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Thermal stress for all-ceramics rolls used in molten metal to produce stable high quality galvanized steel sheet

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Abstract

The zinc coated steel sheet has been mostly used for automobile and other industries because of its high corrosion resistance. This paper deals with the development of new ceramics support roll used for a continuous galvanizing pot to manufacture stable galvanizing steel sheet. Usually stainless steel rolls coated by tungsten carbide are used to support and stabilize the strip in a continuous galvanizing pot, which is filled with molten zinc. However, corrosion and abrasion arise on the roll surface only in a few weeks, and causing the deterioration of quality of plating. Although developing all-ceramics rolls is most desirable, risk of fracture has to be reduced when the ceramic roll dips into molten metal. In this paper, therefore, how to reduce the thermal stress is considered when the ceramic rolls are installed in molten metal using finite volume method and finite element method. The usefulness of silicon nitride having extremely high conductivity is also discussed.

Keywords: Thermal stress; Surface treatment; Machine element; Ceramics; Roll

1. Introduction

The zinc coated steel sheet has been used for automobiles, refrigerators, and washing machines etc. because of its high corrosion resistance [1]. In recent years, several continuous galvanizing lines are constructing to meet the demand for those industries. To improve the quality of plating strips, automation technologies to control the zinc coating thickness and galvannealing were considered [2,3]. Fig. 1 shows the layout of a continuous galvanizing line [1–6]. Strip coils rolled by the cold rolling mill are automatically mounted on the pay-off reel. After subsequent welding, the strip is passed through an automatically controlled annealing furnace to be heated to a specific temperature, and then dipped in a zinc bath through a protective gas atmosphere. In the

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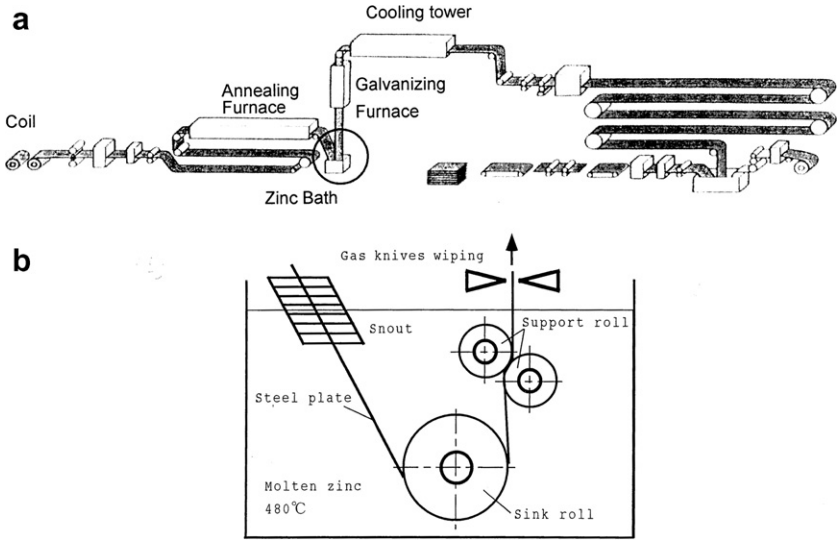

Fig. 1. (a) Layout of continuous galvanizing line; (b) detail of zinc bath.

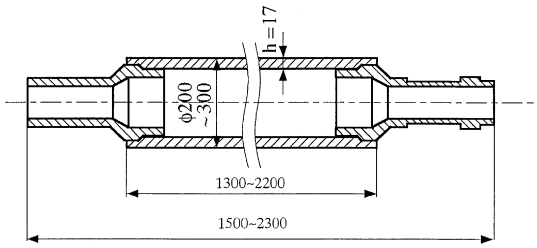

Fig. 2. All-ceramics support roll.

molten zinc bath, the strip changes the direction by the sink roll; after rectifying the warping of the plate by a pair of support rolls, the steel sheet is withdrawn from the pot. A wiping nozzle provided immediately above the zinc bath sandwiches the strip, and controls the zinc coating thickness to the specified value by the discharged gas. With galvanneald steel, the coated strip is heated in the galvannealing furnace, where the degree of alloying between the zinc coating layer and substrate is controlled. After passing through the temper mill and tension leveler, the strip is subjected to chromate treatment and oiling, and cut into suitable sized sheets.

In the molten zinc bath, the sink rolls and the support rolls are usually made of stainless steel [7–9]; however, since the molten zinc has a high temperature 480 °C, corrosion and abrasion arise on the roll surface only in a few weeks, and causing the deterioration of quality of plating. Therefore, every two or three weeks, continuous galvanizing lines must stop to change the rolls. Thanks to its excellent high-temperature strength, all-ceramics rolls as shown in Fig. 2 have attracted much attention [7]. However, risk of fracture has to be reduced when the ceramic roll dips into molten metal and operates. In this paper, therefore, how to reduce the thermal stress will be considered when the all-ceramics rolls are installed in molten metal using finite element method. The use of special silicon nitride that has extremely high thermal conductivity [10] will be also considered to reduce the thermal stress. It should be noted that those thermal stresses are harmless for stainless steels, but possibly harmful for ceramics because of low fracture toughness.

2. Previous studies for sink and support rolls used in molten zinc

In the molten zinc bath in Fig. 1b, the sink roll has 500–800 mm in diameter, and 1300–2200 mm in length. The support rolls has 200–350 mm in diameter, and 1300–2200 mm in length. They are usually made of stainless steel because of the highest corrosion resistance among all kinds of metals. To improve the corrosion resis-