LIFE STABILIZATION FOR RH SNORKELS BY COOLING OF STEEL SHELL

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ABSTRACT

Recently, demand for high purity steel has increased, and in response, the secondary refining rate for molten steel has become larger. As a result, maintaining the working ratio of the RH degasser has become one of the most important tasks for steel production lines.

One of the shortest refractory life parts in the RH degasser is the snorkel. In particular, sudden damage of an upleg snorkel requires unscheduled replacement of the snorkel, which harms stable steel production.

In most cases of suddenly damaged snorkels, deformation of the steel shell of the snorkel is observed. Therefore, the risk of sudden damage of snorkels might be reduced by preventing shell deformation. It is well known that the strength of steel decreases as the temperature increases, and this degradation has a negative influence on shell deformation. Therefore, in this study, we developed a method for cooling the steel shell by utilizing the gas flow pipes, which are used to lift the molten steel in the refining process.

Keywords: RH degasser; snorkel

INTRODUCTION

A schematic figure of the typical structure of a RH snorkel is shown in Fig. 1. Generally, the RH snorkel is cylindrical in shape and consists of a monolithic refractory on the outer side and lower edge, bricks on the inner side and gas inlet pipes for lifting the molten steel. There is also a water-cooled flange between the lower vessel and the snorkel, and under the flange, there is a cylindrical iron shell, which is used to fix the bricks and prevent suction of air. The steel shell is positioned between the bricks and the outer monolithic refractory.

Generally, two snorkels are used together. One side is the upleg snorkel, which is used to lift the molten steel in a ladle into the lower vessel by gas injection, and the other side is the downleg snorkel which returns the molten steel in the lower vessel to a ladle. After using an upleg snorkel, it is changed to a downleg snorkel by stopping the valve of the lift gas pipe. In case of refractory damage, snorkels are usually repaired by gunning refractories, but when the damaged area is too extensive or the gas pipes of the upleg snorkel are damaged, the snorkel must be replaced as it is beyond repair. In particular, sudden damage of an upleg snorkel requires unscheduled replacement, and this harms stable steel production. Therefore, the aim of this study was to prevent sudden damage of the upleg snorkel.

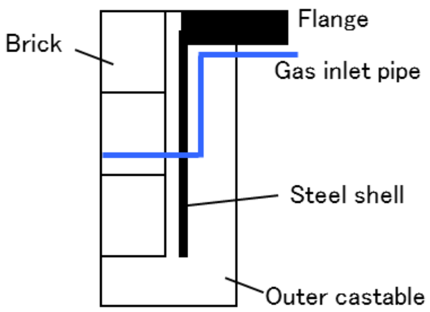

Fig.1 Schematic figure of typical structure of RH snorkel

TYPICAL DAMAGE OF SNORKEL

Sasajima et al. reported that deformation of the lower edge of the steel shell due to thermal expansion of the steel causes erosion of the lower edge of the snorkel and cracks in the outer castable and slag line level. They suggest restraining the deformation of the steel shell caused by thermal expansion by setting bricks surround the outer castable.

On the other hand, Terajima et al. reported that it is possible to restrain the deformation of the lower edge of the steel shell with reinforcing rings welded on the lower edge of steel shell. They also reported that the effect of this measure can be improved by increasing the numbers of rings.

However, few reports contain data on the actual temperature of the steel shell during use. Tawara et al. reported the measured temperature of the steel shell and found that the temperature of shell increases in every treatment and reaches 1,573K. They also reported that the deformation of the lower edge of the steel shell has a relationship with the length of treatment and the frequency of temperatures reaching over 1,073K.

Generally, structural carbon steel such as SS400 is used for the steel shell. It is well known that the strength of these steels decreases at elevated temperature, and when the temperature reaches 1,073K, strength decreases about 10% from that at room temperature. Moreover, when the temperature reaches near 1,350K, the strength of the steel approaches zero. From the above, we inferred that the deformation of the steel shell is caused by the decrease in the strength of steel at higher temperature.

A schematic figure of a damaged snorkel is shown in Fig. 2.

The main life factor of commercial snorkels is damage of the lowest bricks, for example, spreading of the joint, cracking and falling off of the bricks. In most suddenly damaged snorkels, deformation of the steel shell is also observed. However, that deformation occurs only at the lower edge and is not observed at the other parts of the shell.

To measure the actual temperature of the steel shell of the upleg snorkel during use, three thermocouples were installed at three levels on the outer surface of the shell, namely, at the upper level, middle level and lower edge.

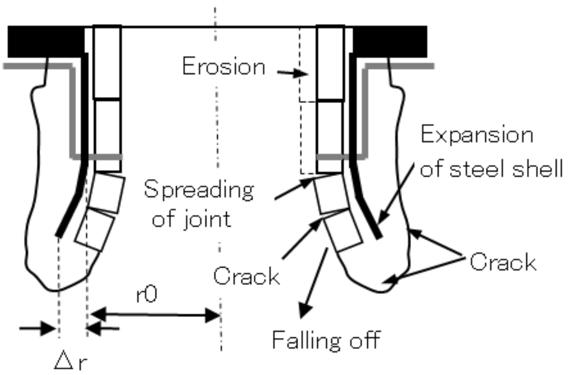

Fig. 2 Schematic figure of damaged RH snorkel

Measurements were made continuously while the snorkel was in use. After using for the downleg snorkel, the deformation of the shell was measured at each levels.

The radius expansion rate was calculated as the percentage of the radius expansion length "Δr" in Fig. 2 relative to the initial radius "r0". The measured results are shown in Fig. 3.

The snorkel was changed to a downleg snorkel due to spreading of the joint during use as an upleg snorkel.

The highest temperature was 1,473K, and the temperatures at the middle and upper levels at the same timing were 921K and 641K, respectively. The diameter increase rate of the lower edge was 5.5%, but the rate of increase of the middle to upper levels was very small.

From these result, we thought that the deformation of the steel shell can be restrained by cooling the shell with the gas flow in the gas inlet pipes when the snorkel is in use as an upleg snorkel.

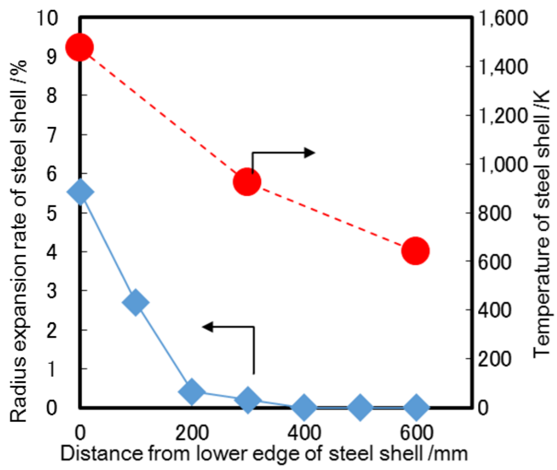

Fig. 3 Radius expansion rate and temperature of steel shell

SNORKEL COOLING TEST

Test snorkels

Two types of snorkels with the cooling pipes arranged in different areas were prepared in order to realize a cooling effect by the lifting gas, and the test snorkels were tested in use at a commercial plant.

The piping areas of the test snorkels are shown in Fig. 4. The gas inlet pipes of the conventional snorkel are arranged so as to minimize the pipe length. In improved Type 1, the gas pipes are arranged over almost the entire area of the steel shell, and in Type 2, the pipes are arranged intensively near the lower edge of the steel shell. Each type of test snorkel was equipped with three thermocouples, as in the conventional snorkel used to

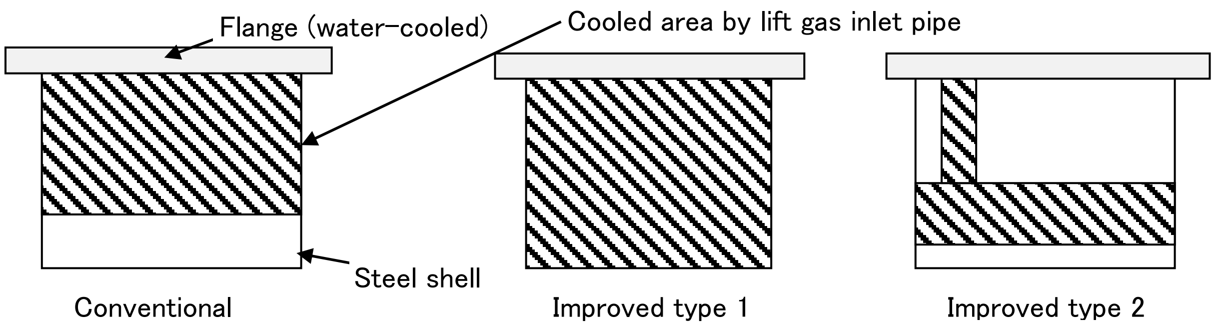

Fig. 4 Schematic image of lift gas inlet pipe arrangement area

measure the temperature in previous chapter. Both types of test snorkel kept a lower temperature than the conventional one.

Results of temperature measurements

The results of measurements of the temperature of the steel shell of each test snorkel when in use as an upleg snorkel are shown in Fig. 5. The temperature means the temperature of the steel shell at each level when the highest value was measured at the lower edge of the steel shell. Higher temperatures were observed near the lower edge, and the highest value was observed in the last stage of the upleg snorkel and when treatment was continued. The highest temperature values were 1229K with Type 1 and 909K with Type 2. In particular, Type 2 showed a drastic decrease in comparison with the maximum temperature of 1473K with the conventional snorkel.

At the levels other than the lower edge, no large difference in temperature was observed between the snorkels.

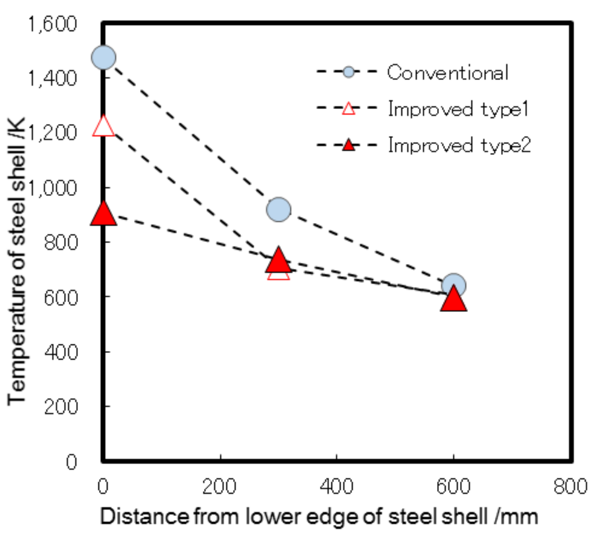

Fig. 5 Maximum temperature of steel shell of upleg snorkel

Situation of refractories and deformation of steel shell

Schematic images of the upleg snorkels after use are shown in Fig. 6. Each test snorkel was replaced systematically. Although slight erosion was seen, no serious damage was observed in any of the test snorkels. Type 1 had a round shape at the lower edge of the snorkel and also displayed many small cracks.

Type 2 displayed lighter damage. Its shape appeared almost new, and no cracks could be observed with the naked eye.

The life of the test snorkels was also extended. Compared with the average life of conventional snorkels, the life of Type 1 was 140% and that of Type 2 was 160%.

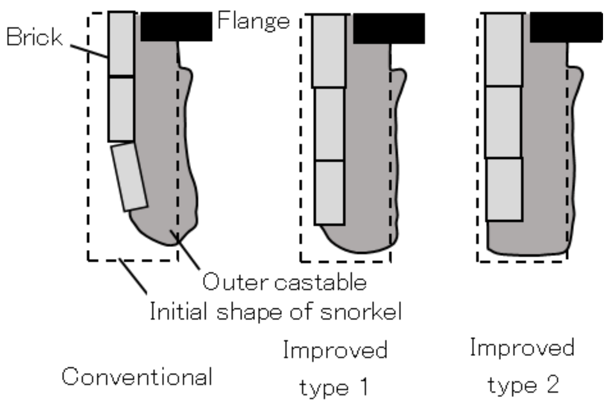

Fig. 6 Schematic images of upleg snorkels after use

Figures 7 and 8 show the radius expansion rate and the highest temperature at each level of the steel shells, respectively. The radius expansion rate of the lower edge of the steel shell was 4% in Type 1 and 2% in Type 2. Type 2 had no deformation at levels other than the lower edge. Although there was no large difference between the snorkels at the middle or upper levels, dramatic improvement was observed at the lower edge of Type 2.

The relationship between the radius expansion rate and the temperature of the steel shell is shown in Fig. 9. The data obtained by Tawara et al. are also plotted in the same graph. From the graph, it can be understood that the radius expansion rate is increased by the elevated temperature of the steel shell.

As a result of this study, stabilization of the life of upleg snorkels is possible by keeping the temperature of the steel shell under 1,230K.

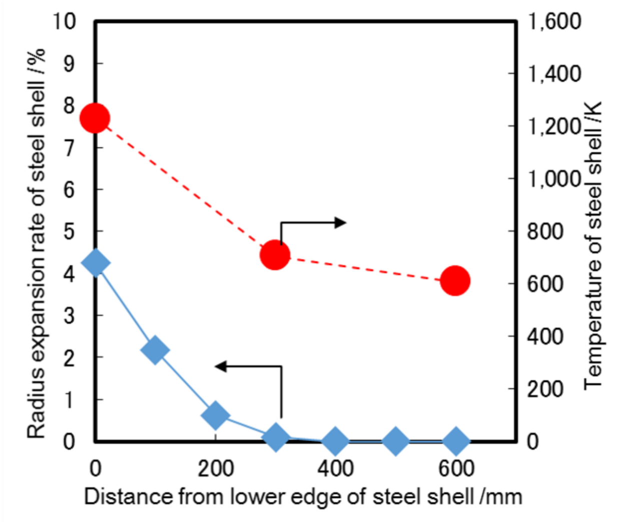

Fig. 7 Radius expansion rate and temperature of steel shell (Improved type 1)

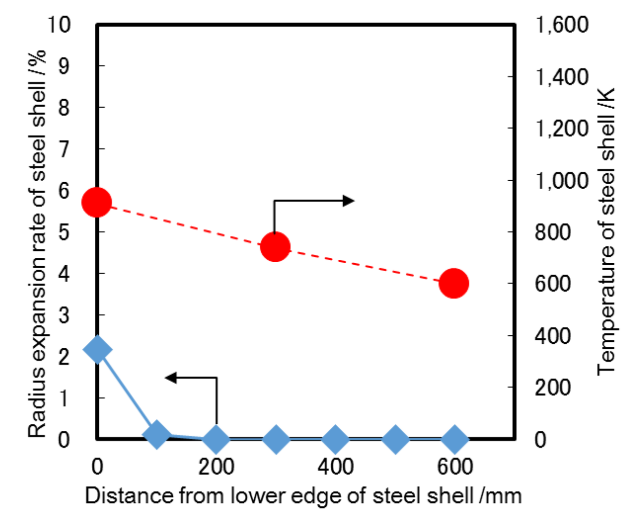

Fig. 8 Radius expansion rate and temperature of steel shell (Improved type 2)

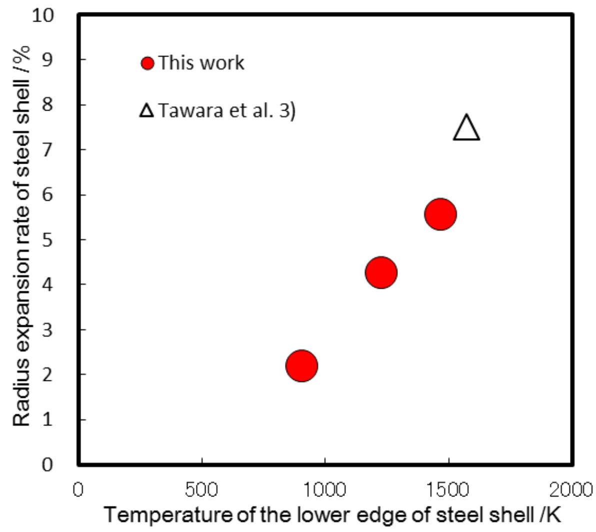

Fig. 9 Relationship of radius expansion rate and temperature of steel shell

CONCLUSION

As a result of a study on suppression of deformation of the steel shell of the RH snorkel, the following three points for preventing sudden damage of upleg snorkels during use were clarified.

a) Deformation of the steel shell occurs due to the decreased strength of steel at elevated temperatures.

b) Sudden damage caused by deformation of the steel shell can be avoided by keeping the temperature of the shell under 1,230K.

c) By placing gas pipes intensively near the lower area of the steel shell, the cooling effect of the gas flow can be obtained in the snorkel. This piping arrangement enhances suppression of the deformation of the steel shell and also suppresses refractory damage.

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