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Development of Mechanical Repairing Technology for Refractories (Rotary Shot Method)

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Abstract

Among conventional repairing technology for refractories, such as spraying or shot casting has been developed for labor saving and skill free of operators. However, the durability of repaired body by such methods was not enough because they usually need much amount of water. On the other hand, we developed a new repairing technology that is rotary shot method, which has a very simple mechanical structure and needs much less amount of water than that of conventional repairing technology. Consequently, it has been enable to achieve a much longer life and labor saving for repairing of steel ladle.

1. Introduction

Generally speaking, refractory linings that have been constructed in a conventional way, such as by spraying or shot casting, are not very durable because they are applied with a considerable amount of water during construction. With the aim of building more durable refractory linings, we developed a new method called the rotary shot method employing original equipment that permits the amount of water added to be reduced significantly as compared with the conventional shot casting method.[1, 2] By applying this new method to the steel ladles used at Nippon Steel's Yawata Works, we could prolong the ladle's life and cut down on labor required for ladle refractory maintenance. This paper describes the newly developed rotary shot method.

2. Development of the Rotary Shot Method

2.1 Pattern of ladle repair at Yawata Works

Fig. 1 shows the profile of the ladle lining and the pattern of ladle repair at Yawata Works before the introduction of the shot casting method. Formerly, the interval between minor ladle repairs was determined by the conditions of the tuyere, impact zone and slagline bricks, and worn or defective bricks were replaced with new ones each time a minor repair was made. Ultimately, when the sidewall was damaged markedly, a major repair was carried out. In the latter part of the ladle repair pattern, the monolithic refractory lining of the sidewall came off, calling for unscheduled repairs. Therefore, the intervals between minor repairs and between major repairs were relatively short. Under such conditions, we have been steadily improving the method of repairing the ladle sidewall in order to prolong the ladle life.

2.2 Comparison of methods for repairing ladle sidewalls

In setting about improving the efficiency of ladle sidewall repairs, we undertook a comparative study of conventional methods of repairing ladle sidewalls. **Table 1** shows the repair methods that have been used at Yawata Works. From among those repair methods, we chose the shot casting method, since it can be applied to many different purposes and was expected to help prolong ladle life because it requires less water to be added than the spraying method. Such being the case, the shot casting method has been applied to repair the ladles at Yawata Works.

2.3 Effect of introducing the shot casting method

It has been reported that there are two types of shot casting method —the double piston type and the squeeze pump type.[3] When the repairs are minor and infrequent, the squeeze pump type is advantageous in view of the smaller material loss and the easier equipment cleaning. Therefore, to repair the sidewalls of our ladles, we intro-

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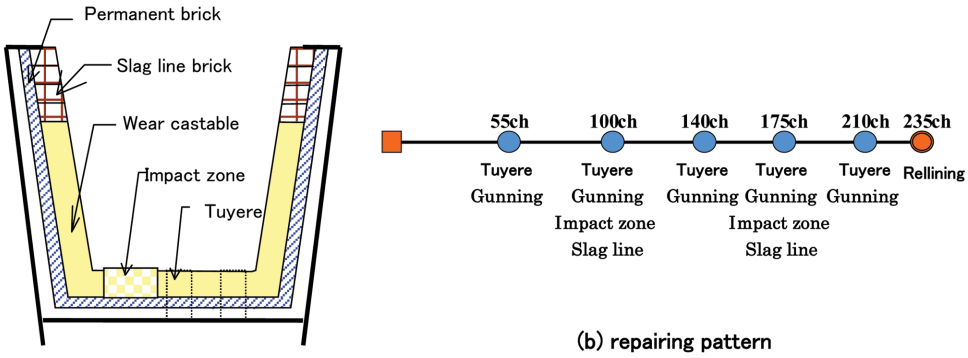


Fig. 1 Lining profile of steel ladle (a) and repairing pattern (b)

Table 1 Comparison of conventional repairing method

	Workability	Durability	Problem
Bricklaying	Bad	Good	Penetration of metal into the joints Loss of demolition refractory
Gunning	Good	Bad	Bad working condition Bad durability
Shot casting	Good	Good	Increase of workforce
Casting	Bad	Very good	Bad workability Necessary for special core

duced the squeeze pump type of shot casting. Under that method, we strove to prolong the interval between major ladle repairs (see **Fig. 2**). As a result, we could achieve a measure of success in terms of prolonging the above interval. On the whole, however, the results were not very satisfactory. Besides, the shot casting method involved several problems in the execution of repairs. Those problems include: (1) preparations for the repair work require much labor, (2) the working environment is poor because the repair work has to be done within the ladle, and (3) the repair work takes much time (see **Fig. 3**, **Table 2**).

In order to resolve those problems, we developed a new repair method (rotary shot method) based on the shot casting method with the major emphasis on improving the durability of the refractory lining and cutting down on labor in the repair work.

2.4 Outline of equipment used in the rotary shot method

Fig. 4 shows an outline of the equipment used in the rotary shot method. In the rotary shot method, unlike the shot casting method, premixed material is put into a hopper, from which a fixed amount of the material is extracted using a screw auger. Activator is then added to the material at the bottom of the hopper, the contents then mixed by the centrifugal force of an impeller and divided into portions of suitable volume. Those portions of the material are projected serially onto the damaged wall surface by the centrifugal force of a rotary disk at the bottom of the impeller.[4)]

The rotary shot method has made it possible to increase the speed of repair work significantly since the repair work itself does not require manual labor. In addition, the method has improved the working environment since the operator can manipulate the rotary shot equipment from outside the ladle being repaired. Furthermore, by providing the equipment with a chain block to move the projector up and down and a platform on which the operation panel is mounted, it has become possible to greatly simplify the preparatory work and cut down on labor in the ladle repair work (see **Fig. 5**).

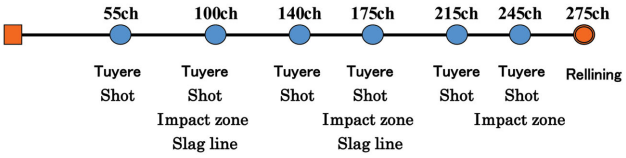


Fig. 2 Repairing pattern of steel ladle after introducing shot cast

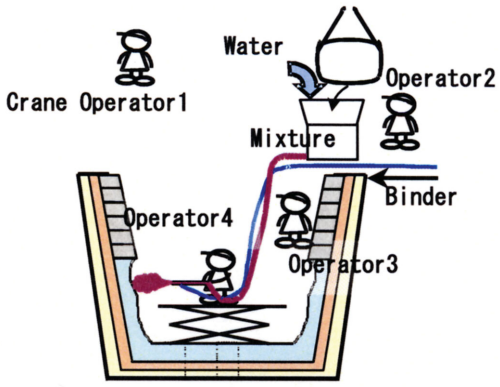


Fig. 3 Steel ladle repairing method by shot cast

Table 2 Problems of repairing method by shot cast

	Squeeze type	Double piston
Addition water	7.8-9.3mass%	5.8-7.0mass%
Workforce	3 or 4 people	
Working hour	Long	Long
Working environment	Bad	
Material loss	50kg/time	1,000kg/time

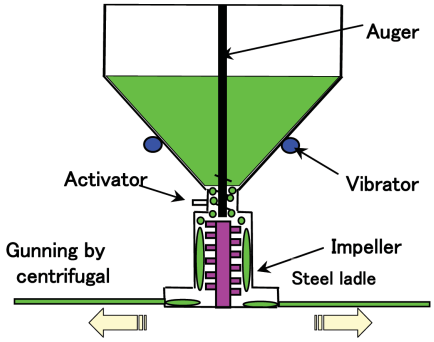


Fig. 4 Outline of rotary shot system

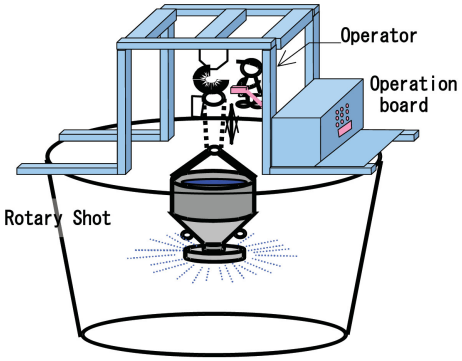


Fig. 5 Steel ladle repair method by rotary shot

2.5 Characteristics of refractory material for the rotary shot method

Fig. 6 shows the relationship between the amount of water added and the apparent porosity for various methods of monolithic refractory lining work. With the conventional shot casting method, which requires pressure-feeding of the refractory material through a pipe, it is necessary to add more water to the material than is required by ordinary castable refractory in order to impart adequate fluidity to the material.[5] By contrast, the rotary shot method does not require pressure-feeding of the refractory material. Therefore, it permits reducing the amount of water added almost to the level for castable refractory material, and thus produces a refractory lining as dense as castable refractory lining.

The rotary shot method was used in the repair of an actual ladle. As a result, it was found that the repair work could be done with the addition of 6 mass% or less of water. In addition, with the aim of improving the durability of refractory lining, we added coarse grains up to 8 mm in diameter to the refractory material using the method applied to ordinary castable refractory.[6] As a result, it was confirmed that the repair work could be carried out without any problem.

2.6 Details of the rotary shot method

The following can be cited as one problem in the rotary shot method. In view of the projection of the refractory material by centrifugal force, the direction in which the refractory material is projected is limited to 360° only in the horizontal plane on which the impeller rotates. However, the sidewall of an actual ladle is subject to local separation of the lining and local wear of bricks in the wall and joint (the part from which the wall rises) as shown in **Fig. 7**. Therefore, the rotary shot method also called for improvements that would enable its application to the repair of those local problems as well.

In order to allow for the repair of local wear of ladles, we provided the rotary shot equipment with a concentrated casting mechanism in addition to the circumferential casting capability. As shown in **Fig. 8**, a guide belt, the turning speed of which is synchronized with the impeller rotational speed, is provided around the periphery of the impeller to allow for unidirectional projection of refractory material (concentrated casting). In order to switch between concentrated casting and circumferential casting, we developed a mechanism which permits swift switching without operator intervention, so that the saving of labor—one of the main development themes underpinning the rotary shot method—is not impaired (see **Fig. 9**).

The incidental functions that were incorporated in the rotary shot method are summarized in **Table 3**. These functions have made it possible to use the rotary shot method to repair ladles easily and efficiently.

2.7 Effects of introducing the rotary shot method

Table 4 compares the rotary shot and conventional shot casting methods. Refractory lining constructed using the rotary shot method is denser than that constructed with the shot casting method. It also affords superior corrosion resistance, 44% better than that of shot casting in terms of its corrosion index. The pace of work with the rotary shot method is about six times faster than with the shot casting method. Furthermore, since the rotary shot method does not require an extra pipe to pressure-feed the refractory material, it has made it possible to eliminate the loss of material and reduce the cleaning time. As a result, the time and manpower required for ladle repair work have been reduced by 59% and 75%, respectively.

Fig. 10 shows the pattern for repair of ladles at Yawata Works following the introduction of the rotary shot method. **Fig. 11** shows the change in ladle life before and after introduction of the rotary shot method. By introducing the rotary shot method, it has become

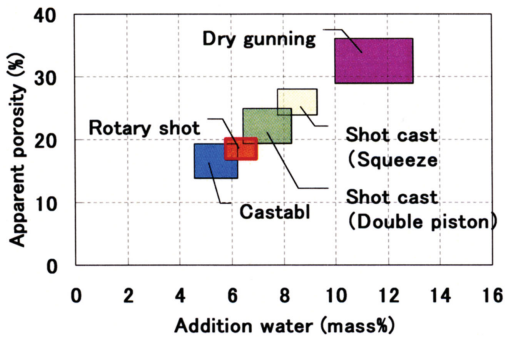


Fig. 6 Relationship between addition water and apparent porosity

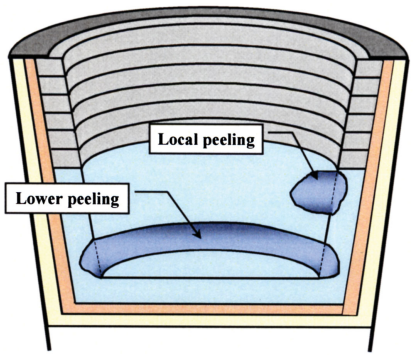


Fig. 7 Typical wear pattern of steel ladle

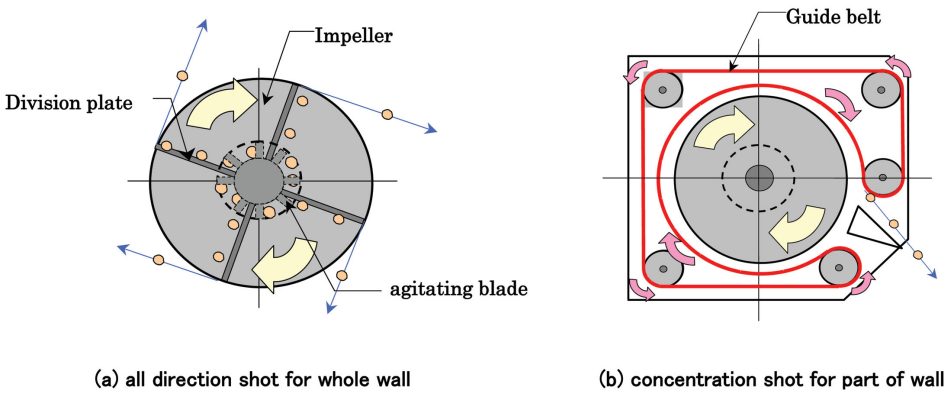


Fig. 8 Mechanism of all direction shot (a) and concentration shot (b)

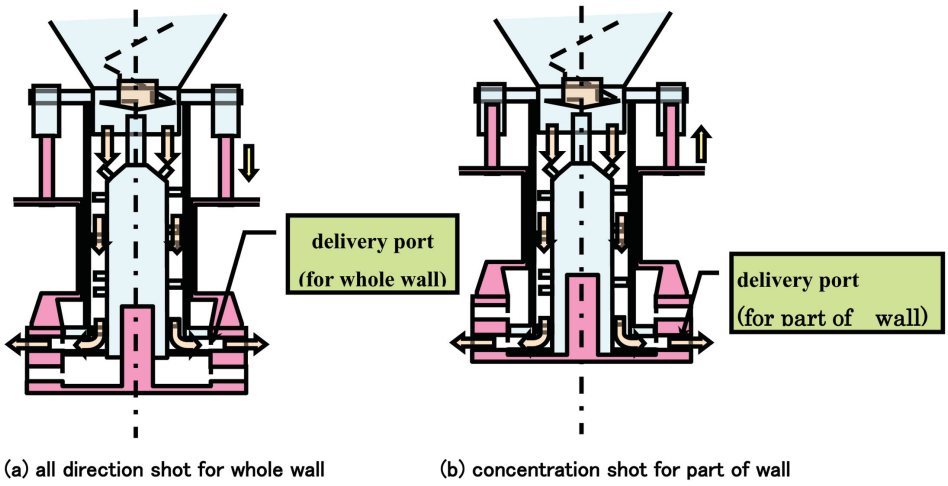


Fig. 9 Exchange mechanism of rotary shot

Table 3 List of an incidental function of rotary shot

Item	Function
Move up and down	Move up and down by electric winch
Operation	Remote control
Changeover system	Automatic quick changing device (changeover time 2s)
Method of addition activator	Automatic control in proportion to discharge speed
Cleaning	① Turn around in water tank, ② High-pressure water washing

possible to ensure the durability of refractory lining material (about 50 charges) in terms of the interval between minor repairs, as well as to stabilize ladle operation between such repairs. As a result, the life of ladles until a major repair has been prolonged remarkably.

3. Conclusion

We developed the rotary shot method as a new way to construct refractory linings. By applying the new method to repair an actual ladle, we confirmed the following points.

(1) Since the rotary shot equipment does not require an extra pipe to pressure-feed the refractory material:
- i) Less water needs to be added to the refractory material → Denser and more durable material
- ii) Material losses can be almost eliminated.
- iii) It is possible to add coarse particles (up to 8 mm in diameter) → More durable refractory lining

(2) Material projection mechanism not requiring human labor
- i) Significant increase in work speed → Shorter construction time
- ii) It is possible to cut down on labor (one-man operation of equipment)
- iii) Improved working environment since the equipment can be operated from outside the ladle under repair.

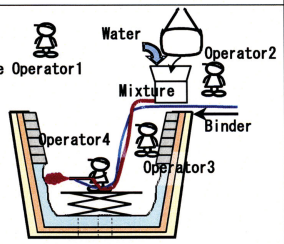
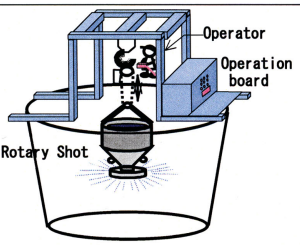
(3) Repairs using dense refractory material
- i) The ladle life is prolonged remarkably.

In the future, we intend to apply the rotary shot method to other types of equipment so as to cut down on labor for their repairs and prolong their life.

References

1) Koga, M., Takita, I., Kataoka, M., Kawasaki, K.: Taikabutsu. 51 (4), 179-187 (1999)

Table 4 Comparison of rotary shot and shot cast (squeeze type)

	Shot cast(Squeeze)	Rotary Shot
Outline of equipment		
Addition water	7.8～9.3 mass %	5.8～7.0 mass %
Corrosion resistance index	100	56
Gunning speed	50kg/min	300kg/min
Working environment	Bad	Good
Material loss	50kg	0
Cleaning time	40min	30min
Total repair time	220min	90min
Man-hour rate	100	25

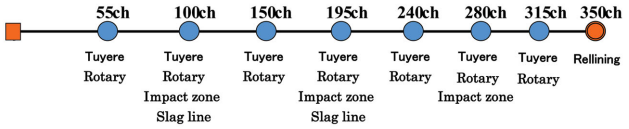


Fig. 10 Repairing pattern of steel ladle after introducing of rotary shot

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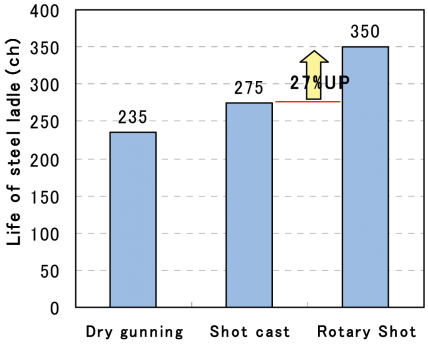

Fig. 11 Comparison of life

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