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Corrosion Resistant Clad Steels†

1. Introduction

Clad steels are composite steel plates in which a cladding material such as stainless steel, nickel alloy, etc. is bonded to one or both sides of a carbon steel or low alloy steel plate (base material). Clad products have outstanding features, as they simultaneously possess the strength necessary in structural members (base material part), combined with corrosion resistance and other functions (cladding material part), and are also economical in comparison with manufacturing a plate consisting of the same material as the cladding material to the base material part. For these reasons, clad steels have been used in various industrial fields, mainly in the shipbuilding, pressure vessels, and energy fields. Against the background of an increasing number of resource development projects in harsh corrosion environments, demand for high corrosion resistance clad steels has increased in recent years. This report presents an overview of corrosion resistant clad steels manufactured by JFE Steel.

2. JFE Steel Corrosion Resistant Clad Steels

2.1 Manufacturing Process of Corrosion Resistant Clad Steel

Clad steels are categorized into roll bonded clad steels, explosion bonded clad steels, overlaid clad steels, from the viewpoint of manufacturing process. JFE Steel manufactures roll bonded clad steels at its West Japan Works (Fukuyama) Steel Plate Mill, which has one of the world's most powerful rolling mills (Maximum rolling load: 9 000 tons). **Figure 1** shows the production flow. As features of roll bonded clad steels, it is possible to manufacture wide and long plates, and products have good flatness and thickness accuracy. It is also possible to apply thermo-mechanical control process (TMCP), which is a steel plate toughening technology continuously developed by JFE Steel over many years. **Figure 2** shows a schematic diagram of TMCP in comparison with the conventional rolling process. In TMCP, toughening can be achieved without sacrificing the weldability of the base material, and as described below, the corrosion resistance of the cladding material can be secured by accelerated cooling.

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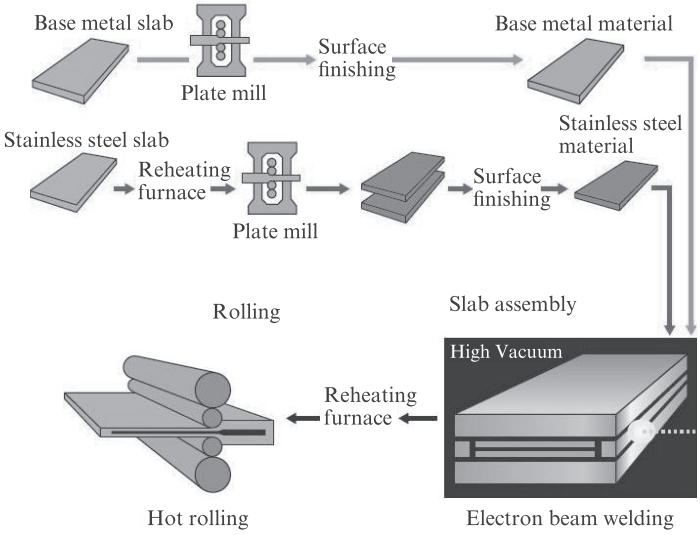

Fig. 1 Schematic illustration of roll cladding process

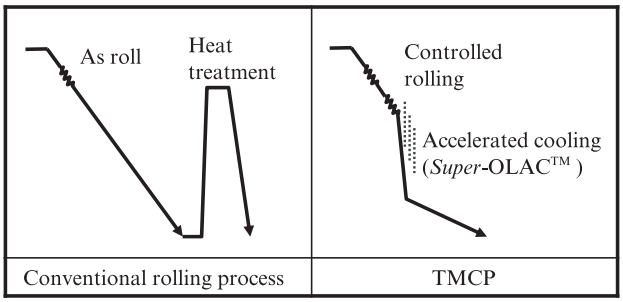

Fig. 2 Conventional rolling process and thermo-mechanical control process (TMCP)

2.2 Stainless Clad Steels

JFE Steel has a production record that includes many stainless clad steels for chemical tankers, reactors for various types of plants, and corrosion resistant alloy (CRA) clad pipes. Stainless clad steels using the Ni-Cr-based stainless steels SUS304, SUS304L, SUS316, and SUS316L and the Cr-based stainless steels SUS410S and SUS410L in the cladding material, and JIS standard (JIS: Japanese Industrial Standards), ASTM standard (ASTM: ASTM International), ASME standard (ASME: American Society of Mechanical Engineers), and API standard (API: American Petroleum Institute) steel grades in the base material are typical products.

Figure 3 shows the effects of the TMCP manufacturing factors, namely, final pass temperature and cooling rate after rolling, on the intergranular corrosion resistance (JIS G 0571: Oxalic Acid Etching Test) of SUS304

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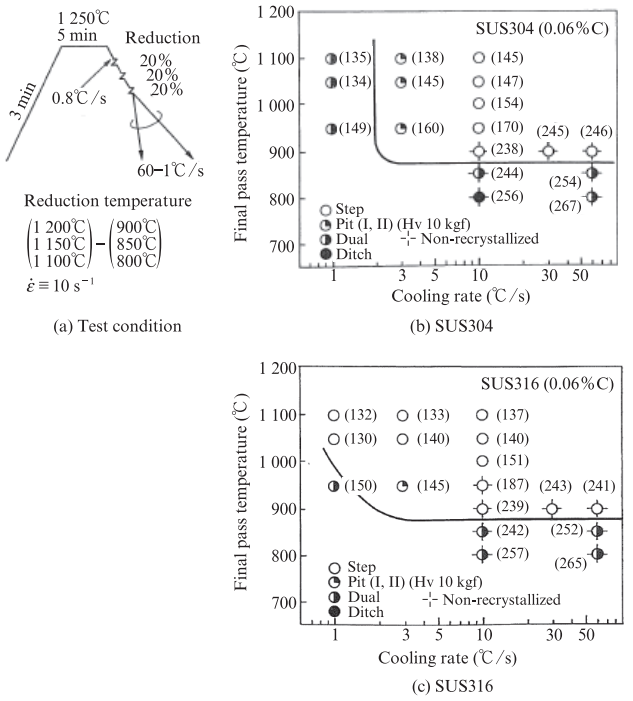

Fig. 3 Effects of cooling rate and final pass temperature on microstructure, hardness and carbide precipitation[1)]

and SUS316. The values in the figure are Vickers hardness. It is known that carbide precipitation in the cladding material during cooling can be suppressed by accelerated cooling after rolling, and satisfactory corrosion resistance can be obtained even without solution treatment[1)]. In 2012, JFE Steel manufactured 2 400 tons of mother plates for 316L clad pipes with API 5L X65 base material by applying TMCP.

Seawater environments could cause pitting corrosion and crevice corrosion in the above-mentioned conventional stainless steels. To date, many types of steel have been developed as seawater resistant stainless steels, but deterioration of corrosion resistance when these steels were used as cladding materials for clad steels had been an issue. JFE Steel originally developed a seawater resistant stainless steel, JSL310Mo, for cladding material use, and realized excellent hot deformability and corrosion resistance on the same level as solution treated materials by optimizing the Ni content and adding a small amount of B in a 25%Cr-4.5%Mo-0.2%N base composition system[2)]. In 2006, stainless clad steel using JSL310Mo as the cladding material was adopted in the waterline area of the new Atlantic research boat "SHIRASE," as illustrated schematically in **Fig. 4**[3)]. Based on the outstanding corrosion resistance of this material, large demand is expected in the future in applications such as icebreakers, steel structures for marine environments, seawater desalination plants, etc.

2.3 Nickel Alloy Clad Steels

JIS H 4551 NW440 (Nickel-copper alloy plate), as

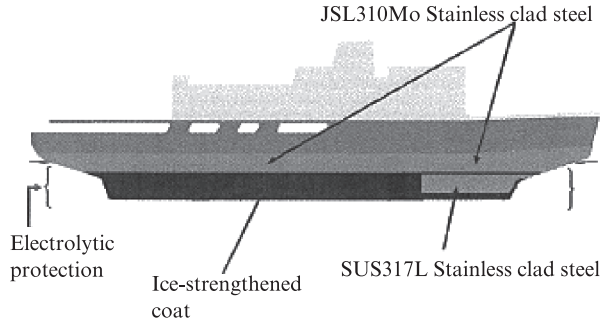

Fig. 4 Applied area of JSL310Mo stainless clad steel for the new icebreaker "SHIRASE"[3)]

well as foreign standards such as ASTM B443 UNS N06625 (Alloy 625) are available as cladding materials for nickel alloy clad steels. Many types of steel are to be used as the base material, as shown in JIS G 3602 (Nickel and nickel alloy clad steels). These nickel alloy clad steels are used in petroleum and gas production and refining plants, line pipes, etc. with products that have high Cl^- concentrations and contain corrosive gases such as H_2S, CO_2 gas, etc. JFE Steel has confirmed that excellent corrosion resistance on the same level as solution treated materials can be secured in both normalizing type clad steels and TMCP type clad steels by reducing the C content of the nickel alloy[4)]. Based on the fundamental research work, JFE Steel has successfully manufactured 3 000 tons of ASTM B424 UNS N08825 (Alloy 825)/API 5L X65 clad pipes by applying TMCP[5)]. Development of new oil and gas fields with harsh condition such as sour environments is increasing and attracting great attention. Consequently, large market growth of nickel alloy clad steel is expected in the future.

3. Conclusion

JFE Steel currently has a corrosion resistant clad steel production capacity of 2 000–3 000 tons per month. Utilization of TMCP technology is one of the strengths of JFE Steel in the manufacture of clad steels. JFE Steel will try to improve quality and cost performance more and more, and will produce and market corrosion resistant clad steels to increase customers satisfaction.

References

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