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Effect of pulsed magnetic field on microstructure of 1Cr18Ni9Ti austenitic stainless steel

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Abstract

The aim of this paper is to investigate the effects of pulsed magnetic field on the microstructure of 1Cr18Ni9Ti austenitic stainless steel. Experimental results indicate that during the solidification of 1Cr18Ni9Ti austenitic stainless steel, applications of pulsed magnetic field can significantly refine its microstructure. And there is an optimal value of magnetic intensity under which the grain size is the finest. Moreover, applications of pulsed magnetic field can significantly reduce the solidification time, and also lead to increase of the initiation and finishing solidification temperature.

Keywords: Pulsed magnetic field; Stainless steel; Microstructure; Solidification

1. Introduction

Electromagnetic processing of materials (EPM) was an effective method to improve microstructure and mechanical properties of materials and was widely studied recently. It has gained great achievement in grain refinement, control of melt flow, improvement of liquid/solid interface morphology, control of crystal orientation, purifying melt, and fabrication of novel materials etc. [1–9]. Development of superconducting magnets would promote and extend its applications to more fields. Now, investigations were mainly focused on the applications of high frequency magnetic field, low frequency magnetic field, dc magnetic field, dc magnetic and electric field, pulse current, and a traveling magnetic field [1,2,6–10]. But the reports about applications of pulsed magnetic field to material process were seldom available. Moreover, 1Cr18Ni9Ti austenitic stainless steel was an important structural material. Therefore, this paper investigated the effects of pulsed magnetic field on microstructure of 1Cr18Ni9Ti austenitic stainless steel.

2. Experiments

The experimental apparatus mainly included power supply of pulsed magnetic field, median-frequency induction furnace, generator of pulsed magnetic field, sand mould, crucible, B-type thermal couple, data acquisition instrument. Fig. 1 was sketch of the experimental apparatus. The generator of pulsed magnetic field was connected with the power supply, and its discharge course was shown in Fig. 2. The studied alloy was 1Cr18Ni9Ti, and its composition was shown in Table 1. The alloy was firstly melted to $1600 \pm 10\,^{\circ}C$, about 140 K above its liquidus temperature. Then the melt was poured into the sand mould, and the pulsed magnetic field was synchronously applied to them. For comparison reason, a series of samples were made without or with different magnetic intensity. Frequency of the pulsed magnetic field was about 1–5 Hz. During cooling course of the melt, its temperature was monitored by a B-type thermal couple connected with a computer. Dimension of the samples was Ø40 mm × 130 mm. The specimens were cut from middle part of the samples after the samples were cooled to room temperature. The specimens were ground, polished, and etched by the reagent of $FeCl_3$(18 g) + HCl(30 ml) + H_2O (100 ml) for microstructure examination. The microstructure was examined by an optical microscope.

3. Results and discussions

3.1. Experiment results

There was not clear chilled zone in the samples due to small cooling ability of the sand mould and high pouring temperature.

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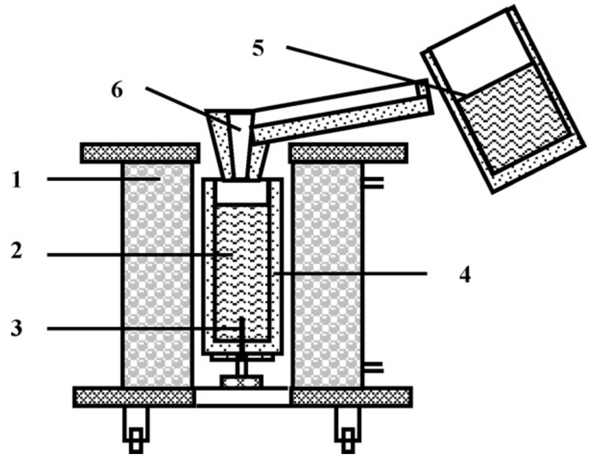

Fig. 1. Sketch of the experimental apparatus: 1, generator of pulsed magnetic filed; 2, melt; 3, thermal couple; 4, casting mould; 5, crucible; 6, pouring cup.

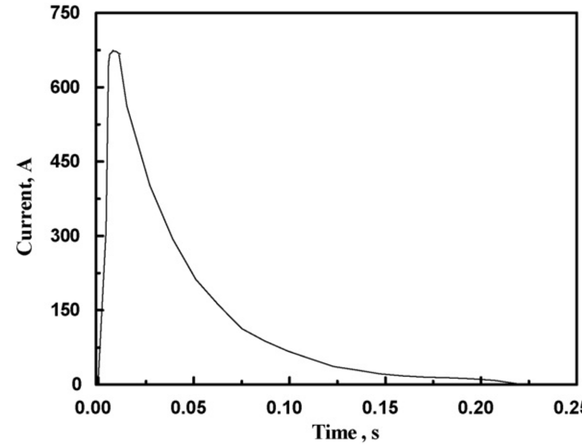

Fig. 2. Discharge course of power supply of pulsed magnetic field.

Table 1
Composition of 1Crl8Ni9Ti austenitic stainless steel (wt.%)

C	0.07
Si	0.29
Mn	0.70
P	0.030
S	0.002
Ni	9.27
Cr	17.47
Ti	0.06
Balance	Fe

Only the columnar and equiaxed zone appeared. Thus, this paper investigated effect of the pulsed magnetic field on the microstructure of the columnar and equiaxed zone, respectively. Fig. 3 is effects of pulsed magnetic field on the microstructure of the equiaxed zone in center of the samples. Results show that the grain size gradually becomes small when the magnetic intensity increases from 0 T (without the pulsed magnetic field) to 0.72 T to 1.10 T to 1.35 T. But when the magnetic intensity is beyond 1.35 T, the grain size gradually increases again with increasing magnetic intensity. Fig. 4 is average grain size as a function of the magnetic intensity for the equiaxed zone. It reveals that when the magnetic intensity is 1.35 T, the average grain size

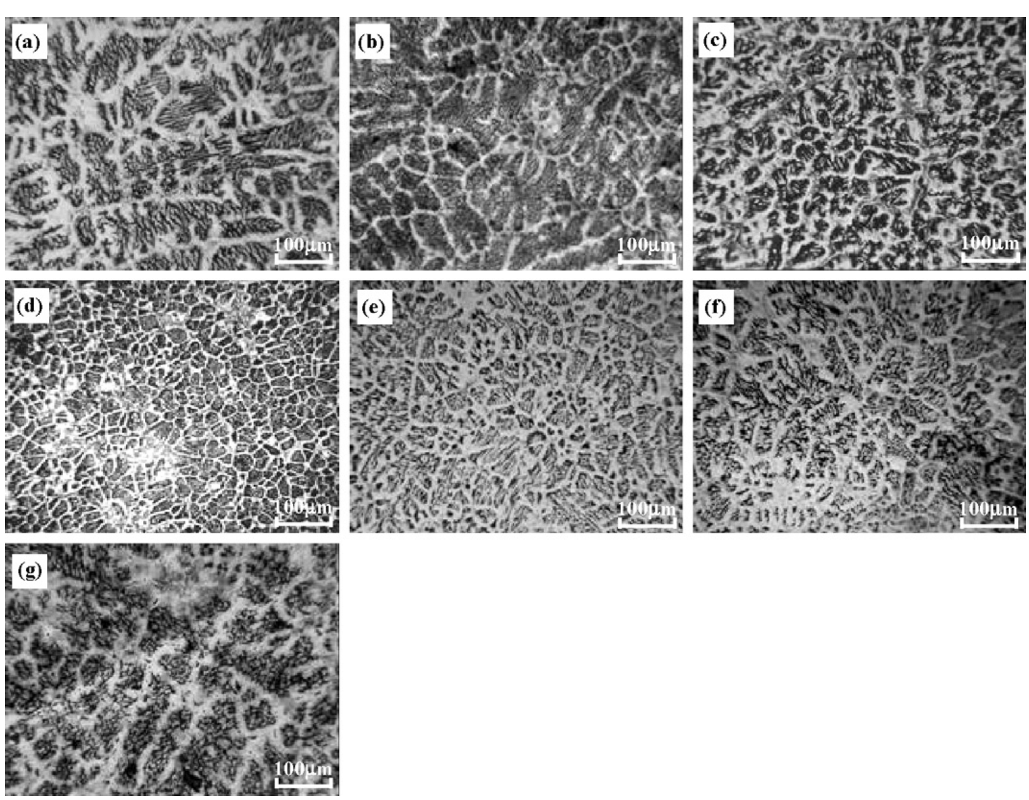

Fig. 3. Effects of pulsed magnetic field on microstructure of equiaxed zone in center of the samples: (a) 0 T, (b) 0.72 T, (c) 1.10 T, (d) 1.35 T, (e) 1.80 T, (f) 2.22 T, and (g) 3.24 T.