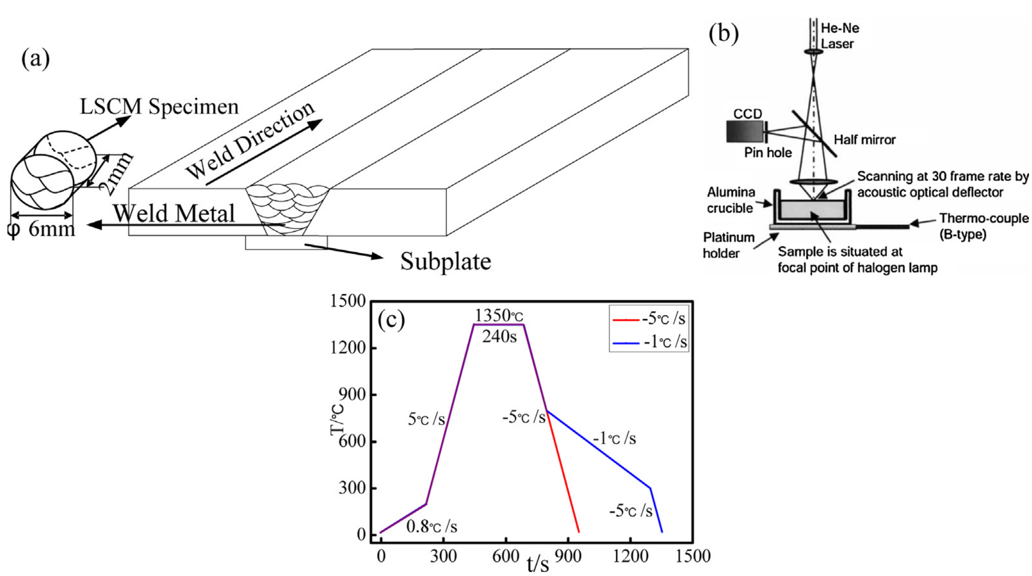

Fig. 1 – (a) Schematic illustration of LSCM specimen cut from the Y-type joint by multi-pass welding; (b) schematic illustration for the optical system in high temperature laser scanning confocal microscopy; (c) LSCM experiment curves of thermal cycles applied to the specimens.

Download English Version:

https://daneshyari.com/en/article/6694877

Download Persian Version:

https://daneshyari.com/article/6694877

Daneshyari.com