Energy-Saving Retrofit Technology Analysis for Fluorine Removal in Aluminium Electrolysis Flue Gas Treatment

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https://doi.org/10.71659/icsoba2025-al058

Abstract

The fluorine removal system is an essential component of the dry purification process for aluminium electrolysis flue gas treatment. Currently, many domestic aluminium smelters face issues such as high operational resistance and excessive power consumption in their fluorine removal systems, presenting significant potential for energy savings. This paper analyses the original fluorine removal system of aluminium electrolysis flue gas in response to the demand for energy-saving retrofitting and proposes an energy-saving retrofitting plan. By retrofitting the gas collection flue at the top of the electrolytic cell, balancing the flue gas flow between electrolytic cells, adding a flue gas duct cooling system, and modifying the main draft fan and its duct system, the operational resistance of the fluorine removal system is reduced, and the efficiency of the main draft fan is improved, leading to a reduction in power consumption. Analysis shows that the fluorine removal system can reduce power consumption by 65 kWh/t Al.

Keywords: Aluminium electrolysis, Electrolysis flue gas purification, Fluorine removal system, Power consumption, Energy-saving retrofit.

1. Introduction

The power consumption per tonne of aluminium for domestic dry fluorine removal systems is between 110–190 kWh/t Al (excluding desulfurization systems), accounting for 0.9–1.4 % of the total power consumption in aluminium electrolysis, with significant variation between different companies. This suggests considerable potential for energy savings. Therefore, retrofitting dry fluorine removal systems to improve energy efficiency can directly lower production costs for aluminium smelters, helping the industry transition to a low-carbon model.

2. Analysis of Operational Resistance Loss in Fluorine Removal System

2.1 Process Flow of Dry Fluorine Removal System

Under the negative pressure of the fan, electrolysis flue gas is collected through the flue gas branches and enters the main flue gas duct outside the plant. The distance between each electrolytic cell and the fan differs, so manual butterfly valves are installed on the flue gas branches to adjust the flue gas flow. This ensures that the negative pressure is the same at the exit of each electrolytic cell, maintaining uniform gas collection efficiency. The collected flue gas is distributed into the flues of each dust collector, where it undergoes an adsorption reaction with a controlled amount of fresh alumina and recycled alumina in the Vertical Radial Injector (VRI) reactor to remove HF. The mixed flue gas then enters the bag filter for solid-gas separation to remove particulate matter. The purified gas, under the negative pressure of the fan, is discharged into the atmosphere via the chimney, while the separated alumina enters the fluidized bed at the bottom of the dust collector. The fluorine-loaded alumina that is captured is partially recycled as an adsorbent, with the remaining part conveyed via an air-driven chute to a bucket elevator for storage in the fluorine-loaded warehouse for use in electrolysis [1].

2.2 Pressure Loss and Power Consumption

The core equipment of the dry fluorine removal system mainly includes the fluorine removal pulse bag filter, the upper gas collection system of the electrolytic cell, the main flue fan, and its associated flue gas duct system. Currently, the total pressure loss of the fluorine removal system typically ranges between 3500 and 5500 Pa, with the pulse bag filter and flue duct pressure losses accounting for over 75 %. These high-pressure losses directly lead to increased power consumption. The relationship between flue gas flow and duct pressure loss is primarily governed by fluid dynamics principles. As shown in the Darcy-Weisbach Equation (1), pressure loss is proportional to the square of the velocity (v^2). For instance, when the velocity increases from 10 to 20 m/s, the pressure loss will increase by a factor of four.

$$\Delta P = \frac{1}{2}\lambda\frac{L}{D}\varrho v^2 \tag{1}$$

where:

ΔP	Pressure loss, Pa
λ	Darcy friction factor, dimensionless
L	Length of the duct, m
D	Diameter of the duct, m
ρ	Flue gas density, kg/m^3
v	Flue gas velocity, m/s

As per Equation (2), when the flue gas flow increases and the duct cross-sectional area remains constant, the velocity increases proportionally.

$$v = {}^{Q}/_{A} \tag{2}$$

where:

v	Flue gas velocity, m/s
Q	Flue gas volume flowrate, m^3/s
A	Duct cross-sectional area, m^2.

When the flue gas flow increases or the duct cross-sectional area decreases, the velocity increases, leading to a significant rise in pressure loss.
The pressure loss impact on power consumption is given in Equation (3).

$$P = \frac{\Delta P \cdot Q}{\eta_1 \cdot \eta_2} \tag{3}$$

where:

P	Power, W
ΔP	Total system pressure loss, Pa
Q	Processing airflow, m^3/h
η_1	Fan efficiency, %
η_2	Motor efficiency, %

There is a nonlinear positive correlation between flue gas volume and duct pressure loss. Velocity serves as a key intermediary variable. The pressure loss of the flue gas purification system is

5. Conclusions

The energy-saving retrofit of the electrolysis flue gas fluorine removal system is of great importance for reducing electrolytic production costs and improving the potroom environment. In production operations, high system pressure loss, poor draft balance inside the cells and low efficiency of the main exhaust fan are the primary causes of excessive power consumption. Energy-saving retrofits for fluorine removal systems must focus on reducing system pressure losses, improving draft balance inside each cell and improving fan efficiency. This paper proposes four technical solutions as a reference for energy-saving and consumption-reduction efforts in fluorine removal, aiming to achieve low-consumption and high-efficiency operation. Traditional energy-intensive environmental protection facilities can indeed attain both economic and sustainable development goals.

6. References

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