KONVENCIONALNI ZGUŠNJIVAČI I NOVA GENERACIJA KOMERCIJALNIH ZGUŠNJIVAČA

CONVENTIONAL AND NEW-GENERATION OF THE COMMERCIAL THICKENERS

Sanja PETROVIĆ[1], Srdjana MAGDALINOVIĆ[1], Miomir MIKIĆ[1],
Daniel KRŽANOVIĆ[1], Sladjana KRSTIĆ[1]
[1]Mining and Metallurgy Institute Bor, Serbia, sanjabugarinovic@yahoo.com

U rudarskoj industriji stalno se pojavljuju novi izazovi i nove tehnologije. U okviru pripreme mineralnih sirovina zgušnjavanje predstavlja najrasprostranjeniju fazu u procesu odvodnjavanja. Dizajn samih zgušnjivača u rudarskoj industriji se godinama razvijao u cilju povećanja sadržaja čvrste faze u zgusnutom proizvodu, postizanju što čistijeg preliva, i u samom pogledu kapaciteta prerade. Počevši od osnova teorije zgušnjavanja, i dalje se istražuju ključni elementi procesa sedimentacije i opcije za izbor zgušnjivača, kao i karakteristike kritičnih komponenti zgušnjivača. Cilj ovog rada je da prikaže opšte stanje u vezi sa projektovanjem, kontrolom i radom savremenih zgušnjivača.

***Ključne reči**: Zgušnjivači. priprema mineralnih sirovina, dizajn*

New challenges and new technologies are constantly emerging in the mining industry. Thickening is the most widely applied dewatering process in mineral processing. The design of thickeners in the mining industry has been developed over the years with the aim of increasing the solid phase content at the discharge, achieving the cleanest overflow, and in terms of processing capacity. Starting with the basics of thickening theory, the key elements of the sedimentation process and thickener selection options, as well as the characteristics of critical thickener components, are further explored. The aim of this paper is to present a general overview of the design, control and operation of modern thickeners.

***Keywords**: thickeners, mineral processing, design*

1 Introduction

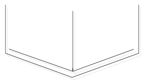
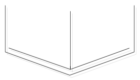
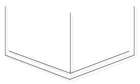
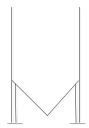
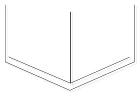
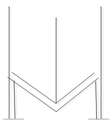
Thickeners are widely used in various industries including mining, coal, chemical, wastewater management, and paper industry. Sedimentation of solid particles within a liquid by the gravity influence is the most common procedure used in the mineral industry, especially in thickeners that are integral parts of mineral processing plants [1]. Intensive research and most of the theoretical and practical knowledge in the sedimentation field were developed during the 20th century and they refer to the so-called conventional thickener [2]. The different sizes, shapes and configurations of thickeners reflect their different design intent and degree of technology adoption [3].

The conventional thickeners are characterized by the fact that the ratio of diameter to height is large (the diameter of these thickeners can be greater than 100 m) and that the feed pulp is diluted as it enters the equipment [4]. Due to its large diameter, this thickener occupies a large area and has a small production capacity per unit area. On the other hand, the challenge in the management of tailings moves toward finding alternate uses. In order to minimize natural water usage is to use thickened tailings and tailings paste technology, where water is returned from the process plant, minimizing discharge to the tailings storage facility (TSF). The initial density of the tailings discharged to the TSF result in a smaller volume of the tailings discharged, thus requiring less TSF storage capacity [5].

Innovation in thickener design to enable higher density production has a long history. The beginnings of Deep Cone thickeners go back to the 1960s. Large High density thickeners were pioneered in the late 1980s. It can be said that during the previous decades, great progress was made in terms of reducing the size of the thickener, i.e. reducing the diameter of the thickener and sedimentation surface required for the same solids loading rate. This reduction in tank diameter, from conventional to modern designs called "high capacity", "high density" and "deep cone or paste thickener" was realized by the development of the two important items. The first item refers to the development of high-performance synthetic flocculants, and the second item refers to the evolution of high-efficiency thickener loading systems [6].

Table 1 presents the main characteristics of thickener operation and the different thickener components where a significant reduction in tank diameter can be seen, from "conventional" to modern designs called "high capacity", "high density" and "deep cone". or "paste thickener" [6, 7]. Different thickener sizes, shapes and configurations reflect their differing design intent and extent of technology adoption.

Table 1. Typical thickener geometry [6, 7]

Geometry		Sludge bed, m	Residence time	Max. diameter, m	Factor ″K″	Paste production	Solids Underflow, %
	Thickener (~ 10º)	1	Medium	125	<30	No	1 = Low (15-40%)
	Thickener HCT(~ 10º)	1	Medium	100	<30	No	1 = Low (15-40%)
	Thickener HRT(~ 10º)	1	Medium	100	<30	No	1 = Low (15-40%)
	Thickener Cone 60º (without mechanism)	2-6	Low	15	-	Yes	2 (15-50%)
	High Density Thickener HDT (~ 15-20º)	3	High	100	>100	Yes	3 (30-60%)
	Deep Cone Thickener (~ 30-45º Cone)	8	High	50	>150	Yes	4 (40-80%)

The different types of thickening technologies mostly establish the amount of water that can be extracted from the tailings, and hence the characteristics of the pulps that are transported to the TSFs. Significant performance improvement of industrial thickeners is based on the selection of conditions that provide the desired properties regarding settling test behavior, such as free settling velocity, final solids concentration, viscosity, or yield shear stress [8]. Figure 1 presents the relative underflow yield stress as a function of thickener design [9].

Considering thickener performance, underflow rheology is typically discussed in terms of its yield stress. The slurries behave like a Newtonian fluid at low solid phase concentrations, However, at a sufficiently high solids phase concentration, particle interactions increase to the point where the suspension exhibits resistance to deformation. The yield strength is a function of solids concentration and usually increases rapidly as the solids concentration approaches that of the fully bonded matrix [10].

Regarding copper industry, conventional thickeners and High rate thickeners produce slurries between 50 and 60 wt% whith a low yield stress (< 40 Pa), while High density and Paste thickeners can produce slurries over 65 wt% with yield stress over 100 Pa [9].

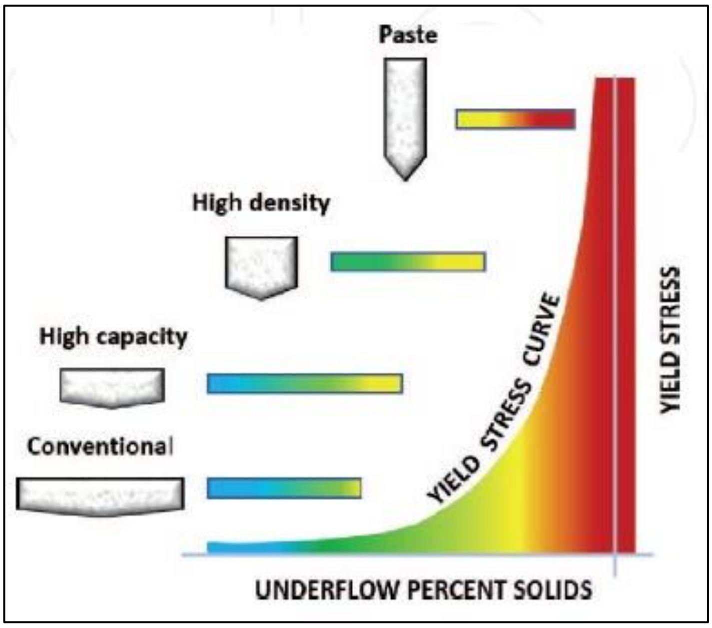


Figure 1. Relationship between the type of thickener and properties of the underflows (solid concentration and yield stress) [9]

2 Conventional and new-generation thickeners

2.1 Conventional Thickener

Conventional thickeners are the most commonly used thickener in dewatering plant. Conventional thickeners were developed following the pioneering work by Hazen and Dorr [3]. These thickeners characterized by low solids loadings and shallow feedwell configuration. However, due to the larger diameter, its area is larger and the production capacity per unit area is lower. According to the number of working surfaces, it can be divided into single-layer, double-layer and multi-layer thickeners. The thickeners can be classified into two types depending on location of rake driving mechanism. They are known as centrally driven or peripherally driven.

The feed well of the thickener is one of the elements that determine the effectiveness of all the following stages in the sedimentation process [1]. The feed well controls and directs the flow. In conventional thickeners, feed wells are cylindrical and frequently baffled. In Lamellas and other types of thickeners, the feed wells can be an adjacent tank, a rectangular channel adjacent to the operating elements, a launder, a feed box, or an adjustable jet [1, 6]. Thickener rakes are essential in the transport of sediment bed material to the underflow in conventional thickeners [9].

2.2 High Capacity Thickener/High Rate Thickener

Investigation and developments in thickening technology over the past 15 years have enabled significantly higher underflow densities to be achieved [11, 12]. Investigation on the thickener innovative design features leads to the acceptance much greater thickening mechanisms and effective operation with specific flocculants, with results in the implementation the thickeners of "high capacity", namely "High capacity thickener" or even "High rate thickener" [6].

New tools have recently been used to analyze sedimentation, consolidation and thickener design. Computational Fluid Dynamics (CFD) was used to analyze the dilution and the flocculant dispersion in feedwells and to determine the forces of sediment on rakes [12].

With the development of the High capacity thickeners numerous problems related to conventional thickeners and the use of polymers have been resolved [13]. A High capacity thickener is characterized by a feedwell that is introduced into a deep position that reaches the position of the sludge layer so the flocculated feed is mixed directly with the thickened sludge. The feedwell at a lower position contributes to that the ultrafine non-flocculated particles remain trapped in the sludge bed. A High capacity thickener has the advantage of creating a clear overflow a dense underflow. It can be assumed that the zone of free settling in the high-capacity thickener, which is typical for a conventional thickener, is eliminated, and therefore two zones are characteristic: clean water at the top and thickened sludge at the bottom of the thickener. High rate thickeners include a number of innovative design features. These thickeners include systems that automatically thin the pulp, simultaneously optimizing performance and flocculant consumption [13]. High rate thickener design was presented in Figure 2A.

2.3 High Density Thickener

High density or High compression thickeners can be either a conventional or a High capacity one, but the main characteristics of this thickener type is higher height compared to the conventional and the High capacity thickener. This feature enables to obtain a higher concentration of the thickened sludge.

2.4 Deep Cone Thickener

High settling rate, low-turbidity overflow, and high-concentration underflow are the main characteristics of Deep Cone Thickener [14].

Deep Cone Thickeners are a newer alternative designed to produce high viscosity muds. This thickener type use very deep mud beds and steep floors to be able to produce and discharge sludge nearby the pumpability limit and operate at very high rates in terms of thickener surface area [14, 15] which is often applied for tailings management and other cases where a high underflow slurry density is required. Like the High rate thickener, the Paste thickener uses high flocculant dosage and optimised feed slurry dilution to achieve acceptable solids settling rates [15].

The increased underflow slurry density requires a higher rake torque for a given thickener diameter. The Deep Cone Thickener design was presented in Figure 2B.

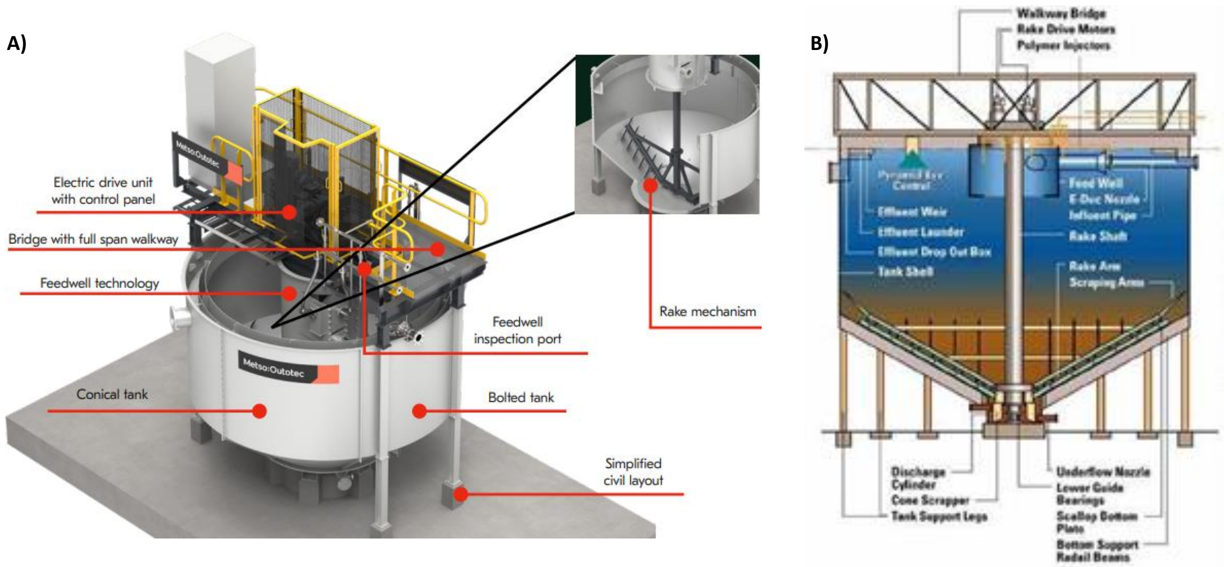


Figure 2. A) High Rate Thickener [16] and B) Eimco Deep Cone Thickener [17]

Different terminology can be found for the thickener designs by various manufacturers. Many of them segregate the designs by the rheology of the underflow. For example, Outotec uses the terms High Compression and Paste, FLSmidth uses the terms High Density and Deep Cone, Westech uses the term Deep Bed Paste Thickener, Delkor uses High Density and Paste [14].

The important measurable parameters for thickener control include: thickener feed flow rate, feed density, underflow density, overflow clarity, bed level, bed mass, rake torque, rake height, solids settling rate, and underflow rheology. All these parameters and measurements of these are not easy and one must factor in accuracy and reliability to select and install the proper equipment.

The instrumentation and controls can be collected into the following:

– Rake drive and control
– Solids inventory

– Flocculant control
– Overflow clarity
– Underflow density
– Underflow viscosity

3 Conclusion

The improvement in thickener design is the main goal of many thickener companies. Today it is possible to design smaller, more stable thickeners that operate at higher flux rates. The important key for the successful operation of almost any thickener is good flocculation and great attention was paid to this aspect of the thickener design. Thickening to higher underflow densities by High density technology and Deep cone thickening technology has become a widespread practice worldwide. The development in the flocculant industry, the development of new feeding systems with dilution devices, as well as the effect of highly efficient mixing have influenced the development and successful operation of the new generation of thickeners.

Acknowledgments

This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Grant No. 451-03-68/2022-14/200052.

4 References

[1] **Parsapour, G., F. Molhem, H. Montazari, E. Arghavani, G. Biniaz, S. Banisi**, Performance improvement of the Sarcheshmeh Copper Complex Cu-Mo thickener using a vane type feedwell, *International Journal of Mining and Geo-Engineering*, 53-1 (2019), pp. 79-82.
[2] **Concha, F., R. Bürger**, Thickening in the 20th century: a historical perspective, *Mining, Metallurgy & Exploration*, 20 (2003), pp. 57-67.
[3] **Miller, M.,** Thickener design, control and development, in Conference: *ALTA*, Perth, Australia, 2018.
[4] **Franks, D. M., D. V. Boger, C.M. Cote, D. R. Mulligan**, Sustainable development principles for the disposal of mining and mineral processing wastes, *Resources Policy*, 36 (2011), pp. 114-122.
[5] **Fabian, K., M. Jacobs, A. Hooshiar, E. Ngwenya**, The impacts of using thickened tailings on water management and CAPEX of tailings storage facilities, Paste 2015: Proceedings of the 18th International Seminar on Paste and Thickened Tailings, Australian Centre for Geomechanics, Perth, pp. 535-546, 2015.
[6] **Grima Olmedo, C., A. Ramirez Gomez, D. Gomez-Limon Galindo, J.A. Butragueño Muñoz**, Review of equipment for mine waste: from the conventional thickener to the deep cone for paste production, *Dyna*, 90 (2015), pp. 359-365.
[7] **Baczek, F.**, Thickening Mineral Slurries to High Underflow Densities and Paste. Internal Report Dorr-Oliver Eimco. Annual Meeting. 2004.
[8] **Gladman, B.J., S.P. Usher, P.J. Scales**, Proceedings of the Ninth International Seminar on Paste and Thickened Tailings, Limerick, Ireland, pp. 5-23, 2006.
[9] **Jeldres, R.I., M. Jeldres,** Clay Science and Technology, *Intech Open*, 2021.
[10] **Schoenbrunn, F., M. Bach**, The development of paste thickening and its application to the minerals industry; An industry review, *BHM*, 160 (2015), pp. 257–263.
[11] **Rudman, M., K. Simic, D.A. Paterson, P. Strode, S. Brent, D. Šutalo**, Raking in gravity thickeners, *International Journal of Mineral Processing*, 86 (2008), pp. 114-130.
[12] **Farrow, J., P. D. FawelL, R. R. M. Johnston, T. B. Nguyen, M. Rudman, K. Simic, J. D. Swift**, Recent developments in techniques and methodologies for improving thickener performance, *Chemical Engineering Journal*, 80 (2000), pp. 141-155.
[13] **Lu, J. Z., J. P. Grau**, Proceedings of 51th Annual Conference Metallurgist of CIM (COM 2012), Niagara, CN Canada, pp. 363-373, 2012.

[14] **Schoenbrunn, F**., Proceedings of the 14th International Seminar on Paste and Thickened Tailings, Paste 2011, Australian Centre for Geomechanics, Perth, Australia, pp. 19-23.
[15] **Gollaher, T. J. L. Johnson, M.T. Biesinger, A. H. L. Accioly,** Paste thickening tailings - Recent examples of a rapidly emerging technology. SME Annual Meeting and Exhibit, 2010.
[16] https://www.mogroup.com/globalassets/pdfs-and-other-downloads/metso-outotec-hrt-s---leaflet-en.pdf
[17] **Baczek, F**., Internal Report Dorr-Oliver Eimco. Annual Meeting. 2006.