PASTE THICKENER TECHNOLOGY FOR MINE BACKFILL

J. Stephen Slottee
PasteThick Associates
Salt Lake City, UT

Jerold Johnson
PasteThick Associates
Salt Lake City, UT

Introduction

The use of a thickener, without filtration, to produce a non-settling paste (also called thickened tailings) with non-Newtonian rheology has been practiced in Australia for many years for the disposal of red mud. The application of paste thickening technology outside of alumina is relatively new. Interest and installations in paste thickening are rapidly growing. Water shortages and environmental pressures make consideration of thickening tailings to solids concentrations within the paste range necessary in most new tailings projects. The paste thickeners at the DeBeers CTP plant in Kimberley, South Africa are the latest example of paste tailings disposal on the surface, also called "stacking". Houman (2003) The use of a paste thickener as an alternative to filtration for mine paste backfill is a more recently developed application.

This paper describes the principles of design and general operating characteristics of a paste thickener compared to the conventional and high-rate thickener. The application and operating performance of paste thickeners in mine backfill is discussed as an example. An integrated approach to process design is described that matches the performance of the thickener, pumping system, and application on a common rheological basis to ensure that none of these steps prevents achieving process performance targets.

Paste Thickener Design

Characteristics of Paste

The commonly used term "paste" is a suspension of solids characterized by relatively non-settling, non-segregating particles at high concentration compared to settling slurries. As the name implies, paste has a self-supporting structure as shown in Figure 1.

Figure 1

Paste is generally described as a Bingham plastic, characterized by a yield stress. Yield stress is measured in units of pressure and is related to the force required to make a paste flow. The shape exhibited by a paste that is not flowing is a result of the presence of a yield stress. Yield stress can be measured directly with a laboratory viscometer. The yield stress curve is correlation of yield stress with solids concentration. Slump, measured in units of distance, is an indirect measurement of yield stress and is used by the underground mining industry as an indication of the rheology and solids content of a tailings paste. An ASTM 12 inch slump cone test is the standard method used to measure slump (ASTM, C 172-82: "Standard Method of Sampling Freshly Mixed Concrete"). As shown in Figure 2 a slump cone is filled with sample, the cone is manually lifted, and the distance the paste sample "slumps" is measured. Slump and yield stress have an inverse relationship. As yield stress increases, the measured slump decreases, all other parameters equal.

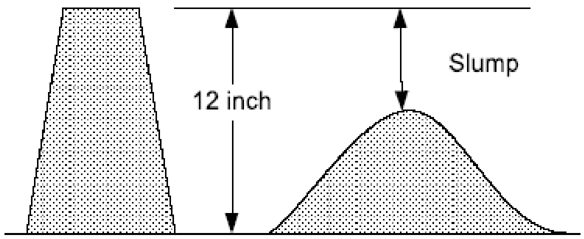

Figure 2

The slump and non-settling nature of paste is produced from naturally occurring clays, silts, and fine sands. The solids content for a given slump is determined by the specific gravity and particle size distribution of the solids. Rheological and transport characteristics of paste are mainly dependent on the content of fine particles (less than 20 micron). The rheological character of paste is a result of the interaction of solid particle of different diameters and volumes making percent volume an appropriate way to characterize solid concentrations. However, industry convention is to use weight percent. In these terms paste concentrations can be as high as 75-90 wt% for base metal tailings depending on particle size and solids specific gravity.

The high viscosity of pastes makes pipeline design critical. Pastes are generally pseudoplastic where the viscosity decreases with shearing such as in pumping and pipe line flow. The slump of paste produced by a thickener, for example, may be higher than the slump at the end of the pipeline delivering the paste to the mine stope. More detailed descriptions of a paste can be found in sources such as Boger (1999) and Robinsky (1978) and for pipeline design, Paterson (2003).

Paste Thickener Design

The concept of deep cone thickening was developed in the 1960 and 70s in the British coal industry. Over the years the deep cone thickening idea has been combined with modern day flocculation techniques, feedwell design, and improvements on the design of the tank, rake and underflow discharge system to produce the modern deep cone type paste thickener. This thickener is characterized by a height to diameter ratio typically greater than one to one with unit areas (m^2/tph) several times smaller than for conventional and high-rate thickeners. The mud bed height in a deep bed thickener is much higher (several meters) than the level in a high rate thickener which more than compensates for the effect of smaller area on underflow solids concentration. The combination of the high aspect ratio and steep cone angle also facilitates the discharge of paste underflows.

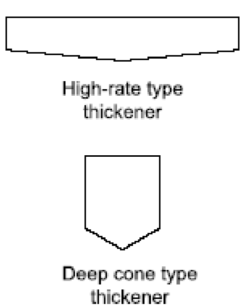

Figure 4

Understanding yield stress is a key parameter in paste thickener design. Under gravity a tailings paste will flow to a point dictated by the yield stress and stop. The paste must move through the thickener and be delivered to the pumping system for transportation to the application point. With proper interpretation the operating range of a paste thickener can be located on the yield stress curve (Figure 3) revealing the maximum underflow paste solids concentration and the minimum concentration below which the suspension will be a settling slurry.

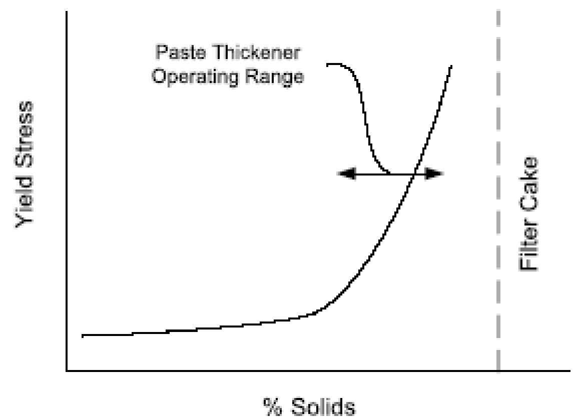

Figure 3

Bed depth distinguishes paste thickeners from other types of thickeners. Bed depths in a deep cone type paste thickener may be 10m or higher, creating compression forces which drive up the underflow solids concentration. Because of these depths, the concept of unit area, m^2/tph has little meaning for a deep cone style paste thickener. For a given diameter and tonnage throughput, a paste thickener may have a wide range of bed depths, producing a similarly wide range of underflow densities. Because of the understanding required for relating paste rheology, bed depth, and thickener design to paste production, the number of producers of this style of thickener is limited and currently includes GL&V, Outokumpu, and WesTech.

Paste Thickener for Mine Paste Backfill

The Paste Backfill Process

Hydraulic backfill using sand-sized particles from cycloning for mine support has been used for over fifty years. Paste backfill, which incorporates fines as well as coarse particles, such as the complete spectrum of a mill tailings particle size distribution ("total tails"), is a more recent development. The design of a paste backfill system is dependent on the backfill materials available at the mine site, such as mill tailings. Paste is produced by filtration or thickening. If backfill strength is required, the paste is mixed with a binder, such as portland cement, and water is added to adjust the slump as necessary for pumping and pipeline flow. The paste/binder mixture is pumped to the mine borehole for gravity transportation to the stopes. The slump required in the mine is a function of the mining plan and cycle time for accessing stopes. Typically a slump of 6-10 inches is required. If the tailings are too fine to produce the required strength with binder addition the tailings may be mixed with alluvial sand or crushed rock to produce a wider particle size distribution and higher strengths as described by Landriault (1995). Mine backfill with a paste is also a method of tailings disposal, in which case a binder may not be used. Brackebusch (1994) discusses the advantages of the advantages of paste backfill systems over more conventional methods of backfill.

Preparing Paste for Mine Backfill with a Thickener

The conventional method of paste preparation is to dewater the tailings from a mill operation in a high-rate slurry thickener followed by filtration. Filters include drum, disc, and horizontal vacuum filters. Water may be mixed with the filter cake to achieve the desired slump for transfer to the binder mixer.

The slump and solids content required for paste backfill is determined by the mining plan which includes such parameters as mining method, cycle time for accessing stopes, binder (such as cement) requirement, safety (such as controlling rock bursts), availability of backfill material, the mine layout and so forth. Designs are site specific and include a wide range of paste requirements. The lowest slumps (higher solids content) of this range require filtration. For the highest slumps (lower solids content) producing the paste directly from a thickener becomes an alternative to diluting filter cake.

There are no hard criteria for distinguishing where the paste thickener option becomes viable. Experience with pilot and full-scale operations suggests for slumps greater than 9 inches, the paste thickener is an alternative to filtration for producing the required paste. For slumps between 8 and 9 inches, the paste thickener should be evaluated as a possible better option. For slumps of 8 inches and lower, the paste thickener is unlikely to be an option to filtration. These operating ranges are strongly determined by solids particle size, throughput rate, and the behavior of the paste under the shearing produced during pumping and pipeline flow. Figure 5 shows a typical flowsheet for preparing paste with addition of a binder.

Thickeners, including paste thickeners, are fundamentally continuous processes. In many cases the

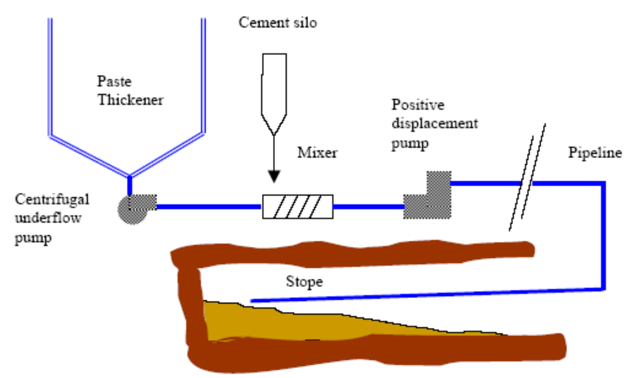

Figure 5

paste is intermittently required in the mine, depending on the mining plan. Development of procedures and mechanical design to meet a requirement for discontinuous operation has been a significant step for the use of a paste thickener in mine backfill. Experience has shown a properly designed paste thickener can function effectively in semi-batch operation. This is in part because a paste is non-settling and the thickener is designed with exceptionally high torque capacity for the raking mechanism. Storage time, the resulting underflow slump and solids content must be matched with the mining plan cycle time.

Operating Results in Mine Paste Backfill

Experience with paste thickeners for mine backfill is growing as the technology becomes better known and full-scale plants develop operating histories.

In one example, the paste plant consists of a thickener, cement silo, building housing the flocculant preparation system, electrical and control panel, and a positive displacement pump. The thickener operates by making and storing paste produced from cycloned base metal tailings (s.g. 3.2-3.4) from the mine. During the backfill portion of the cycle the stored paste is pumped at slumps of as low as 9½ inches (measured at discharge of the thickener centrifugal underflow pump) and solids content of as high as 79-80 wt% to a mixer for cement addition.

In another application, the paste plant consists of a thickener, cement silo, building housing the flocculant preparation system, electrical and control panel, and a positive displacement pump. Using base metal mill tailings (s.g. 2.7-2.9), the thickener has produced 8-9 inch slumps and 76-78 wt% solids, after underflow pumping.

The improvement in mine productivity with a paste backfill system is shown in another example where paste backfill is pumped to excavated stopes to allow for underhand cut and fill mining methods, and reduce dilution by reducing the amount of sand from fill that is recycled back into the mill in the primary ore. The paste backfill system uses a paste thickener and filter combination to produce 76 wt% solids backfill.

An Integrated Approach to Designing Paste Thickener Systems

The installations described above show that for an appropriate application a paste thickener can effectively produce the required paste for backfill. However, operation and design of backfill systems using paste thickeners have not been without problems. The problems generally developed because an integrated systems design approach was not used to match the paste thickener with paste transportation, binder (cement) addition, paste setup time, backfill strength, and other issues related to mining methods.

An integrated systems design of thickened tailings and paste processes, whether for surface disposal or mine backfill, is essential for the successful operation. Jewell (2002) A systems approach recognizes that rheological properties of a paste are a common design basis from the thickener to the pumps and pipeline design and to the application. Designing one part of the process, such as the thickener, without integrating the rheology of the thickener underflow with the transportation system, binder requirements, and mining plan will usually lead to problems.

Figure 6 shows the concept of designing paste systems starting with the application and working back to the paste thickener. Using mine paste backfill as an example, determination of the strength requirements for the stope backfill must be completed before required slumps are determined and the tailings dewatering technology, filters or a paste thickener, is selected. Cemented stopes must reach the required strength in a time period that allows the mining activity (blasting, hauling, etc) to proceed on schedule. In addition to specifying required underflow solids content or slump, the mine backfill design must specify thickener cycle time. Matching the paste thickener operation with the mine cycle time requires a design for the necessary holding time in the thickener, and an operating procedure to produce the required paste characteristics on a cycle time required by the mine.

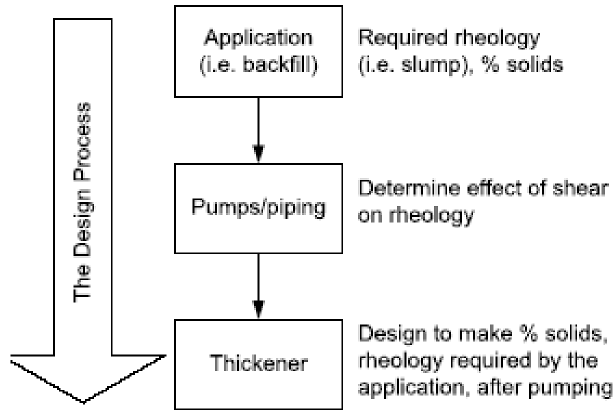

Figure 6

Conclusions

Paste thickeners are an established alternative to conventional and high rate thickeners for the surface disposal of tailings as a paste or thickened tailings. In underground mining the paste thickener is an emerging option to the conventional solution of filtration for a paste backfill application.

Unlike conventional thickeners, the deep cone style paste thickener operates with a deep bed of solids, utilizing time and compression forces to achieve high solids concentrations, well into the range where the suspension exhibits the non-settling characteristics of paste.

With the right particle size distribution, paste thickeners without filters can effectively produce paste for mine backfill requiring slumps of 9 inches and higher, after shearing. Depending on the application slumps approaching 8 inches may be produced. For applicable tailings and backfill requirements, the paste thickener offers an alternative to filtration for the production of paste.

The design of a paste thickener process always starts with the definition of the solids concentration and rheology of the paste at the application point. Working up the flow sheet, the pumping and pipeline and the thickener are designed to produce the required application rheology.

References

1. Abbott, J. et. al. (1973) "Coal preparation plant effluent disposal by means of deep cone thickeners", 6th International coal preparations congress, Paris, October 1973.
2. Boger, D.V. (1999) "Rheology and the Minerals Industry", Min. Proc. Ext. Met. Rev., Vol 20, Overseas Publishers Association, 1999.
3. Brackebusch, F.W (1994) "Basics of paste backfill systems". Mining Engineering, October 1994.
4. Houman, J., Johnson, G. (2003) "Commissioning and Operation of the Paste Thickening Farm at Kimberley Combined Treatment Plant", International Seminar on Paste and Thickened Tailings, Melbourne, 2003.
5. Paterson, A. (2003) "The Hydraulic Design of Paste Transport Systems", International Seminar on Paste and Thickened Tailings, Melbourne, 2003.
6. Jewell, R.J., Fourie, A.B. and Lord, E.R. (2002) "Paste and thickened tailings – A guide". The University of Western Australia, 2002.
7. Landriault, D. (1995) "The Present State of Paste Fill in Canadian Underground Mining", 97th Annual General Meeting of C.I.M. Rock Mechanics and Strata Control Session, Halifax, Nova Scotìa, May 14-18, 1995.
8. Robinsky, E.I. (1978) "Tailings Disposal by the Thickened Discharge Method for Improved Economy and Environmental Control". Tailings Disposal Today, Proceedings 2nd International Tailings Symposium, 1978.