# Supporting Information for

## Inhibition of the reaction between aluminium dust and water based on the HIM

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## A. The wet dust collector

The arrow indicates the direction of the air flow. The dust airflow enters the wet dust collector from the dust suction hole and filters through water. Finally, the clean air is discharged from the air outlet. The fan and motor remove hydrogen from the collector. The hydrogen concentration sensor monitors the concentration of hydrogen in the wet dust collector. When the concentration of hydrogen in the collector reaches 1%, the alarm device sounds to give an alarm signal. Then, the production line will stop to make sure that no more aluminium dust is generated. The workers will evacuate to safe areas. If an explosion occurs, the pressure-relief device will open in time to release the over-pressure inside the collector. These safety-technical measures do not solve hydrogen fire or explosion problems fundamentally. Furthermore, because of the existence of hydrogen, these devices must be explosion proof. The Ex level should not be less than DIICT4, and the cost of these safety-technical devices can be rather high.

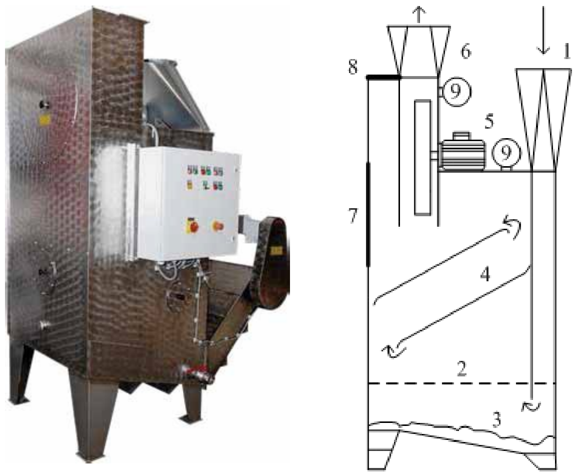


**Fig. S1.Physical and structural diagram of the wet dust collector**(1, dust suction hole; 2, water line; 3, deposited aluminium dust; 4, air baffles; 5, fan and motor; 6, air outlet; 7, inspection hole; 8 pressure-relief device; 9, hydrogen concentration sensor and alarm device)

## B. The aluminium and water reaction tester

The aluminium and water reaction tester, as shown in Fig.S2 has good air tightness. Before the start of the experiments, 500kPa $H_2$ was injected into the reactor for an air tightness test. During the test, the temperature in the reactor was maintained at 50°C. The air tightness test was conducted for 8 h, after which the pressure inside the reactor was still 500kPa. The positive pressure pump(FCY 2015, Chengdu Air Sea Electrical and Mechanical Manufacturing Co., Ltd) and vacuum pump(DAP-6D, 12 series ULVAC KIKO, Inc) were used to adjust the initial pressure of the reactor. The adjustment range of the initial pressure was -100 kPa to 200 kPa. A flow meter(DYSBG1111,Beijing Duo Yi Hui Yuan Technology Co., Ltd) could control the volume of $CrK(SO_4)_2{\cdot}12H_2O$ solution added to the reactor. The use of such a flow meter avoids errors caused by human factors. The reactor was a double-layer quartz glass tank. The reaction temperature was controlled by circulating water of a certain temperature in the middle of the double quartz glass. The pressure sensor (3051,Rosemount Co.,American) and temperature sensor (K,Yanzheng Co.,Shanghai) recorded the pressure and temperature values in the reactor, respectively. Before the experiments, a certain amount of aluminium powder was put on the aluminium tray. Next, the $CrK(SO_4)_2{\cdot}12H_2O$ solution was added to the reactor by the flow meter. The temperature and pressure required by the reaction were adjusted. Finally, the aluminium powder on the tray was evenly thrown into the reactor liquid through the motor rotation.

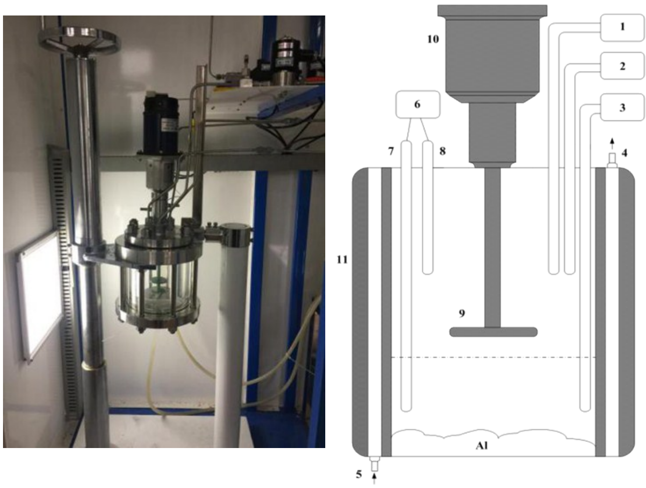


**Fig.S2 The aluminium and water reaction tester** (1Positive pressure pump; 2 Vacuum pump; 3 Flowmeter; 4 Circulating water outlet ; 5 Circulating water inlet hole; 6 PC; 7 Temperature sensor; 8 Pressure sensor; 9 Aluminium tray; 10 Motor; 11 Double-layer quartz glass reactor)

## C. The hydrogen evolution

$$\alpha = \frac{(P - P_{initial})(V - V_{solution})}{n_0 RT}$$

$\alpha$ -- hydrogen evolution
*P*--gas pressure in the reactor, kPa
$P_{initial}$ -- initial pressure in the reactor, kPa
*V*--reactor volume,1 L
$V_{solution}$ -- the volume of the solution added into the reactor, L
$n_0$--the mole of aluminium powder added into the reactor, mol
*R*--gas constant, 8.314 J/(mol·k)
*T*--gas temperature, K

## D. Derivation of equation (11)

Assume that the aluminum particles' radius is R. When the aluminum particles react with water to the time t, the radius is $r_c$. The molar density of Al is $\rho_{Al}$. Q is the flux of water directed towards the core. $k_g$ is the first order rate constant for the surface reaction. $C_{H_2O}$ is the concentration of water.

$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2\uparrow$

$$n_{Al} = \rho_{Al}V$$

$$Q=\frac{dn_{H_2O}}{4\pi r^2 \cdot dt}$$

$$4\pi R^2 Q_R = 4\pi {r_c}^2 Q_{r_c}$$

$$-\frac{dn_{Al}}{S\cdot dt} = -\frac{1}{4\pi R^2}\cdot\frac{dn_{Al}}{dt} = -\frac{{}^{1}/_{3}}{4\pi R^2}\cdot\frac{dn_{H_2O}}{dt} = \frac{1}{3}k_g C_{H_2O}$$

$$-dn_{Al} = -\rho_{Al}\cdot dv = -4\pi\rho_{Al}r_c^2 dr_c$$

$$-\frac{1}{4\pi r_c^2}\rho_{Al}4\pi r_c^2\frac{dr_c}{dt} = -\rho_{Al}\frac{dr_c}{dt} = \frac{1}{3}k_g C_{H_2O}$$

$$-\rho_{Al}\int_R^{r_c} dr_{Al} = \frac{1}{3}k_g C_{H_2O}\int_0^t dt$$

$$t = \frac{3\rho_{Al}}{k_g C_{H_2O}}(R - r_c)$$

$$1 - \frac{r_c}{R} = 1 - \left(\frac{r_c^3}{R^3}\right)^{1/3} = 1 - (1-\alpha)^{1/3} = kt$$

$$1 - (1-\alpha)^{1/3} = kt$$

## E. Analysis of Economic Input

On the basis of a field survey of the atomized aluminium powder production enterprise, a hydrogen concentration sensor and alarm device, explosion-proof electrical components and a pressure-relief device were installed. Fig.S3 shows this safety-technical equipment installed on the wet dust removal system. The fan works 24 h per day to remove hydrogen from the wet dust collector, the fan's motor(TRA 1050, Siemens) is an explosion-proof type, and the EX grading is DIICT4. A hydrogen concentration sensor(Zhuzhou Tuoda Electronic Technology Co., Ltd., S10) is installed to analyse the hydrogen concentration in the collector. When the hydrogen concentration reaches 1%, the alarm device will sound, and the production line will be stopped. At this time, no more aluminium dust can be imparted into the water of the dust collector while the fan keeps working to remove hydrogen already existing in the collector. All the electrical components in the system are explosion proof, and the EX level is not less than DIICT4. A pressure relief device(Hoerbiger, EVN2.0) is installed on the dust collector. It can be used to release overpressure caused by a hydrogen fire or an explosion accident. The design life of the safety-technical equipment system is 10 years. The hydrogen concentration sensors and the pressure relief device must be tested every year.


S4


a b c d

**Fig. S3 The prevention and protection devices:** a)fan with explosion-proof motor; b)hydrogen concentration sensor; c)explosion-proof cabinet; d)pressure-relief device.

Though this safety-technical equipment is installed, there is still the risk of hydrogen fire or explosion accidents. By design, when the HIM is used, hydrogen will no longer exist in the wet dust collector. The fan only has to work during the wet dust collector operation, which is approximately 8 h a day, thus using less electrical energy. During the field survey, a dust sampler was used at the dust inlet of the collector to calculate the weight of the aluminium dust generated per minute. The average weight of aluminium dust sucked into the wet dust collector was 0.494g per minute. Therefore, 865,488 g of aluminium dust will be sucked into the wet dust collector over the design life time of the safety-technical system. According to the results of the hydrogen inhibition experiment, the concentration of the $CrK(SO_4)_2{\cdot}12H_2O$ solution should be not less than 0.062g/L. The volume of water in the wet dust collector is approximately 940L; thus, 58.28g of $CrK(SO_4)_2{\cdot}12H_2O$ is needed. To maintain the $CrK(SO_4)_2{\cdot}12H_2O$ solution's concentration at not less than 0.062g/L, another 17,887g of $CrK(SO_4)_2{\cdot}12H_2O$ must be added to the water during the design life of the safety-technical system. Table S1 shows a comparison of the detailed economic input between the safety-technical equipment and the HIM.

**Table S1 The comparison of economic input(10 years)**

| Prevention and Protection Device | | Hydrogen Inhibition Method | |
|---|---|---|---|
| Device | Economic Input $ | Device and Chemical | Economic Input $ |
| Explosion-proof motor | 23,238.59 | Motor | 20,333.76 |
| Hydrogen concentration sensor and alarm device | 14,524.12 | $CrK(SO_4)_2 \cdot 12 H_2O$ | 21.11 |
| Explosion-proof electrical components | 11,619.29 | Electrical components | 4,006.65 |
| Pressure-relief device | 43,572.35 | Pressure-relief device | 0 |
| Power | 40,000 | Power | 13,333 |
| Calibration fee forhydrogen concentration sensors | 5,809.6 | Calibration fee forhydrogen concentration sensors | 0 |
| Test cost of pressure-relief device | 4,357.24 | Test cost of pressure-relief device | 0 |
| Total | 143,121.19 | Total | 37,694.52 |