Utilization of Sliding Gate Nozzle in Japan*

By Masayoshi OHNISHI,** Takumi NISHIO*** and Toshio TERASHIMA****

Synopsis

In Japan, the slide gate nozzle has been practically used since 1968 and at present it is utilized at more than 115 plants of 80 firms. Especially, this nozzle is indispensable for ladles and tundishes for continuous casting. Owing to the improvement of quality of the refractories, i.e. the parts made of refractory materials, and the mastery of operation technique, the frequency of repeated use without exchange of the refractories has increased up to about six times in continuous casting and three times in top pouring respectively. As to the mechanism of the nozzle, there have been developed a rotary type that contains a revolving “slide plate” having two or more boxes of different size and also a three layer type for tundishes in continuous casting for the purpose of preventing the movement of long nozzle in the mold. Automation of continuous casting operation is now being completed utilizing the slide gate nozzle.

I. Preface

Corresponding to the recent development of such steelmaking techniques as degassing in ladle, ladle refining and continuous casting, ladle refractories have suffered from severer conditions such as rise of tapping temperature and long time holding of molten steel bath, etc. Because of this reason, in the conventional process in which a stopper is installed inside of a ladle such accidents as melting away of a stopper head brick or sleeve bricks and softening of an axial rod of stopper (made of steel) were inclined to happen and it was hard to obtain safety of operation. And the sliding gate nozzle, not yet introduced in Japan at that time, appeared to be an effective means to cope with these troubles, because it needed not using a conventional stopper.

The basic idea of this apparatus had already been patented in U.S.A. in 1885*** (Fig. 1), but it was firstly put into practice at Benteler Steel Works in West Germany in 1964,† and was used practically by National Steel Corporation in U.S.A. in 1967.‡ Between 1968 and 1970 its utilization began internationally, and in Japan it was utilized at 115 plants of 80 firms between 1968∥ and 1973. There were made some improvements of apparatus’ mechanism, refractories’ quality and operational technique during the said period in Japan and the particulars are described hereunder.

II. Special Feature of Ladle Installed with Slide Gate Nozzle

When the slide gate nozzle is installed in a ladle the ceramic refractories are not dipped into molten steel bath and accordingly, bath of high temperature can be held in a ladle for hours. Therefore, the nozzle has such a large merit which allows to keep various refining operations safe and stable. The conventional ladle has been used only as a vessel to keep molten steel already refined in furnace, but owing to development and practical application of the slide gate nozzle the ladle can now be used as a vesse for refining in which metallurgical reactions can be proceeded. Furthermore, a ladle installed with a slide gate nozzle has the underwritten merits.

1) As casting operation is possible by remote control a safe operation can be kept.

2) Automatic control of pouring rate of molten steel is easier.

3) It is unnecessary to set a stopper in pre-heated ladle and therefore, it is possible to pre-heat a ladle until just before tapping. Accordingly the decrease of temperature of bath in ladle is comparatively small.

4) The slide gate nozzle can be repeatedly used as many as several times without exchanging the nozzles’ refractories, and the exchanging can be done in such a short time as less than 15 min from the outside of the ladle. Therefore, spalling of lining bricks and looseness of joints due to cooling can be avoided and

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Thus lining with basic bricks can be applied.

III. History of Development and Practical Application of Slide Gate Nozzle in Japan

The first slide gate nozzle in Japan was adopted for a 50 t ladle in October, 1968. In 1969, some speciality-steel makers used it for ladles for RH- or DH-degassing, etc. And the adoption not only made it possible to keep the operation safe and stable regardless the treatment time and bath temperature, but also greatly contributed to the reduction of workers' mental burden. From 1969 to 1971 a rapid development of the larger of which the hole diameter is 70 to 100 mm was made for larger ladles of 100 to 300 t. It was used for a ladle of BOF for the first time in July, 1969. On the other hand, a new kind like cassette type which allows exchanging in a short time corresponding to the tapping cycle of BOF was developed. So the slide gate nozzle was adopted to ladles of 250 to 300 t BOF in 1971 to 1972, and such a remarkable progress proved that the techniques of mechanism and refractories had been fully developed. Furthermore, together with the remarkable progress of continuous casting after 1971 the number of adoption of the slide gate nozzle was so rapidly increased that it was used at 73 plants in 1972 and 115 plants in 1973. Figure 2 shows the most popular slide gate nozzle. Besides this, a rotary type that contains a revolving slide plate having two or more holes of different size has been developed and it is being used at a certain quarter in order to change the flow rate of molten steel in wider range during teeming. Further, a three layer type for tundishes in continuous casting was also developed for the purpose of preventing the movement of its "collector nozzle" or the long nozzle due to the sliding of the slide plate. At present, all of those ceramic refractories used for the slide gate nozzle are home-made in Japan after a good many researches. They have the underwritten quality.

IV. Development of Refractories of Sliding Gate Nozzle in Japan

Because the flow rate of molten steel is controlled by opening and closing a hole through "bottom plate" and "slide plate" by means of sliding the latter on the former, quality of sliding parts made of refractory material is very important. The sliding surfaces are polished very precisely at the accuracy of less than 5/100 mm because they have to fix each other so that the molten steel in a ladle does not leak from the sliding surface. Also, higher hot strength and fewer abrasion and corrosion are required.

Refractory materials mainly used are mullite and corundum which are shaped, burnt, impregnated with tar and baked. Besides these, zircon is used at some quarters.

Refractory materials for the "ladle nozzle" are classified according to operational conditions and steel grades. In order to prevent clogging of the nozzle due to sticking of skull and deoxidation products it is recommended to use high-quality-fireclay, high-silicious or silicon-carbide-containing refractories for steel grades of higher aluminium or titanium content and high-alumina or zircon for carbon steel.

As to the "collector nozzle" just like the "ladle nozzle" the refractory materials are selected according to operational conditions and steel grades. When applied to tundishes for continuous casting, long nozzles of fused-silica or alumina-graphite of 500 to 100 mm length are used as "collector nozzle" and the molten steel can smoothly pass through them without pre-heating. Table 1 shows examples of quality of the refractories.

V. Results of Practical Applications in Japan

1. Application to Ladles for Ingot Pouring

The slide gate nozzle applied to ladles for ingot pouring saves manpowers of operators and reduces...
Table 1. Quality of Refractories

<table>
<thead>
<tr>
<th>Refractoriness (P.C.E.) SK</th>
<th>Ladle nozzle</th>
<th>Slide plate</th>
<th>Collector nozzle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High alumina</td>
<td>Middle alumina</td>
<td>High alumina</td>
</tr>
<tr>
<td></td>
<td>39 40 33 40</td>
<td>30 40 40</td>
<td>39 33 33</td>
</tr>
<tr>
<td>Apprent porosity (%)</td>
<td>22 18 22 26</td>
<td>(12) 22 20 18</td>
<td>22 22 24 18</td>
</tr>
<tr>
<td>Bulk specific gravity</td>
<td>2.55 2.90 2.55 2.50</td>
<td>(2.60) 2.55 2.85 3.15</td>
<td>2.55 2.55 1.95 1.80</td>
</tr>
<tr>
<td>Crushing strength (kg/cm²)</td>
<td>800 800 500 200</td>
<td>1000 800 1000</td>
<td>800 500 500 200</td>
</tr>
<tr>
<td>Thermal expansion (%)</td>
<td>0.6 0.8 0.6 0.4</td>
<td>0.6 0.7 0.8</td>
<td>0.6 0.6 0.5 0.2</td>
</tr>
<tr>
<td>Refractoriness under load (at 100°C) (2kg/cm²)</td>
<td>1600 1600 1400 1600</td>
<td>1700 1700 1700</td>
<td>1600 1400 1450 1260</td>
</tr>
<tr>
<td>Transverse strength (at 1300°C) (kg/cm²)</td>
<td>— — — —</td>
<td>120 120 120 — — — —</td>
<td></td>
</tr>
<tr>
<td>Chemical composition (%)</td>
<td>Al₂O₃ 79 92 45 —</td>
<td>79 85 92 — 79 45 25 2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SiO₂ 79 7 53 50 20 14 7.0 20 53 55 95</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fe₂O₃ 1.0 0.2 2.0 — 0.5 0.3 0.2 1.0 2.0 2.5 2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ZrO₂ — — — — 45 — — — — — — — —</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SiC — — — — — — — — — — — — —</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C — — — — (4-6) (4-6) (2-4) — — — —</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Those figures in round bracket show characteristic values after tar impregnation.

Photo 1. Slide plate seen after 3 times' bottom pouring with 50 t ladle

manufacturing cost of steel through remote control and mechanisation and also repeated use of the refractories.

In bottom pouring when the frequency of opening and closing the nozzle is few it is used 4 to 6 times in succession without exchanging the refractories. Photograph 1 shows a "slide plate" used for a 50 t ladle as often as 3 times. On top pouring when the opening and closing of a nozzle is made often it is usually used 2 to 3 times repeatedly. As the result, cost of the refractories for pouring in case of conventional nozzle-stopper method can be reduced as much as 20 to 30%.

Troubles in ingot-pouring by means of a slide gate nozzle is so few as 1/10 comparing it with the case of the conventional nozzle stopper method. Generally, in the first 6 months after a slide gate nozzle is put into practice the accident rate is 0.2 to 0.3% due to inexperience of machine operation, poor setting of refractories or misjudgement of repeated use, etc., but the said rate decreases sharply down to 0.02 to 0.03% after that owing to improvement of operator's knowledge and skill.

2. Application to Ladles for Continuous Casting

As of January, 1974 there were 102 continuous casting machines all over Japan and about 25 casting machines are under construction. Since the holding
time of molten steel in ladle in case of continuous casting is 80 to 120 min the slide gate nozzle is indispensable and up to now every ladle has been installed with the slide gate nozzle. Figure 3 shows yearly tendency of relationship between the numbers of installation of continuous casting machines and that of adoption of the slide gate nozzles. The repeated using frequency of the slide gate nozzle refractories in the case of continuous casting is 3 to 4.5 times usually, but one example was shown that the repeated using frequency reached to 7 times for a ladle for a 300 t BOF. Photograph 2 shows a "slide plate" of a 300 t ladle used for continuous casting as often as 6 times. In order to use the refractories for many times not only the proper selection of refractories' quality but also the mastery of operation of the machine is needed.

3. Application to Tundishes for Continuous Casting

Automation of continuous casting operation is now being completed utilizing the slide gate nozzle not only for ladle but for tundish. The system is consisted of a control system which keeps the weight of molten steel in tundish fixed and another system which keeps the location of upper surface of molten steel in mold fixed. Figure 4 shows a flow chart of the automatic casting system. Thus, the molten steel surface in mold can be controlled automatically within 5 mm.

VI. Conclusion

In Japan, since the sliding gate nozzle was introduced first in 1968 and applied to ladles for ingot-pouring its utilization has proceeded remarkably up to now accelerlated by the spread of continuous cast- ing, owing to the improvement of the mechanism of machine and the quality of the refractories. At present many ladles are installed with the sliding gate nozzle and the frequency of repeated use of the nozzle's refractories has increased. Automation of continuous casting operation is how being completed utilizing the slide gate nozzle not only for ladle but also for tundish.

REFERENCES
1) D. D. Lewis: U. S. Patented 10, (1885), No. 311 902.
11) S. Tanaka: Refactories, 24 (1972), 24-419.