

## Technical Paper

## Effects of melt pressure on process stability and bonding strength of twin-roll cast steel/aluminum clad sheet



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## ABSTRACT

Besides casting speed and pouring temperature, melt pressure in cast-rolling zone also affects process stability and bonding strength of twin-roll cast steel/aluminum clad sheet. Different melt pressure in cast-rolling zone is attained by adjusting center channel size inside nozzle in this paper. Under high melt pressure, clad sheet with intact shape and good appearance can be produced. However, the process stability is low and defects like side leakage and melt penetration can occur when casting speed and pouring temperature fluctuate. When melt pressure is too low, the transverse flowing ability of melt decreases and misruns appear in the sheet. Melt wetting and distribution on steel surface are more uniform and solid/semisolid contacting time is longer under high melt pressure. As a result, bonding strength increases when melt pressure is high.

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## 1. Introduction

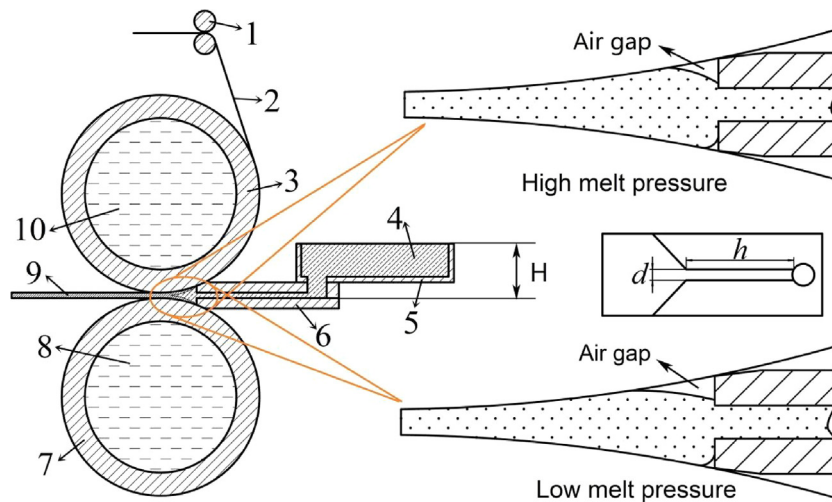
Metallic clad sheets combine merits of two or more metals and thus have wide applications in many fields for their comprehensive properties which cannot be fulfilled by unilaminar metals [1–3]. Stainless steel (SS)/aluminum clad sheet is one of these because of its excellent heat conductivity, corrosion resistance, mechanical properties as well as low density [4,5]. Unlike rolling, the widely used method to produce SS/Al clad sheet at present [6,7], twin-roll casting (TRC) can produce sheet directly from melt and has superiorities such as shorter routines and lower capital investment and operational costs as a result [8]. Moreover, the short solid/semisolid contacting of Al melt and steel in TRC results in a stronger bond than in rolling bonded sheets [9].

During TRC of clad sheet, process parameters such as pouring temperature and casting speed decide both casting stability and bonding strength of the sheet. Hagaa and Suzuki [10] investigated two kinds of TRC process for clad sheet, which were based on the so-called melt drag caster. In the first method, two nozzles were attached to a single roll to form base and cladding metals respectively. Melt head in the nozzle controlled the cladding thickness and could not be too high, to avoid melt leakage at the seam between

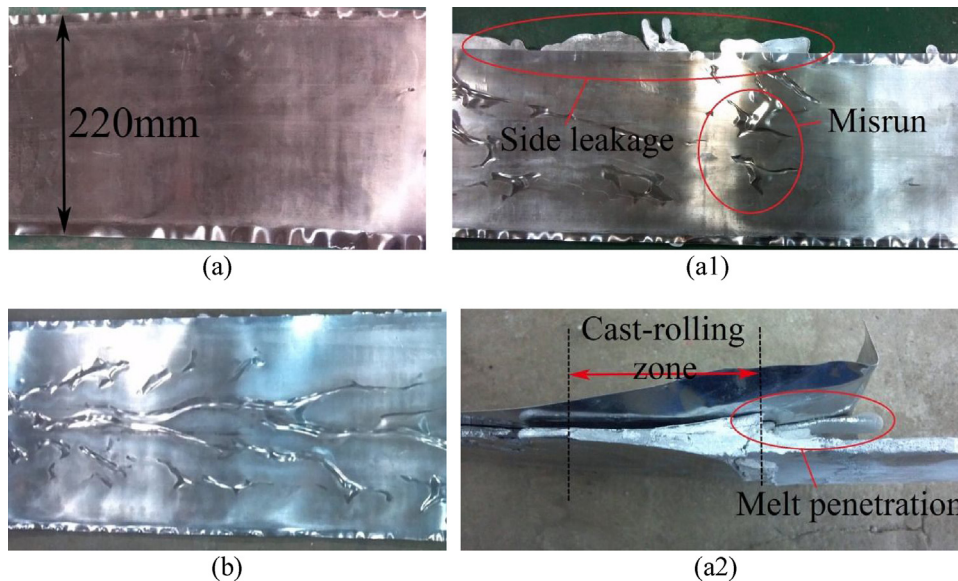
nozzle and base metal. In the second method, two vertically set rolls were used and the clad sheet was horizontally cast. Cladding metal could not bond to base metal when cooling distance was 150 mm and cladding melt temperature was 600 °C and could when the two values were smaller than 100 mm and 600 °C respectively. When casting speed was higher than 20 m/min, the two metals couldn't bond to each other. Hagaa and Takahashi [11] studied the process for a composite strip on a twin-roll caster. Steel core with different diameters was used and the inserting of the core didn't affect the process stability. The composite was with a good steel/aluminum interface. Grydin et al. [9] experimentally produced a SS/pure Al clad sheet on a vertical twin-roll caster by inserting SS strip through the seam between roll surface and nozzle. Set-back distance and roll gap were set to 50 mm and 2.3 mm respectively. The clad sheet had high bonding strength when melt temperature inside the nozzle and casting speed were 685 °C and 3.25 m/min respectively. Bae et al. [12] investigated the TRC process for an Mg/Al clad sheet on a horizontal twin-roll caster. Al strips were inserted through the seams between nozzle and surface of upper and lower rolls. Casting parameters such as melt temperature and casting speed were not shown in the work. Chen et al. [13,14] investigated horizontal TRC process of an SS/Al clad sheet by experiment and simulation. The effects of pouring temperature, casting speed and roughness of steel strip surface on process stability and bonding strength were studied. Two kinds of sheet defects: steel surface wrinkles and misrun are found when the combination of casting speed and pour-

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**Fig. 1.** Schematic diagram of twin-roll casting of clad sheet and solid/semi-solid contact under different melt pressure in nozzle: 1-Pinch roll; 2-SS409L strip; 3-Upper roll; 4-AA1100 melt; 5-Sluice; 6-Nozzle; 7-Lower roll; 8, 10-Cooling water; 9-Clad sheet; H-Pressure head; d-Channel width; h-Channel length.



**Fig. 2.** Clad sheets under different melt pressure in nozzle: (a) high melt pressure; (b) low melt pressure; (a1) side leakage and misrun in high pressure sheet; (a2) melt penetration in high pressure sheet.

ing temperature is not proper. Bonding strength of the clad sheet is decided by solid/semi-solid contacting time and rolling reduction and decreases after the steel strip surface is brushed. The best casting speed and pouring temperature are 1.25 m/min and 700 °C respectively.

During TRC, besides casting speed and pouring temperature, another parameter that has great effect on process stability is melt pressure in cast-rolling zone [15]. The contacting condition of melt and cladding strip may also be changed by the alternation and volatility of melt pressure. Moreover, casting speed, melt temperature and melt pressure are highly interconnected with each other. That means the sheet defects caused by improper casting speed and melt temperature may be avoided by adjusting melt pressure, as it is shown in our previous work [14] that the highest bonding strength was not attained under the parameters for good sheet shape. As a result, the bonding strength might be further improved. In this paper, we studied the effect of melt pressure in cast-rolling zone on process stability and bonding strength of a horizontal TRC

SS/Al clad sheet. The paper aims at providing more information for the successful control of the technology.

## 2. Experimental

The cladding TRC process was carried out on a horizontal twin-roll caster that has two rolls 500 mm in diameter and 500 mm wide. The roll is made up of a roll shell and a core with many grooves on its surface for cooling water. A refractory nozzle was used to direct AA1100 melt (composition in wt% was Al- 0.47Si- 0.26Fe) into roll gap. Stainless steel 409L (composition in wt% was Fe- 11.87Cr- 1.15Si- 0.21Al- 0.13Ti- 0.13Mg- 0.13Ni) strip 0.25 mm in thickness was used as cladding strip and inserted through the seam between upper roll surface and the nozzle. To make the strip contact tightly with upper roll surface, a home-made pinch roll was used to exert tension on it. The schematic diagram of the equipment is shown in Fig. 1. Temperature of AA1100 melt in the nozzle (pouring temperature) and casting speed were 700 °C and 1.25 m/min,

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