An Analysis of Microscopic Morphology and Organization of 1Cr18Ni9Ti

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Keywords: Pulse Weld, Microscopic Morphology, Metallurgical Structure, 1Cr18Ni9Ti.

Abstract. With self-developed pulse weld device, stainless steel 1Cr18Ni9Ti is pulse welding repaired under three different conditions. Metallographic specimens are prepared respectively. Metallographic observation results show that the size of pores in the fusion zone and the pulse weld layer increases along with thickness of the patches. Crystal grains in fusion zone are cellular and thick, while the crystal grains of pulse weld layer are mostly thin and long cellular or columnar dendrites, and the direction of the crystal grains grows almost perpendicular to the pulse weld surface. The matrix metal which is a bit far from fusion area presents no significant structural change.

Introduction

1Cr18Ni9Ti, a kind of Cr-Ni acid-proof stainless steel with good mechanical properties and strong corrosion resistance, is widely used in the production of many kinds of corrosive liquid storage containers and pipes, diamagnetic instruments, medical equipments, etc. To repair the defects such as corrosion pits and scratches that may occur during the preparation and use phase, pulse weld technology is developed and applied in this paper. Through analyzing the microscopic morphology and organizational structure of the pulse weld layer under different condition, the pulse weld parameters are optimized.

Pulse Weld Repair Device

The pulse weld device which is experimented for pulse welding 1Cr18Ni9Ti in this paper is self-developed, and the principle block diagram of its power supply is shown in figure 1. The device can work in two kinds of power supply mode. One is the mains supply mode, and the other is battery packs supply mode which is convenient for weld repair in large containers internal. In the later mode, the battery packs is the 48V lithium batteries. A full bridge converter which is used as charging circuit is accessed between lithium batteries and energy storage capacitors. The output of the full bridge converter is 5~15V DC.

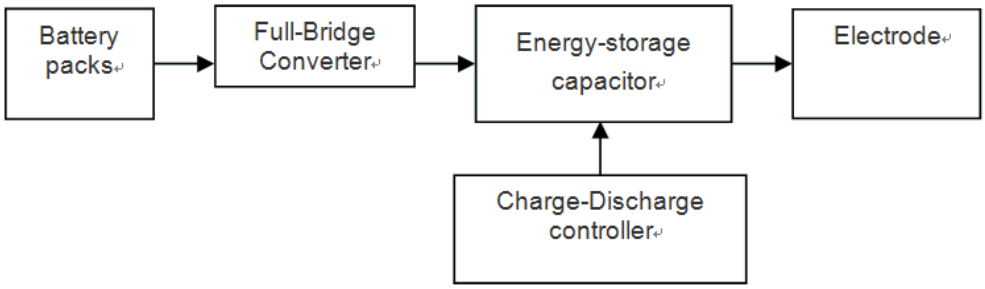


Fig.1 Block diagram of pulse weld power

Related parameters of the power supply are listed as follows:
Lithium batteries: 48V, with a protective plate of 20A, capacity 15Ah;

Energy storage capacitor: four in parallel, single capacity 470μF, withstand voltage 60V;
Full bridge converter: power 600W, inverter frequency 25KHz;
Capacitor charging voltage: 5~15V, continuous adjustable;
Output frequency: 1~50 Hz, continuous adjustable.

Preparation of Specimen

The materials of the samples and patches are 1Cr18Ni9Ti. At first, three *length*×*width*×*thickness*= 50*mm*×20*mm*×8*mm* strip samples are intercepted from a plate by wire-electrode cutting method. Then the surface of the samples is disposed to remove oxide and grease dirt. In order to comparatively analyze the weld repairing effects under different pulse welding conditions, weld layers are prepared on the three samples with three patches that have different thickness. The corresponding parameters of pulse welding are shown in Tab.1.

Tab.1 Experimental data

	Welding condition 1	Welding condition 2	Welding condition 3
Thickness of the patch [mm]	0.1	0.2	0.3
Welding voltage[V]	7	9	14
Pulse frequency[Hz]	20	10	3

After the preparation of weld layer, a wafer about 5mm thick is intercepted from each sample along the width of the sample. Then metallographic specimens (figure 2) are prepared according to the preparing method [1, 2] (plastic inlay) of metallographic sample (the section of the pulse weld layer tends up).

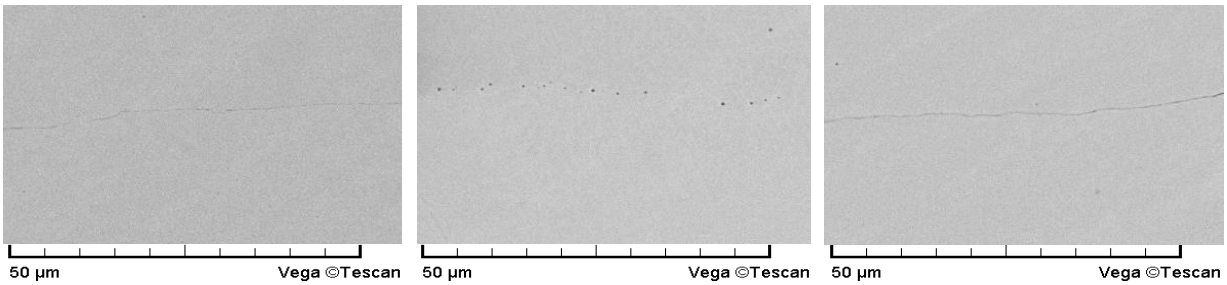
Fig.2 Metallographic specimens

Microstructure and Organization of Pulse Weld Area

The furniture for observing the microstructure and organization of the pulse weld area is a TESCAN scan-ning electron microscope (SEM). Its model is Ⅱ XMLL.

Pores in Fusion Zone

In the observation, a certain number of pores (figure 3) are found in the fusion zone of the samples prepared under all of the three welding conditions. Under the magnification of 2000 times, only a few minute pores can be observed on the sample which thickness of patch is 0.1*mm*, and the patch and matrix are combined well. The pores increase in size slightly and form an intermittent welding line on the sample which thickness of patch is 0.2*mm*. Welding line becomes continuous and visible on the sample which thickness of patch is 0.3*mm*. Thus, the size of pores in the fusion zone increases along with the thickness of the patches. In order to ensure the substrate and the patch combined tightly, the patch materials in small thickness and low welding voltage should be adopted.

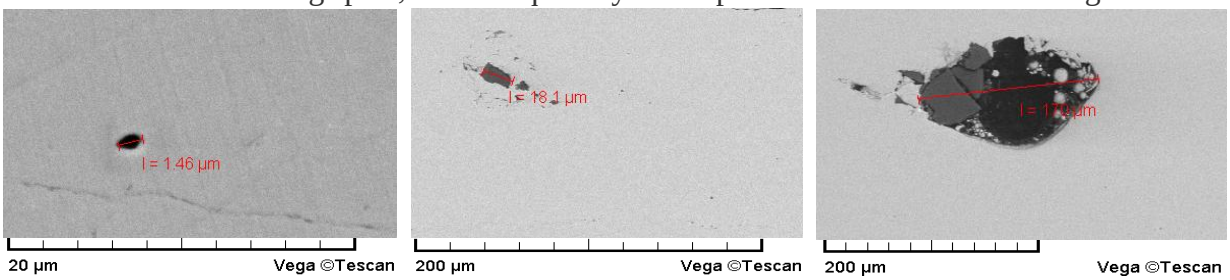


The samples from left to right in turn correspond to pulse welding condition 1, 2, 3

Fig.3 The pores in fusion zone

Pores in Pulse Weld Layer

The pores in pulse weld layer are shown in figure 4. The figure shows that only a few scattered pores are found in the pulse weld layer of all of the three samples. The largest sizes of the pores among the pulse weld layers which are respectively prepared with patches 0.1*mm*, 0.2*mm* and 0.3*mm* are 1.46*μm*, 18.1*μm*, 170*μm*, an order of magnitude difference in turn. This suggests that the size of pores in the pulse weld layer significantly increases along with thickness of the patches. The possible reasons are: the greater thickness of the patches, the greater size of the welding spots, the less number per unit area of the welding spots, thus the quantity of the pores is more and the size is greater.

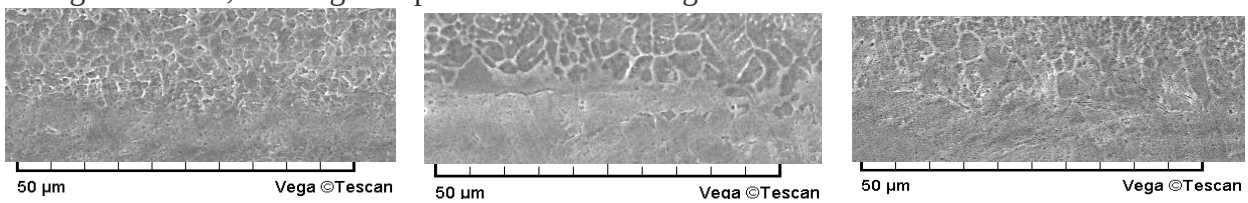


The samples from left to right in turn correspond to pulse welding conditions 1, 2, 3

Fig.4 The pores of the weld layer

Analysis of Metallurgical Structure

Metallurgical structure in pulse weld layer can be observed in the SEM after sample corroded (the ratio of corrosion reagents is: water (100ml) + HCl (25ml) + FeCl3 (8g)). Under the three pulse welding conditions, welding area presents the following characteristics:



The samples from left to right in turn correspond to welding conditions 1, 2, 3

Fig.5 The metallurgical structure of fusion zone

1. Crystal grains in fusion zone and heat-affected zone are closely connected and they are mutual penetration, interacting crystallization (Fig.5). Crystal grains in this region are cellular, thick, and between the crystal grains is smooth-transition, organizational seal without mutation. The causes of this phenomenon are: when the liquid metal in the fusion zone is solidifying, the matrix metal near fusion zone, which owns the same chemical composition and crystal grain type as the metal in fusion zone, plays the role of a molten pool wall. Crystal firstly grows up from the melt border connected to the matrix [3]. At the same time, the temperature gradient between the metal in fusion zone and melt

border is large, but the growth speed of spontaneous nucleation grains is relatively low, so the morphology of the fusion zone after solidification is often the cellular organization.

2. Crystal grains in weld layer are mostly thin and long cellular or columnar dendrites, and the growth direction of the grains is almost perpendicular to the substrate surface of the weld. Specimen with the thickness of 0.3 mm is particularly obvious (Fig.6). This suggests: the molten pool becomes smaller and the temperature drops with the crystal grains growing from the fusion zone to weld layer internal, so the temperature gradient in the unfrozen liquid becomes smaller and supercooling degree of composition increases gradually, then the crystal grains grows into cellular dendrites or columnar dendrites [4]. On the other hand, most of the "branches" orientation is consistent, which suggests that the cooling speed of crystallizing is fast, and the horizontal growth of the "branches" is insufficient, so it is beneficial to improve the mechanical properties of the weld layer on the main direction of the "branch".

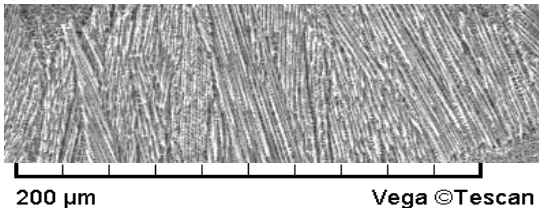


Fig.6 Dendrites of weld layer

3. There are faintly visible crystal grains in the tiny area of matrix near the fusion zone, but there are no obvious characteristics in the area a little far away from the weld (Fig.7). Only the rolling lines can be observed even though lengthening the corrosion time of specimen preparation, while the crystal grains similar to weld layer is not found. The reasons may be: in a pulse cycle, the proportion of heat input time is very small, most of the time is spent on heat rejection and cooling, so the weld process has little or even no heat-affected on the matrix (in the actual pulse welding repair process, the matrix has no apparent temperature rising), and the phenomenon of recrystallization does not happen in the matrix while it happens in the fusion zone and welding repair area. Therefore, intergranular corrosion does not occur in the preparation process of metallographic specimens, and thus crystal grains (crystal boundary) in matrix are invisible [4].

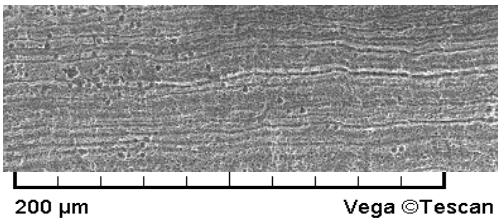


Fig.7 Micrograph of sample matrix

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