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The Latest Melt Refining Technology in Furnace for Environmental Improvement

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In complying with ever tightening regulations for emission of HCl, Cl_2, and particulate matter, various melt refining processes in furnace have been applied to reduce or to replace chlorine gas. In the last decade, many technical papers have been submitted on innovative, in-furnace melt refining processes using rotary nozzle injector [1-10]. Some of these papers reported in detail that synthetic anhydrous carnalite flux could successfully remove alkali and alkaline earth elements and could reduce inclusions. In contrast, Japanese aluminium industry had started to apply static flux feeders injecting salt flux early on to avoid chlorination in furnaces. The salt flux contains special chloride to reduce alkali or alkaline earth metal, and it has acquired good reputation for many years. It is also well known that a salt flux containing magnesium chloride is difficult to be practically injected even through static lance pipes. It was due to clogging in piping, which is caused by higher humidity in Asia than in other areas. It is also well recognized that injecting salt flux through rotary nozzle is not easy due to clogging inside a nozzle. The extent of clogging depends on the specification of the salt flux, and it shall be an issue for us to overcome in the future. This paper introduces actual results using a rotary nozzle system to inject a fused synthetic anhydrous carnalite flux, leading to complete elimination of chlorination in furnace.

Keywords: *melt refining, rotary nozzle injector, fused carnalite flux, salt flux*

1. Introduction

For the last decade, aluminium cast houses have been challenged to reduce chlorine gas injected into molten aluminium alloy in furnace to remove inclusions and alkali or alkaline earth elements, etc. Since 1980, instead of chlorine gas, salt fluxes containing ammonium chloride (NH_4Cl) have been injected through static lance pipes of salt flux feeders (Fig. 1 & 2) to reduce Na and Ca. It works well but generates much smoke, as well as leaving the possibility for hydrogen from ammonium chloride to remain in molten metal. So far the rotary nozzle injecting systems -- mobile-type PHD-50 system (Fig. 3) and automated, stationary-type HD-2000 System (Fig. 4 & 5) -- have been introduced in aluminium industry. These systems are applied for injecting bi-gas of chlorine to reduce chlorine gas and for injecting fused synthetic anhydrous carnalite flux (Promag F, comprising of $K_3Mg_2Cl_7$) to replace chlorination. Below are actual examples demonstrating elimination of chlorination in furnaces of cast houses and comparison with results using HD-2000 System.

Fig. 1 Mass-flow type salt flux feeder with static lance pipe

Fig. 2 Turntable type Salt Flux Feeder with static lance pipe

Fig. 3 PHD-50 unit injecting bi-gas with rotary nozzle

2. HD-2000 System Injecting Promag F Ended Chlorination in Holding Furnace

2.1 Evaluation of Promag F in advance and history until terminating chlorination

Before installing the HD-2000 System, Promag F had been evaluated by using various application methods such as agitating the melt surface after throwing it onto molten metal, exposing Promag F on dry hearth in the holding furnace prior to metal flowing into the holding furnace, injection through static lance pipe of salt flux feeder (Fig. 1 & 2), and etc. That evaluation took around two years. Promag F was confirmed as effective in removing Na and Ca at adequate addition rate, which depends on application techniques.

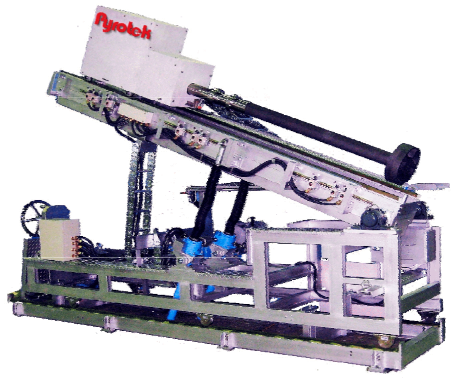

Fig. 4 HD-2000 System injecting bi-gas of chlorine and nitrogen gas

The first HD-2000 System (Fig. 4 & 5) was installed to inject bi-gas of chlorine to reduce chlorine gas, which also spotlighted other advantages such as homogenizing melt and promoting temperature uniformity throughout holding furnace.

The purpose of applying HD-2000 in experiments described below was to compare the performance between injections by rotary nozzle and static lance pipe. It was found that usage of chlorine gas could be reduced by 83% (to one-sixth of original amount) with the HD-2000 System (Fig. 4 & 5) injecting bi-gas of nitrogen and chlorine gas. Chlorine odor was not detected during the treatment by HD-2000. Thus, it reflected that chlorine gas injected through static lance pipes did not react efficiently in molten aluminium.

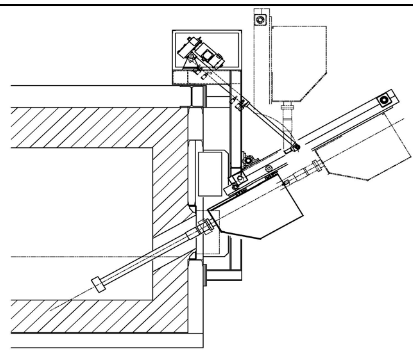

Fig. 5 HD-2000 System mounted on stationary furnace injecting bi-gas of chlorine and nitrogen gas

After the first successful demonstration of applying Promag F and HD-2000 System, in the ensuing two years, three more HD-2000 Systems (Fig. 6) were installed to inject Promag F. Finally, chlorination in furnace was eliminated in the cast house. This technique also brings outstanding cost benefits by removing the need of equipment for chlorine pollution abatement.

2.2 Typical results of hydrogen reduction with HD-2000 System (Fig. 6) injecting Promag F

Table 1 summarizes the final operating conditions. Various addition rates of Promag F were practically assessed to minimize the operating costs. The initial addition rate of Promag F was 14 kg/20 ton of molten metal (0.07% by wt), and 6 kg (0.03% by wt) was fixed in the end. It should be noted that the rate depended on metal quality required. To achieve this low addition rate, firstly,

Table 1 Operating conditions of HD-2000 System (Fig. 6)

Furnace capacity	20 ton aluminium
HD-2000 rotary speed	400 rpm
Promag F per charge	6kg (0.03%)
Promag F flow rate	500g/min
Nitrogen flow rate	300 liter/min
HD-2000 treating time	Promag F with N_2 for 12 min + N_2 for 8 min

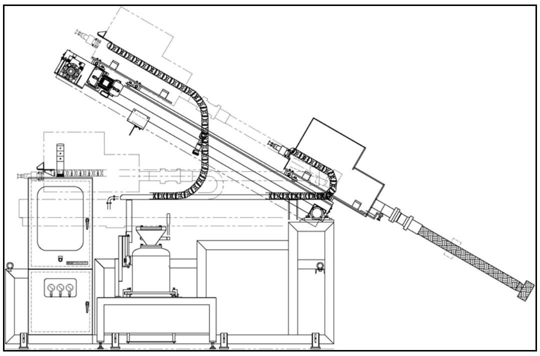

Fig. 6 HD-2000 System injecting Promag F

Promag F was injected at 500 g/min for 12 minutes together with nitrogen gas at 300 liter/min.

Then only nitrogen was injected for 8 minutes to increase the efficiency of removing Na, while minimizing the addition of Promag F to 0.03% by weight of molten aluminium. A great number of treatments by the HD-2000 System have demonstrated that when Promag F is being melted in molten aluminium, injection of only inert gas to stir the melt can result in higher efficiency for removal of Na, Ca and inclusions. Under the conditions of Table 1, 6 kg (0.03% for a 20-ton aluminium melt) of Promag F is regarded as the minimum addition rate to meet quality requirements of molten aluminium in a 20-ton furnace.

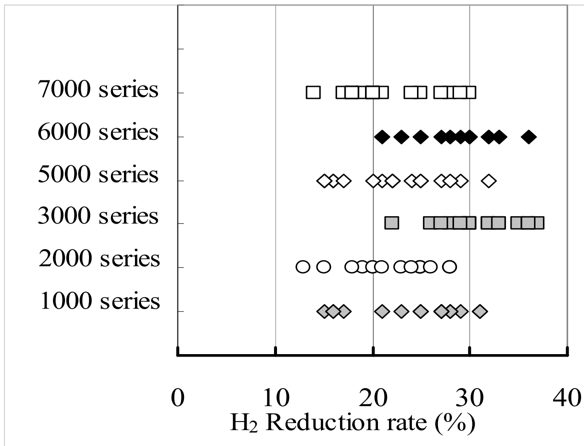

Fig. 7 H_2 reduction rate with HD-2000 System injecting Promag F

Fig. 7 shows typical hydrogen reduction rate by alloy type. Through many trials, we verified that the addition rate of Promag F depends on furnace design, metal quality before treatment, as well as operating parameters set for the HD-2000 system.

2.3 Typical results of sodium reduction with HD-2000 System injecting Promag F

Fig. 8 shows the Na reduction for alloys AA5000 series under the operating conditions of Table. 1. After HD-2000 System injecting Promag F at 0.03% of weight of molten aluminium, all resulting Na levels met the specifications for casting billet.

The amount of dross generated after HD-2000 treatment with Promag F was not measured, but the amount is expected to be not much even compared with chlorination through lance pipes. It is because HD-2000 in operation generates little turbulence.

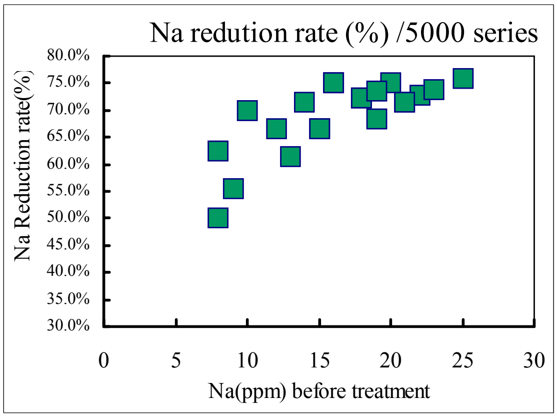

Fig. 8 Initial Na concentration versus Na reduction rate (%) using HD-2000 System injecting Promag F

As seen in Fig. 9, the PHD-50 (similar to the HD-2000) in operation generates little turbulence.

The results proved that eventually chlorination in furnace was completely terminated and 500g of chlorine gas per 1 ton aluminium alloy could be avoided. Additionally, the in-furnace treatment of the HD-2000 system with Promag F could reduce the burden on the in-line degasser (GBF, Gas Bubbling Filtration or SNIF, Spinning Nozzle Inert Flotation) or would enable them to achieve better performance.

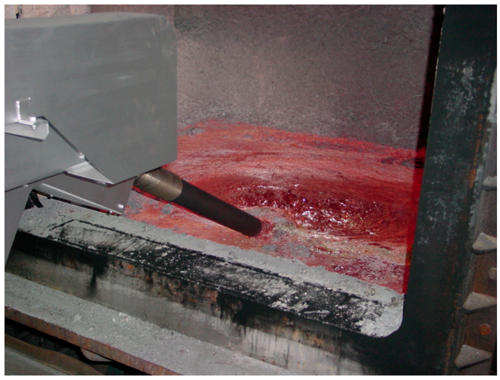

Fig. 9 PHD-50 in operation generates little turbulence

3. Comparison Data using Mobile-type Rotary Nozzle Unit (Fig. 10, PHD-50) in Furnace for AA3000 Series Alloy

3.1 Parameters for melt refining process in furnace

Two conditions were fixed: 32 ton of AA3000 series alloy and use of nitrogen gas as carrier gas. Other variables were:

- Salt flux feeder (Fig. 1) using static lance pipe versus PHD-50 (Fig. 10) using flux injector
- Promag F versus salt flux containing ammonium chloride
- Addition ratio of each flux
- Time of injecting flux with N_2 carrier gas and time of injecting carrier gas only (for improving refining efficiency)

Fig. 10 PHD-50 equipped with flux injector

Combinations of above parameters were simplified into four sets of conditions shown in Table 2.

Table 2. Operating Conditions

No.	Operating Conditions
#1	0.12% salt flux containing ammonia chloride (38kg) + N_2 280 liter/min/ salt flux feeder for 40 min
#2	0.10% Promag F (32kg) + N_2 280 liter/min/salt flux feeder for 40 min
#3	0.05% Promag F (16kg) + N_2 280 liter/min/salt flux feeder for 16 min
#4	0.05% Promag F (16kg) + N_2 280 liter/min / PHD-50 for 16 min + N_2 for 10 min

Our experience also shows that most salt flux cannot be injected through rotary nozzle injector.

For many years, the salt flux containing ammonium chloride has been injected with feeders in Japan. Such practice has a good reputation for effective removal of alkali and alkaline earth metal from aluminium alloy, despite generating much white smoke.

3.2 Results of sodium and hydrogen reduction, and dross / smoke generation

Fig. 11 shows hydrogen reduction rate (%). Fig. 12 shows Na reduction rate (%). Average initial Na concentration was at a very low level of 3 - 4 ppm. Then high Na reduction rate cannot be expected under such low initial Na content. In contrast, Fig. 8 indicates higher Na reduction rate for 15 – 25ppm Na before treatment.

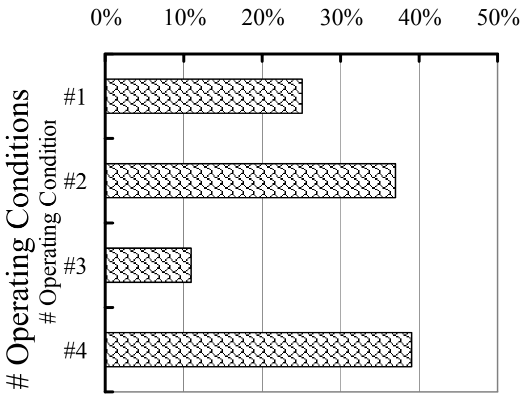

Fig. 11 H_2 reduction rate by Operating Condition #

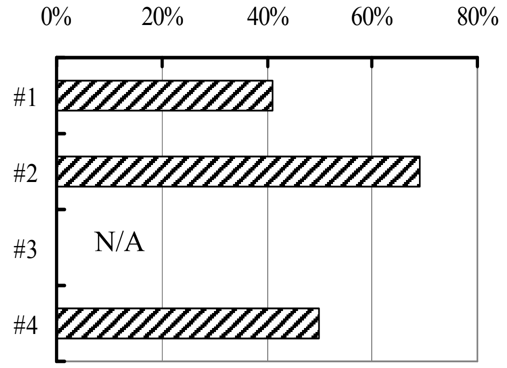

Fig. 12 Na reduction rate by Operating Condition #

The value for Na reduction data could not be recorded for Operating Condition #3, but it could be estimated to be less than 50%.

Fig. 13 shows Operating Condition #4 generating minimal amount of dross.

Table 3 below summarizes test results described in Fig. 11, 12 and 13, showing #4 as the optimum combination.

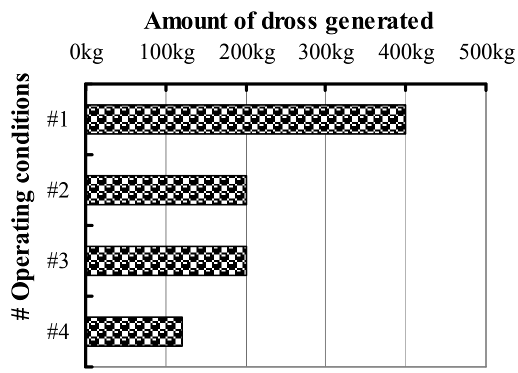

Fig: 13 Amount of dross generated by Operating Condition #

Table 3 Test results of each operating condition showing reduction rates of hydrogen and sodium, and generation of dross. (Hydrogen level was analyzed by H-MAT2000.)

Op Con.	Furnace Treatment for 32 MT of AA3000 series alloy	Avg. H_2 reduction rate (%)	Avg. Na reduction rate (%)	Avg. dross generation (kg)	Smoke visually observed
# 1	0.12% solid flux / flux injector 40 min	25%	41%	400	much smoke
# 2	0.10% Promag F / flux injector 40 min	37%	69%	200	little smoke
# 3	0.05% Promag F / flux injector 16 min	11%	N/A	200	little smoke
# 4	0.05% Promag F / PHD-50, 16 min + N_2 for 10 min	39%	50%	120	little smoke

Above results are further described below:

1) Fused synthetic anhydrous carnalite flux (Promag F) generates little smoke, light odor and less dross.
2) Rotary nozzle injection system can reduce the addition rate of Promag F, owing to its metal circulation efficacy. It can also reduce dross generation owing to low turbulence. And, it can treat a large volume of melt throughout furnace, whereas it is not possible for a flux feeder with static lance pipe to achieve the same result.
3) It is now well realized that mobile-type PHD-50 for multi furnaces was not practical because the operation is difficult and operator can easily make mistakes. In contrast, HD-2000 System can be automated. It does not require difficult operations such as fixing operating position and inserting the rotary nozzle into molten aluminium.
4) The combination of rotary nozzle system (HD-2000) and Promag F is preferred, as it requires less flux addition, generates less dross, and distributes the treated metal uniformly throughout furnace.
5) This combination also reduces the burden on the in-line degasser (GBF, SNIF, etc) or enables them to achieve better performance.
6) Adding salt flux contributes to inclusion removal and reduction of alkali or alkaline earth elements, as well as giving the desire dross feature designed into the salt flux recipe.
7) So far the salt flux containing ammonium chloride has been applied to reduce alkali or alkaline earth metal from aluminium alloy in furnace for many years in Japan. It is widely recognized for its effectiveness, despite generating much smoke. However, at the moment most salt flux cannot be injected through rotary nozzle due to clogging in the nozzle.

4. Conclusion

Dispersion of synthetic anhydrous carnalite flux through rotary nozzle injecting system is a realistic process to replace chlorination for refining molten aluminium alloy in furnace. Additionally, rotary nozzle injecting bi-gas of chlorine carried by argon or nitrogen can dramatically reduce chlorine gas emission. Today, rotary nozzle system injecting Promag-F continues to penetrate the aluminium industries owing to its ecologically friendly nature, which would eliminate or reduce chlorine gas usage. This refining process can also reduce dross generation and promote uniform temperature field of molten aluminium throughout the furnace.

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