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Novel side dams including advanced laminated ceramic for twin roller continuous casting

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Abstract

Novel side dams for twin roller continuous casting were fabricated. The side dams were divided into three zones and were prepared with different materials to meet working demands. Al_2O_3–ZrO_2 laminated ceramic was used as a key part to overcome immense friction and wear and frequent thermal impact during the whole casting process. A series of experiments for laminated composite were carried out, and the results indicated that the laminated composite presents rather excellent comprehensive properties including considerable fracture strength and fracture toughness, high critical thermal shock temperature difference and good tribological properties. These superior comprehensive properties are mainly attributed to the special laminated structure with expected residual stress in different layers. Furthermore, the side dams were successfully applied in the twin roller continuous casting in the laboratory. The side dams exhibit good working ability under extremely tough conditions and the steel strips produced by continuous casting present good qualities.

Keywords: B. Interfaces; C. Thermal shock resistance; C. Wear resistance; E. Structural applications

1. Introduction

Twin roller continuous casting, a sort of near-net-shape technology, presents numerous advantages on economical production of thin strips, such as low energy consumption, low equipment and operating costs, and rapid solidification [1–8]. The schematic illustration of twin roller continuous casting is shown in Fig. 1a, and side dams in contact with the rollers act as un-replaceable roles on keeping molten metal from leakage in whole casting process.

Side sets for containing molten metal of twin roller continuous casting can be divided into two kinds, one is electromagnetic dams (EMD), and the other is solid side dams [7,8]. However, high cost of electromagnetic equipment and potential danger once equipments being out of good condition are both considerable factors for EMD, especially for experimental research. Thus, our research is focused on the solid side dams.

During casting process, molten metal is frequently dumped into pool region surrounded by rollers and dams, along with rolls rotate to drag metal strips (see Fig. 1a). So side dams have to suffer extremely tough working conditions such as iterative thermal impact (especially more than 1000 °C for steel and iron), heavy abrasion against rolls and strips at high temperature, as well as erosion from different molten metals. Therefore, for side dams it is necessary to have good combinations of properties including excellent thermal shock resistance associated with wear- and erosion-resistance. So far, research on materials for side dams is seldom reported [7–10]. And in the earlier working, we have experimented tens of stuffs such as high temperature ceramics and refractory materials for side dams, unfortunately no solo commercial material was successfully found out. (Some materials can be used as the dams only in a rather limited times, generally one or several casting processes).

In our present study, by analyzing working conditions in different locations of the dam sheets, we divided the sheets into three zones (see Fig. 1b), accordingly designed novel composite dam sheets including both ceramic and refractory materials. The mechanical properties, thermal shock resistance and wear resistance of the key zone made of Al_2O_3–ZrO_2

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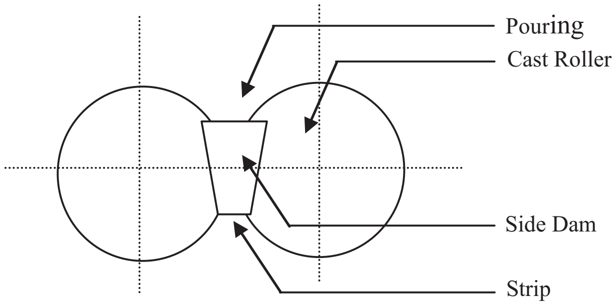
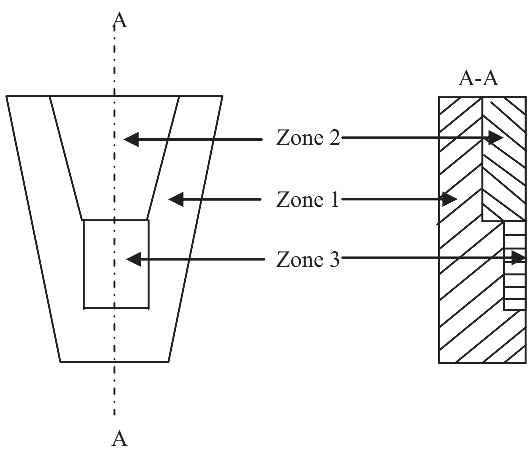


a) Schematic of twin roller continuous casting



b) Structural diagram of novel side dam set

Fig. 1. Schematic illustration of twin roller continuous casting and structural diagram of novel side dam set.

laminated ceramic were investigated, as well as the ceramic was observed and analyzed. Furthermore, the novel side dams were successfully fixed and applied in the twin roller continuous casting equipment.

2. Experimental procedure

2.1. Structural design of side dams

As shown in Fig. 1b, novel side dams were designed, which have three working zones made up of different materials, respectively. Zone 1 is named as ‘‘the substrate’’, which is used to hold and fix the zone 2 and zone 3. According to our design, it seldom meet molten metal but may contact rotating rollers during casting process, so excellent strength and wear resistance of it are required, as well as good thermal resistance and low thermal conductivity are also considerable for the reason of thermal insulation. Therefore a sort of asbestos–cement board with a low cost was selected as the substrate. Zone 2, in contrast, which contacts molten metal frequently but does not meet rotating rollers under working condition, was fabricated with fused silica board because of its superior comprehensive properties including excellent thermal shock resistance, thermal insulation and corrosion resistance to molten metal (both asbestos–cement and fused silica material are not further discussed because they are easy to prepare). Zone 3, a key part of the side dams, is always under extremely terrible conditions such as immense friction and wear occurred from frozen metal strips and rollers, and frequent thermal impact of molten metal. Therefore, it must have good high temperature strength and wear resistance, combining with good thermal shock resistance. Besides, it must also exhibit a smooth surface to obtain high-quality strips with regular and smooth edge but without crack and gap. Accordingly, ceramic or ceramic matrix composite is probably the best selection.

Zones 2 and 3 were inlaid into the substrate by using a binder with good high temperature resistance, and then the whole dams were polished to become flat.

In the following section we discuss the ceramic composite which was applied for zone 3.

2.2. Preparation and analysis method of the ceramic composite

It is hard to find out a proper candidate applied for zone 3 due to its extremely rigorous demands on properties described above. Ultimately, a laminated ceramic with excellent comprehensive properties was considered.

ZrO_2 powder with 0.6 μm average particle size (containing 3 mol% Y_2O_3 as sintering stabilizer) and Al_2O_3 powder with 0.5 μm average particle size (containing 0.5 wt% MgO as sintering aid) were selected to prepare laminated composite. The composite includes two surface layers and one center layer, and the thickness of them are $d_1 = 0.3 \pm 0.1$ mm and $d_2 = 5.4 \pm 0.2$ mm, respectively. So the total thickness of the composites d is 6.0 ± 0.4 mm (see Fig. 2).

In order to obtain residual compressive stress in the surface layers (The reason will be discussed later), 5 wt% $Al_2O_3 + ZrO_2$ in the center layer and 30 wt% $Al_2O_3 + ZrO_2$ in the surface layers were selected, respectively (actually series of both laminated and un-laminated composites with different compositions were studied, but they are not the point of this paper and here we just study the best one in the whole series).

The composite powders were dry-pressing molded at room temperature using a 60 T double-pressing machine. Then the compacts were sintered at 1620 °C for 90 min in air.

The critical thermal shock temperature difference ΔT_c under a quick cooling condition was tested by the residual fracture strength method [11]. Different temperatures (ΔT) from 150 to 600 °C with an interval of 50 °C were designed.

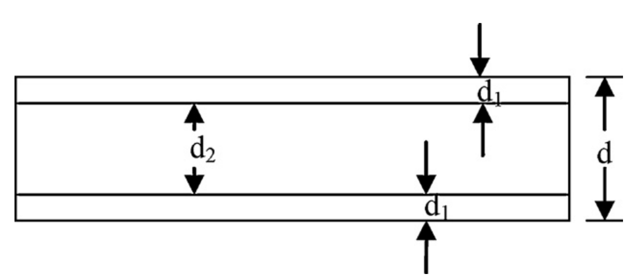


Fig. 2. Schematic of three-layer composites.