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The preparation and property research of the stainless steel/iron scrap clad plate

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ABSTRACT

As an attempt to recycle iron scraps, a new method is proposed to produce stainless steel clad plate by hot rolling. Iron scraps (Q195) were cold pressed into stainless steel pipe (304), and were subsequently hot rolled to produce composite clad plates at 1250 °C. Experiments showed that the iron scraps could be compressed into solid steel and joined well with the outer stainless steel surface using the proposed method. The shear strength of the bimetallic interface formed is about 273 MPa after seven pass rolling. The clad plates produced show good bending ductility. Element diffusion occurred at the interface during the hot rolling processes. The peak hardness appears in the vicinity of the interface due to the severe plastic deformation under high temperature and pressure during the rolling processes.

1. Introduction

Recycling of metals, especially iron and steel, is the most important technologies for material circulation because of their large consumption as described in Chino et al. (2002). Nowadays, remelting is the widely used method for iron scrap recycle, for example, in Japan, about 40 million tons of iron scraps were recycled by remelting per year as described by Chino et al. (2004); however, during the remelting process of iron scraps, lots of iron scraps are lost due to oxidation. The remelting processes also lead to increase of energy consumption, high costs of labors and severe issues for environmental protection. Therefore, better ways should be found to recycle the iron scraps.

Through searching the relevant literatures, solid-state recycling was found to be a possible way for direct recycling. Several fundamental techniques have been developed for solid-state recycling. Gronostajski and Matuszak (1999) studied the recycle of aluminum and its alloys chips by plastic deformation. Gronostajski et al. (2000) demonstrated that cold pre-compacting and hot extrusion could be applied to the production of composite materials with aluminum chips. But the chips have to be transformed into powder by milling in these recycling processes as discussed in Fogagnolo et al. (2003). Cui et al. (2011) demonstrated that cyclic extrusion compression could be used to direct recycle the aluminum chips. Currently the solid-state recycling technology has been extensively used to recycle soft metals; however, there are few applications for recycling iron scraps.

Stainless steel clad plates have been widely used in many fields due to their excellent mechanical and corrosion resistance properties. Hot rolling is a commonly used process to manufacture clad plate as described in Peng et al. (1999). In spite of the favorable effects of hot rolling on commercial and good productivity of clad plates, using this technology to recycle iron scraps has not been paid much attention by investigators. The main goal of this paper is to fill the gap in this field.

Some researchers have been studied the microstructures and mechanical properties of clad plates. Ding et al. (2011) studied the interface characterization of hot-rolled stainless/carbon steel clad. Xie et al. (2011a) discussed the microstructure and properties of stainless steel clad plate produced by vacuum rolling cladding. However, there are little data available describing the bonding behavior at the interface between stainless steel and iron scraps. In this paper, a new method to produce stainless steel/iron scrap clad plates through hot rolling was proposed, and the interface bonding property between stainless steel and iron scraps has been experimentally investigated. The billet preparation and hot rolling process of the stainless steel/iron scrap clad plate were introduced first, and then the tests of bonding strength of the bimetal interface and the bending property of the clad plates were discussed. Finally, the microstructures, element diffusion and micro-hardness close to the bonding interface of the clad plate were investigated.

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Table 1
Composition of test materials.

Material	Composition, mass fraction, %				
	Cr	Ni	Mn	C	Fe
304 stainless steel	18–20	8–9	0.75	0.08	Bal.
Q195 iron chips	–	–	0.25–0.50	0.06–0.12	Bal.

2. Material preparation and experimental procedure

The billet was made up of type 304 stainless steel pipe and Q195 iron scraps. The composition of the test materials is summarized in Table 1. The outer diameter, wall thickness and length of the stainless steel pipe were 20 mm, 2 mm and 170 mm. In order to remove the oxide and other impurities, the inner wall of the stainless steel pipe was cleaned briefly using sandpaper. This process could also increase surface roughness and make the fresh metal exposed, which was beneficial for the bonding of the two metals. A 10 mm deep cross-shaped groove was cut at both ends of the stainless pipe for the seal welding. The iron scraps used were the by-products from the process of tapping. Fig. 1 shows the external appearance of the iron scraps. The average thickness, width and length of the iron scraps are 0.2 mm, 1 mm and 6 mm, respectively. The iron scraps were initially cold pressed into the stainless steel pipe at a pressure of about 741.5 MPa, see Fig. 2. This pressure can produce compacted iron scraps with a density of about 6.27 g/cm^3. To prevent oxidation of the scraps during heating, moderate amount of graphite powder was added at the two ends of the compacted iron scraps. Fig. 3 shows the finished billet. The average length of the billet was 150 mm.

In the experiment, a rolling mill with a roller diameter of 200 mm was used to carry out the rolling process to produce the clad plate. The roll speed was 0.1 rev/s. The billets were heated in a muffle furnace at the temperature of 1250 °C for 30 min. A total of seven rolling passes were used to produce the final clad plate. The amounts of thickness reduction for each pass were 4 mm, 4 mm, 3 mm, 3 mm, 2 mm, 1 mm, and 1 mm, respectively. After each rolling pass, the specimens were kept in the furnace for 5 min for temperature preservation. One workpiece was reserved after each pass, and cooled in air for later experiments.

The sizes and morphology of the workpiece cross-sections are shown in Fig. 4. A 4% nitric acid alcohol solution was used for etching of the iron scrap side. It is easy to distinguish the interface between the two metals because the etching exposed the microstructures of the iron scrap side while the stainless steel side had no change after the treatment. It can be observed that the distribution of the stainless steel layer was uniform and the iron scraps filled the internal space of the stainless steel pipe, and the two metals were combined tightly without any cracks. This showed that the workpieces were uniformly pressed during the rolling processes. The iron scraps are non-continuous medium with good flowability. Under the pressure of the rollers, the iron scraps flow and fill the whole internal space of the stainless steel pipe.

The shear strength and the bonding rate of the two metals are the two basic parameters to measure the property of the clad plate as described in Gou (1995). Fig. 5 shows the tensile

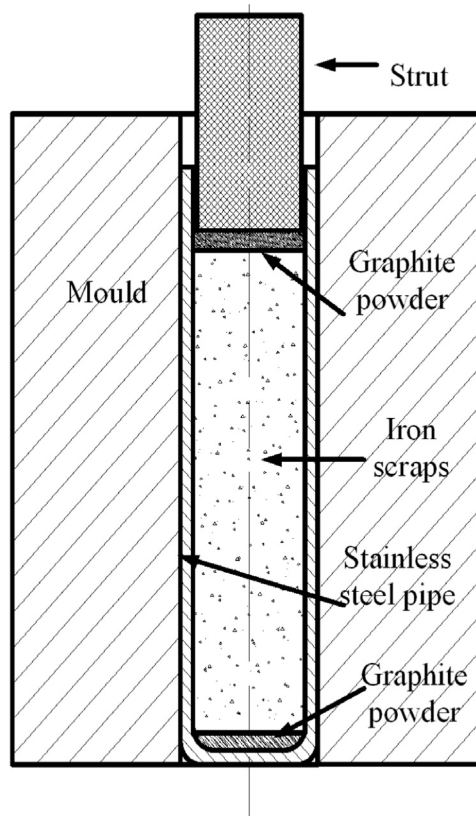

Fig. 2. Schematic diagram of billet preparation.

Fig. 1. External appearance of the iron scraps.

Fig. 3. Photograph of the finished billet.