New Slide-gate System for Long Refractories Life

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Abstract

We have developed a new generation ladle slide-gate system called SST for molten steel flow-rate control at steelmaking plants. SST has many advantages such as 1) reduction of refractory consumption, 2) reduction of component parts, 3) shortening of exchange time and 4) simplified refractory exchange work[1), 2)]. Plate bricks for the SST are shaped to an optimum compact size based on thermal stress analysis and fixed by a unique fixation method. Those plate bricks provide higher performance due to the elimination of the stress concentration in the working region thereby avoiding crack formation in this critical region. In addition, the SST uses actuator power not only for moving the lower plate but also for loading and releasing the surface pressure, so that plate exchange work is much easier than that of a conventional gate system.

SST has been used at ArcelorMittal Tubarão since May 2012 with plate brick consumption being decreased drastically[3)]. This paper describes the development and the trial results of SST at ArcelorMittal Tubarão in terms of refractory service life and various great benefits to steel ladle operation.

1. Introduction

Three BOFs and three continuous slab casters are in operation at ArcelorMittal Tubarão Plant. Ladle capacity is 320 tons, and ten ladles are in operation and another ten ladles stand by.

SST was installed in a ladle 10 trial campaigns (totally about 1,700 heats) were carried out from May 2012. Fig.1 shows a photograph of an SST installed at the bottom of a ladle. The average refractory service life of conventional slide-gate systems is 20 heats for the upper nozzle, 5 heats for the plate and 2 heats for the lower nozzle. The specific targets of the trial were improvement of plate service life, decrease in the amount of refractory consumption (kg/steel ton), shortening of refractory exchange time and simplified refractory exchange work for the slide-gate system.

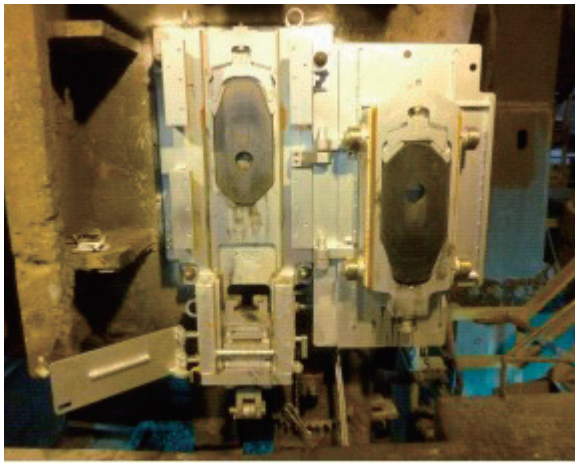

Fig.1 Installation of SST onto steel ladle at ArcelorMittal Tubarão.

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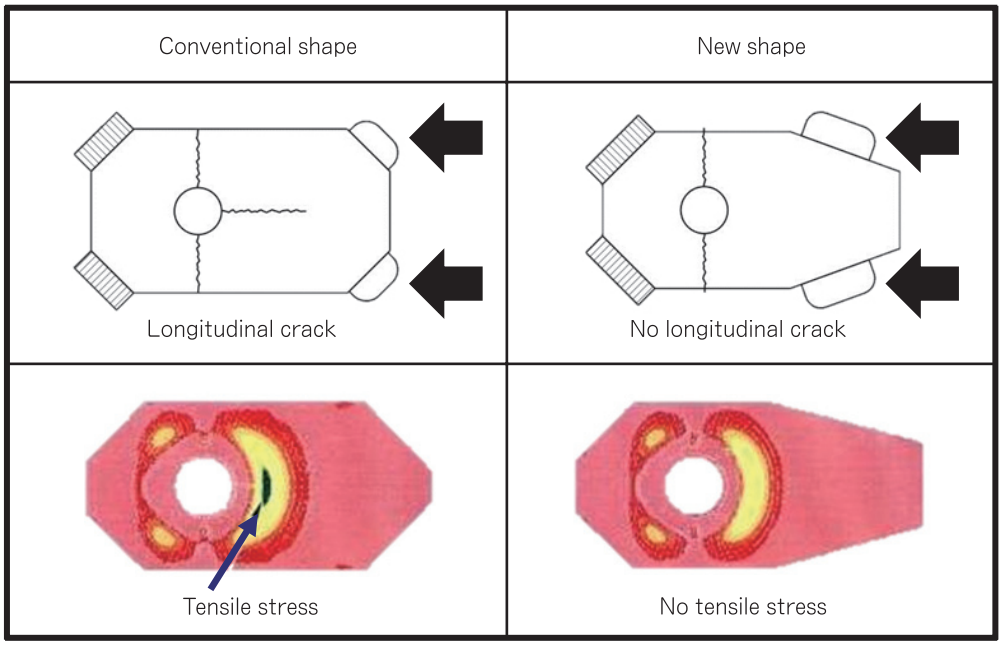

Fig.2 Optimum shape of plate brick.

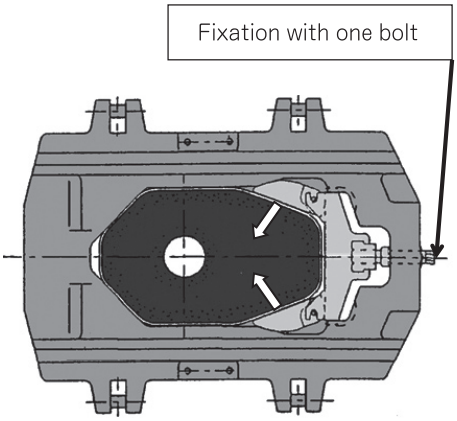

Fig.3 Plate brick fixation method of SST.

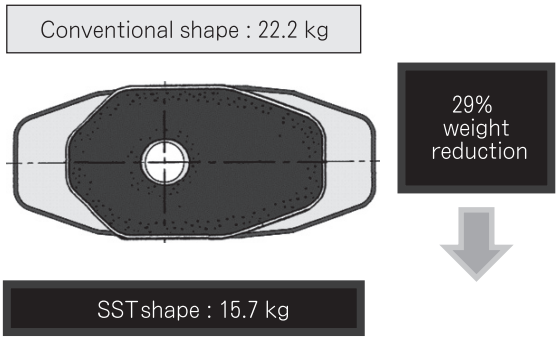

Fig.4 Plate brick shape of SST at ArcelorMittal Tubarão.

2. Optimizing Plate Brick Geometry and Fixation

It is important to prevent slide-gate plate bricks from cracking, especially along the sliding (longitudinal) direction, to achieve precision steel flow control and longer service life. Common plate materials are crack-sensitive because they have very hard characteristics and dense texture. In order to reduce cracking through geometrical design, we ran a stress calculation and found an optimal geometrical design (Fig.2).

There are mainly 4 methods of securing: 1) two-point fixing with two individual bolts, 2) four-point fixing with four individual bolts, 3) four-face fixing with one bolt, and 4) mortar setting in a slide-gate housing. Four-face fixing with one bolt (3) as shown in Fig.3 was selected for the SST. This method secures the plate brick uniformly at four faces. We observed that it prevented longitudinal cracking and also reduced other cracks (mainly 45−90 degrees from sliding direction) at actual practice.

The unit weight of the developed plate brick was 29% lighter than the conventional as shown in Fig.4.

3. Trial Schedule

At ArcelorMittal Tubarão an electric cylinder mounted on steel ladle wall was used as the SST power source (Fig.5). Depending on working conditions, either a

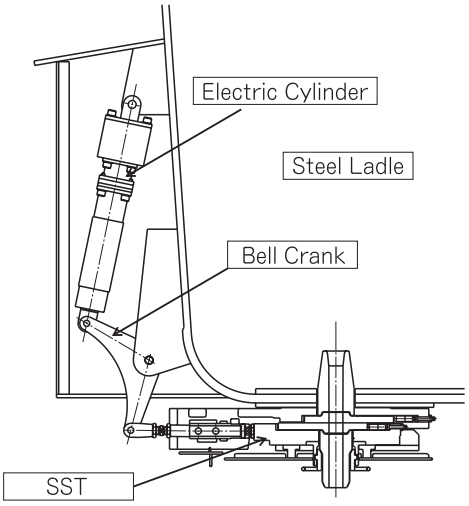

Fig.5 Outline of SST power source at ArcelorMittal Tubarão.

Table 1 SST trial schedule at ArcelorMittal Tubarão

Campaign	Date		Steel ladle life (heats)
	Start	End	
1st	2012/5/31	2012/7/23	146
2nd	2012/8/19	2012/10/20	180
3rd	2013/4/12	2013/5/31	180
4th	2013/6/22	2013/8/10	180
5th	2013/8/28	2013/10/5	141
6th	2014/8/13	2014/9/29	178
7th	2014/10/9	2014/11/21	178
8th	2014/12/5	2015/1/15	177
9th	2015/2/1	2015/3/24	169
10th	2015/4/9	2015/5/19	178
Preventive Maintenance: general cleaning and checking free height of free spring			
Total			1,707 heats

hydraulic or electrical cylinder can be selected as the SST power source. Hydraulics cylinders are widely used as the power source of the slide-gate system as it is easier to handle and maintain than the electric one.

Table 1 shows the SST trial schedule at ArcelorMittal Tubarão. The trial was conducted from May 2012 through May 2015 for 10 campaigns, totaling 1,707 heats.

4. Trial Results

4. 1 Service life of plate brick

Table 2 shows the typical properties of the SST alumina carbon plate brick used in this trial.

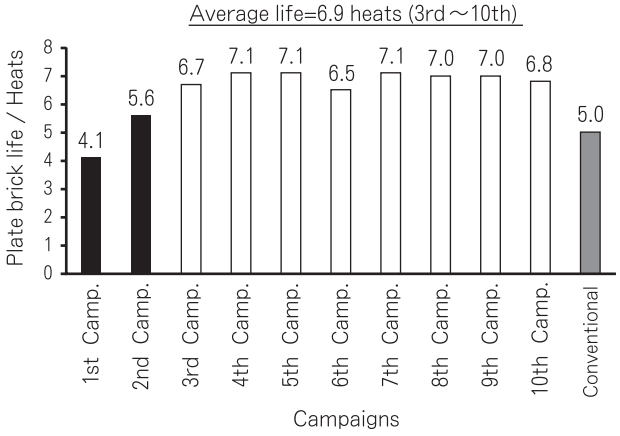

Fig.6 Comparison of plate brick service life.

Table 2 Typical properties of SST plate brick at ArcelorMittal Tubarão

Specification		Al_2O_3-C
Apparent Porosity (%)		9.0
Bulk Density (g/cm^3)		3.25
Cold Crushing Strength (MPa)		130
Chemical Composition (wt%)	Al_2O_3	84.0
	SiO_2	1.0
	ZrO_2	5.0
	C	6.0

The conventional slide-gate system also uses alumina-carbon material. The service life of the conventional plate brick was an average 5.0 heats in 2012. This was the benchmark in this trial, although at present, the plate brick for the conventional slide-gate system has been improved and service life has also increased.

Fig.6 shows a comparison of SST and the conventional plate brick service life. The service life of the SST plate brick was greatly increased reaching an average of 6.9 heats. The 1st and 2nd trials are excluded as they carried out operator and worker training.

Fig.7 shows the appearance of a used plate brick. This lower plate cast 8 heats of carbon steel during 2nd campaign. There are cracks perpendicular to the sliding direction but there is no cracking along the sliding direction. The plate surface appears to be in very good conditions.

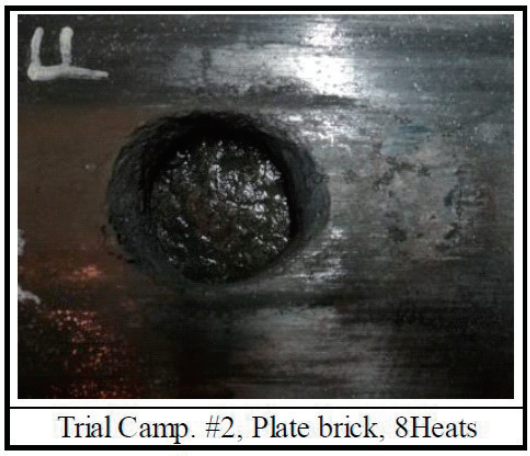

Fig.7 Appearance of used SST plate brick.

4. 2 Plate brick exchange time

A working flowchart showing average working times at the ladle yard are shown in Table 3. The working procedures of the conventional slide-gate system are complex. It takes 570 seconds average to replace the plate bricks. The SST takes an average of only 170 seconds to replace the plate bricks, reducing time by about 70%. That was mainly achieved by automatic surface pressure loading and releasing, and quick plate brick exchange with lightweight one bolt fixation plate brick.

4. 3 Reduction of component parts and maintenance cost

The coil spring is one of the most important parts of slide-gate system. Its performance usually deteriorates during use because of the heat cycles. Coil spring used in a conventional gate system is naturally cooled through the gate housing. The SST force-cools the coil spring, which gives a longer coil spring service life (Fig.8). Coil springs of conventional gate system are usually replaced in less than 500 heats. On the other hand, those of the SST have been working more than 1,707 heats. Based on the extent of their deterioration, we estimate that they could be used for more than 2,000 heats.

The SST has automatic surface pressure loading and releasing, and its mechanism and structure are very simple. We succeeded in reducing mechanical component parts to one-half compared with our previous slide-gate system (Figs.9 and 10).

Table 3 Working flowchart of plate brick exchange

	Conventional			SST	
1	Open large protection cover	10 sec	1	Open small protection cover	10 sec
2	Unfasten 4 bolts with air wrench to release surface pressure	120 sec	2	Change select pin position for driving	10 sec
3	Remove hot connecting pin for driving	50 sec	3	Release stopper	5 sec
4	Release two clampers for surface pressure	20 sec	4	Drive the slide case to release surface pressure	5 sec
5	Open slide case	5 sec	5	Open slide case	5 sec
6	Unfasten 2 bolts to remove two used plate bricks	40 sec	6	Unfasten 1 bolt to remove two used plate bricks	20 sec
7	Exchange plate bricks with case condition checking	80 sec	7	Exchange plate bricks with case condition checking	60 sec
8	Fix 2 bolts for two new plate bricks	40 sec	8	Fix 1 bolt for two new plate bricks	20 sec
9	Close slide case	5 sec	9	Close slide case	5 sec
10	Fix two clampers to load face pressure	20 sec	10	Drive slide case to load face pressure	5 sec
11	Connect drive-rod	50 sec	11	Set stopper	5 sec
12	Fasten 4 bolts with air wrench to load face pressure	120 sec	12	Change operating lever position for casting	10 sec
13	Close large protection cover	10 sec	13	Close small protection cover	10 sec
	Total time of actions 1→13	570 sec		Total time of actions 1→13	170 sec

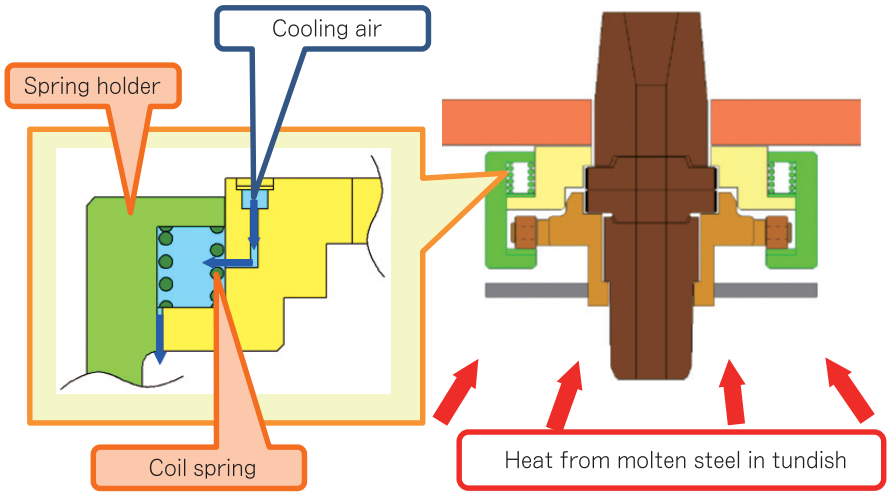

Fig.8 Forced-cooling coil spring system.

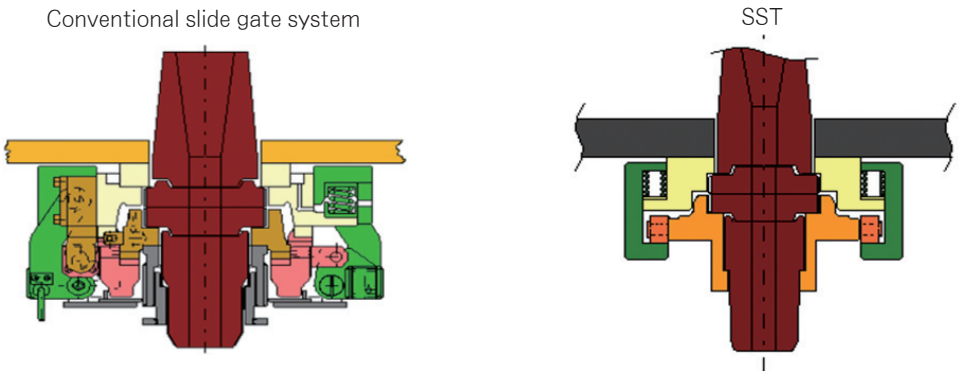

Fig.9 Schematic drawings of SST and our conventional slide gate system.

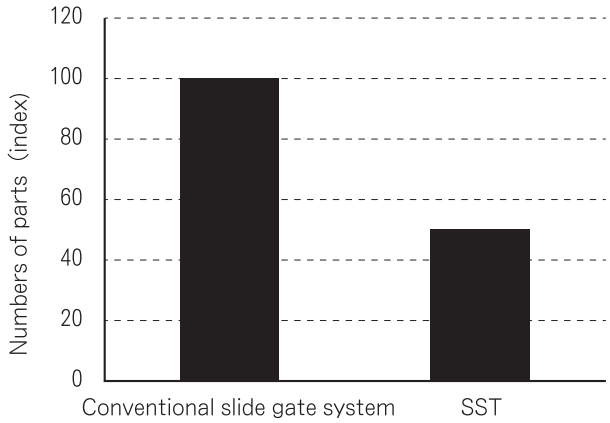

Fig.10 Comparison of numbers of component parts.

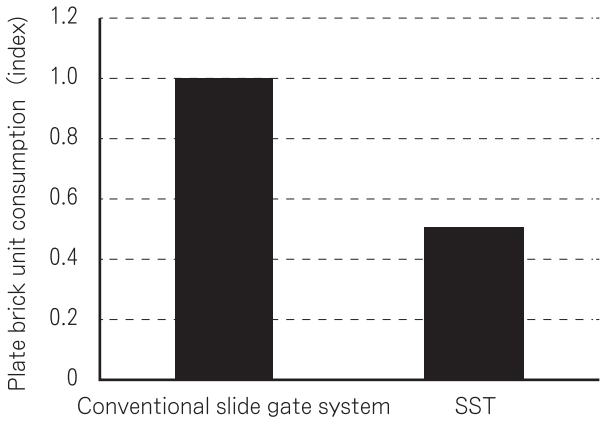

Fig.11 Comparison of plate brick unit consumption.

5. Discussions

The SST shows various advantages over a conventional slide-gate system.

The unit weight of an SST plate brick is an average of 15.7kg compared to 22.2kg average for the conventional one. The service life of the SST plate brick is an average of 6.9 heats compared to a 5.0 heat average for the conventional one. Therefore the SST reduced unit consumption of the plate brick by 49% as shown in Fig.11.

In the case of a conventional slide-gate system with two bolts fixation, it is not easy to bolt the plate brick evenly.

Uneven fixation sometimes causes cracking at a slant to the sliding direction. Computer calculation reveals that the cracking extends from the plate bore to the fixing point. Fig.12 is a photograph of an actual example of the cracking. Uneven stress causes plate brick cracking, resulting in air sucking and severe damage.

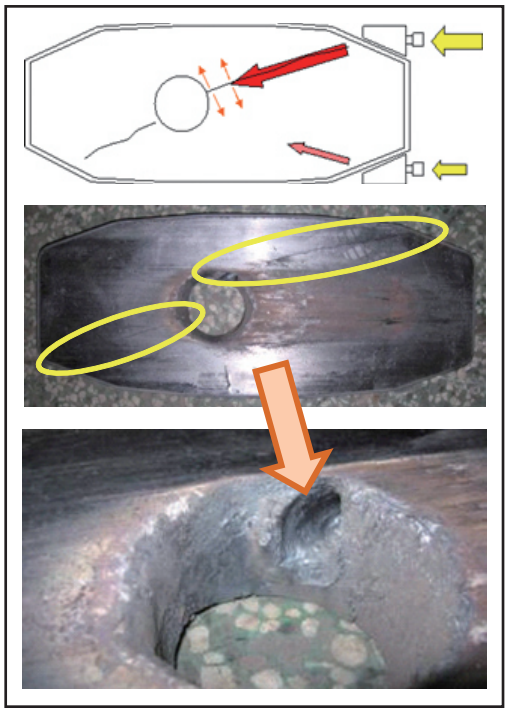

Fig.12 Crack and damage of plate brick in conventional slide gate system.

As ArcelorMittal Tubarão carefully checks the surface roughness of the plate brick in use by a test called the "Smoking Test" (inspection method without opening slide-gate system), steel leakage is not very common even when using a conventional gate system. Of course modifying the plate material itself could improve cracking (spalling) resistance. As spalling resistance is often incompatible with abrasion resistance, it is very hard to solve the cracking issue just from by modifying material.

The SST can fix a plate brick uniformly with one bolt. It prevents cracking along the sliding direction and reduces the extension of other kinds of cracking as mentioned above. Therefore, the SST accepts most abrasion resistant plate materials, which contributes longer ser vice life.

6. Summary

The SST has shown numerous benefits such as 1) reduction of refractory consumption, 2) reduction of component parts, 3) shorten exchange time and 4) simplified refractory exchange work at this trial.

According to the results of this trial, ArcelorMittal Tubarão has decided to keep using the SST and increase the number of SSTs.

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2) K. Yamamoto, M. Osada and A. Takata: Shinagawa Technical Report, **52**, 63-68 (2009).
3) Pontes Junior J. C, V. Carvalho, W. Correa1, Douglas F. Galesi and H. Morii: Abstracts and Proceedings of UNITECR2015, ECREF (2015) No.O030.