Performance Improvement of Wide-Channel Welded Plate Heat Exchanger for Bayer Precipitation Process

Qiu Ying[1], Zhang Manli[2], Wang Xinyan[3] and Zhang Limei[4]
1. R&D Engineer
2. Chief executive
3. Sales manager
4. Export Manager
Shanghai Heat Transfer Equipment, Shanghai, China
Corresponding author: by101010@163.com
https://doi.org/10.71659/icsoba2025-aa028

Abstract

In wide-channel welded plate heat exchangers, uneven flow distribution is a common issue and so a risk of scaling in the channel with smaller flow rate exists. Based on coupled CFD-DPM-Erosion numerical simulation framework, the research investigates and optimizes the erosion rate at the inlet of the second pass and the flow distribution among channels in wide-channel welded plate heat exchangers. Compared to the original design, the optimized structure demonstrates that, under varying slurry flow rates and solid concentrations, the deviation and the standard deviation of flow in the least-flow channel from the average flow is separately no more than 2.2 % and 0.94 %. Meanwhile, compared to the original design, the optimized structure demonstrates that, under varying slurry flow rates and solid concentrations, the max. erosion rate decreases by 1 to 2 orders of magnitude. This research ensures uniform flow distribution and smaller erosion rate in the second pass, laying the foundation for improving alumina production quality and extending equipment service life.

Keywords: Plate heat exchanger; Flow distribution

1. Introduction

Wide-channel welded plate heat exchangers are widely used in Bayer precipitation process due to their advantages of high heat transfer efficiency, small footprint, and compact structure. However, due to the unique characteristics of Bayer precipitation process, a large amount of aluminium hydroxide scaling adheres to the heat transfer plates, particularly in flow channels/regions with low flow velocity.

Figure 1 illustrates typical scaling deposits in the flow channels of a multi-pass heat exchanger. In wide-channel heat exchangers with multiple passes (number of passes greater than 2), the liquid-solid two-phase fluid enters the second pass via the baffle plate. Due to the reduced flow velocity near the baffle region, scaling tends to accumulate more readily in these areas. This study will (1) investigate the flow characteristics near the baffle zone in multi- pass wide-channel welded plate heat exchangers; (2) propose an optimized design to achieve uniform flow distribution; (3) evaluate the performance of this optimized design under varying solid concentrations and flow rates.

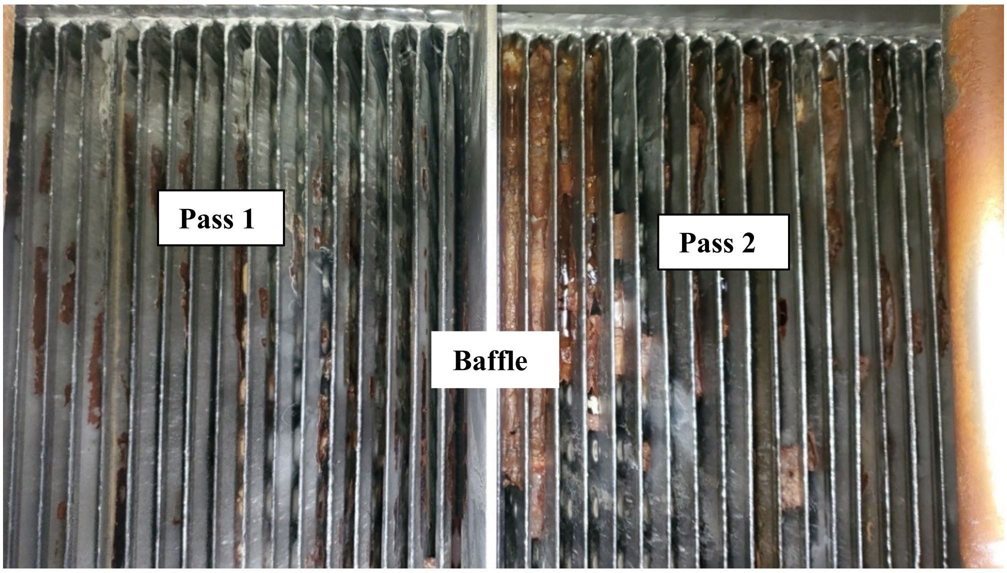

Figure 1. Scaling deposits in flow channels adjacent to the baffle plate.

2. Governing Equation

2.1 Liquid Phase Governing Equations

Within the Eulerian framework, the three-dimensional liquid-phase flow field is described by using a liquid-phase governing equation based on local averaging.

$$\frac{\partial(\rho)}{\partial t} + \nabla \cdot (\rho \boldsymbol{u}) = 0 \quad (1)$$

$$\frac{\partial(\rho \boldsymbol{u})}{\partial t} + \nabla \cdot (\rho \boldsymbol{u}\boldsymbol{u}) = -\nabla P + \nabla \cdot (\tau) - S_p + \rho \boldsymbol{g} \quad (2)$$

where:
ρ density,
$\boldsymbol{u}$ velocity vector
$\boldsymbol{g}$ acceleration of gravity
P pressure
$\boldsymbol{\tau}$ stress tensor
$\boldsymbol{S_p}$ liquid−solid interaction force

Based on Newton’s third law, $\boldsymbol{S_p}$ in the mesh containing N particles is given by:

$$S_p = \frac{1}{V_{cell}} \sum_{i=1}^{N} F_{d,i} \quad (3)$$

where:
$\boldsymbol{F}_{d,I}$ traction force of the liquid phase acting on particle i.

The liquid-phase turbulent energy and turbulent dissipation rate in the liquid−solid two-phase flow field are described using Standard k-ε:

Thermal imaging technology offers a promising solution for non-invasive scaling diagnosis. By detecting localized temperature anomalies caused by scaling blockages (e.g., foreign materials or scaling deposits), this method can identify scaling zones with high precision. Specifically, regions affected by liquid-solid two-phase scaling exhibit localized temperatures approaching those of the cooling water side due to reduced heat transfer efficiency, as illustrated in Figure 9. This thermal signature enables operators to pinpoint scaling locations and perform targeted maintenance, avoiding unnecessary full-system shutdowns.

Implementing thermal imaging-based monitoring ensures that heat exchangers operate at peak efficiency, minimizes energy losses, and extends service life by proactively addressing scaling risks. Future work should focus on integrating this technology with predictive maintenance algorithms to further optimize operational reliability in Bayer-process alumina production.

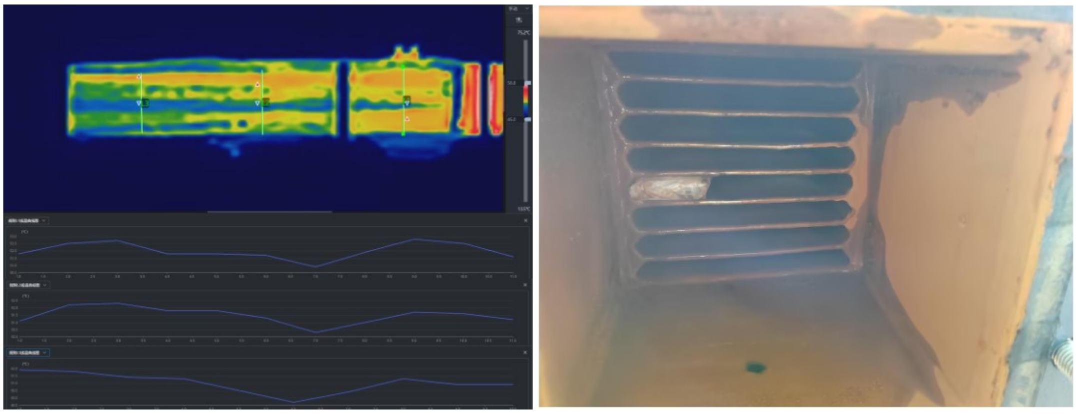

Figure 9. Experimental results of thermal imaging technology in scaling diagnosis for wide-channel welded plate heat exchangers.

7. Reference

1. Ren Libo, Long Xiangyi, Wang Xiaowei. Erosion Investigation of dimple wall using erosion-coupled dynamic mesh. *ACS Omega*, 2023,8, 39303-39314.