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Vacuum filters versus filter presses: rethinking technology selection for tailings dry stacking

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Abstract

Tailings are an unavoidable byproduct of mineral and metal ore processing and represent a growing challenge in terms of safe and sustainable storage. One increasingly adopted solution is dry stacking, where tailings are mechanically dewatered to such an extent that they can be transported and stacked without risk of liquefaction. A residual moisture content below 15 wt.-% is commonly considered a practical threshold. For this purpose, filter presses are widely used. Operating in batch mode at pressures up to 25 bar, they can reliably achieve low residual moisture levels. However, the technology comes with significant disadvantages: high wear on filter cloths, the need for large and complex infrastructure and reliance on highly skilled operating as well as maintenance personnel – all contributing to high capital expenditures (capex) and operating expenses (opex).

A promising alternative – particularly for coarser tailings ($x_{50} > 50$ µm) – is the application of vacuum disc filters. Although the achievable residual moisture is somewhat higher due to limited pressure differentials, they offer considerable advantages in terms of capital and operational expenditures.

This paper explores the feasibility of using vacuum disc filters for dry stacking of tailings. It starts with Atterberg limit tests on different tailings materials, demonstrating that the residual moisture content required for safe stacking depends strongly on the specific material system and does not necessarily need to be in a range below 15 wt.-%. Next, a comparative assessment of filter presses and vacuum disc filters is provided, focusing on both technical performance and economic factors, illustrated with data from an industrial case study. The paper concludes by questioning the dominant role of filter presses and assessing the conditions under which vacuum filters could realistically emerge as a viable and perhaps superior alternative in modern tailings management.

Keywords: *tailings filtration, tailings stacking, vacuum disc filter, filter press, residual moisture*

1 Introduction

Tailings are an inevitable byproduct of mineral and metal ore processing. Since grades in orebodies continuously decline, the volumes of tailings generated are steadily increasing. As a result, the mining industry faces growing challenges – particularly with regard to the safe and sustainable storage of these materials. This raises a critical question: Where should these materials go?

Traditionally, tailings slurries are deposited in large-scale ponds. While this method has long been the industry standard, it comes with significant drawbacks. The valuable process water contained in the slurry is largely lost through evaporation. Moreover, tailings storage facilities present considerable safety risks: dam failures can result in catastrophic consequences, including loss of life and severe environmental damage. As a result, the industry is under increasing pressure to develop innovative solutions for tailings management. Filtration technologies have emerged as a promising approach in this context (Fränkle et al. 2024; Davies 2011; Morrill et al. 2020).

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One strategy is the use of tailings for underground mine backfilling. In this method, the tailings slurry undergoes filtration (usually by vacuum filters) followed by the addition of cement. The resulting cemented tailings paste is then pumped back into the underground voids, providing long-term ground stability while simultaneously reducing the volume of tailings that require surface storage (Grice 1998).

Another widely applied approach is dry stacking. Here, tailings are mechanically dewatered to a point where they can be transported and compacted without the risk of liquefaction (in practice, a residual moisture content of around 15 wt.-% is commonly used as a benchmark). Unlike paste backfilling, dry stacking is usually carried out using filter presses and pressure differences of up to 25 bar. Despite their effectiveness, these systems operate in batch mode and are associated with significantly higher maintenance and operating costs, as well as complex infrastructure requirements compared to vacuum filters (Davies 2011; Hahn & Dobler 2025).

The abovementioned disadvantages of filter presses raise the question of whether vacuum filter technology can also be used to achieve sufficient storage stability for dry stacking of tailings. To address this issue this paper evaluates the technical and economic feasibility of vacuum filters as an alternative to conventional filter presses. First, Atterberg limit tests are used to determine the residual moisture required for sufficient storage stability. Subsequently, the economic and technical aspects of filter presses and vacuum filters are compared and critically discussed. Finally, the results are used to assess the potential of vacuum filters for dry stacking of tailings.

2 Material and methods

2.1 Atterberg limit test

A key parameter for determining the transition from the liquid to the plastic state of a soil is the liquid limit. One commonly applied approach to obtain this value is the Atterberg limit test, as described in DIN EN ISO 17892-12 (Deutsches Institut für Normung e.V. 2022). The method is particularly advantageous due to its straightforward application, the short duration required for execution and evaluation, and the low equipment costs.

The corresponding experimental setup is illustrated in Figure 1. It consists of a grooving tool (not shown here), a base plate (5) with rubber feet (6), a sample cup (1), a hook (2) with a central support beam (3) and a cam mechanism (4) driven by an electric motor. The motorised cam lifts the sample cup by 10 mm and subsequently allows it to drop onto a predefined contact point (7) located on the base plate (Deutsches Institut für Normung e.V. 2022).

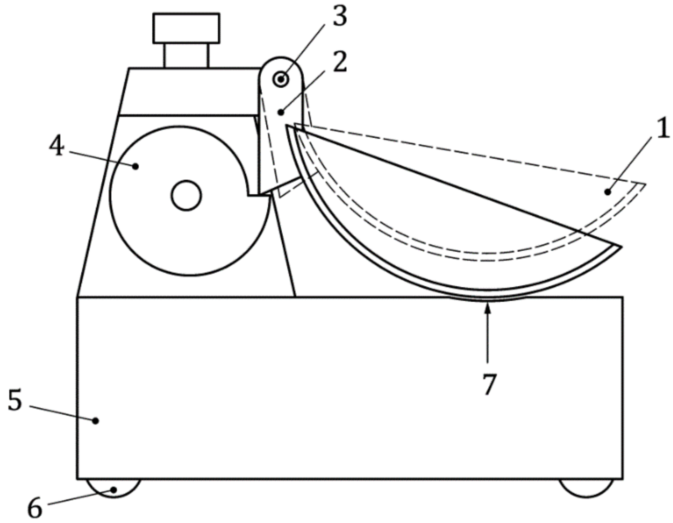

Figure 1 Schematic illustration of the test setup (taken from Deutsches Institut für Normung e.V. 2022)

At the beginning of the procedure, a paste with a known residual moisture content (RM) (refer to Equation 1) is placed into the cup and evenly distributed with a spatula to ensure a minimum layer thickness of 10 mm. After smoothing the sample surface, a groove is cut through the entire depth of the layer. The cup is then raised and dropped at a constant rate of 2 cycles per second until the groove closes over a length of 10 mm. The number of cycles required for this closure is recorded and plotted against the corresponding water content, whereby the liquid limit is defined as the water content at 25 turns (Deutsches Institut für Normung e.V. 2022).

$$RM = \frac{m_L}{m_L + m_s} \tag{1}$$

where:

m_L = liquid mass

m_S = solid mass.

3 Results and discussion

3.1 Liquid limit of various tailings

To evaluate whether tailings materials exhibit similar behaviour with respect to storage stability, Atterberg limit tests were conducted on 5 representative products. Product 1 was a zinc tailings with a median particle size of 79 µm and a solid particle density of 2.7 kg/cm³, Product 2 was a zinc/copper tailings with a median diameter of 27 µm and a density of 3.9 kg/cm³. Products 3–5 were copper tailings with median particle sizes ranging from 9 to 38 µm and solid particle densities between 2.7 and 3.4 kg/cm³. The particle size distributions of the examined samples are depicted in Figure 2.

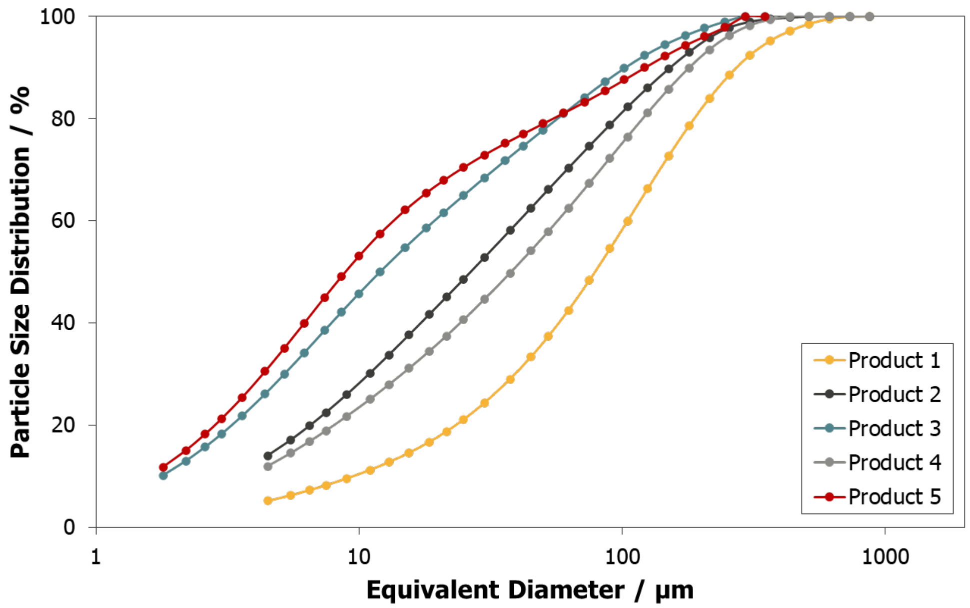

Figure 2 Particle size distribution of examined tailings systems. The median particle sizes range between 9 and 79 µm

The experimental results are shown in Figure 3. For all systems, a clear and consistent trend can be observed: as the residual moisture content increases, the number of cycles required to close the groove are reduced. This relationship follows a linear-logarithmic trend. It is determined by the changing degree of saturation within the particulate network and is in agreement with findings reported in the literature (Deutsches Institut für Normung e.V. 2022).

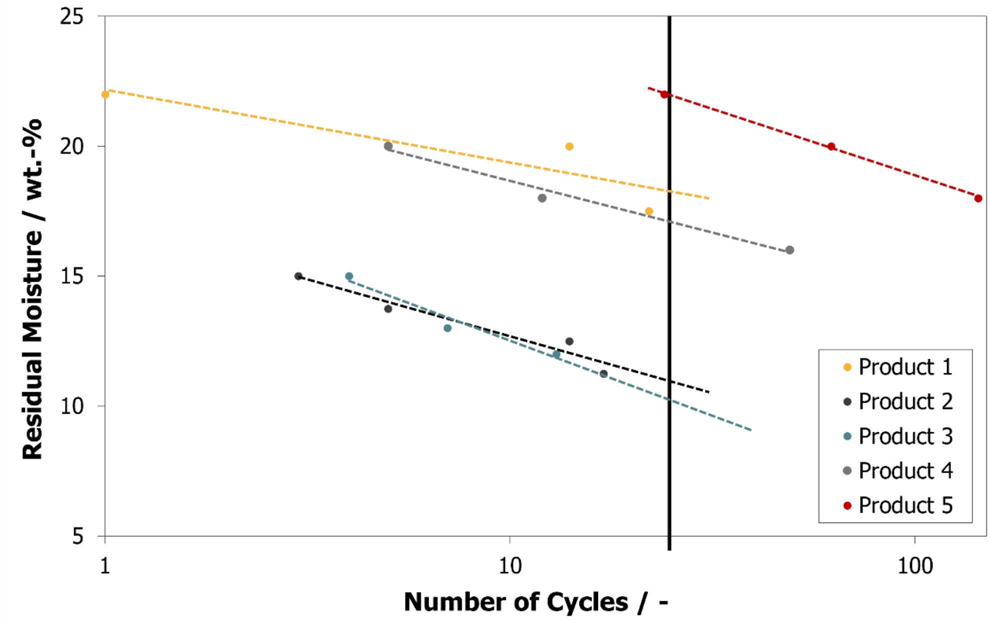

Figure 3 Atterberg limit tests for various tailings. It can be seen that tailings materials exhibit different and product-specific properties with regard to their liquid limits

Pronounced differences between the tailings systems are evident in both the slope and the intercept of the single regression lines. As a result, the liquid limits determined for the 5 products vary substantially, ranging from 10.2 to 21.9 wt.-% (refer to Table 1). Interestingly, the detected disparities do not correlate with either particle size or solid density, indicating that additional factors – such as mineralogy or particle surface properties – may play a decisive role.

Table 1 Calculated liquid Limits of various tailings

Material system / -	Liquid limit / wt.-%
Product 1	18.2
Product 2	10.9
Product 3	10.2
Product 4	17.0
Product 5	21.9

In summary, the data demonstrates that tailings materials exhibit different and product-specific properties with regard to their liquid limits and thus their storage stability. Consequently, the frequently applied target residual moisture value of 15 wt.-% – commonly used as a benchmark for mechanically stable tailings stacks – cannot be considered universally valid across different tailings systems.

From a process engineering perspective, this insight is of particular relevance: achieving the stability does not necessarily require the use of a high-pressure difference filter press. In many cases, conventional vacuum filters are probably sufficient to meet the stability targets. The effects of these findings (especially in terms of cost-effectiveness) will be discussed in the following section.

3.2 Effects of applying vacuum disc filters instead of filter presses

The subsequent section provides a cost calculation for Product 4 (selected because it features sufficient storage stability even when the residual moisture content is 17.0 wt.-%; a value that can be reliably achieved with vacuum filtration), focusing on the capex and opex associated with the use of vacuum disc filters and filter presses. The values for the vacuum disc filter are derived from laboratory test data, whereas those for the filter press are based on results obtained with a hydraulic press, supplemented by empirical data and assumptions.

Within the hydraulic press trials, purely mechanical pressing resulted in a residual moisture content of approximately 17.0 wt.-%, while an additional gas-driven dewatering step – associated with a reduction in throughput – lowered the content to values between 11 and 13 wt.-%. In all cases, the solids concentration of the feed material is 67 wt.-% and the solids throughput is 100,000 t/d.

Table 2 summarises the technical device parameters and the calculated capex costs. First of all, it can be seen that the residual moisture achievable with a filter press is significantly lower than that obtainable with a vacuum disc filter. These differences are due to the higher-pressure differences associated filter presses and the dewatering step following the pressing procedure. The situation changes when the operation is interrupted prior to the dewatering stage: in this case, the moisture values determined by the laboratory press are roughly equivalent to those obtained with a vacuum disc filter. However, storage stability is not impaired here either, as the residual moisture content does not exceed the critical liquid limit of 17.0 wt.-% in any case.

Table 2 Estimation of capital expenditures (capex) costs: vacuum disc filter versus filter press

Parameter	Unit	Vacuum disc filter	Filter press (with dewatering step)	Filter press (without dewatering step)
Solids throughput	t/d	100,000	100,000	100,000
Residual moisture	wt.-%	17.0	11.0–13.0	17.0
Filter area per unit	m²	352	2,800	2,800
Specific throughput	t/m² h	1.75	0.425	0.50
Throughput per unit	t/unit h	616	1,190	1,400
Filter operating / installed	–	7/9	4/5	3/4
capex per unit (including auxiliary)	EUR	2,000,000	13,000,000	13,000,000
Total capex	**EUR**	**18,000,000**	**65,000,000**	**52,000,000**

Furthermore, the table indicates a specific throughput of the vacuum disc filter that is approximately 3.5 to 4 times higher than the one of filter presses. In absolute figures, between 2381 m² (vacuum disc filter) and 9804 m² (filter press with dewatering step) are required for the entire separation task, corresponding to 7 (vacuum disc filter) and 4 (filter press) units. The estimated total investment costs amount to EUR 18,000,000 for the vacuum disc filter system and up to EUR 65,000,000 for the filter presses. Hence, vacuum filtration requires only about 28–35% of the capex of filter presses, representing a considerable economic advantage.

Another key aspect are the operating costs. These include energy consumption, usage of filter aids (e.g. flocculant), cloth replacement as well as spare parts and are listed in Table 3.

Table 3 Estimation of operating expenses (opex) costs: vacuum disc filter versus filter press

Parameter	Unit	Vacuum disc filter	Filter press (with dewatering step)	Filter press (without dewatering step)
Energy requirement per unit	kW	350	750	600
Total energy requirement per year (8,760 operating hours/year)	kWh/y	21,462,000	26,280,000	15,768,000
Total energy cost per year (0.1 EUR/kWh)	EUR/y	2,146,200	2,628,000	1,576,800
Flocculant dosage (filter aid)	g/t	0	0	0
Total filter aid cost per year	EUR/y	0	0	0
Number of clothes changes per year	–	6	8	8
Quantity of cloths per unit	–	180	560	560
Cost per cloth	EUR	50	300	300
Total costs of clothes per year	EUR/y	378,000	5,376,000	4,032,000
Spare parts per unit	EUR	40,000	260,000	260,000
Total costs of spare parts per year	EUR/y	280,000	780,000	780,000
Total opex	**EUR/y**	**2,804,200**	**8,784,000**	**6,388,800**

Due to the smaller quantity of units, the energy consumption for filter presses – despite higher requirements per unit – is similar to that for vacuum filters. Assuming identical residual moisture values, the energy costs for the press are around EUR 600,000 lower than those for disc filters, whereas, in operation with a dewatering step, the costs are around EUR 500,000 higher compared to vacuum technology. Although the cost of filter aids equal 0 EUR/y for all scenarios, there are significant differences in terms of filter cloth and spare parts. As a result, the annual operating costs of a filter press significantly exceed those of a vacuum disc filter, reaching 228% (without dewatering) and 313% (with dewatering) of the vacuum filter opex.

All in all, the conducted considerations clearly demonstrate that vacuum disc filters offer substantial advantages over filter presses, with respect to capital and operating costs. For tailings systems that exhibit sufficient mechanical stability at residual moisture contents above 15 wt.-%, vacuum filtration should therefore be considered a viable and cost-effective alternative to filter presses for future applications.

4 Conclusion

This paper indicates that the commonly applied benchmark of 15 wt.-% residual moisture for the safe storage of tailings is not universally valid. Atterberg limit tests according to DIN EN ISO 17892-12 revealed that the required moisture content for mechanical stability strongly depends on the specific material system and factors like mineralogical and surface properties. Several tested tailings products showed sufficient stability even at residual moisture levels above 15 wt.-%, highlighting the need for a more material-specific approach.

This finding opens up new opportunities for tailings management. For suitable (of course, not for all) tailings systems, vacuum disc filters can provide a technically feasible and economically attractive alternative to conventional filter presses. Based on an economic analysis conducted for this purpose, vacuum disc filtration can be implemented with approximately 65 to 72% lower investment expenditure and significantly lower operating costs, primarily caused by simpler infrastructure, lower maintenance requirements and reduced demand for cloth and spare parts.

In conclusion, the future selection of tailings dewatering technologies should not rely on rigid residual moisture benchmarks but rather be based on material-specific stability criteria.

Acknowledgement

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