Application of Shell Heat Exchanger Supplied with Compressed Air for Pot Sidewall Cooling

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https://doi.org/10.71659/icsoba2024-al025

Abstract

Heat removal from the cell in aluminium smelter is essential for temperature controlling. Sidewall cooling helps the formation of side ledge inside the cell. Many aluminium smelters including PT Inalum are currently using compressed air direct cooling to the sidewall of the pot. These air jets inefficiently cool the sidewall as the cooling pattern is non-uniform and the limited air to pot shell retention time eventually requires more compressed air to be utilized. On the other hand, compressed air is needed for other daily operational works so the pressure has to be kept as the requirement. Therefore, Shell Heat Exchanger (SHE) with air supply is introduced for sidewall pot cooling. This technology increases the pot cooling efficiency and eventually reduces the compressed air needed for cooling. Experiment results at PT Inalum showed approximately 15 % compressed air saving by using SHE compared to direct cooling.

Keywords: Sidewall cooling, Shell Heat Exchanger (SHE), Compressed air.

1. Introduction

The shell sidewall temperature of aluminium cell tends to increase overtime during the operational life of the aluminium electrolysis pot, because the capacity creep normally applied in smelters. Heat transferred from the liquid electrolyte through frozen ledge is approximately equal to the heat flow through the sidewall lining from frozen ledge to the steel shell. This heat produced inside the pot eventually cause the ledge erosion. Besides that, capacity creep in smelting cell by increasing the amperage of existing cells also contributes to the sidewall ledge erosion. It has been reported that ledge thickness has decreased from 15–20 cm to 1–3 cm when pot amperage increased from 186 kA to 210 kA for a particular cell design [1]. This is due to the greater heat flow through the cell walls. Stable ledge needs to be maintained for adequate life of the sidewall materials. The ledge erosion will lead to the increasing of pot steel shell temperature.

This steel shell has its maximum tolerance of the heat based on the material resistance. Shell temperatures in excess of 500 °C have been measured in the last decades in aluminium smelter worldwide [2]. The temperature higher than pot shell material resistance will eventually cause the pot leakage and the pot has to be cut out. Therefore, the high sidewall temperature needs to be cooled externally to prevent the pot from leakage during operation. Traditionally, sidewall cooling is implemented by direct cooling using compressed air through tubing hose to cool the sidewall hotspot locally. Compressed air increases the convective heat transfer coefficient between ambient air and the shell exterior thus permitting rapid cooling of the shell. However, there are some constraints regarding this cooling method:

a) Direct cooling using tubing hose supplied with compressed air increase the dust aeration and dispersion within the potroom due to unconfined air flow. This issue leads to health hazard which cause respiratory diseases and eye injuries for the worker in the aluminium reduction potroom [3].

b) Less contact time between the compressed air and pot shell being cooled due to the unconfined air flow to the ambient.
c) Not amendable to waste heat recovery in the future because the heated air from the cooling process is not captured [4].

2. Heat Exchanger Concept

Shell Heat Exchanger (SHE) was introduced to overcome the constraints of traditional direct cooling method. This technology has several advantages such as: the ease of installation because it is installed on-line at the inter-cradle space of the pot, localized compressed air contact with the shell side hot spot and increasing the contact time between cool air and the hot spot which eventually lowers the compressed air consumption. Figure 1 demonstrates the operation of SHE for cell sidewall cooling. The air is introduced into the exchanger in such way that additional ambient air is entrained. The air flows up the gap between the steel shell and the SHE and then exits through the top part of the exchanger. The cell wall is cooled while the exchanger outlet air is heated.

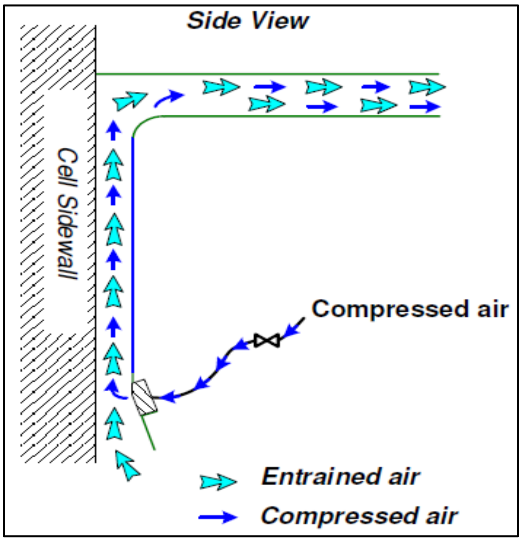

Figure 1. SHE supplied with compressed air working principle [3].

3. Heat Exchanger Prototype Installation

A prototype of Shell Heat Exchanger (SHE) with 20 cm width and 18 cm length was designed and fabricated in the PT Inalum workshop. The dimension of SHE was determined by on-site measurement of the PT Inalum pot sidewall. The pot sidewall dimension difference caused SHE dimensions to be variable. Material used for SHE is aluminium due to its low density (2 710 kg/m^3) compared to other common materials such as steel (7 850 kg/m^3) or copper (8 940 kg/m^3). This low density brings advantage for the manual installation of SHE at the pot sidewall. Besides, aluminium also provides high thermal conductivity (237 W/m·K) which increases the heat transfer in the system to be more effective. The prototype was then installed online at a PT Inalum operating pot sidewall.

SHE prototype was installed on the corner sidewall of the pot (sidewall 1–4, 13–16, 17–20, 29–32). The pot sidewall numbering configuration at PT Inalum is demonstrated in the Figure 2. Typically, corner sidewall has a higher chance to be overheated and be cooled by air injection. It is caused by the metal pad movement due to magnetohydrodynamic (MHD) flow of the electrolyte in the pot which tends to attack the corner side ledge which resulted in high temperature of the sidewall around the corner area of the potshell [5]. This is why the majority of the pot cooling in PT Inalum was installed on the corner sidewall.

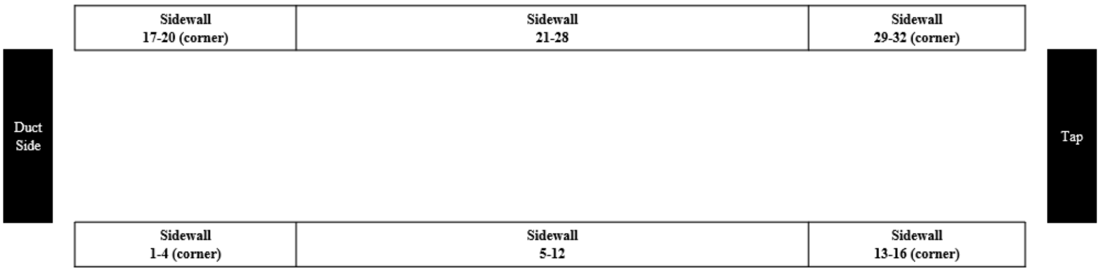

Figure 2. PT Inalum pot sidewall intervals numbering.

4. Testing and Result

The Shell Heat Exchanger (SHE) was installed online by hanging it on the inter-cradle of a pot until the exchanger body touched the steel shell as shown by Figure 3. The dimension of each compartment is 71 cm width and 19 cm length with 11 cm inter-cradle space. Compressed air was supplied to the inlet side of the SHE through a pressure regulated valve and tubing hose. The heated air that has already exchanged heat with the sidewall exited through the outlet side of the SHE. Figure 4 illustrates the cool air supplied (blue arrow) contacted with the pot sidewall surface and the temperature increased due to the heat transfer and then exits through the outlet of SHE (red arrow).

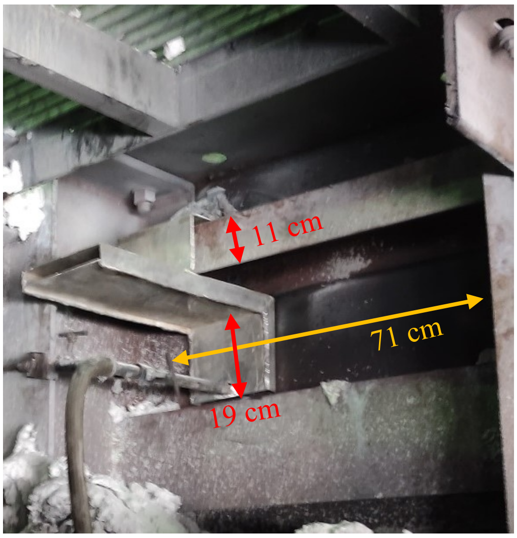

Figure 3. SHE installation at pot sidewall.

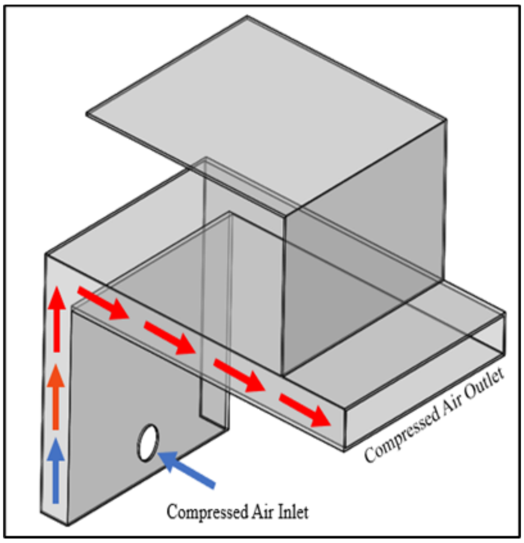

Figure 4. Compressed air-cooling flow.

An experiment was done at PT Inalum on several active pots operating at 196 kA. SHE was mounted to the central inter-cradle of a potshell. Based on PT Inalum procedure, the sidewall temperature of more than 330 °C has to be cooled with direct cooling method using tubing hose with 0.01 m^3/s volumetric flow of compressed air. The effectivity of Shell Heat Exchanger (SHE) was analyzed by the method described as follows:

a) Determine the pot which the corner sidewall is being cooled with direct cooling using tubing hose;
b) Measure the temperature of the sidewall (direct cooling) using thermos-gun every 10 minute for 1 hour;

c) Stop the compressed air supply and swap the cooling method by installing the SHE on the sidewall of the pot;
d) Adjust the compressed air flow by regulating the inlet valve starting from 95 % opening and decrease per 5 % opening (95 %, 90 %, 85 %) successively;
e) Measure the temperature of the sidewall (SHE installed) using thermos-gun every 10 minutes for 1 hour per parameter;
f) Plot the data on the graph and compa[re the effectivity of those 2 methods.

The direct cooling and SHE supplied with compressed air tests were conducted on the same sidewall in a close time range to ensure that the pot condition during the testing of those 2 methods was still approximately the same (pot voltage, noise, side ledge profile). This is essential as the pot condition is changing depending on the operating condition of the pot. This experiment was done on 5 different reduction pots in order to achieve better conclusion and statistical relevant results of the testing. The temperature data was taken every 10 minutes by thermo-gun measuring.

If the temperature obtained by Shell Heat Exchanger (SHE) with supplied compressed air is lower than the direct cooling method, it is shown that the SHE cooling method is more efficient compared to the existing direct cooling method. The experiment stopped when the sidewall temperature using the SHE with supplied compressed air is higher than the temperature of direct cooling method after regulating the compressed air supply every 5% decreasing successively. The comparison of tests result is demonstrated by the figures below.

Figures 5–9 show that the utilization of Shell Heat Exchanger (SHE) for sidewall cooling could reduce by 15 % the compressed air supply on average, compared to direct cooling method using only tubing hose with compressed air supply. This is promising as we can save the energy needed to produce the compressed air and allocate the compressed air to other operational needs. The conclusion of the experiment is shown in the table below.

Table 1. Compressed air flow reduction using SHE with compressed air supply.

Pot Number	R307	R412	R421	R424	R319
Compressed air reduced by, % of inlet valve	15	20	15	15	10

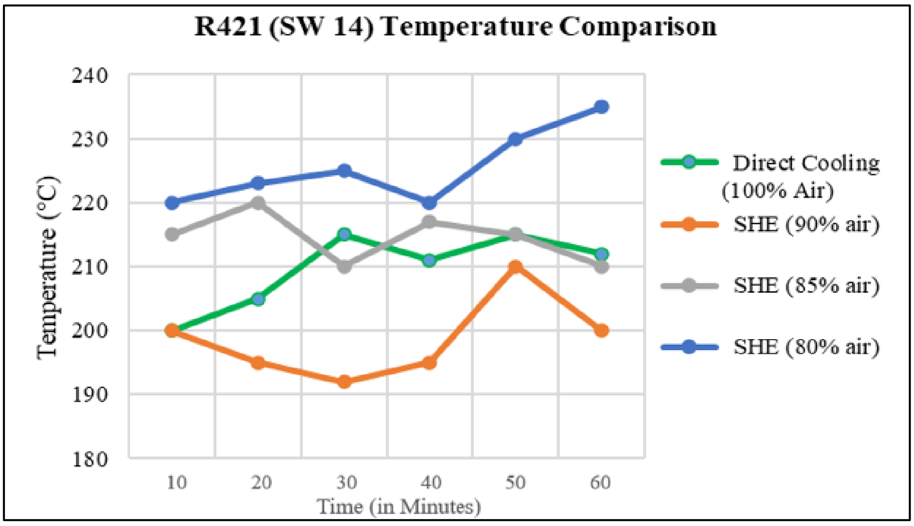

Figure 5. Cell R421 sidewall no.14 cooling temperature comparison.

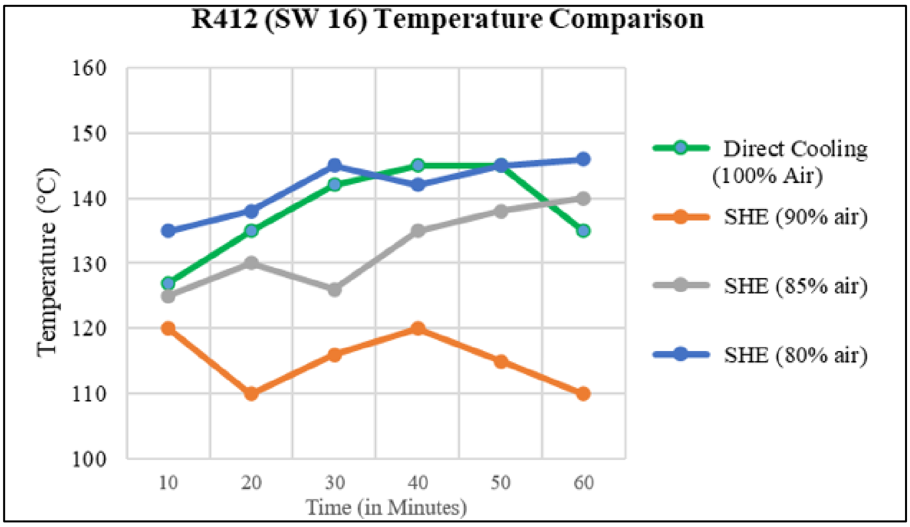

Figure 6. Cell R412 sidewall no.16 cooling temperature comparison.

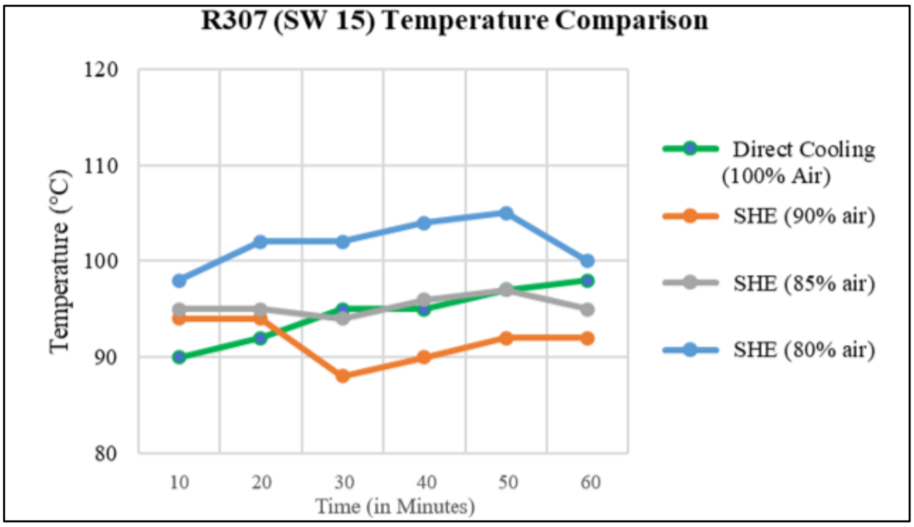

Figure 7. Cell R307 sidewall no.15 cooling temperature comparison.

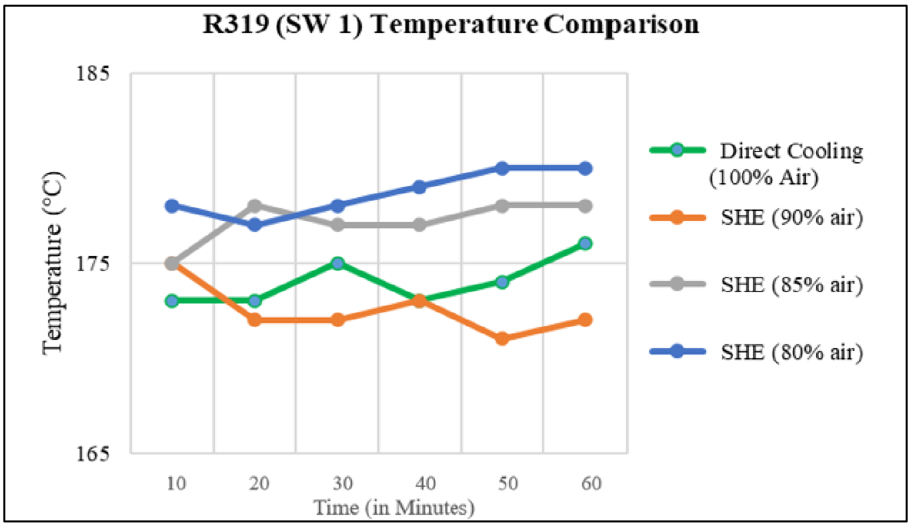

Figure 8. Cell R319 sidewall no.1 cooling temperature comparison.

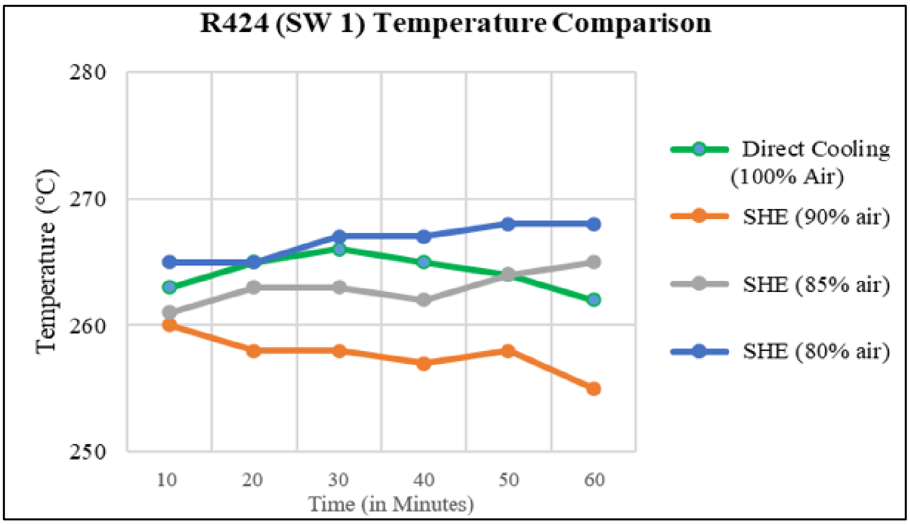

Figure 9. Cell R424 sidewall no.1 cooling temperature comparison.

5. SHE Application in Normal Operation

Shell heat exchanger with 85 % compressed air opening was implemented in one of operating reduction pot sidewall cooling replacing the existing direct cooling method at PT Inalum R214. After 1 week, a picture was taken with thermal camera; Figure 10 shows the temperature of sidewall (SW) 15 around the SHE (sp 3) is 212 °C. It is almost the same with the direct cooling method which applied at point sidewall 14 (sp 7) with 205.3 °C. This result shows that the sidewall temperature cooling using direct method with 100 % compressed air has approximately equal efficiency compare to the SHE cooling method supplied with 85 % compressed air. The temperature in the figure (± 200 °C) also shows that SHE is applicable for sidewall cooling due to the fact that it is still very far from the maximum steel shell temperature limit around 400 °C. However, the sidewall temperature of a pot indeed depends on the condition of the pot (pot voltage, noise, bath temperature) itself during daily operation.

Figure 10. Reduction pot sidewall thermal profile picture.

The utilization of Shell Heat Exchanger (SHE) for normal operating aluminium reduction pot brings several advantages such as the decrease of dust aeration and dispersion within the potroom, ease of installation on the inter-cradle of pot sidewall, energy saving due to lower compressed air needed for the sidewall cooling and also includes the potential to utilize the waste heat for recovery. However, there is also a constraint in the SHE utilization. Visual checking on the pot sidewall is impossible to be conducted due to the SHE coverage of the surface of the sidewall. In this situation, the temperature of the sidewall around the area covered by the SHE still can be considered as a reference.

6. Conclusions

Shell Heat Exchanger (SHE) supplied with compressed air is a promising way to conduct the reduction pot sidewall cooling compared to the traditional direct cooling method. SHE cooling method could potentially reduce 15 % of the compressed air usage compared to direct cooling method. In addition, this improvement also results in the spared compressed air availability to be allocated for other important operational uses in the aluminium production plant. Shell heat exchanger also has advantage on its ease of installation on the sidewall of the pot. Other dimensions of Shell Heat Exchanger (SHE) should be tried to evaluate the effect in its efficiency.

7. References

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