DEVELOPMENT OF PURGING PLUGS WITH HIGH PERFORMANCE AND LONG LIFE[1]

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Abstract
Due to the current economic situation, productivity improvement and cost reduction of refractories are strongly demanded. And purging plugs used for agitating steel on hot metal ladle is not an exception. Properties demanded for purging plugs as high gas blowing success rate; properties of metallurgical reaction and a satisfactory gas blowing for stirring performance; and long life. There are two types of purging plugs, porous plug which is focused more on a reliable bubbling, and slit plug (through-bore type) which is more focused on service life. However it is essential to develop the good characteristic of it, and reduce the week point of both types. The report will have as subject, a successful development of great characteristic of porous plug.
Key words: Refractory; Secondary steel making; Porous plug.

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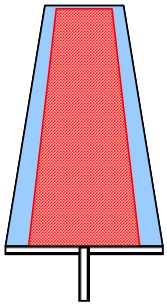
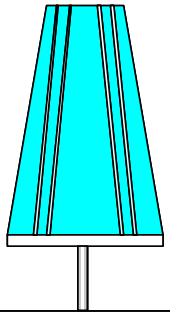
1 INTRODUCTION

Recently, as growing of importance on secondary refining process to produce high grade steel at steel plants, purging plug for ladle bottom bubbling also has been increasing its importance because of its better characteristics for stirring molten steel than lance pipe.
The purging plugs are generally classified into two types. One is porous plug that has characteristic of excellent bubbling reliability. Another is slit plug (alias directional type plug) and it has characteristic of long life. Table 1 shows the comparison between the two types of purging plug.

Table 1. Comparison between two tipe of purging plug

	Porous plug	Slits plug
Design	Porous brick 	Castable 
Bubbling Reliability	Very good	Normal
Durability	Normal	Very good
High Flow rate	Good	Very good
Low flow rate	Good	Good
The amount of user in Japan	≧90%	≦10%

Generally, 2 points are often cited as weak points of porous plug, one is short service life and another is less capacity of big flow rate.
We succeeded to develop a new material for porous plug which improved above 2 points significantly and it also achieved good results in effective ladle operation. We would like to report this new development of porous plug below.

2 AIMS OF DEVELOPMENT

Figure 1 shows Damage pattern, factor and development point of porous plug. Concerning to damage pattern, oxygen lancing is considered as the biggest factor. So we focused development point on reducing oxygen lancing and improving material resistance against oxygen lancing. From this view points, our target of development are: small pore size, raw material shape, higher refractoriness. At the same time, enough porosity is necessary to keep big flow rate.

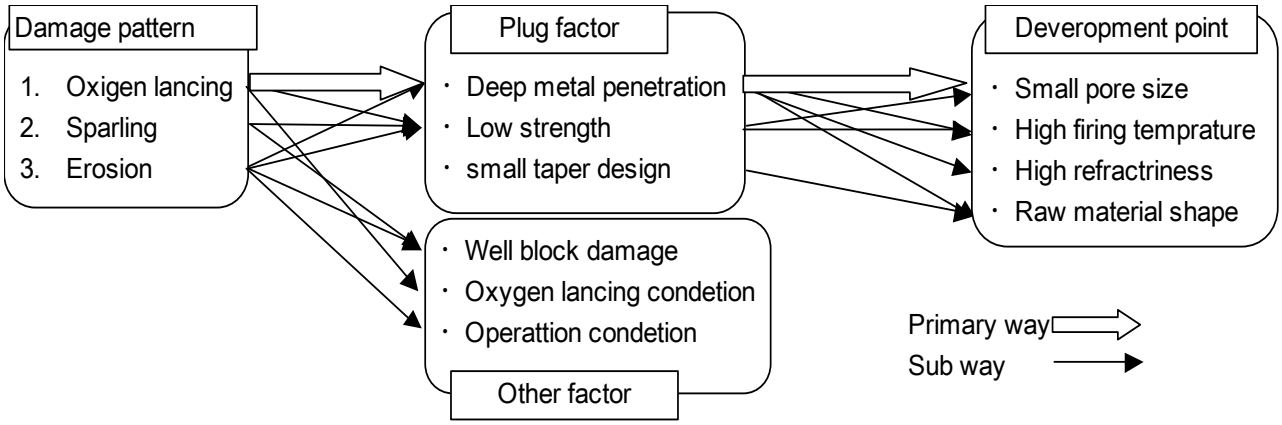


Figure1. Factors and development point of porous type material.

Generally, improving service life and getting big flow rate are trade-off and incompatible characteristics. But we thought it could be achieved by adjusting raw material and production process, especially firing temperature.

3 PROPERTIES OF THE IMPROVED POROUS MATERIAL

Table 2 shows the typical properties of new material for porous plug. The features of the new material are small pore size and big flow rate without reducing strength.

Table 2. Typical properties of porous brick

	New	Conventional
A.P. [%]	24.9	23.5
B. D. [–]	2.79	2.87
C.C.S. [Mpa]	75	76
Chemical Cop. [%]		
SiO2	6.1	6.2
Al2O3	87.0	88.9
Cr2O3	3.7	1.7
ZrO2	3.0	3.0
Avg. pore size	**Small**	Normal
Flow Index	**160**	100

Distribution of pore size is shown in Figure 2. The new material has 30% smaller pore size than conventional. This characteristic reduces metal penetration and you can expect longer life of porous plug by reducing oxygen lancing time and frequency.

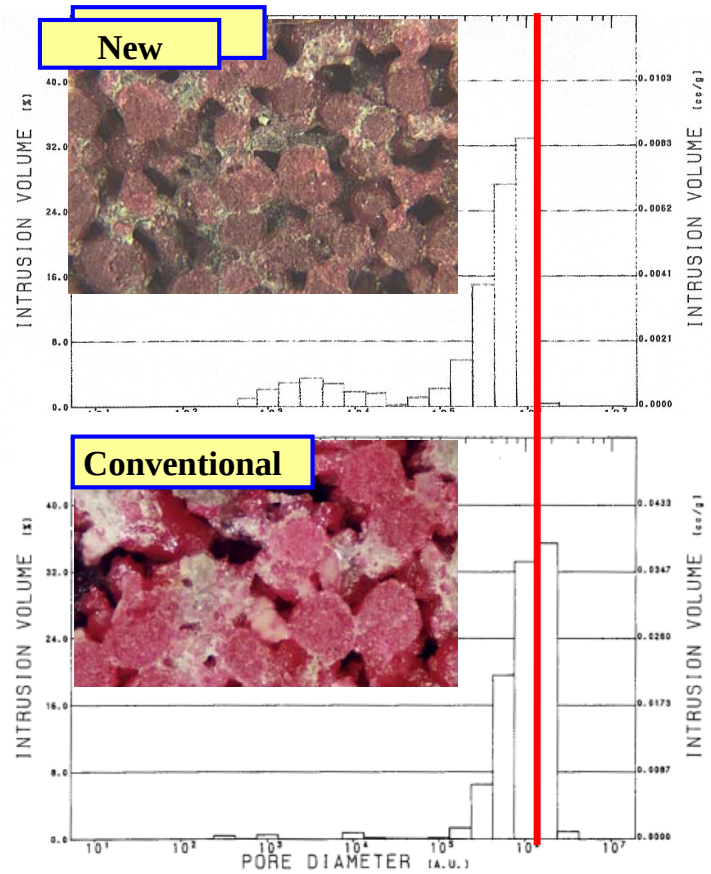


Figure 2. Distribution of pore size and micrograph.

4 EROSION TEST

Erosion resistance against molten steel (1.650°C) is relating to service life.
Table 3 shows the test result. The new material had 13 mm erosion and 6.2 mm metal penetration. It is about 12% improvement from conventional one.
Although the lab. result is still below than our expectation, we expect the new material gets more improvement on service life, because its higher refractoriness and smaller pore size effect synergistically on resistance against oxygen lancing, primary damage pattern.

Table 3. Result of erosion resistance test of porous type material

	New	Conventional
【Condition 】 Temp ：1650 ℃ Slag ：C/S ＝2.0 Time:60min.		
Erosion （mm）	**13.0**	14.7
Penetration(mm)	**6.2**	7.1

5 RESULTS OF THE NEW DEVELOPED POROUS PLUG ON EFFECTIVE LADLE OPERATION

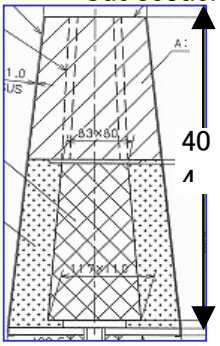
We made tests of the new developed porous plug on effective ladle operation at steel plants that had bubbling trouble with slit plug. Table 4 shows operation conditions in the steel plants. Plant A used to operate only with lance pipe for stirring molten steel, but as increasing of high grade steel production, they started bottom bubbling by purging plug. First, they tried both slit plug and porous plug, and after the test, they adopted our porous plug.

Table 4. Operation condition in steel plants

Steel plant	Gas flow rate [Nl/min]	Plug length [mm]	Back up lance
A	700	404	Yes
B	700	454	No

Table 5 shows the test result at Plant A comparing between porous plug and slit plug. Remarkable point is significant superiority of bubbling reliability. Although service life was same as slit plug, bubbling time is more than double as you see in Table 5.
At the same time, the porous plug kept gas flow rate enough for bubbling operation throughout the test.

Table 5. comparable results in steel plant A

Steel plant A	Slits type	Porous type
Hot face		
Cut section 		
Oxygen Lancing	yes	yes
Bubbling time [min]	158	330
Bubbling reliability [%]	**50**	**86**
Residual Length [mm]	255	257
Steel Penetration [mm]	11	0

6 SUMMARY

Our new development of porous plug material achieved to balance both reliable bubbling of porous plug characteristic and long life and big flow rate of slit plug ones without trade-off. Small pore size and high refractoriness led the development successful conclusion.
The new material can be applied to big flow rate operation which could use only slit plug due to flow rate, and you can also get reliable bubbling without worrying of short life.
We believe this new development can contribute much to steel plant operation.