

Ceramic Welding for No.31 Hot Stove Wall of Blast Furnace at CSC

TAI-HU HUANG

*Ironmaking Department
China Steel Corporation*

The refractory bricks at No.31 Hot Stove's combustion chamber wall were found damaged during the revamping of No.3 Blast Furnace from Oct. 1, 2017 to Feb. 26, 2018. The damaged area was near the hot-blast outlet main and there were hot spots measured with the temperature of the shell being measured at over 200°C. Which may deteriorate the strength of the shell, or even melt steel parts.

Traditionally, temporary repair work like injection or partial replacement of brick during the cool-down period of the environment was usually the adopted method. This time though the ceramic welding technique was introduced and applied to the damaged bricks which can increase the thickness of broken bricks and reinforce the structure of the remaining bricks. Consequently, following ceramic welding, the shell temperature at the damaged area remained at about 100°C. This achievement proved that such a critical area could be repaired without having to cool down the Hot Stove under a well designed and prepared plan.

Keywords: Hot Stove, Combustion Chamber, Refractory Repair, Ceramic Welding

1. INTRODUCTION

The No.3 blast furnace of CSC was revamped from Oct. 1, 2017 to Feb. 26, 2018 and the No.34 hot stove was rebuilt at the same time which was completed by May, 2019. During the revamping period, No.31, No.32 and No.33 hot stoves were insulated and the condition of the bricks of the hot blast outlet were checked. On Nov. 3, 2017, the first inspection found the damaged area near the hot-blast outlet main of the combustion chamber of No.31 hot stove, where silica brick had collapsed, revealing the porous brick insulation layer. Ten days later, the second inspection found the bricks had continuously fallen, the damaged area was about 2.5 meters width, 1 meter high, as shown in Figure 1. The lining configuration of the hot blast outlet area of the hot stove is shown in Table 1. There are 6 layers of refractory materials, from the hot blast area to the iron shell, which is respectively silica brick (SGT-N) and three layers insulating brick (SV, B6, FP23S), rock wool and unshaped refractory(CN140G). The most severe part of the damaged area was where the silica bricks (SGT-N) and porous silica insulation bricks (SV) had completely fallen, the area was about 1 m * 0.6 m, the thickness was 346 mm. The remaining bricks could have continued to fall down because the upper bricks were unsupported.

In addition, there were hot spots on the east and the northeast side of the combustion chamber shell. The

temperature exceeded to 200°C and continued to be high, which would reduce the strength of the iron shell and might even melt it. It is necessary to carry out an emergency repair to continue the function of No.31 hot stove. And also ensure the normal operation of the three hot stoves after revamping of the No. 3 blast furnace.

2. PLANNING

There were three repair plans that had been proposed after intensive discussions. There were pros and cons to each plan, the first plan was to install brackets and heat shields inside the combustion chamber, so workers could enter and repair the bricks. It could be completed quickly, but risked damaging the remaining bricks through drilling of the iron shell and installing the bracket. In addition, the workers would be taking a risk working at such high temperatures. The second plan was to cool down the hot stove and to repair the damaged bricks. This repair plan is safer than the first one, and also the normal maintenance method for hot stoves. However it is also risky. Loose bricks might fall and cause injury to workers. Besides, the process of construction may take a lot longer and might not be finished before the completion of No.3 blast furnace revamping. The third repair plan was to adopt ceramic welding which had been used for the coke oven wall repair. It was performed by operators who were standing outside of the chamber, so if you can't see the damaged

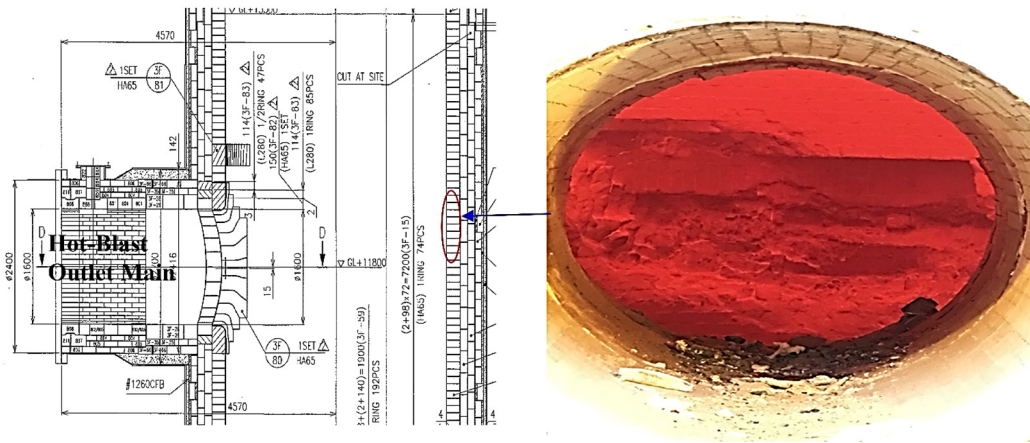


Fig.1. Damaged area near the hot-blast outlet main of the combustion chamber.

Table 1 The lining configuration of the hot blast outlet area.

Material	IRON SHELL	CN 140G	ROCK WOOL	FP23S	B6	SV	SGT-N
Thickness (mm)	20	45	35	106	118	124	222

area, you can't fix it.

The final decision was made to adopt the ceramic welding technique. It had the least interference with the revamping project of No.3 blast furnace and the least damage to the existing wall lining bricks of No.31 hot stove. The damaged area would be sprayed with a 30 to 50 mm thickness of ceramic weld with no other further repairs being required after the ceramic welding. Only monitoring of the temperature of the iron shell by thermometer and thermal imager would be required. If there is a hot spot on the iron shell, the injection of mortar would be carried out to the inside of the iron shell for cooling. After the No.34 hot stove was renewed, the No.31 was shut down for large-scale maintenance.

2.1 Introduction of Ceramic Welding

The ceramic welding technique has been applied to the repair of the coke oven chamber walls for more than 20 years. The ceramic welding process utilizes a dry mixture of refractory powder and metallic fuels (Table 2). This mixture is projected onto the area to be repaired using air and water-cooled lances. Conveyed by a stream of oxygen, the mixture ignites on the hot repair surface in an exothermic reaction in excess of 2000°C. The material coalesces with the brickwork forming a ceramic bond and restoring the refractory to its original state.

The repaired brick surface can last for several years

Table 2 The specification of ceramic welding material.

(1) Bulk Density	2.0 g/cm ³
(2) Expansion Rate(AT 1200°C)	<1.25-1.30%
(3) Open Porosity	<17.0%
(4) Thermal Conductivity at 800°C	1.85 W/m. °C
(5) SiO ₂	>90%
(6) Residual Quartz	<2 %
(7) Crushing Strength at 25°C	60Mpa
(8) Refractoriness Under Load	1670°C

in a stable temperature area, even for decades. Compared to wet gunning, semi-dry gunning or brick replacement in a hot atmosphere, with the following advantages:

- (1) The ceramic welding area has excellent adhesion and the original brick will not be affected by water.
- (2) Ceramic welding does not interfere with production and it is safer and more efficient in comparison with brick replacement.

2.2 Ceramic Welding Test

Up to two layers of damaged bricks have fallen in the combustion chamber of the hot stove, exposing B6 high-aluminum insulation bricks. Their maximum operating temperature is 1400°C. The temperature during the ceramic welding process may cause melting and deteriorate the strength of the combination of two different materials. Therefore, a test was arranged. Figure 2 shows the B6 insulation bricks being preheated to 500°C in the coke oven chamber and then ceramic welding being carried out.



Fig.2. B6 insulation bricks where ceramic welding was carried out in the coke oven chamber.

After the ceramic welding, the surface combination between the two different materials was found to be good by visual check as shown in Figure 3 and a test at the laboratory confirmed the strength of the ceramic welding material and B6 insulation brick can reach ~1MPa, the bonding strength is similar to silica brick (~1.3MPa). So ceramic welding can be suitably applied to the combustion chamber of a hot stove.

2.3 Equipment Manufacturing for Ceramic Welding

Ceramic welding is performed in a hot status. In order to reduce the heat loss of the coke oven wall, it was necessary to install 6 heat shields from the top to the bottom of the opening. When performing ceramic welding, only one shield is taken at a time according to the repair position. The hot air outlet main of the hot stove has a

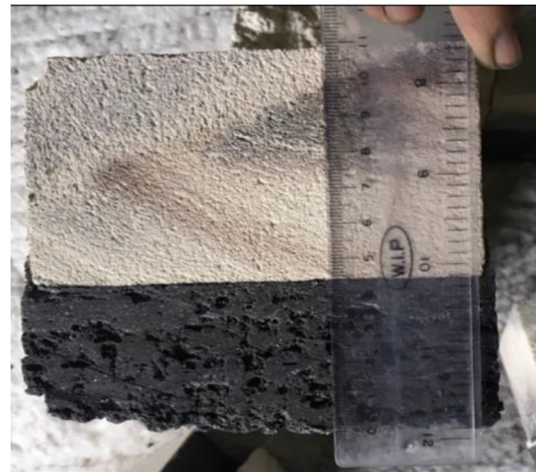


Fig.3. The surface combination between two different materials.

circular opening and different working environment in comparison with the coke oven chamber. Therefore, the design of the heat shield is completely different. It is necessary to consider the steel structure of the material, the support position for the ceramic welding pipe, the size of the opening and installation method.

The diameter of the hot air outlet main is 1.6 meters. If the heat shield is divided into several pieces, it is not easy to fix it. In addition, the ceramic welding pipe bracket must be designed behind the heat shield. Therefore, it must be integrated into one piece. The damaged area of the brick is about 2.5 meters width and 1 meter high. The calculated width of the bracket is 1.3 meters, which can cover the damaged area. In order to control the 70kg ceramic welding pipe, the length of the bracket extends into the combustion chamber by 2 meters. The temperature of the chamber is about 1000°C. The material is made of SUS301S in order to prevent the bracket from being thermally deformed. The outer frame of the shield is bent by channel iron and the two sides of the middle frame are covered with 50mm ceramic blanket and expanded metal lath. Two openings of 500mm x 800mm on the shield are reserved. The openings can be opened according to the ceramic welding position. The designed heat shield weighs 220kg. (as shown in Fig.4)

The methods of ceramic welding are different between the combustion chamber of the hot stove and coke oven chamber. Therefore, the ceramic welding nozzle needed to be redesigned and changed from the original 90° to 30°, and the pipe length design to 6.5 meters, and according to the coke oven ceramic welding experience, if the pipe temperature is too high, it may become blocked by the material, so 3 air-cooled and 2 water-cooled pipes were made, with SUS304 material being used. Figure 5 shows the spray demonstration after the water-cooled pipe was made.

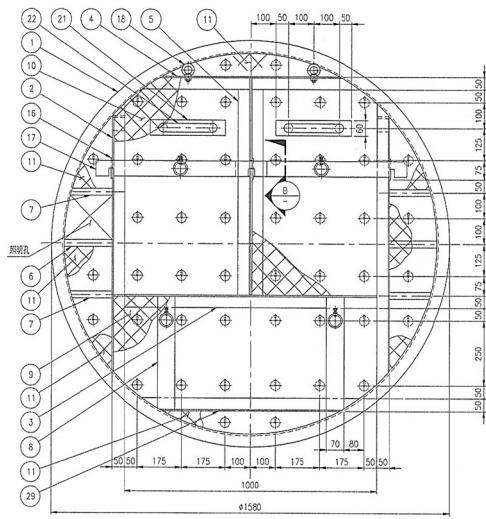


Fig.4. Sketch of the designed heat shield.

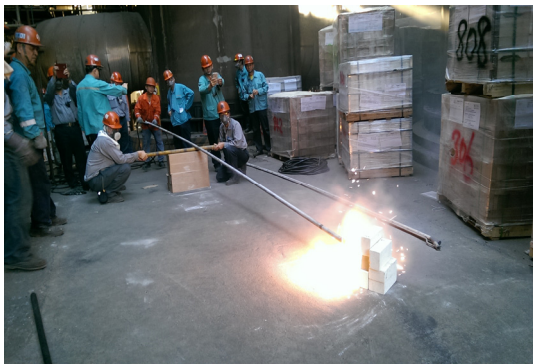
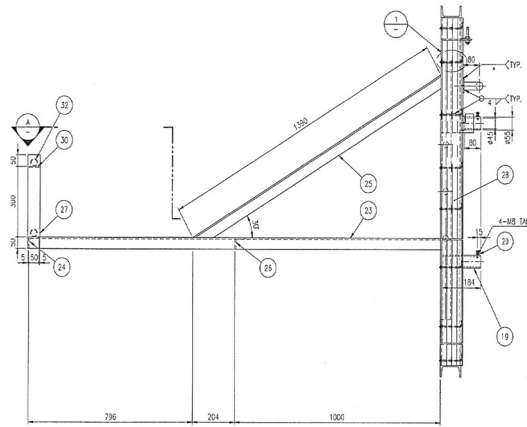


Fig.5. The spray demonstration after the water-cooled pipe was made

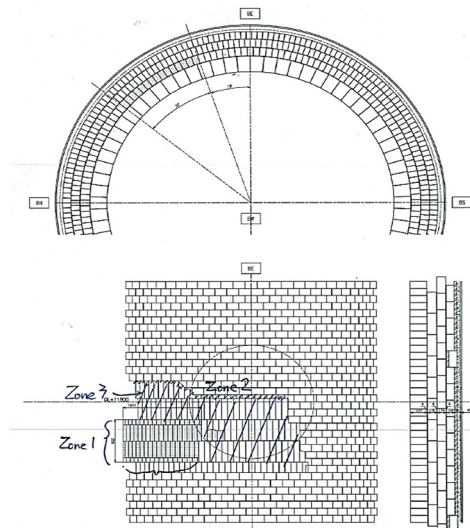


Fig.6. The damaged area identification pattern.

3. REPAIR OF DAMAGED BRICKS OF COMBUSTION CHAMBER

3.1 Damaged Area Confirmation

Due to the large-scale collapse of the combustion chamber brick with up to 346 mm in depth, it is impossible to weld all of the damaged area by ceramic welding in the limited time. To avoid any further continuing damage of the bricks caused by cooling, the temperature should be maintained at around 1000°C. The planned shutdown time of No.31 hot stove was 19 hours, 7 hours for the water-cooled blind sealing plate that was disassembled and assembled, and 12 hours for installing and uninstalling the heat shield and time for carrying out the ceramic welding.

The critical area for ceramic welding needed to be confirmed in advance. By drawing a damage area identification pattern (Fig.6), the damaged area could be divided into three zones. The first zone was the primary repair area, which had two layers of collapsed brick as well as a hot spot area detected from iron shell. The

measurement of the area was about 1 meter wide, 0.6 meters high, ceramic welding would spray about 30~50 mm thickness in this area; the second zone was above the first layer of collapsed brick, in this area the depth of the first layer brick was up to 220mm, after callapsing, the upper bricks were unsupported and may have continued to fall, so using the ceramic welding can strengthen this area; the third area was the slightly less damaged or collapse of the first layer of brick. This zone would be the final repair, which had minor effect on the operational performance of the hot stove. The thickness and extent of the spray would be determined accordingly at the time.

3.2 Repair Arrangement

The ceramic welding repair was arranged for Dec.

8, 2017. On the previous day, ceramic welding equipment, lances, hoses, oxygen cylinders and ceramic materials were transported to the site and positioned to avoid any interference with the removal of the water-cooled blind sealing plates as well as the installation of the heat shield on the hot air outlet main closure.

The water-cooled blind sealing plate was installed at the flange of the hot air outlet main, and mainly isolated the hot stove and the hot air main pipe, so that the hot stove could be insulated during the revamping. It needed to be detached before the ceramic welding operation. Then the ceramic welding heat insulation shield was installed in the interior of hot air outlet main. The heat shield must be fixed by wire to the hot air outlet of the combustion chamber because the front end of the heat shield has a ceramic welded pipe support frame. After the heat shield is pushed in to position, in order to prevent it from tilting, both sides needed to be fixed to the outlet main by steel wire.

The planned welding time of the ceramic welding was 8 hours, and the actual working time was 7 hours. There were 6 welders and 12 assistants working alternatively. Due to the high heat radiation and unstable hot airflow coming from the hot air outlet main, it was necessary to adjust the suction by opening the exhaust valve of the hot stove. It took about 5-10 minutes for each welder to perform the ceramic welding by taking it in turns. The ceramic material consumed 460 kg in total. The repair team successfully completed the ceramic welding operation after 7 hours. (Figure 7).

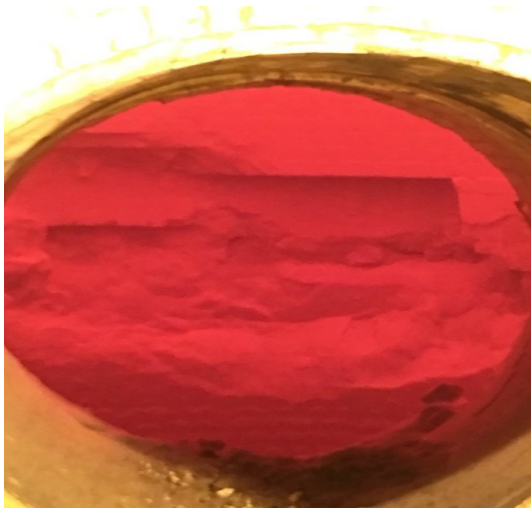


Fig.7. The status of bricks after applying ceramic welding on Dec. 8, 2017

4. CONCLUSIONS

- (1) The refractory brick of the hot air outlet of the hot stove was damaged and needed emergency treatment. After various repair plans are evaluated, the

ceramic welding repair method was adopted. This method was applied to the hot stove for the first time and through the cooperation of the China steel team and thorough pre-planning, the repair was therefore successfully completed.

- (2) After the ceramic welding, the iron shell hot spot of No.31 hot stove was kept at 100°C (Fig.8), and the further collapse of the bricks were prevented (Fig.9). It was put back into operation upon the completion of No.3 blast furnace revamping on Feb. 26, 2018 until the shut down for large-scale maintenance in July 2019.
- (3) The ceramic welding repair method was established, and can be listed as one of the repair options for damaged bricks of the hot stove.

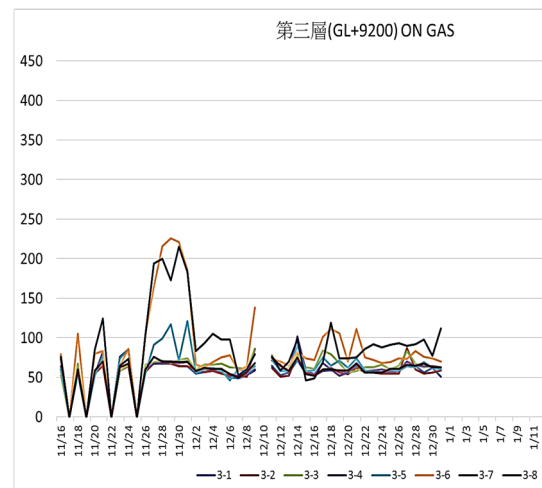


Fig.8. The iron shell hot spot decreased to around 100°C after applying ceramic welding.



Fig.9. The status of the ceramic welding area after the cooling down of No.31 hot stove on July 5, 2019.

REFERENCES

1. Hung-Jung Yen, Kuo-Jen Wu, Introduction of Coke Oven Refractory Repair and Application of Ceramic Welding in China Steel Corporation, 1996.
2. CHING-HENG SHAO, Suggestion for Lining Brick Repair of Hot Blast Outlet Main of No.31 Hot Blast Stove, 2017.
3. Yi-Kai Sun, Kuo-Hua Huang, Cooling Down, Repairing, Heating Up Operation of #31 Hot Stove at No.3 Blast Furnace, 2001.
4. Chung-Tsai Chang, Brick Lining Repair of Checker Chamber Dome in the No.41 Hot Stove, 2006. □