



Grain refinement of horizontal continuous casting of the CuNi10Fe1Mn alloy hollow billets by rotating magnetic field (RMF)

Zhiming Yan^a, Xintao Li^{a,b}, Zhiqiang Cao^a, Xiaoli Zhang^a, Tingju Li^{a,*}

^a State Key Laboratory for Materials Modification by Laser, Ion and Electron Beams & School of Materials Science and Engineering, Dalian University of Technology, Dalian 116085, China

^b Gaoxin Zhangtong Co. Ltd., Zhangjiagang 215600, China

ARTICLE INFO

Article history:

Received 3 June 2008

Accepted 5 July 2008

Available online 11 July 2008

Keywords:

Rotating magnetic field (RMF)

Casting

Crystal structure

Metal and alloys

Microstructure

ABSTRACT

Rotating magnetic field (RMF) is used in horizontal continuous casting of CuNi10Fe1Mn alloy hollow billets. The result shows that the formerly inhomogeneous columnar grain macrostructure turns into homogeneous equiaxed grain with the application of RMF. The microstructure without RMF transforms from coarse and disordered dendrites to dense dendrites which have obvious orientation, while the microstructure with RMF from center to edge displays the evolution from spherical grains to disordered dendrites without orientation. The mechanical properties are improved remarkably.

© 2008 Elsevier B.V. All rights reserved.

1. Introduction

CuNi10Fe1Mn alloy is a kind of Cu-based alloys which is widely used as cooling-condition materials in shipping, electric power industry and seawater desalted industry et al. [1]. But the solidification structure of horizontal continuous casting of CuNi10Fe1Mn alloy hollow billets is inhomogeneous coarse columnar grain structure in cross-section which has badly negative effect on the subsequent rolling procedures [2]. So it is urgent to improve the solidification structure.

It has been demonstrated that the liquid metal acted by RMF is subjected to electromagnetic stirring which has the advantages of refining the solidification structure of the ingot and reducing the segregation and shrinkage cavity [3,4]. RMF had been successfully applied to horizontal continuous casting copper hollow billets [5], but few studies had been carried out on CuNi10Fe1Mn alloy hollow billets. This paper studied the effect of RMF on grain refinement of CuNi10Fe1Mn alloy hollow billets.

2. Experimental

The schematic view of experimental apparatus is shown in Fig. 1. The RMF is generated by the three-phase-three-pole induced coil outside the graphite inner-mold.

The nominal composition of CuNi10Fe1Mn alloy (wt.%) is: 10Ni, 1.4Fe, 1.0Mn and Cu is rest. After a series of systemic experiments, the best experimental parameters of horizontal electromagnetic continuous casting of CuNi10Fe1Mn alloy hollow billets were obtained and shown in Table 1. The specimens for macrostructure were polished and etched by a solution of 50 ml HNO₃ and 50 ml H₂O, while for microstructure were polished and etched by a solution of 3 g FeCl₃, 4 ml HCl and 96 ml C₂H₅OH. The tensile test was performed according to GB/T228-2002 standard. This paper studied the effect of RMF on macrostructure, microstructure and mechanical properties of

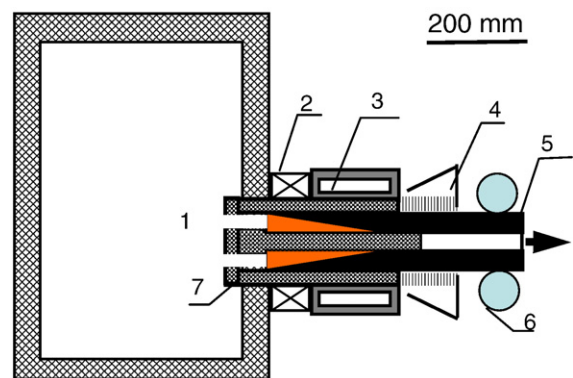


Fig. 1. Schematic view of experimental apparatus: (1) tundish, (2) coil, (3) primary mold, (4) secondary mold, (5) hollow billets, (6) drawing system, (7) graphite inner-mold.

* Corresponding author. Tel.: +86 411 8470 6220; fax: +86 411 8470 8940.

E-mail address: tjuli@dlut.edu.cn (T. Li).

Table 1

Experimental parameters of horizontal electromagnetic continuous casting of CuNi10Fe1Mn alloy hollow billets

Items	Values
Casting temperature	1230 °C
Casting speed	0.0058 m/s
Drawing time	0.5 s
Pausing time	0.4 s
Reversing time	0.2 s
Pausing time	0.4 s
Cooling water	
Primary	1.8 m ³ /h
Secondary	2 m ³ /h
Cooling water temperature	20 °C
Hollow billet size	Φ83×21 mm
Input current intensity(I)	120 A
Electromagnetic frequency	50 Hz

CuNi10Fe1Mn alloy hollow billets, and discussed its action mechanism of grain refinement.

3. Results

3.1. Effect of RMF on macrostructure

During horizontal continuous casting, the bottom area permits good heat dissipation because of its own gravity, while in top area, gap, which forms between the initial solidification shell and graphite inner-mold due to solidification contraction, affects heat dissipation [5]. Therefore, the macrostructure is inhomogeneous, which reveals a division into a top area of fine columnar grains and a region of coarse columnar grains in bottom area, as shown in Fig. 2(a). After the imposition of RMF, the inhomogeneous columnar grain structure changes to homogeneous equiaxed grain structure, as shown in Fig. 2(b).

3.2. Effect of RMF on microstructure

The microstructures of CuNi10Fe1Mn alloy are shown in Fig. 3, where the samples are all obtained from bottom areas without and with RMF. The microstructure without RMF is dendrite from center to edge. The dendrites in center are coarse as shown in Fig. 3(a), while in 1/2 radius have orientation in certain extent as shown in Fig. 3(c), and in edge are dense and have obvious orientation as shown in Fig. 3(e). The microstructure with RMF from center to edge displays the evolution from spherical grains to disordered dendrites without orientation. The microstructure in center which is similar to the spherical grain of rheocasting is thin and uniform as shown in Fig. 3(b), while in 1/2 radius is the mixture of spherical grain and rosette shape grain as shown in Fig. 3(d). The dendrites in edge are thin and dense without orientation as shown in Fig. 3(f).

3.3. Effect of RMF on average grain size and average dendrite arm spacings

Fig. 4 reveals the effect of RMF on average grain size and average dendrite arm spacings. When the input current intensity reaches 120 A, the average grain size is about 0.56 mm, compared to that without RMF is 6.1 mm. The average dendrite arm

spacings from center to edge are refined correspondingly. The RMF provides not only a grain refinement, but a refinement of microstructural morphology (dendrites).

3.4. Effect of RMF on mechanical properties

Fig. 5 shows the effect of RMF on mechanical properties of CuNi10Fe1Mn alloy hollow billets. The tensile strength is increased of about 20% and the elongation is improved of about 66% compared to those without RMF.

4. Discussion

When alternating current is imposed, the coil generates a rotating electromagnetic field in the melt. This field, in turn, creates an induced eddy current in the melt in opposite phase to the imposed alternating current. As a result, the melt is subjected to electromagnetic body force caused by the interaction of the eddy current and rotating magnetic field, which can be expressed as follow [6]:

$$F = J \times B = (1/\mu)(\nabla \times B) \times B. \quad (1)$$

Where J is the induced eddy current; B and μ represent the magnetic flux density and magnetic permeability respectively; ∇ is Hamilton operator.

The low temperature melt near the edge of graphite inner-mold is taken to the center of the hollow billet by the electromagnetic body force, and the temperature gradient in the melt reduces. The dendrites on the solid–liquid interface are disturbed by the temperature and concentration fluctuation, and the roots of the dendrites are easy to be fused off. The compulsive convection caused by RMF generates shearing force, plenty of dendrites are broken off. The dendrites which are fused off and broken off are distributed uniformly in the melt by RMF and offer cores for nucleation, so the nucleation rate increases.

After temperature and concentration fluctuation, the temperature and concentration field of the internal melt are uniform which reduce the temperature gradient and restrain the growth of dendrites. With the application of RMF, the nucleation rate increases while the temperature gradient reduces that promotes the transformation from dendrites to equiaxed grains and the grains grow in a uniform condition. The crystallization takes place simultaneously which causes the formation of a fine and homogeneous structure over the cross-section.

Owing to the different effect of primary cooling water on solidification from center to edge, the microstructure without RMF transforms from coarse and disordered dendrites to dense dendrites which have obvious orientation. With the stirring effect of RMF, the temperature and concentration field of the internal melt are uniform. The fused off and broken off dendrites offer cores for nucleation and

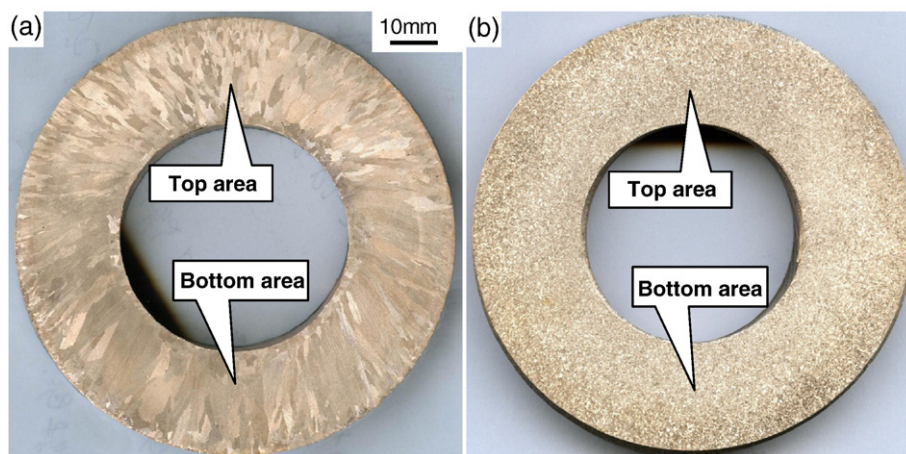


Fig. 2. Effect of RMF on macrostructure of CuNi10Fe1Mn alloy hollow billets: (a) Without RMF, (b) With RMF, $I=120A$.

Download English Version:

<https://daneshyari.com/en/article/1650462>

Download Persian Version:

<https://daneshyari.com/article/1650462>

[Daneshyari.com](https://daneshyari.com)