REPORT

Development of High Durability Basic Materials for Slide Valve Plate SVR-FB7, SVR-FB8

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Abstract

Although basic materials for slide valve (SV) plates used for corrosive steel grades have high corrosion resistance, they are vulnerable to repeated cycles of heating and cooling. Therefore, in many cases they are replaced after one charge of use. Therefore, we have developed new, high-durability basic material SVR-FB7 and SVR-FB8, that can be used repeatedly, by improving the weak points of basic materials. The newly developed materials have been used for multiple charges as ladle plates in steelworks with good results.

1. Introduction

Al_2O_3-C material is widely used for SV plates because of its well-balanced corrosion and spalling resistance. However, for Ca-treated steels and other corrosive steel grades, basic materials with high corrosion resistance are used[1]. However, while basic materials have high corrosion resistance, they have low spalling resistance and are basically replaced after a single use. In particular, SV plates for ladles are randomly used for various steel types, and the combination of Al_2O_3-C material, which can be used multiple times for general steel grades, and basic material, which can be used only once for corrosive steel grades, makes the SV plate replacement work irregular and frequent. This causes problems such as an increase in the amount of refractory material discarded and an increase in the replacement workload. If the basic material could be used multiple times, the SV plates would not need to be replaced according to the steel grade, and these problems could be solved.

Our product, SVR-PB50, a MgO-C material, has been used as a ladle SV plate and TD SV plate. However, it has not been possible to use it for multiple times. We focused on damage after use and developed a basic material that can be used multiple times by improving its weak points.

2. Damage Types of Basic SV Plate

2. 1 Crack damage

The most characteristic damage in basic SV plates is crack damage. Cracks in basic SV plates are caused by thermal spall due to the high thermal expansion of the main material, magnesia. If the brick material also contains alumina, the volume expansion of the alumina reacting with magnesia forming secondary spinel at high temperatures can also be a factor in structural spalling.

2. 2 Sticking and peeling damage on sliding surfaces

Sticking and peeling damage is a phenomenon

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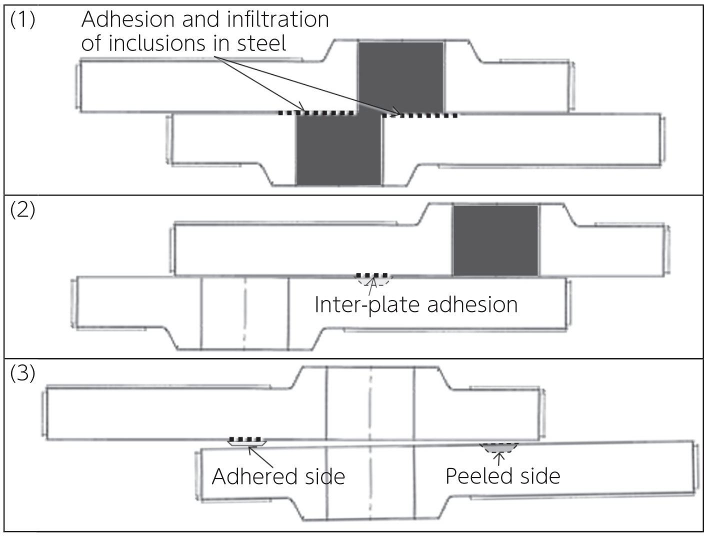


Fig. 1 Process of damage to sliding surfaces due to surface peeling followed by inter-plate adhesion.

in which sticking occurs between facing SV plate surfaces and the sliding surfaces are damaged by peeling of the stuck refractory surfaces during sliding [2]. A typical occurrence of sticking and peeling damage is described below.

(1) During casting (SV position: half open, Fig. 1(1)).
The opening of the SV is throttled for flow control. At this time, inclusions in the steel come into contact with the exposed sliding surfaces. A small amount of steel inclusions physically or chemically adhere to or infiltrate the sliding surface.

(2) Finished casting (SV position: closed, Fig. 1(2)).
The SV plates are moved to the maintenance area in a closed state. As the temperature decreases with time, the adhered inclusions solidify and stick between the SV plate surfaces.

(3) Under maintenance (SV position: Fully open, Fig. 1(3)).
In the maintenance area, the SV plate is slid around for oxygen cleaning and inspection. During sliding, if the refractory surface peels off at the stuck part, damage will increase (i.e., sticking and peeling damage).

Sticking is thought to occur as the temperature around the refractory decreases after casting is finished. Since it does not occur during casting, when the temperature keeps high, it does not affect flow control during continuous use. However, if sticking and peeling damage occur in SV plates at lower temperatures, the resulting unevenness of the sliding surfaces can lead to metal withdrawal and inter-face air suction. Such temperature drop occurs between charges for ladle SV plates and during reuse for TD SV plates. Sticking and peeling damage to SV plates often occurs in corrosive steel grades such as Ca-treated steel, and basic materials with high corrosion resistance are no exception.

2. 3 Wear damage on outer periphery of sliding surfaces

In an SV system with multiple SV plates, friction occurs on the sliding surfaces of the SV plates because the SV plates are frequently slid with loads applied from above and below. Therefore, if the strength of the sliding surfaces is low, wear damage will occur. The wear damage focused on in this report occurs on the periphery of the sliding surfaces and is different from the wear damage around the inner hole that is in contact with the molten steel. This type of damage occurs in materials with resin bonds or undeveloped carbon bonds in the microstructure, such as non-fired or low-temperature-fired materials[3, 4], and can also occur in materials other than basic materials.

Fig. 2 shows the areas where peripheral wear damage is likely to occur. This area is located away from the inner bore through which molten steel passes and does not reach high temperatures (>1000 ℃). However, as shown in Fig. 3, these areas coincide with the area where the sliding surfaces are exposed to air for a long time during or after casting, suggesting that oxidation of the sliding surfaces at low temperatures (<800 ℃) contributes to wear damage.

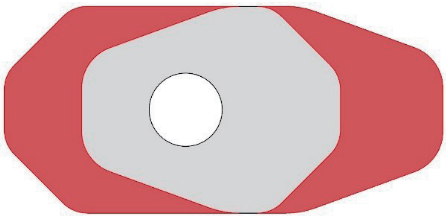


Fig. 2 Peripheral area of wear may occur as shown in red.

3. Damage Countermeasures

3. 1 Improvement in spalling resistance

MgO-C material, which has the highest corrosion

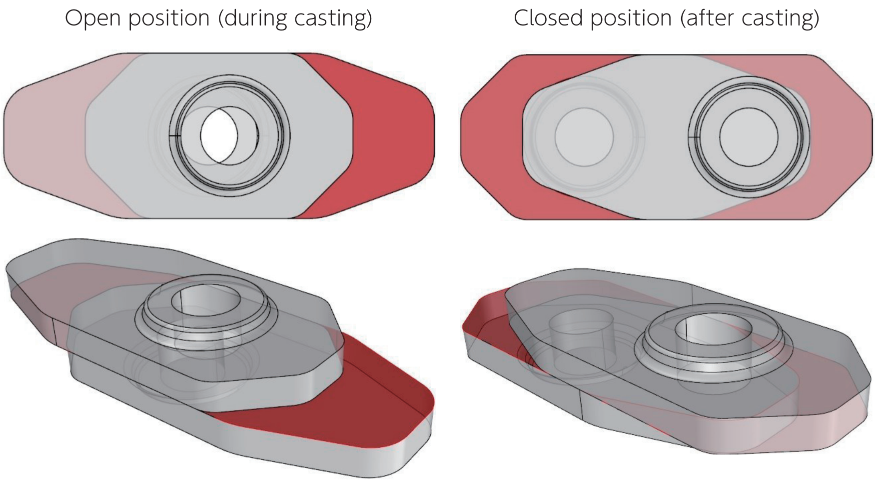
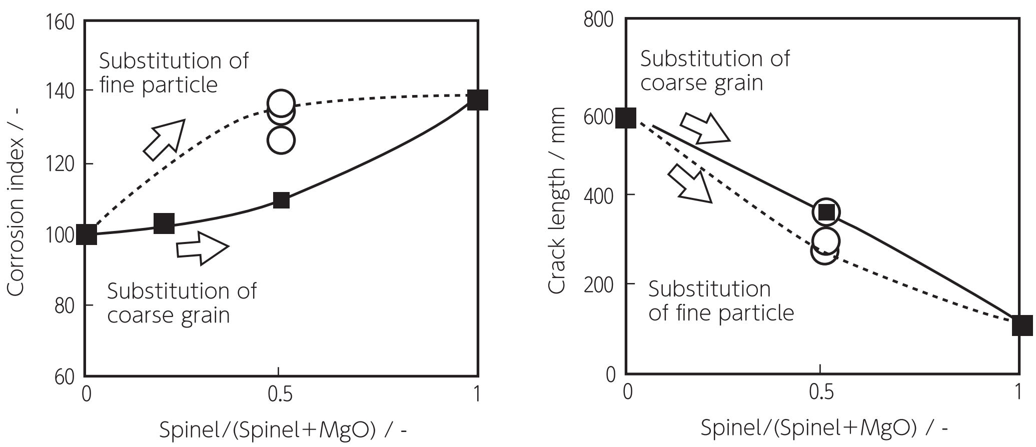


Fig. 3 Area of sliding surface exposed to the air shown in red.



Method: 1650 ℃×5 h,
Slag: $CaO:Al_2O_3:FeO$=35:35:30.

Method: Dipping specimen in molten pig iron.
Evaluation: summation of total crack length.

Fig. 4 Comprehensive diagram of influences of grain size and fraction of spinel on corrosion and spalling resistance evaluation results[5].

resistance among basic materials, has high corrosion resistance against CaO and FeO, but its thermal expansion coefficient is high and its thermal spalling resistance is very low. Therefore, we investigated the improvement of thermal spalling resistance by replacing a part of magnesia with spinel to make MgO-Spinel-C materials.

Spinel has lower thermal expansion than magnesia and, unlike alumina, does not expand in volume due to secondary spinel formation. It also has higher corrosion resistance than alumina. Although the corrosion resistance of spinel is inferior to that of magnesia, the use of spinel on the coarse-grained side minimizes the degradation of corrosion resistance and improves the thermal spalling resistance (Fig. 4).

3. 2 Improvement in resistance to sticking and peeling damage

When inclusions in steel, mainly $CaO-Al_2O_3$ liquid-phase oxides, adhere to sliding surfaces, they infiltrate into the refractory structure by creating a low-melting-point liquid phase between the refractory and the inclusions, causing sticking and peeling damage. Therefore, it is effective to use non-oxide materials that do not easily get wetted by the liquid oxide as a method to suppress sticking and peeling damage. Therefore, we investigated the effect of carbon materials on sticking and peeling damage resistance based on MgO-Spinel-C material.

We compared materials in which carbon material A added to the base material was completely replaced by carbon materials B, C, and D with different characteristics, and materials in which both carbon materials A and D were added. Evaluation of sticking and peeling damage resistance was performed as shown in Fig. 5. The shear load simulates the force applied during sliding of the SV plate. The lower the shear strength between specimens bonded by slag, and the smoother the fracture surface after the shear test, the higher the sticking and peeling damage resistance.

The test results are shown in Figs. 6 and 7. Among the carbon-substituted materials, the shear strength of the specimen with carbon material D was the lowest, and the specimen with carbon materials A and D simultaneously showed even lower shear strength. The specimen with carbon material A showed a peeling of the refractory surface on the fracture surface after the shear test, whereas the specimen with carbon materials A and D did not show any peeling.

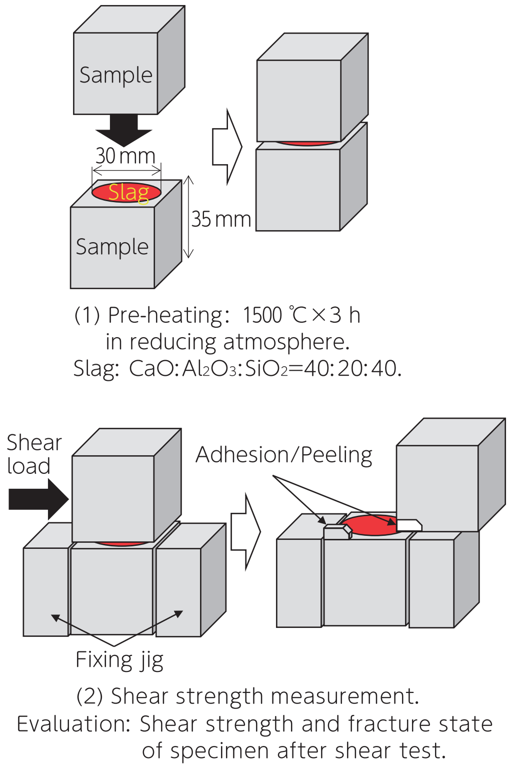


Fig. 5 Evaluation method for the resistance of adhesion and peeling damage.

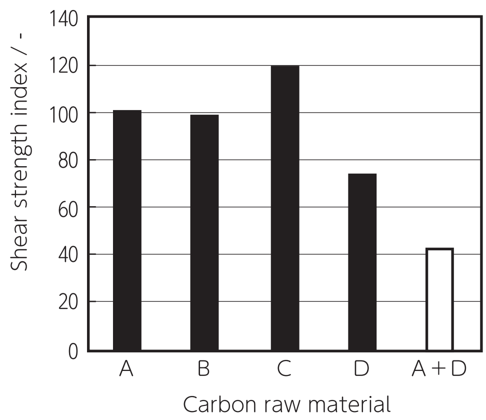


Fig. 6 Shear strength index of specimens bonded with slag as an adhesive.

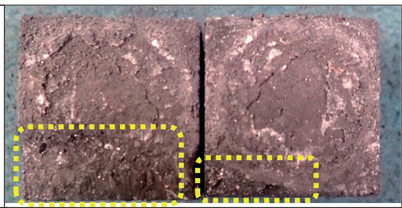
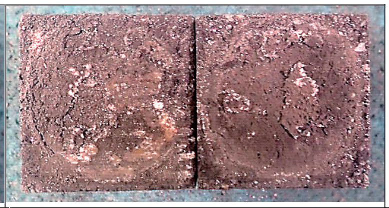
Fracture surface		
Carbon raw materials	A	A+D

Fig. 7 Fracture surface after the shear test.

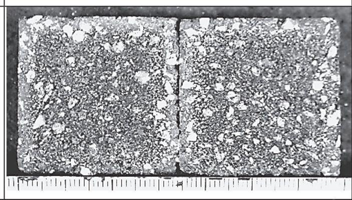
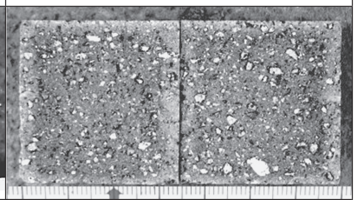
Material	Conventional	Developed
Cut section		
Oxidation depth index / -	100	71
C.C.S. index after oxidation / -	100	124

Fig. 8 Result of oxidation test at 600 ℃ × 3 h in air.

3. 3 *Improvement in wear resistance*

To reduce peripheral wear damage, improvement of oxidation resistance in the low-temperature range was investigated. Major antioxidants such as Al, Si, and B_4C are not sufficiently effective at low temperatures below 600 ℃ [6]. Therefore, as countermeasures the following were investigated:

- Reduction of air permeability by optimization of particle size distribution.
- Strengthening of metal bond after firing by increasing the amount and fineness of metal additives.

The oxidation resistance was evaluated by the thickness of the oxide layer after heating at 600 ℃ for 3 hours in air and the compressive strength after oxidation. The test results are shown in Fig. 8. Compared to the conventional material, the thickness of the oxide layer of the developed product was reduced by 29 % and the compressive strength after oxidation was improved by 24 %.

3. 4 *Developed materials*

Table 1 shows the quality of the materials we developed based on our investigation results. SVR-PB50 is our conventional basic material, which can be used once without any problem, but it is not suitable for multiple uses because it causes significant damage due to cracking when used more than once.

SVR-FB7 is a newly developed material with improved spalling resistance and improved resistance to sticking and peeling damage, and SVR-FB8 is a material with improved wear resistance in addition to these features.

Both newly developed materials can be used multiple times, and have been used more than five times as SV plates for ladles in steelworks with excellent results.

Table 1 Typical properties of basic materials for slide valve plate

Brand name	SVR-PB50	SVR-FB7	SVR-FB8
	Conventional	Developed	Developed
Chemical composition / mass%			
MgO	92	50	50
Al_2O_3	–	38	38
C	4	6	6
Metal	α	α	β (fine)
Apparent porosity / %	10	9.0	9.0
Bulk density / $kg \cdot m^{-3}$	3000	2990	2990
Cold crushing strength / MPa	80	95	105

4. Conclusion

Based on MgO-Spinel-C material, which has high corrosion resistance and spalling resistance, we have developed basic SV plate materials suitable for multiple uses by improving the sticking and peeling damage resistance and wear resistance. The use of the basic material for multiple uses eliminates the need to use it in combination with Al_2O_3-C material, which cannot be used for corrosive steel grades. This reduces irregular and frequent replacement of SV plates, thereby reducing the amount of refractory waste and the load of replacement work.

References

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