New Products & Technologies

New Skid Buttons with Ceramic Composite Metal for Slab Reheating Furnace*

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1 Introduction

In stocks (slabs) heated in a slab reheating furnace, insufficiently heated spots called skid marks occur where the slab is in actual contact with the skid buttons. These skid marks caused reduced width and thickness dimensional accuracy after rolling and have a markedly negative effect on quality. Furthermore, since these all portions of the material, including these areas, must attain a specified temperature, the entire slab must be heated to above the target temperature. For this reason, skid marks also pose an energy-consumption problem.

Conventional skid buttons of cobalt-based heat-resistant cast steel have low high-temperature strength and are apt to deform under compressive loading after a short period of service. Skid marks increase as this deformation becomes greater. To solve these problems and reduce skid marks, Kawasaki Steel developed a new heat resistant, high strength ceramic composite metal and applied this material to skid buttons of greatly increased height. This paper presents an outline of the new ceramic composite metal skid button, which has been commercialized following joint development with Kubota, Ltd.

2 Characteristics Required of Skid Buttons

The layout of a typical hot strip mill is shown schematically in **Fig. 1**. A slab reheating furnace heats and soaks slabs cast by the continuous caster to temperatures suitable for downstream hot rolling. As shown in **Fig. 2**, skid buttons are installed on the water-cooled skid beams in a walking-beam reheating furnace; they support slabs in a furnace atmosphere of 1 200 to 1 300°C. The skid buttons are cooled by the water-cooled skid beams, which produces local cooling of the underside of a slab where it is in contact with the skid buttons. To minimize such cooling, the height of the skid button is increased. With the conventional heat-resistant cast steel, however, insufficient high-temperature strength limits the maximum possible skid button height to 120 mm.

The application of sintered fine ceramics combining high-temperature strength and heat-insulation characteristics has also been attempted. These materials, while adequate in strength, may crack or break under repeated mechanical loading, a problem attributable to the

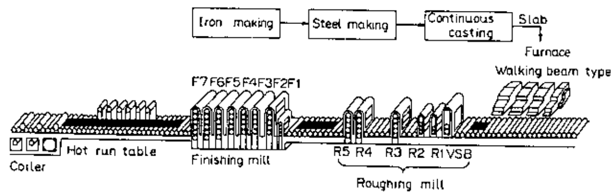

Fig. 1 Layout of hot strip mill

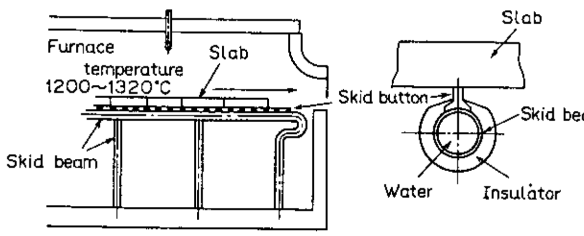

Fig. 2 Schematic view of heating furnace

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insufficient toughness of the ceramic material. Accordingly, a satisfactory skid buttons would combine the toughness of metal and the strength of ceramics.

3 Research into Ceramic Composite Metals

3.1 Material Design

Particle-strengthened alloys made by combining ceramics and cobalt-based heat-resistant alloys are considered cermets according to the classification of composite materials. Carbide-bearing ceramics were selected for use in skid buttons in consideration of the area of reaction interface with metal, specific gravity, thermal expansion coefficient, and corrosion resistance in an oxidizing atmosphere of about 1 300°C. Cobalt alloys (Co-Cr-Fe) were selected in view of their oxidation properties at high temperature, high-temperature strength, and granulatability of powder. Composite ceramic ratios of 10 to 90% were then evaluated. It was found that strength is insufficient at ratios below 30%, while there were toughness problems at ratios above 70%, indicating a suitable ratio range of 30% to 70%.

3.2 Method of Fabrication

As shown in **Fig. 3**, ceramic composites are manufactured by using an inert-gas shielded arc to melt a composite rod in the form of a metallic tube filled with mixed and granulated powders of ceramics and metals with the base metal. This process produces a deposited ceramic composite metal. The conventional method of fabricating skid buttons involved the very difficult process of depositing a composite material containing ceramics in multiple layers. However, good quality and properties became possible with development of a new method of fabrication which adopts heat control from preheating to postweld heating. In addition, the shielded arc welding process is used in this method, and feeding of the composite rod is automated.

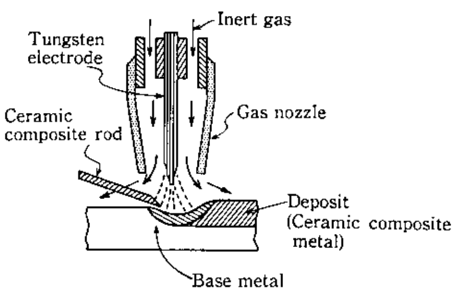

Fig. 3 Welding procedure of ceramic composite metal

3.3 Material Characteristics

A comparison of the material characteristics[1] of a composite metal containing 50% ceramics and the conventional metal is shown in **Table 1** and **Fig. 4**. The ceramic composite metal provides much better compressive strength and oxidation resistance at high temperatures than the conventional metal. The toughness of the ceramic composite metal was very low due to the presence of ceramic material. However, when cracking resistance under repeated mechanical impact loads was evaluated using an experimental apparatus which simulated the service environment of a reheating furnace, it was ascertained that the ceramic composite metal posed no problem for practical application. This ceramic composite metal makes possible design of skid buttons with greatly increased height because of its high compressive strength at high temperatures, one of the important

Table 1 Comparison of material characteristics between conventional and ceramic composite metal

		Conventional metal	Ceramic composite metal
Chemical composition (wt. %)		Cobalt alloy (<0.15% C, 27.0 Cr, 40.0 Co, 17.0 Ni)	Cobalt alloy + Ceramics
Compressive strength (kg/mm²)	1 000°C	0.37	0.60
	1 200°C	0.12	0.25
	1 300°C	0.05	0.21
Oxidation resistance (mm/year)	1 000°C	0.12	0
	1 100°C	0.21	0.10
	1 200°C	0.70	0.26
Impact value (kg·cm/cm²)	RT	100	22
	1 000°C	210	25

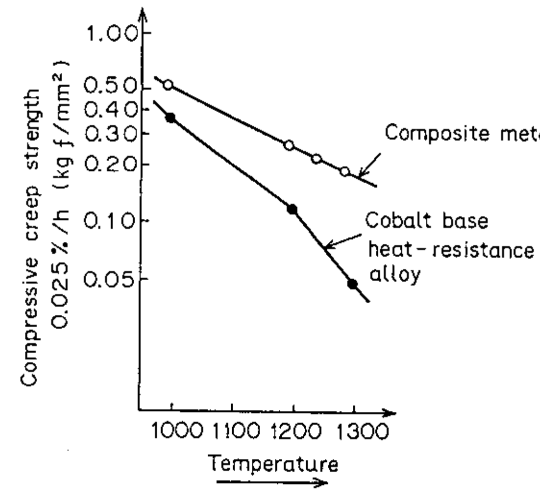

Fig. 4 Comparison of compression strength between original and composite material

characteristics required of skid buttons.

Main features of the new ceramic composite metal are:

(1) Compressive strength at high temperature is two to three times that of conventional metal.
(2) Oxidation resistance at high temperatures is two to three times that of conventional metal.
(3) The ceramic composite metal, which has a coefficient of thermal conductivity of about 60%, is an excellent heat-insulation material.
(4) Although it shows impact values as low as 1/8 those of the conventional metal, the ceramic composite metal poses no problem in terms of cracking resistance under impact loads at lifting and lowering speeds ordinarily used with walking beams.

4 Optimum Shape Design of New Skid Buttons[2)]

Minimal skid button width is desirable in order to reduce skid marks, although a surface area large enough to withstand the compressive loads which occur in service is necessary. Skid buttons must be capable of withstanding the kind of rapid cyclic thermal loading to which they are subject in an actual furnace, where rapid heating and cooling occur repeatedly.

In the present study, the relationship betwen button shape and the maximum principal stress generated in the button was analyzed by the finite element method to determine an optimum composite metal shape capable of withstanding both impact loads and thermal loads. Results of this analysis are shown in **Fig. 5**. It was found that the lower the width-to-length ratio, the higher the principal stress, and conversely. Principal stress had its minimum value when this ratio was 1.0. Based on these results rapid heating and cooling thermal cycles typical of actual furnace conditions were applied to buttons of various width-to-length ratios in experimental and actual furnaces, and the deformation of the buttons was observed. At width-to-length ratios of less than 0.34, the tops of the buttons yielded and deformed in a concave shape.

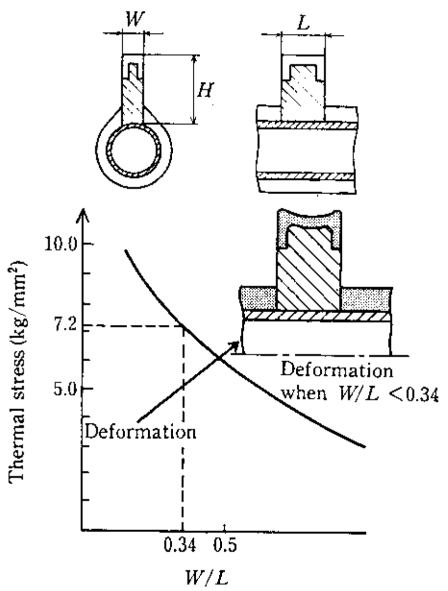

Fig. 5 Change in thermal stress obtained by FEM with the factor showing the shape of skid metal W/L

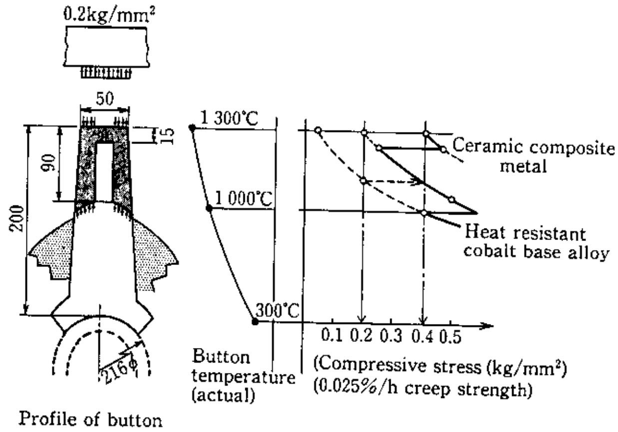

Fig. 6 Change in temperature and compressive stress with position on the new type button

In consideration of these results, the width-to-length ratio was set at 0.34 or more and the minimum possible button width in terms of the strength of the new heat-resistant material was adopted.

It was also necessary to design the new skid button so as to minimize cost. The relationship between the profile, temperature, and compressive strength of the button is shown in **Fig. 6**. By applying the ceramic composite metal to the periphery of the top and the top surface of the button of a conventional cobalt-based heat-resistant alloy, it was possible to ensure a compressive strength sufficient for the entire button. By minimizing consumption of the relatively more expensive ceramic composite metal, overall costs were minimized.

A comparison of the shape of the new and conventional skid buttons is shown in **Fig. 7**. **Photo 1** shows

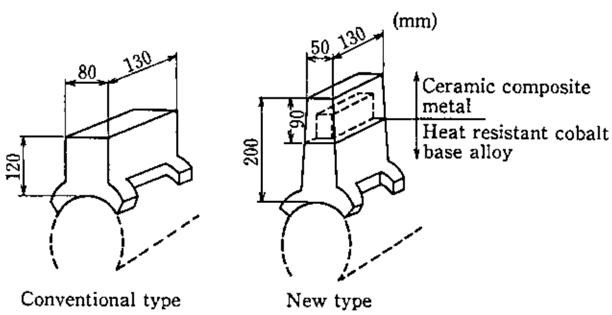

Fig. 7 Comparison of profiles between conventional and new type skid buttons

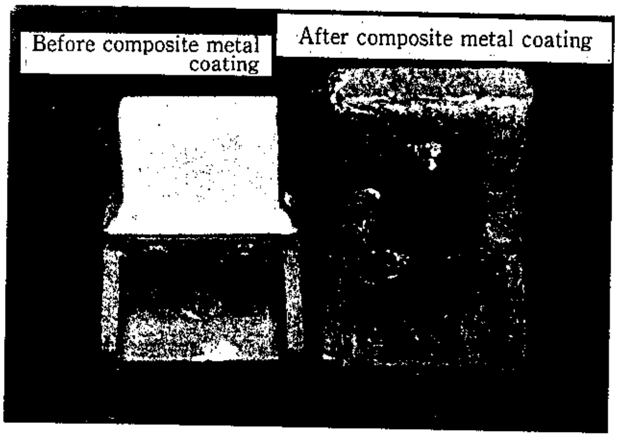

Photo 1 View of new skid button by ceramic composite metal

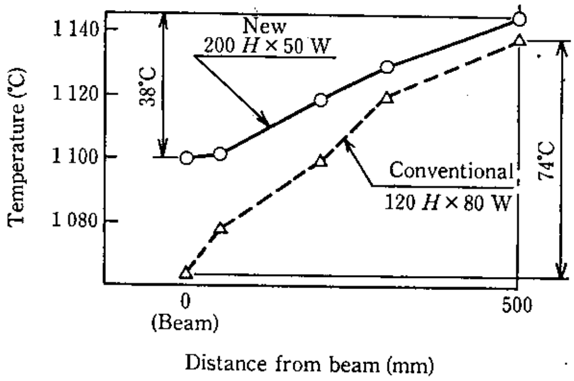

Fig. 9 Comparison of slab temperatures between conventional and new type skid button

the appearance of a skid button before and after the deposition of the ceramic composite metal.

5 Evaluation of Heat Transfer Characteristics[3)]

The experimental apparatus shown in **Fig. 8** was fabricated to determine the effect of skid button shape and the arrangement of the water-cooled beams on skid buttons. The likely heat transfer characteristics of the buttons in an actual furnace were also studied using this apparatus. Slabs with the thickness of actual slabs were used and PR thermocouples were embedded in both the buttons and the slabs to analyze the heat transfer characteristics of the buttons. In this experiment, the slabs were heated at the same rate as in an actual furnace. Results of temperature measurements of the underside of the slabs at the point of contact with the buttons are shown in **Fig. 9**. The temperature around the new skid buttons (height, 200 mm; width, 50 mm) increased faster than with the conventional buttons (height, 120 mm; width, 80 mm). The difference in the temperature for points immediately above the buttons and between the beams (500 mm distant from the beams) decreased by half during soaking.

The heat transfer coefficient and shadow coefficient of the skid buttons were quantitatively determined from this temperature curve. It was also possible to analyze heat transfer characteristics using the relationship between button height and width and skid marks.

6 Results of Application to Actual Furnace[4)]

A reheating furnace is provided with two types of beams: walking beams for lifting and transferring slabs, and fixed beams for supporting the transferred slabs. Usually eight to ten beams are installed in a reheating furnace. Skid marks are most apt to occur in the soaking zone, where the slab temperature is highest. Fixed beams, with which the duration of contact with the slabs is long, are the most serious cause of skid marks. Therefore, the new skid buttons were installed on the fixed beams in the soaking zone of one of the reheating furnaces at Mizushima Works. A description of this furnace is given in **Fig. 10**. About two years have elapsed since the reheating furnace went into service with the

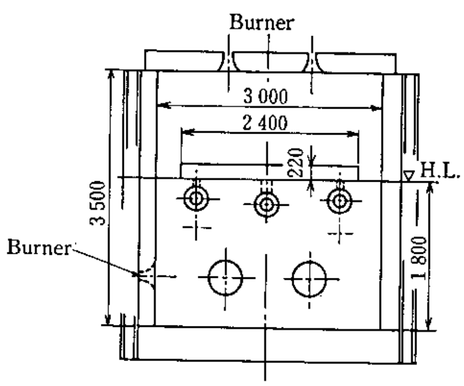

Fig. 8 Experimental device for measurement slab temperature

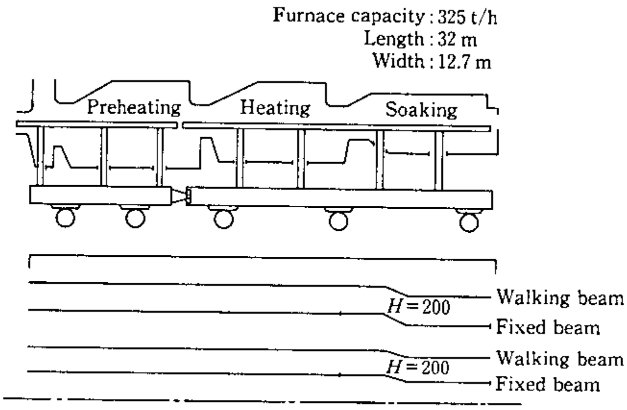

Fig. 10 Specifications and profile of reheating furnace of Mizushima hot strip mill

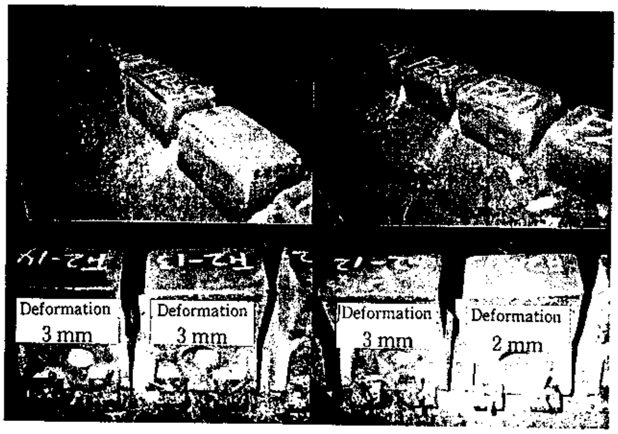

Photo 2 View of new button after 1.5 years of service (Value of creep deformation about 2~3 mm)

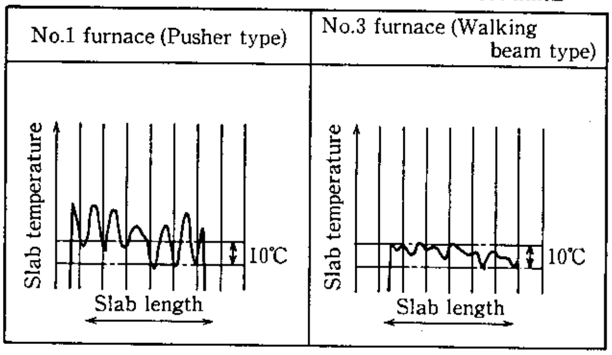

Fig. 12 Comparison of slab temperatures at the delivery roughing mill between pusher type and new walking beam type furnaces

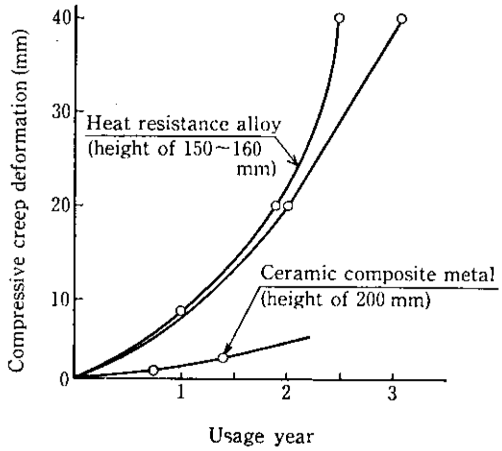

Fig. 11 Comparison of values of compressive creep deformation between heat resistant alloy and ceramic composite metal

new skid buttons. The condition of the new skid buttons after 1.5 years of service is shown in **Photo 2**. Cracks in the buttons were initially feared, but did not occur in any degree, and the amount of deformation of the buttons was very slight at 3.0 mm after 1.5 years of service. A comparison of values for compressive creep deformation in skid buttons of the conventional heat-resistant alloy and the new ceramic composite metal is shown in **Fig. 11**. It is apparent that the new material has sufficiently high resistance to compressive creep deformation.

An example of an investigation into skid marks after slab reheating, conducted with pyrometers installed on the delivery side of the roughing mill, is shown in **Fig. 12**. Skid marks were decreased by about half in the reheating furnace provided with the new skid buttons.

7 Concluding Remarks

The reduction of skid marks occurring in slab reheating can contribute greatly to the improvement of product quality, as well as to energy-saving. Skid buttons with an optimum shape, i.e., of narrow width and large height, for minimizing the local cooling problems caused by water-cooled skid beams are effective in reducing skid marks.

Conventional skid buttons of cobalt-based heat-resistant cast steel suffer deformation after a short period of service due to insufficient strength at high temperatures, and skid marks increase correspondingly.

To solve these problems, Kawasaki Steel developed a new type of skid button using ceramic composite metal. The new skid button is fabricated by the deposition of a ceramic composite metal combining the toughness of metal and the strength of ceramics over a heat-resistant alloy button which offers adequate compressive strength and certain cost advantages.

This new type of skid button makes possible a substantial increase in button height, and thus helps control cold-spotting and thereby reduce skid marks. As a result, the new skid button contributes to the qualitative improvement of rolled products, energy-saving in the reheating furnace, and a reduction in furnace maintenance costs.

References

1) K. Takagi, T. Naito, M. Obashi, N. Kawauchi, H. Hiraishi, and Y. Yamakami: *Tetsu-to-Hagané*, 71(1985)5, S342
2) K. Takagi, T. Naito, T. Inoue, M. Obashi, H. Hiraishi, and A. Shinosaki: *Tetsu-to-Hagané*, 73(1987)12, S1131
3) M. Obashi, K. Takagi, T. Inoue, T. Naito, Y. Shintaku, and S. Sakamoto: *Tetsu-to-Hagané*, 73(1987)12, S1130
4) M. Koide, T. Inoue, M. Obashi, O. Nakatani, K. Takagi, and T. Naito: *Tetsu-to-Hagané*, 73(1987)12, S1132