High Performance Ladle Bricks

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Abstract

In the steel making processes, ladles are widely used as transporting containers and/or refining facilities of molten steel. Recently, solutions for improving not only the durability but also the environmental issues are strongly demanded. We have various kinds of high performance ladle bricks to satisfy these requirements.

1. Introduction

In the steel making processes, ladles are widely used as transporting containers and/or refining facilities of molten steel. The operating conditions of a ladle vary depending on the functions of the ladle. Various materials have been developed for use in the ladle lining for the various conditions in order to improve durability and decrease refractory cost.

In addition to these requirements, further functions have been demanded on refractory such as the contributing to improve the quality, energy saving, working environment and so on. We have developed various high performance ladle bricks in order to meet these requirements as described in this paper.

2. Issues of Ladle Bricks

1) Energy saving

As the growth of the conscious regarding the global environmental issues, demands for energy saving have been increasing strongly in the steel making processes which require a lot of energy consumption. In the ladle lining, carbon containing bricks such as MgO-C bricks and Al_2O_3-MgO-C bricks are used widely, however, the application of these bricks accompanies an issue of high heat losses from the shell of the ladle because they contain high thermal conductive carbon.

In order to reduce such heat loss, the installation of the insulating materials between the shell and the refractory lining is one of the countermeasures. However, this method generally results in the increase of the wear rate and slag infiltration thickness of bricks because the temperature in the brick lining becomes high[1),2)]. As a result of temperature rise in the brick lining, amount of heat storage in the ladle lining increases, which may cause higher heat losses when the ladle is used intermittently[3)]. Therefore, from view point of decreasing heat loss, ladle bricks with the low thermal conductivity and heat storage are preferable.

2) Quality of steel

Demands for improving the quality of steel and the production of high quality steel have been increasing year by year. Along this movement, the durability of several conventional ladle bricks has decreased in some cases. For example, the erosion of high alumina bricks is accelerated by the temperature rise and the prolonged refining time for refining high quality steel, which may accompany severe joint erosion or steel penetration. On the other hand, carbon pick up from carbon containing bricks into ultra low carbon steel is another issue relating the quality of steel. Thus, bricks that performs long and stably without the risk of chemical contamination of steel are required.

3) Environment

Along with energy saving, not only the ecological environment around the plant but also the working environment such as noise, vibrations, dusts and odors are issues to be improved. For example, resin bonded carbon containing bricks emit unfriendly fumes and odors during the preheating of ladles due to the decomposition of phenol resin. Although the amount is little in general, toxic components such as phenol and cresol are included in the fumes, which may cause an environmental issue. In order to solve this issue, we developed low fume emission carbon containing bricks in which resin is not used as the binder.

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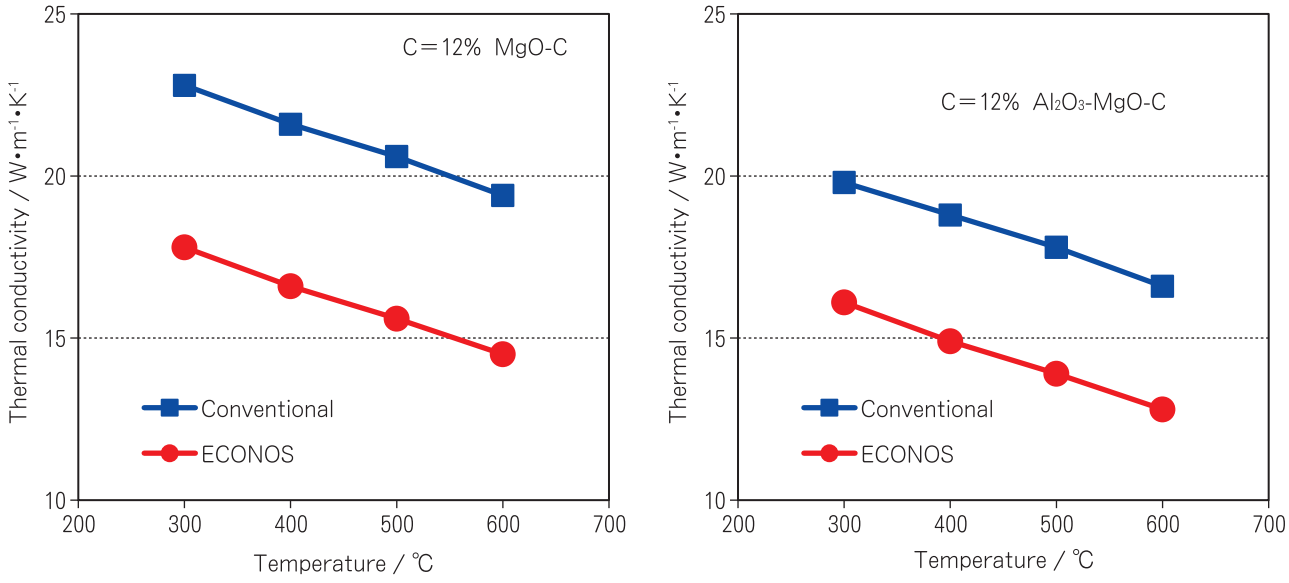

Fig. 1 Thermal conductivity of ECONOS bricks.

Table 1 Typical properties of ECONOS

Quality	MgO-C	Al_2O_3-MgO-C	Al_2O_3-SiC-C
Brand and codes	ECO-M3B	ECO-A2B	ECO-A2E
Chemical composition [mass%]			
MgO	77	10	
Al_2O_3		71	66
SiO_2			12
SiC			6
C	15	10	12
After drying			
Apparent porosity [%]	4	5	9
Bulk density	2.95	3.05	2.8
Cold crushing strength [MPa]	35	35	40
Thermal conductivity [W/m℃] at 600℃	16	10	12
Applications	Steel ladle	Steel ladle	Torpedo car

3. The Line-up of High Performance Ladle Bricks

3. 1 ECONOS (Low thermal conductivity, low fume carbon containing bricks)

ECONOS are “eco-friendly” carbon containing bricks which have low thermal conductivity and low fume emission properties. The features of ECONOS are as follows;

1) Thermal conductivity of ECONOS is approximately 30% lower than that of ordinary bricks which contains the same amount of carbon. (Fig. 1)
2) ECONOS technology can be applied to all kinds of carbon containing bricks such as MgO-C, Al_2O_3-MgO-C and Al_2O_3-SiC-C bricks.
3) ECONOS do not emit fumes and odors during the preheating because phenol resin is not used.
4) Joint erosions and local erosions like “rat holes” are reduced.

Typical properties of several ECONOS are shown in Table 1. In general, MgO-C ECONOS are used in the slag line and Al_2O_3-MgO-C bricks are used in the metal zone of ladles. On the other hand, Al_2O_3-SiC-C ECONOS are used in the lining of torpedo cars. Fig. 2 shows a comparison of ladle shell temperatures between an ECONOS lining and a conventional lining. The shell temperatures of the ECONOS lining were lower than those of the conventional lining by approximately 50℃ in both areas of the slag line and the metal zone[4]. In Fig. 3,

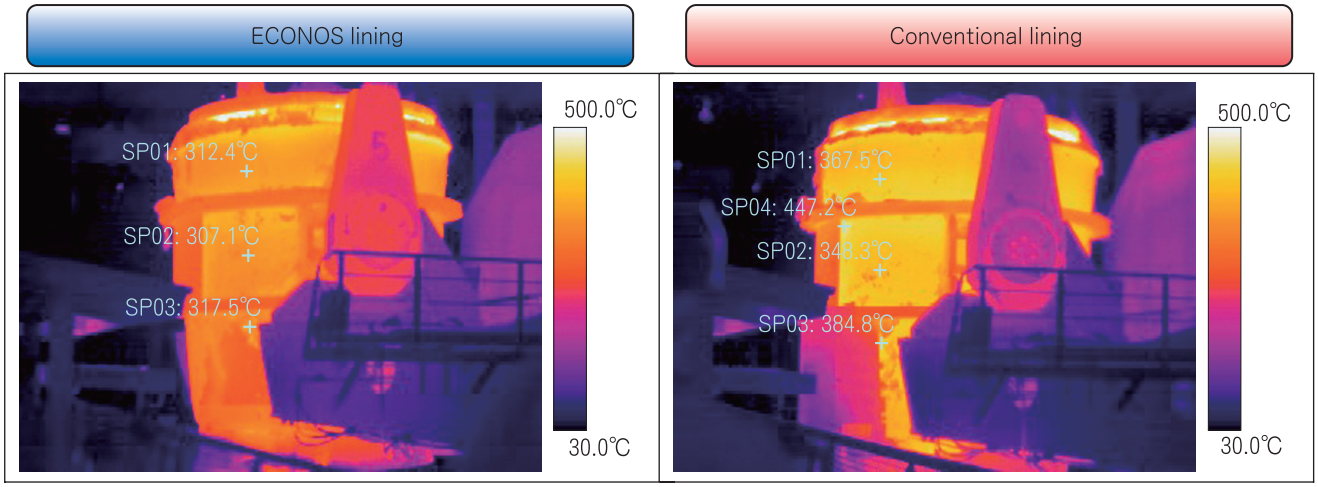

Fig. 2 Comparison of shell temperatures between ECONOS and conventional linings.

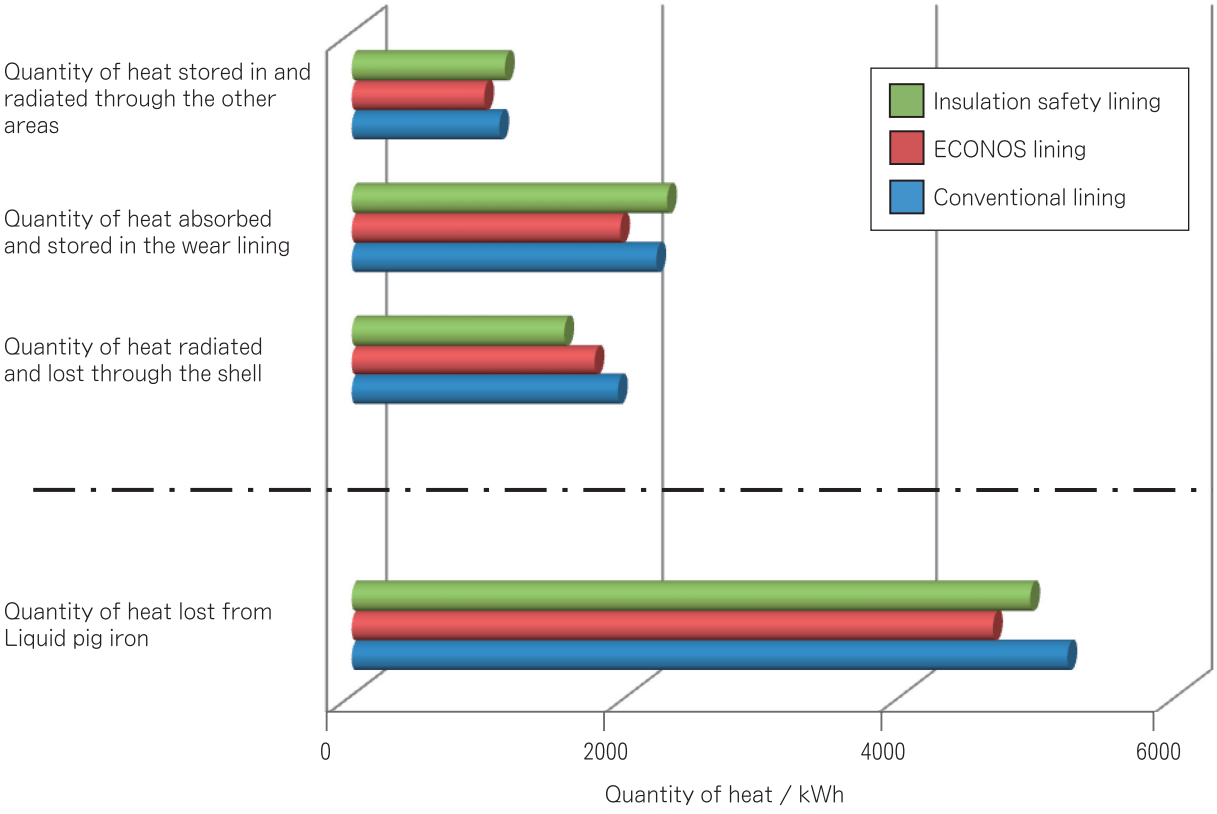

Fig. 3 Balance of heat quantity lost from liquid pig iron during torpedo transport.

comparisons of heat loss quantities calculated with various lined torpedo cars are shown. From the view point of the quantity of heat radiated and lost through the shell, the insulating safety lining shows the lowest number, however, the ECONOS lining showed the lowest number in the total quantity of heat loss including the quantity absorbed and stored in the wear lining and other areas. In the work lining insulation by using ECONOS, both the

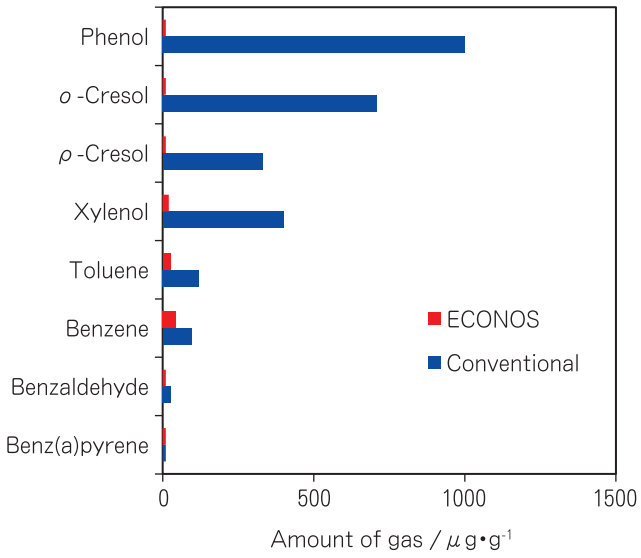

Fig. 4 Aromatic components emitted from MgO-C bricks during the heating.

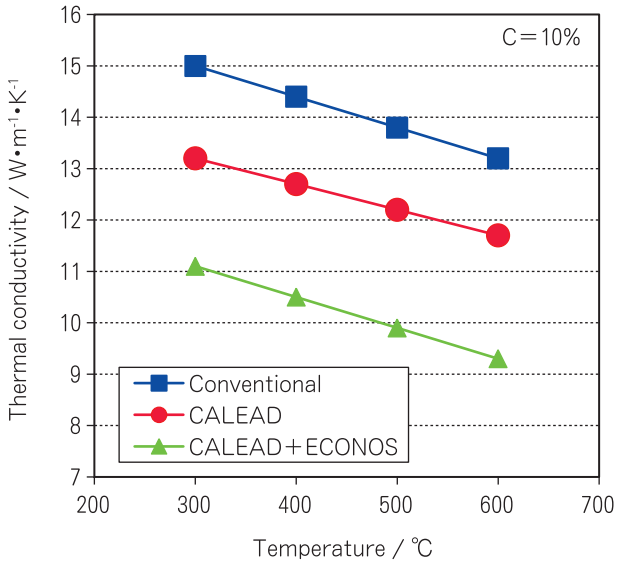

Fig. 5 Thermal conductivity of Al_2O_3-MgO-C bricks.

quantity of heat radiated from the shell and stored in the wear lining are suppressed because the temperature in the wear lining drops more than that of the conventional lining.

Fig. 4 shows a comparison of fume components emitted from ECONOS and ordinary MgO-C bricks during heating. The reason why we call ECONOS' environmental friendly bricks' is that they emit little phenol, cresol and other aromatic components.

Table 2 Properties of raw materials

	White fused alumina	Brown fused alumina	Chinese bauxite	Special alumina
Apparent porosity /%	5.3	2.9	9.8	3.2
Bulk density	3.74	3.84	3.18	3.36

Table 3 Typical properties of CALEAD

Quality	Al_2O_3-MgO-C	
Brand	Conventional	CALEAD
Chemical composition [mass%]		
Al_2O_3	65	61
MgO	18	18
C	10	10
After drying		
Apparent porosity [%]	6.4	7.1
Bulk density	3.27	3.00
Cold crushing strength [MPa]	34	30

3. 2 CALEAD (Light weight Al_2O_3-MgO-C bricks with high corrosion resistance)

A special alumina raw material is used in CALEAD, which makes the brick body light without affecting the corrosion resistance and durability of bricks compared to ordinary bricks. Physical properties of several alumina raw materials are compared in Table 2. The special alumina raw material has lower bulk density than those of fused alumina materials even though its apparent porosity is low. Typical properties of a CALEAD are compared to those of an ordinary bricks in Table 3. The features of CALEAD are as follows;

1) The bulk density of CALEAD is lighter by approximately 10% than those of ordinary Al_2O_3-MgO-C bricks which contain the same amount of carbon.
2) The thermal conductivity of CALEAD is lower by approximately 10% than those of ordinary Al_2O_3-MgO-C bricks which contain the same amount of carbon. The thermal conductivity can be lowered even further when the ECONOS technology is applied to the CALEAD (Fig. 5).

Not only the heat loss by the radiation through the shell but also the heat storage absorbed in the work lining can be suppressed by the application of CALEAD because the heat storage is determined as a function of the weight of the refractory in the lining. Therefore, CALEAD has an advantage in saving heat and energy even when a ladle is used intermittently. Of course, the total weight of a ladle with CALEAD lining is lighter than that of ordinary linings, which will contribute the

Table 4 Typical properties of ALTIMA

Quality	Al_2O_3-MgO		
Type	Standard type	Lightweight type	Penetration suppression type
Chemical composition [mass%] Al_2O_3 MgO	 88 7	 77 13	 87 7
After drying Apparent porosity [%] Bulk density Cold crushing strength [MPa]	 11.6 3.28 43	 10.0 3.10 60	 7.3 3.25 40
Permanent linear change After 1500℃-3h	+1.7	+2.0	+2.5

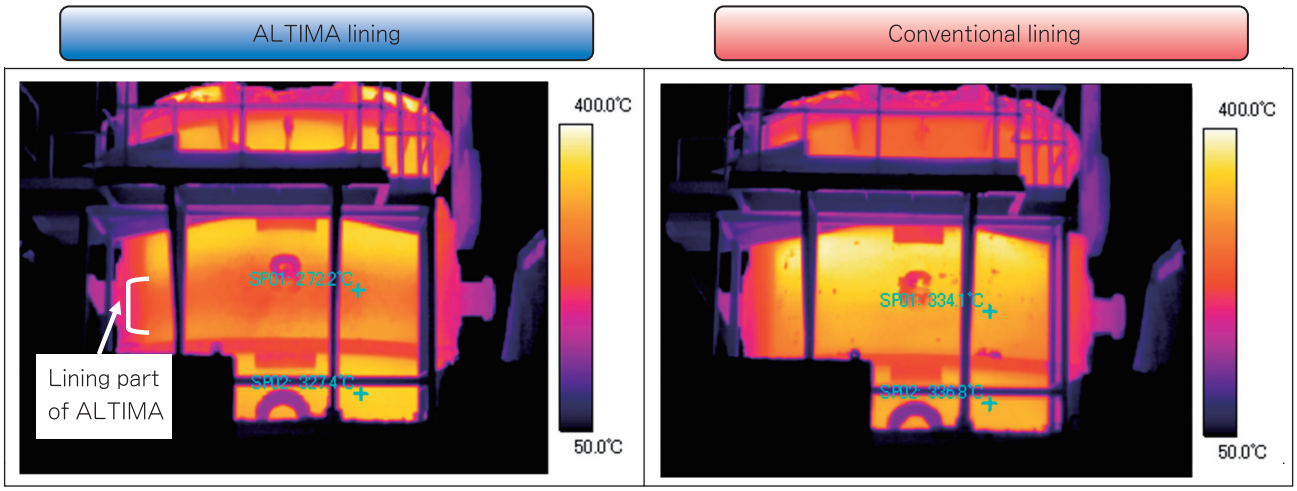

Fig. 6 Comparison of shell temperatures between ECONOS and conventional linings.

increase of molten steel in a ladle if the capacity of the crane is critical in the steel mill.

3. 3 ALTIMA (High performance unburned Al_2O_3-MgO bricks)

ALTIMA are carbon free unburned Al_2O_3-MgO bricks which can be used mostly in the metal zone of ladles including bottoms. The original idea in developing ALTIMA was to make bricks which have very similar properties to Al_2O_3-MgO castables, which are widely used in the integrated steel mills in Japan. The features of ALTIMA are;

1) Thermal conductivity of ALTIMA is very low and there is no risk of carbon pick up because they are carbon free bricks.
2) Joint erosion and metal penetration through brick joints are minimal because ALTIMA have both appropriate permanent linear changes and creep deformation abilities.
3) ALTIMA show very similar properties to Al_2O_3-MgO castables. However, they can be installed without special equipments such as mixers, molds, vibrating facilities and drying facilities which are necessary to install castables.

We have developed several variations of ALTIMA such as a standard type in which high purity alumina is used, a light weight type like CALEAD, and a low slag penetration type by the use of a special additive. Typical properties of ALTIMA are shown in Table 4.

Comparison of shell temperatures between ALTIMA lining and ordinary Al_2O_3-MgO-C lining are shown in Fig. 6. ALTIMA was used in the middle part of the metal zone surrounded by ordinary Al_2O_3-MgO-C bricks. The shell temperature of the area where ALTIMA was installed was approximately 50℃ lower than that of other areas. Fig. 7 shows a photograph of ALTIMA after use when the ladle lining was demolished. The bricks retained tight construction and there was no joint erosion or metal penetration into the back of the wear lining.

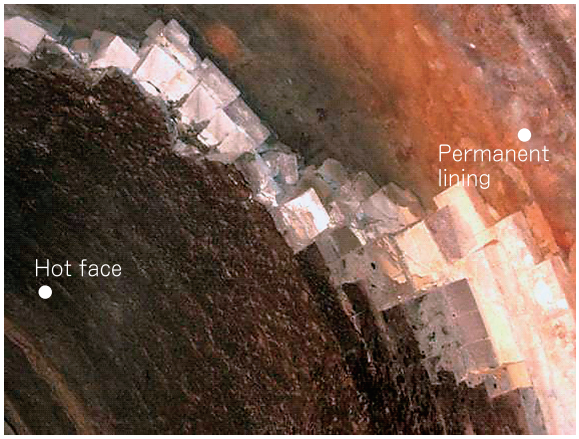

Fig. 7 Appearance of ALTIMA lining after use.

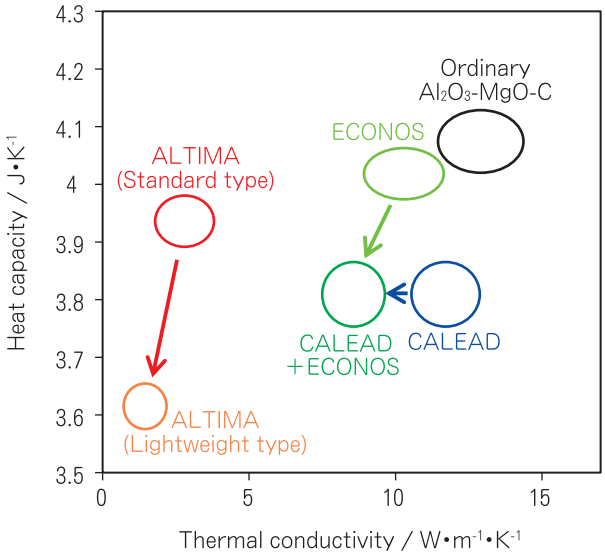

Fig. 8 Relationship between thermal conductivity and heat capacity.

3. 4 Comparison of thermal properties ofmetal zone bricks

Reducing heat loss from the metal zone of ladles should be very effective because the refractory in the metal zone contact with molten steel directly. Al_2O_3-MgO-C ECONOS, CALEAD and ALTIMA are designed to be used in the metal zones. The relationship between the thermal conductivities and the heat capacities of these bricks are shown in Fig. 8. All of these bricks have lower thermal conductivities and heat capacities than ordinary Al_2O_3-MgO-C bricks. ALTIMA have the lowest thermal conductivity among them, which will contribute the reduction of the heat loss. Furthermore, the light weight ALTIMA and CALEAD, which have low heat capacities as well as low thermal conductivities, give the wider options to customers for achieving better performance in ladle operations.

3. 5 Ultra low carbon MgO-C bricks for the slag line

MgO-Cr_2O_3 bricks are generally used in the slag line of ladles for refining ultra low carbon steel in order to avoid carbon pick up issues. Although MgO-Cr_2O_3 have very good erosion resistance, their durability is limited because of the high frequency of structural and thermal spalling, especially when the ladle is used intermittently. In order to solve this issue, we developed ultra low carbon MgO-C bricks for such applications. Typical properties of ultra low carbon MgO-C bricks are shown in Table 5. As shown in Fig. 9, the 1.5% carbon bricks performed better than the ordinary MgO-Cr_2O_3 in the actual ladle. Carbon pick up in this trial was minimal and was in the acceptable range.

For the lining of ultra low carbon steel ladles, the combination of ultra low carbon MgO-C bricks in the slag line and ALTIMA in the metal zone is widely and successfully used in Japan.

4. Conclusion

Issues and several solutions regarding ladle bricks were described in this paper, and summarization is shown in Fig. 10. We continue to make efforts to meet our valued customers' requirements which change day by day.

Table 5 Typical properties of ultra low carbon MgO-C bricks

Quality	MgO-C		
	MGT-1BS43	MGT-1BS39	MGT-1BS32
Chemical composition [mass%]			
MgO	91	90	88
C	0.5	1.5	3
After drying			
Apparent porosity [%]	6.6	6.8	5.3
Bulk density	3.10	3.10	3.12
Cold crushing strength [MPa]	78	76	45

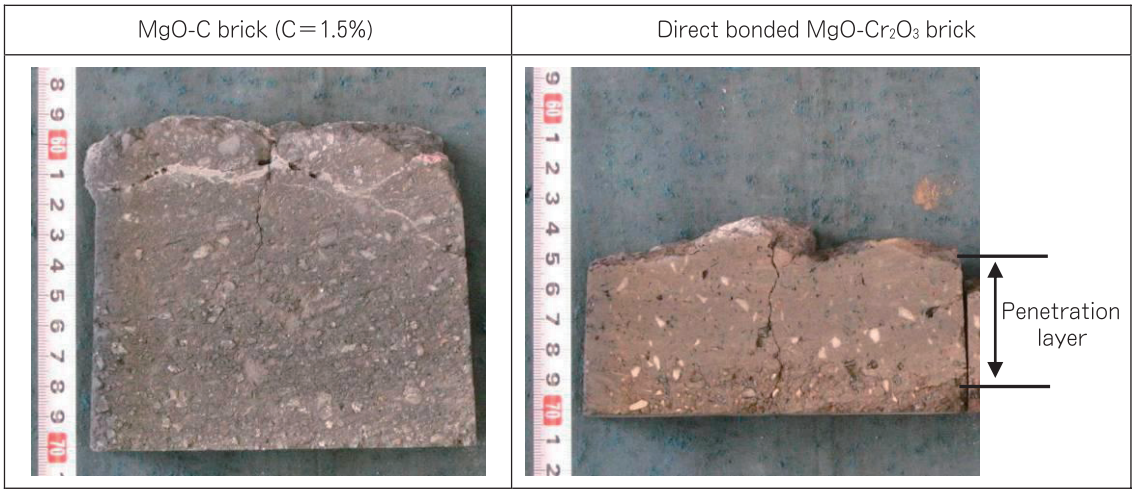

Fig. 9 Cut sections after use.

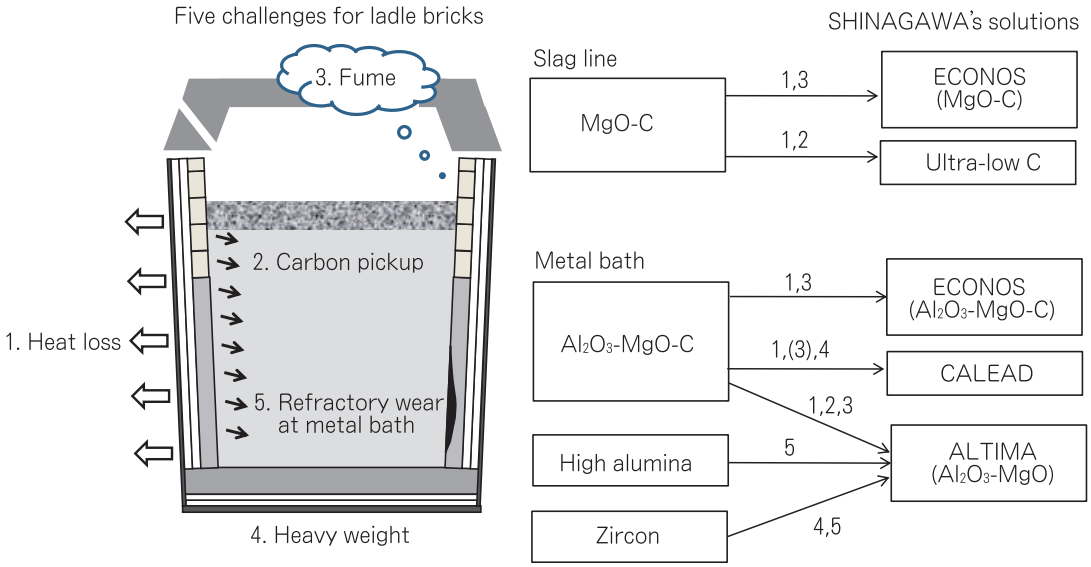

Fig. 10 Summarization of issues and several solutions regarding ladle bricks.

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