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Some opportunities to increase performance of tailing thickener, case study: Gol-E-Gohar iron ore beneficiation plant

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ABSTRACT

Thickener is a major and convenient applied equipment for tailings dewatering in mineral processing plants. Past investigations have shown that feed slurry dilution can improve flocculation efficiency by affecting both floc size and density. Advantages of the thickener feed dilution method include reduced flocculent consumption, increased settling flux, and enhanced bed/sediment compressibility. Gol-E-Gohar iron complex is one of the largest iron concentrate producers in Iran and is located in Kerman. Gol-E-Gohar thickeners Performance was monitored through daily inspections. High flocculent consumption and turbidity of recycled water were major thickeners problems. Inspections showed that the high solid content of the thickeners feed was the major issue. Diluting pump method was used to decrease the solid content of the thickeners feed. Also, the reduction of used flocculent dosage happened by 45 % via Flocculent preparation improvement. The number of flocculent distribution points was increased from 4 points to 9 .for enhancing flocculent solubility, water with less total dissolved solids was used for flocculent preparation. The modifications resulted in the very clear thickener overflow water (turbidity less than250 ppm) and flocculent consumption was decreased from 114 g/t (gram per thickener feed tailings) to 43 g/t, in other words, there was a 65% decrease in flocculent consumption.

Keywords: *Flocculent, Iron tailing, Slurry dilution, Thickener*

1. Introduction

Thickener is the most widely applied equipment for tailings dewatering in mineral processing. The sedimentation process in thickeners starts by entering the pulp through the feedwell. Slurry after its energy being taken away, slowly and without any further turbulence moves downwards the thickener. Solid particles are settled at the bottom of the thickener and the clear water overflows from the top. After the initial sedimentation, solid particles are transferred to the thickener bed and influenced by shear and compression forces. The compaction process has resulted from the weight of the material in the upper layers on the thickener bed and shear forces are due to rake movement, vertical rods on the rake within the thickener bed, and the slope of the conical section [1].

Dilution of slurry feed can improve flocculation efficiency [2, 3] by affecting both floc size and density [2, 4, 5]. The advantages of thickener feed dilution include reduced flocculent consumption, increased settling flux, and enhanced bed/sediment compressibility [6, 7, 8]. It is worth noting that thickener feed dilution is crucial in cases where its solid loading is too high. Two methods exist for thickener feed dilution comprising diluting pumps and self-dilution systems [7, 9]. Eductor, also known by the commercial name of E-DUC, is the most common self-diluting system used in thickeners which were introduced and patented by EIMCO [10]. Banisi and Yahyaei (2008) introduced an approach for sizing the thickeners based on feed dilution. It was found that clarity of the thickener recycled water was improved with feed dilution and also stated that dilution rate in educators was affected by thickener feed rate [11]. Flocculent solutions are typically mixed with the feed slurry through addition to the feedwell, although feed pipe addition can be used concurrently or as an alternative. Solid-liquid separation of tailings slurries in gravity thickeners relies on the efficient mixing of slurry and dilute polymer flocculent solutions within the feedwell. Minimising the duration of shear effects on flocculent solution transport to the feedwell is essential, as the potential for increased flocculent demand and reduced flocculation efficiency can easily exceed any benefit from improved feedwell mixing [12]. The design of the feedwell and its performance affects the overall performance of the thickeners [13, 14]. The primary forces presented in sedimentation separations are gravity, buoyancy, and friction. Some factors influencing these forces are liquid density, particle density, particle size and shape, particle flocculation, and particle concentration. The solids settling and rate of separation can be theoretically related to these factors, and therefore, control thickener design within the specified process requirements [15].

The Gol-E-Gohar Iron Complex located in the south of Iran, is one of the largest Iron ore concentrate producers of this country. In this complex, in wet Iron ore processing plants, slurry thickeners are used to recycle water of tailings slurry. The recycled water from the thickeners overflow stream should not contain any solids. In this research, an inspection of the dewatering process revealed some defects that have a major impact on the dewatering equipment performance in terms of flocculent usage, recycled water amount, and thickener overflow water clarity. Then appropriate solutions are proposed to increase dewatering performance. Required modifications that have a major effect on the process have been done with low costs.

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1.1. Process flowsheet of the Gol-E-Gohar plant (line 5, 6, and 7)

There are three identical processing lines in this plant. The Plant mainly consists of several different systems such as primary grinding, the first stage of magnetic separation, secondary grinding, and secondary stage of magnetic separation, flotation, concentrate dewatering, tailing thickening, transport, and water recovery.

In the following paragraph, a general review of the plant is given. At the beneficiation, the homogenized materials are conveyed to a dry grinding unit where they are ground by high pressure grinding rolls (HPGR) in the close circuit with a dry vibrating screen. The screen undersize is transferred to a secondary grinding circuit consisting of a ball mill in a close circuit with a hydrocyclone cluster. The ball mill product is transported to the first stage of magnetic separation called cobbing. Under the function of the cobbers, the liberated tail is separated from valuable minerals. Tailings leave out the drum to tailing thickener while the valuable minerals are transferred to the second stage of magnetic separation consists of roughers and cleaners, lined in two successive stages. Here some additional tail is separated from the materials and transferred to the tailings thickener. The concentrate goes to the final stage of magnetic separation (Re-Cleaning) which works also as a dewatering unit before final dewatering by vacuum belt filters. The moisture of the filtered concentrate should be less than 8 percent. There are thickener and tanks which are utilized for water recovery to the process line. Under the operation of the thickener, a great amount of water is recovered which is distributed to different points throughout the plant as wash water or diluting applications (Figure 1).

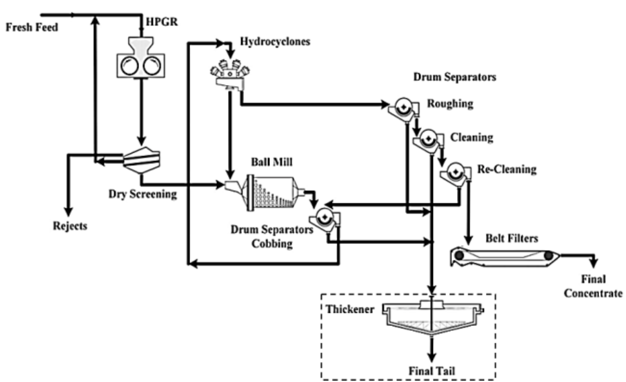


Figure 1. General arrangement of equipment in the Gol-E-Gohar plant (Line 5, 6, 7)

1.2. Tailing dewatering of Gol-E-Gohar Iron Complex (line 5, 6, 7)

Thickeners with a diameter of 28m are used for the dewatering of tailings. Thickener overflow water is used as recycled water in the plant, thickener underflow stream is pumped to the tailings basin. According to the design, the thickener feed dry solids density is 3180 kg/m^3. Thickeners overflow water must be clear (<250 ppm) for use in the plant. The technical data of tailing thickeners equipment are displayed in Table 1.

Table 1. The technical data of thickener.

Solid feed rate	Slurry flow rate	Feed solid	Solid in underflow	Height	Bottom slop
Max. 156 t/h	2300–2500 m3/h	4–6%	≥50%	3.8 m	9 deg

The performance of Gol-E-Gohar thickeners was surveyed through daily inspections over a specified period (2 months). High flocculent consumption and the presence of suspended solids in recycled water are problems of lines 5, 6, and 7 thickeners. In this research, the plant audit was used to find the design and operating issues and propose appropriate solutions in order to increase the efficiency of the thickener.

2. Materials and Methods

Several samples of thickener feed, overflow, and underflow were taken to determine solids content, over a period of 2 months. The samples were immediately filtered, dried and their solids content was determined. Also, the feed flow rate of the thickeners was estimated using mass balance Eq. (1).

$$TF = Ff - Cons - (Rs + Rb) \quad (1)$$

Where TF is the thickener dry feed rate (t/h), Ff is the dry fresh feed rate (t/h), Cons is the dry concentrate (t/h), Rs and Rb are the rejects of the screen top deck, and the ball mill trommel screen oversize part (t/h), respectively. Notably, the pH values of all slurry samples used in this study were ~ 7–8.

2.1. Thickener streams monitoring

Thickener designed maximum feed capacity is 156 tph of tailings. Monitoring of thickener operation conditions showed, overfeeding thickener causes to increase in the solid content of the feed (more than 14%). overloading of thickener caused some problems and reduced the efficiency of the tailing dewatering process. Figure 2 shows the thickener feed rate in the 120 shift. This figure shows thickener is often operated in overloaded mode and fed more than designed maximum feed capacity.

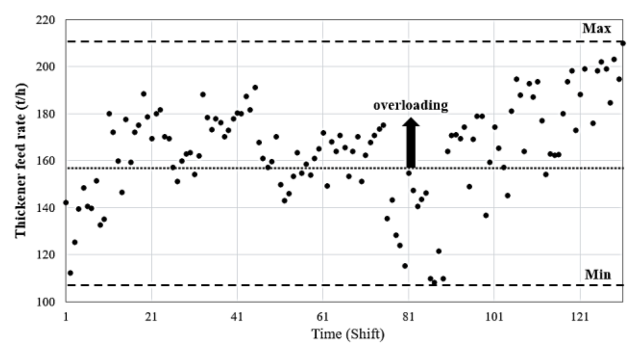


Figure 2. Thickener feed rate (t/h) in 130 shifts

According to the design, feed magnetite content and plant fresh feed rate (t/h) are 72 % and 405 (t/h), respectively. Monitoring of thickener operation revealed that fluctuations in thickener operation (figure 2) are the result of variations of feed magnetite content (49-65%) and fresh feed rate (300- 460 (t/h)) (that caused fluctuations in tailings rate that go into thickener) (figure 3), as well as, lack of thickener feed solid content control in the circuit (figure 2).

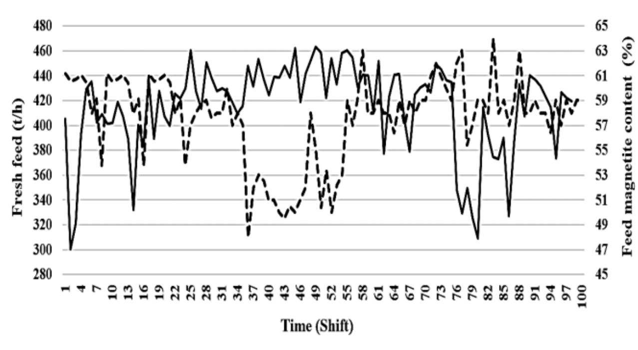


Figure 3. Feed magnetite content (%) and fresh feed rate (t/h)

According to the initial design, the magnetite content of fresh feed and maximum thickener feed rate is 71.6% and 156 (t/h), respectively. Figure 4 shows thickener feed rate versus plant yield (%)(produced Iron ore concentrate rate over plant fresh feed rate). Low magnetite content of feed has increased thickener feed rate (plant tailings) (Figure 4) because Gol-E-Gohar plant (lines 5, 6, and 7) design based on magnetite recovery (because of not installing WHIM separators).

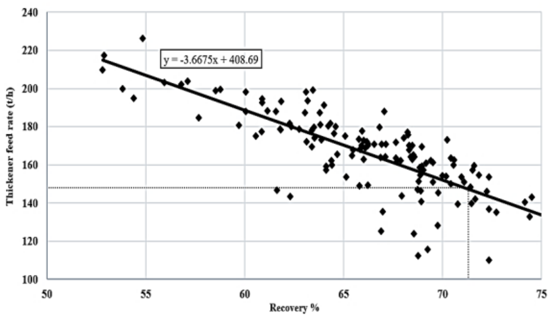


Figure 4. Thickener feed rate (t/h) in 130 shifts

Figure 5 shows the critical (figure 1a) and best (figure 1b) thickener overflow condition. The critical overflow condition occurs when the solid content of the thickener feed is more than 20%, which case leads to excessive consumption of flocculent and very turbid thickener overflow. In critical and best conditions, the solid content of the thickener overflow is 5% and more than 1000 ppm, respectively. The precipitation of thickener overflow ultra-fine particles in plant recycled water tanks reduces their capacity, clogging the belt filter cloth, increasing moisture of concentrates, and decreasing process efficiency. For this reason, operators have to reduce or shut down fresh feed (almost 30 min), this happens at least once per shift (8 hours).

(a) (b)

Figure 5. Thickener overflow in the critical (a) and best (b) condition before modifications

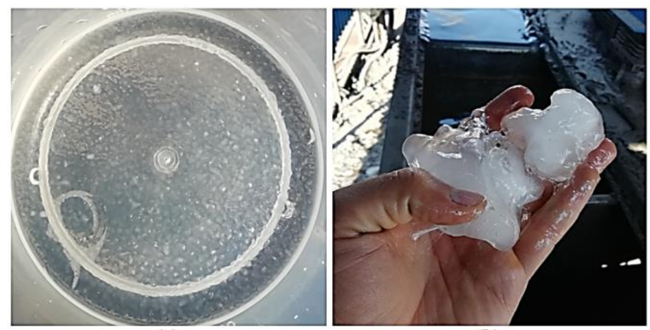
2.2. Thickener flocculent consumption monitoring

According to the design, flocculent consumption is 15 g/ton, but the high solids content of the feed caused an increase in consumption up to 100 g/ton averagely. The flocculent solution preparation unit is not suitable for proper dissolving because of incorrect dry flocculent wetting, dissolving, mixing, and lack of solution retention time. As a result of failure to ensure proper polymer solution preparation, unsolved particles in the solution consequently will aggregate into larger pieces and chunks (figure 6). These larger pieces and chunks dissolve slower and often can plug equipment causing mixed systems and even process operational disruptions. The use of high TDS water (12467 ppm), Low flocculent preparation time (30 minutes), improper solution adding points to thickener feed slurry, and lack of a proper diluting water point to a prepared solution are factors that reduce the efficiency of the flocculation process. Flocculent solutions typically provide the best performance at ≤ 0.1% concentrations. To optimize flocculent mixing system sizing, these solutions are often designed to be mixed to 0.25-0.50% maximum concentration [16]. Once dissolved, the flocculents will dilute readily with teed in the water downstream of the feed pump to obtain the final target 0.1% concentration.

3. Results and Discussion

3.1. Effect of feed solid content

The result of laboratory batch settling tests for the solids contents of 5, 13, and 20% are shown in Figure 7. The mud line height versus time was measured. Settling velocities were calculated by determining the slope of the initial linear settling zone using regression analysis. There is a significant difference between the settling rate of slurry in 5, 13, and 20% of feed solids concentration indicated by shapes of settling curves. The settling velocities calculated from the initial linear settling zone for the feed solids concentrations of 5,13 and 20% were found to be 13.54, 4, and 1.43 mm/s, respectively. The settling velocities showed free settling phenomenon is considerable in low solids content.



(a) (b)

Figure 6. Unsolved particles (a) and wasted polymer chunks (b)

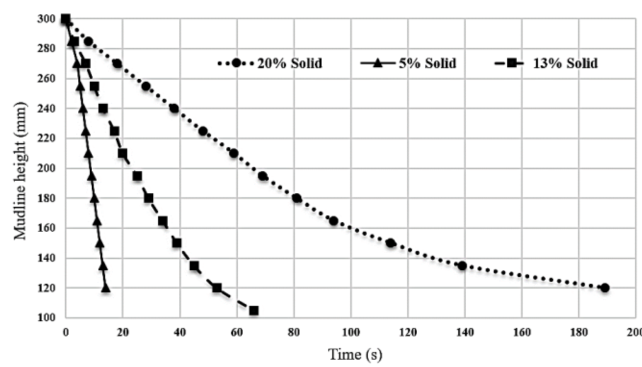


Figure 7. The results of settling tests for solids concentration of 5, 13 and 20%

3.2. Effect of preparation water TDS

Investigations have shown that the TDS of water for preparing flocculent solution is crucial for their solubility. In similar conditions, water with different TDS is used to prepare flocculent. High water TDS, results in low settling velocities because some part of the flocculent will be consumed by dissolved solids, so the settling rate decreases (Figure 8).

3.3. Effect of feed characteristics

The plant feed is provided from two mines with different ore characteristics (i.e. magnetite, hematite, clay content, etc.). Variations in plant feed result in different plant tailings (thickener feed) with different sedimentation characteristics (Table 2). Sedimentation tests were performed for feeds type A and B in percentages of solids 5, 13, and 20% under completely identical conditions. The results showed that the plant feed type had an important impact on the settling velocities. Investigations showed that as the solids content increases, the effect of the type of feed on thickening becomes more significant (Table 2).

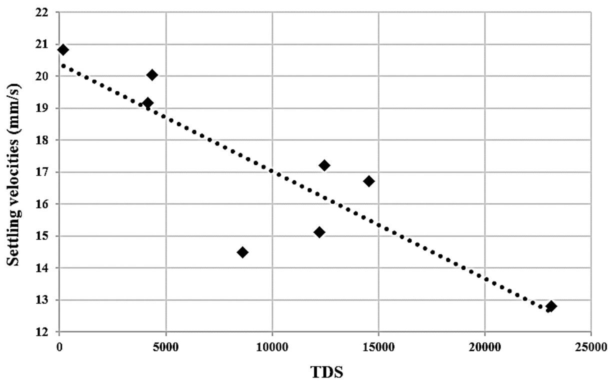


Figure 8. The results of settling tests for different TDS of water used to make flocculents (Gol-E-Gohar Laboratory)

Table 2. The results of settling tests for different solids concentration and feed type

Solids Concentration (%)	Settling velocities		
	A	B	Δ (%)
5	13.54	11.99	13
13	4	3.48	15
20	1.43	1.14	25

When the amount of hematite and pyrite in fresh feed increases, iron content in the tailings will increase. Pyrite and hematite have a high density compared to other tails (clay, silica, etc.), so they settle more easily. In other words, flocculent consumption will decrease. The size (45 microns>%) of the thickener feed is shown in Table 3. Feed is fine for feed type B, also Fe% is lower than type A. Since flocculent functions by adsorption on the surfaces of suspended solids, it was expected that the flocculent dosage should be rather high in order to achieve similar settling velocities.

Table 3. Thickener feed characteristics

Thickener feed	A	B
Size fraction under 45 microns Size	48.5	54.4
Fe (%)	24.9	19.7

3.4. Thickener feed dilution and flocculent preparation optimization

Under low pulp density conditions, sedimentation has been monitored, and was found that the settling rate of the suspension was higher than the high pulp densities because the free settling phenomenon is considerable in low solids content. The proposed method in this research could be easily implemented by the plant personnel and does not involve any complex design features that exist in the available commercial systems. The first step is to find the optimum solids concentration of the feed. Upon finding the desired feed solids concentration, the next step is to calculate the dilution water needed to change the plant feed solids concentration to the desired value. This can be readily done using the feed flow rate and the corresponding percent solids. Dilution water is taken from the clear water of the thickener overflow. In order to have a stable operation, it is necessary to have a clear water reservoir from which the water for dilution could be provided (Figure 9).

For preventing spots and unsolved particles (Fish Eye Pieces) in the prepared flocculent, some modifications were done as follows:

- Flocculent residence time increased by 45%.
- The number of injection points increased from 4 points to 9.
- Adding 60% of flocculent in the path of thickener feed and 40% in the feedwell (Figure 9).
- Water with less TDS was used to make the flocculent.
- The flocculent concentration of preparation and injection was controlled.

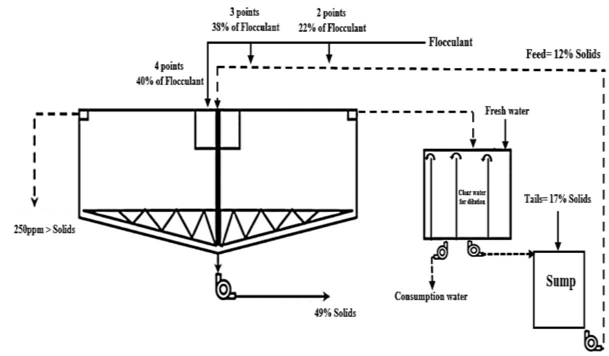


Figure 9. Overview of thickener flocculent addition system and feed dilution

The dilution tank with a diameter of 4m and a height of 5m was used to change the average feed solids concentration from 17% to 12% (Figure 10).

(a) **(b)**

Figure 10. The dilution pump (a) and dilution tank (b)

3.5. Modification results

After modifications, the thickener overflow became completely clear water (<250 ppm). Also, overflow flowering was eliminated even in critical conditions (Figure 11).

Figure 11. The thickener surface after modification in the operation condition

Spots and unsolved particles (fisheye) in the prepared flocculent were eliminated. After thickener feed dilution flocculent consumption was decreased from 114 to 82 (g/t). Then flocculent consumption was decreased from 82 to 43 (g/t) because of flocculent preparation process optimization (and more flocculent solution adding points). In other words, there was a 65% decrease in flocculent consumption. (Figure 12). The concentration of preparation and injection flocculant and also solid content of thickener feed were controlled. These standardizations decreased flocculant consumption fluctuations.

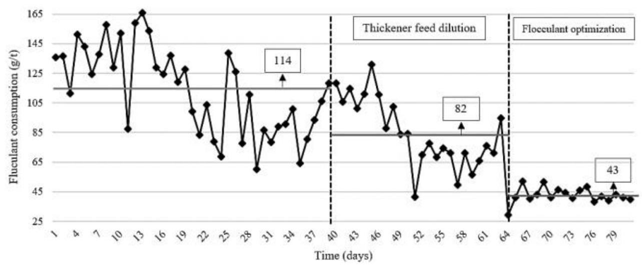


Figure 12- Flocculent consumption before and during modifications

4. Conclusions

The Gol-e-Gohar iron ore complex is one of the largest iron producers in Iran and is located in southern Iran. The performance of Gol-e-Gohar thickeners was surveyed through daily inspections for more than 2 months. A High amount of flocculent consumption and the presence of suspended solids in recycled water were problems in thickeners. Inspections showed the high solid content of thickeners feed was a big obstacle because of the low weight recovery of fresh feed. The diluting pump method is used to decrease the average solid content of the thickeners feeds from 17% to 12%. After the modifications, the thickener overflow completely clear water (<250 ppm) and flocculent consumption decreased from 114 to 43 (g/t), in other words, there was a 65% decrease in flocculent consumption.

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