Applying CFD Modelling and FEA to Enhance Bauxite Residue Slurry Flow through Distribution Rings in Filter Presses

Thomas Grillot[1], Simon Gravel[2] and Nicolas-Alexandre Bouchard[3]
1.Research Professional
Cural laboratory, UQAC, Saguenay, Canada
2. Research Scientist
Aluminium, Rio Tinto, Saguenay, Canada
3. Principal Adviser Processing & Technology
Development & Technology, Rio Tinto, Saguenay, Canada
Corresponding author: simon.gravel3@riotinto.com
https://doi.org/10.71659/icsoba2024-br004

Abstract

In November 2019, Vaudreuil commissioned its bauxite residue filtration plant (BRFP), to treat thickened bauxite residue using four (4) filter presses. Each filter press is capable of holding 0.25 m^3 of material per filtration chamber. These chambers are assembled by joining two plates covered with filter cloths and two pairs of distribution rings. The bauxite residue slurry enters the chambers with high velocity causing significant stresses on all filter components due to the combined high density and abrasive properties of the slurry. This leads to short and long-term components failures. The main issue is the excessive wear and increased maintenance costs related to the frequent replacement of filter cloths and distribution rings. This paper provides an overview of the potential of modern numerical methods like computational fluid dynamics (CFD) in helping to determine fluid velocity and more importantly flow patterns inside the chambers. CFD coupled with finite element analysis (FEA) to assess the structural integrity of the distribution rings and plates, valuable insights can be gained for geometric adjustments to reduce filter cloths wear, extend their life cycle and improve the overall performance of the filter presses. As a result, reliability of the BRFP can be enhanced.

Keywords: Hydrogen Reduction, Al_2O_3 leaching, Fe separation.

1. Context and Current Situation

The Rio Tinto Vaudreuil Bauxite Residue Filtration Plant (BRFP), located in the Saguenay Lac St-Jean region, in Quebec, Canada, installed four (4) Diemme GHT.2500.F18 filter presses with membrane squeezing for the treatment of bauxite residue [1]. This filtration process allows for a significant reduction in drying time for the residue compared to the previous method of mud farming. It also increases the longevity of the disposal area by maximizing its surface area and reduce the plant’s environmental impact [2, 3, 4].

The bauxite residue undergoes an initial washing step in a counter-current washing circuit before entering dedicated deep thickeners and the slurry is pumped to the BRFP for the final filtration step. Each filter press consists of a stack of alternating recessed and membrane plates, as shown in Figure 1, covered with high-performance filter cloths to form the filtration chambers of 0.25 m^3 in volume. The bauxite residue slurry is introduced into these chambers through distribution rings with an average flowrate of 2.5 m^3/h where hydraulic pressure from the feeding pump forces the filtrate through the cloths, forming the filter cake. To minimize residual moisture in the filter cake, an additional high-pressure step with membrane squeezing is applied to achieve a final moisture content between 25 % and 30 %. Once filtration is complete, the plate stack opens, and the filter cake is discharged from the filters and transported to the disposal area by a series of conveyors [4].

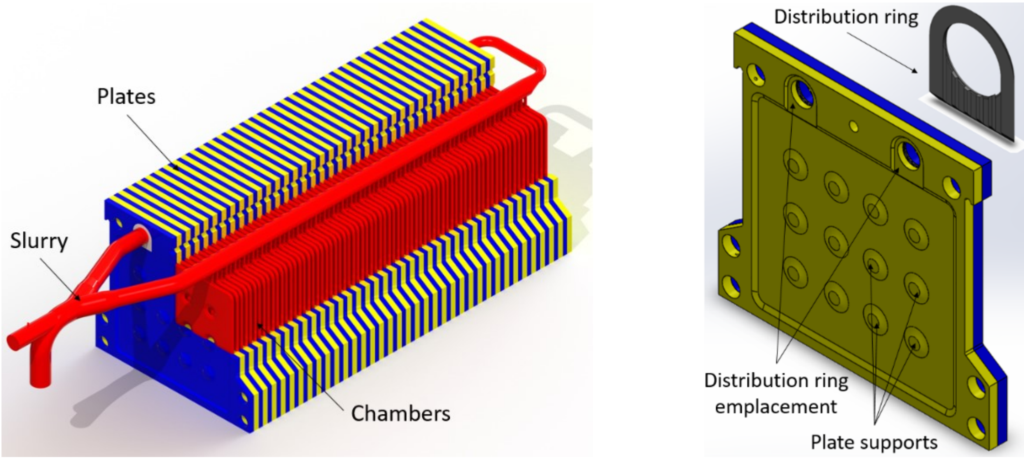

Figure 1. Model of a filter press. Left: the plate stack with slurry, Right: two plates and distribution ring.

Since the commissioning and ramp-up of the BRFP, the filtration chambers filling step has always been a challenge mainly due to the properties of the bauxite residue slurry. Considering the enormous strain that the filter presses are under during the filtration process and the inability to physically monitor the flow and behaviour of the slurry inside the filtration chambers, modern numerical methods like Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) are excellent tools for troubleshooting and assessing improvements. This paper presents how CFD and FEA improved the performance of the filter presses by studying the effect of fluid dynamics through various distribution ring designs and understanding their structural integrity under normal operating pressure.

2. State of the Art

A homogeneous distribution of the slurry within the chambers of the filter press is essential to maximize filtration capacity and ensure the quality and uniformity of the filter cake. Techniques like mechanical smoothing or jet distribution systems can help achieve this goal. Prior to filling, mechanical smoothing of the mud could improve filtration capacity by 15 % and reduce the water content of the filter cake by 10 % [5]. Minimizing void spaces in the filter cake is crucial for increasing solids content and reducing the volume of generated waste. Approaches such as assisted compaction or optimization of mud rheology can help achieve this. The utilization of a rheology modifier to optimize mud rheology has been showed to reduce voids in the filter cake by 20 % and increase solid content by 5 % [6]. Shortening the filling and unloading time of filter press chambers can enhance the overall productivity of the system. Automation of operations and optimization of filling parameters play a significant role in achieving productivity increase. This has resulted in a 25 % reduction in cycle time and a 10 % increase in production [7].

A recent study using a numerical model to optimize the filling of filter press chambers [8] indicates that increasing the feed concentration improves filtration capacity but may reduce cake uniformity, with only a 6 % increase in solid concentration in the cake. Additionally, chamber geometry and plate arrangement influence mud flow under different patterns referred to as “spider” or “umbrella.” Despite these advancements and recent studies, issues with filter cloth tear still occurred. This paper provides an in-depth analysis of the process to further increase filter press productivity.

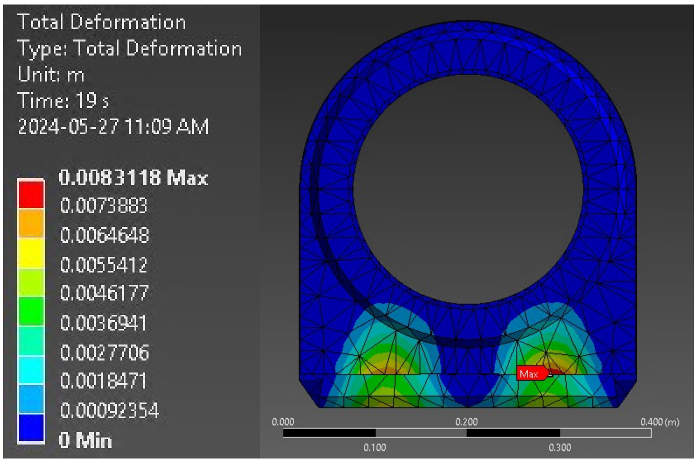

Figure 10. Total deformation for the pyramidal support distribution rings.

6. Conclusions and Options for Future Studies

Modern numerical methods, such as CFD and FEA, can assist in the optimization of the design of filter presses for the treatment of bauxite residue. This study demonstrates how these tools can successfully identify critical areas of stress and wear, thereby enabling the development of innovative solutions to enhance the overall performance of filter presses.

The CFD analysis provided detailed visualization of the slurry flows inside the filtration chambers, revealing the direct impact of the high entry velocity of the flow on the wear of the filter cloths. The initial design of the distribution rings directed a high-velocity jet directly onto the cloth, leading to significant abrasion and premature wear. This paper demonstrates that various designs can be easily tested using CFD to evaluate flow patterns and measure the reduction in slurry velocity in critical zones. The FEA complemented the study by evaluating the structural strength of the distribution rings under pressure and demonstrated that crossflow support is essential to prevent blockage of the slurry passage.

In conclusion, the use of modern numerical methods like CFD and FEA opens new perspectives to optimize filter presses for the treatment of mining residues. These tools allow for in-depth analysis of the complex phenomena occurring within the filtration chambers. This work can serve as a starting point for significant progress in the field, helping to reveal and measure phenomena that are typically invisible and difficult to assess with current technologies. It can pave the way for the uses of numerical simulation to model slurry as a biphasic suspension, enhancing the understanding of solid-liquid separation inside the filtration chambers. This approach can help identify the flow of the liquid phase in the cake and locate constraint zones to pinpoint areas for improvement. The continued application of these numerical methods in this field will help minimize the environmental impact of the mining industry and enhance the value of mining residues for potential applications.

7. References

1. Francesco Kaswalder, and Andrea Pezzi, Case Study – Installation and startup of a system for red mud filtration with filter presses, *TRAVAUX 51, Proceedings of the 40th International ICSOBA Conference,* 10–14 October 2022, Athens, Greece.
2. Steve Healy et al., Sustainable bauxite residue management guidance, *International Aluminium Institute*, 2022, 34–42, https://international-aluminium.org/resource/sustainable-bauxite-mining-guidelines-second-edition-2022-2/ (Accessed on 27 August 2024).
3. Evans Ken, The history, challenges, and new developments in the management and use of bauxite residue, *Journal of Sustainable Metallurgy,* Vol. 2, No. 4, 2016, 316–331.

4. Simon Gravel et al., Conversion to filtered tailings: commissioning and ramp-up of Rio Tinto's bauxite residue filtration plant, *Proceedings of Alumina 2024, the 12th International Alumina Quality Workshop,* 22–24 April 2024, Dubai, UAE.
5. Prem Ranjan and Manjeet Prem, A filtration layer of slow sand filter, *International Journal of Current Microbiology and Applied Sciences*, Vol. 7, No. 7, 2018, 637−645.
6. Zhengyuan Pan et al., Simulation of performance of fibrous filter media composed of cellulose and synthetic fibers, *Cellulose,* Vol. 26, 2019, 7051−7065.
7. Biao Xie et al., Improving filtration and pulse-jet cleaning performance of metal web filter media by coating with polytetrafluoroethylene microporous membrane, *Process Safety and Environmental Protection,* Vol. 136, 2020, 105−114.
8. Liang Zhang et al., Numerical investigation of a chamber filter press on flow characteristics and influence of parameters under variable working conditions, *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, Vol. 46, No. 1, 2024, 5180–5200.