Shahrood University of Technology
Iranian Society of Mining Engineering (IRSME)

Journal of Mining and Environment (JME)

journal homepage: www.jme.shahroodut.ac.ir

THOMSON REUTERS

Vol. 11, No. 1, 2020, 221-230.
DOI: 10.22044/jme.2019.8807.1769

Comparison between Helical and Elliptical Static Mixers Performance in Column Flotation of Sungun Copper Plant

B. Nemati Akhgar[1*], A. Fathzade[2], B. Golizade[2], and S. Hajilou[3]

1. Mining Engineering Department, Engineering Faculty, Urmia University, Urmia, Iran
2. Process Control and Metallurgy Division, Concentration Department, Sungun, National Iranian Copper Industry, Iran
3. Faravar Pishgam Toseegar Co., Tabriz, Iran

Received 13 August 2019; received in revised form 30 September 2019; accepted 2 October 2019

Keywords

Column flotation

Sparging system

Sungun Copper Plant

Flotation

Hydrophobicity

Abstract

The flotation circuit in the Sungun copper plant consists of two column flotation cells as the cleaners having a fixed-spargers system. In order to achieve the expected aims in the flotation step, there are serious operational challenges such as the fast choking of the static mixers, boiling problem, burping phenomenon and pulp overflow to concentrate lander, and maintenance and control problems. An attempt was made by implementing a new helical static mixer in one of the cleaner cells instead of the old elliptical type to overcome the challenges. The changes resulted in the proper performance of the column, whereas due to choking, the burping phenomenon was eliminated, finer bubbles were produced, and the boiling and overflow problems were solved. Also the static mixer life time was increased up to 7 months in the helical column cells from one month in the elliptical column cells. In addition to 40% air consumption reduction and 20% solid increase in the final product, the grade of Cu and Mo increased by the helical static mixer replacement up to about 18.7% from 16.8% (11%) and to 511.1 ppm from 263 ppm (94%) in the cleaner step, respectively. The recovery of Cu and Mo was increased by about 1.5% and 0.2%, respectively. Finally, the results obtained proved that the effectiveness of finer bubble generation on grade improvement was dependent on the mineral hydrophobicity as the Mo grade increased more than Cu.

1. Introduction

1.1. Column flotation in mineral processing

The column cells in the flotation step of the mineral processing industry was introduced by Wheeler for the first time in 1966 [1], and then large-scale investigations were conducted to provide more information about the column cells [2-6]. In comparison with the other types of flotation cells, the column flotation cells can operate with more froth depth under wash water injection, modifying the metallurgical performance of the column cells [7]. There are different types of mechanical and column cell flotation machines used in a mineral processing plant design, and thus the variety is to make equipment selection difficult to the experts and designers. Also there is no doubt that a smaller flotation circuit with a suitable metallurgical performance is of interest to all designers satisfied with column cell selection and their installation. The design and operation of the column cell is generally dependent on the service times, operational costs, mineralogical properties, selectivity, etc. [2]. The sparging system performance of the flotation column cells has a main roll in operation and investment cost, selectivity, and metallurgical performance, wherein static mixers are used to provide the mixing conditions in the column cells.

As cited before, static mixers can be applied for various scopes such as mixing in continuous conditions, heat transfer, and chemical reactors for aeration in various fields of classical chemicals, petrochemicals, and minerals, pulp, paper, paints

Corresponding author: b.n.akhgar@urmia.ac.ir (B. Nemati Akhgar).

and resins to food, cosmetics, and pharmaceuticals [8-12]. The static mixer design allows providing a good mixing and transporting process in reactors in which they are used. In the static mixers, the fluid is entered by pressure and mixed by passing through a series of flow orientation elements along the axis of static mixers. In comparison with mechanically agitated stirrers, negligible maintenance and wear, low energy consumption resulting in low operation as well as investment of cost, continuous operation, and easy adaptation to use equipment can be named as their main advantages. Production of drop or bubble with a certain mean and distribution is one of the most important of static mixer duties. Pressure drop that is necessary to drive the two-phase flow through the mixer is another important characteristic of the dispersive mixing process [13]. In the static mixers, pressure drop can cause some problems in the industrial process [14], especially in flotation cells of mineral processing plants, wherein fluid consist of solid and fine particles. Therefore, the problems such as complete or partial chocking are not avoidable in the static mixers. Static mixers have an enormous variety of design based on the number and type of elements such as elliptical and helical static mixers. Unfortunately, the static mixer performance has not been fully characterized until now due to complex geometry of the static mixers [14]. Regarding the mentioned problems and increased popularity of static mixers, some new segment design such as helical type is available, optimized through trial-and-error methods based on the previous experience [15-21]. However, there are many studies conducted on sparging systems and related issues in laboratory scale [6, 22-26]. For instance, flow pattern of Newtonian and non-Newtonian fluids, creeping flow and laminar flow regimes and tri-helical static mixer performance were investigated before that [16, 18-20]. In the recent years, the number of investigation on helical static mixers has been increased due to its widespread usage. Bubbly gas–liquid flow in a helical static mixer was investigated by means of multi-phase computational fluid dynamics (CFD) simulations [13]. The results obtained have indicated that the helical mixer is able to provide a certain degree of dispersion in gas liquid systems, and the helical mixer elements can produce a swirling flow. Additionally, visualization and quantitative analysis of dispersive mixing by a helical static mixer has been studied by measuring parameters such as the bubble size distribution, gas hold up, and pressure drop in laboratory scale [8]. Finally, it is worth mentioning that the helical static mixers can be used as a reactor in biodiesel production from palm fatty acid distillate (PFAD) [27]. A brief literature review indicated that although the helical static mixer was investigated using modeling and visualization methods in laboratory scale, there is lack of information about evaluation of their performance using practical observation in industrial scale. This paper aims to make an attempt to compensate for the flaw by conducting a comparison between the elliptical and helical static mixers in column flotation cells of Sungun Copper Plant through industrial observations.

2. Materials and methods; Sungun flotation column cells as case study

2.1. Sungun copper concentrator plant and flotation column cells

The Sungun copper concentrator plant, located in NW Iran, has been designed to concentrate 900 t/h feed with 0.6% copper to produce a concentrate having about 30% copper. The mineral processing in the copper plant begins by a gyratory crusher used to reduce particle sizes of ROM (run of mine) to less than 20 cm. After the crusher and before a SAG (semi-autogenous grinding) mill, a stockpile is considered to make sure feeding of the SAG mill. The comminution operation in the plant is designed to be continued using a 32 ft. SAG mill combined with two ball mills in a close circuit with hydrocyclone.

The hydrocyclone overflow stream with d80 = 90 microns enters the conditioning chamber to be prepared for the flotation process in the primary concentrating step (rougher cells). According to the plant design, the recovery and grade of the product in the rougher steps should be 10% and 6%, respectively. Before the cleaner column cells, the particle size of the rougher product is reduced through ball milling as the regrinding step in a closed circuit by a hydrocyclone with an overflow size (d80) of 40 microns. The cleaner column flotation step involving two 12 m column cells is conducted on the overflow after conditioning. The tail of the cleaner step inserts to 4 RCS mechanical machines as a scavenger step with a volume of 50 m^3. The product of the scavenger step is considered to be resend for regrinding and then the cleaner steps when its tail joints the final tail stream of the flotation step along with a rougher step tail. The cleaner column cells concentrate as feed of the recleaner step is reprocessed using 9 m column cells. The sedimentation of the recleaner step, as the final concentrate (FC), is conducted using a 12 m thickener before the filtration step when the recleaner tail as the circulating load is retreated by the cleaner column cells.

The cylindrical shape and the height-to-diameter ratio can be considered as a prominent feature of the column cells at the first glance. In addition to the apparent characters, the lack of mechanical agitator and application of condensed air for bubbling in spargers of column cells would be notable as the other specific properties of the flotation machines.

Column cells, based on the aeration type, have been divided into the two types of external and internal aeration. In the old type of internal aeration column cells, air is directly introduced into the cell through nozzle, while air introduction into the new type of external aeration is performed using the jet shear mechanism into the column cells. The aerator of Microcel^{TM} model (type CISA) used in the column flotation cells of the Sungun copper plant has been designed to meet the aims of recovery promotion and maintenance requirement reduction [23]. In this type of column, a static mixer is used for bubble generation. The Microcel system consists of a slurry pump recycling slurry from the bottom of the column through several static in-line mixers. The air is compressed into 12 in-line mixers and then mixed with slurry under the high-shear conditions. The mixed pulp is inserted in the column cells and levels up into the collection zone and column surface [23]. In the cells, the froth depth and pulp/air interface depth are measured by a couple of barometers of PT, and wash water is sprayed on it from 20 cm height above the froth surface. There are several problems in the column cells of the Sungun copper concentrator plant, preventing them from operation under satisfied metallurgical performance, as mentioned in the following; fast choking of the static mixers (sometimes even immediately after installation and operation beginning), boiling problem due to bubble ununiformed disturbance in cell volume, burping phenomenon, and consequently, overflow of pulp to concentrate lander, sensitivity to the unpredictable cases, maintenance problems, complicated controls, and inexperienced control operators.

The choking problem in the aeration system is considered as the key issue to solve the other mentioned problems. Based on the fact that the aeration or sparging system as the bubble generator device is known as the heart of the process in column cells [2], the problems may be solved by modification or conduction of essential changes in sparging system.

2.2. Sparging system diagnostics

After an extensive investigation and survey of flotation circuit, it was found that the main problem in the performance of the column cells was related to the sparging system errors, especially due to static mixer chocking. Such problems in columns cell flotation is attributed to the high solid density of particles (3.6 ton/m^3), dysfunctional effects of fine particles and clay minerals, and finally, improper arrangement of elliptical static mixers. Due to the mentioned issues, the chocking problem is unavoidable occurring after the initial times of the static mixer run, even immediately after installation. As chocking occurred, the metallurgical performance of the column cells was slumped, reducing recovery and grade of operation. In addition, the problems of boiling cells (pulp overflow into the concentrate lander), burping cells, coarser bubble formation, and unsteady condition of flotation performance would be responsible for the metallurgical performance of slump as chocking occurred.

As mentioned earlier, the flotation circuit of the concentrator plant in the cleaner step consists of two column cells running parallel to each other. The arrangement allows for manipulating one of them to obtain comparative results. Finally, the column cell No. 2 was selected for exerting the desired changes based on the operational issues in the study. During the changes, parameters such as the wash water system, compressed air flow rate, speed of air pumps and tail pumps, chemical agent consumption, and froth depth were measured and monitored precisely.

2.3. Static mixer changes (replacement of elliptical type by helical type)

The operational records indicated that the application of the elliptical static mixers in the column cells was an incorrect choice regarding the fact that the static mixers used were implemented for mixing in gas-liquid two-phase flows. Due to the shape and element (blade) arrangement of the type of static mixers, a type of resistance occurs against flow [8]. In addition to the resistance, the elliptical static mixers having less free space was chocked quickly by interring segregated bits from rubber rotors and body of spargers or tail and hydrocyclone pumps. On the other hand, the helical static mixers can produce finer bubbles (1200-1400 microns), promoting an overall bubble carrying capacity, and consequently, the metallurgical performance of the column cells. The type of static mixers produce a homogenous mixture of pulp and fine bubbles as the air and pulp are mixed under a high-shear condition, passing through the helical static mixer elements. In the helical static mixers with a higher free space than that for the elliptical ones, the mixing operation is performed exponentially much better. The design of the implemented helical static mixers is depicted in Figure 1. After the design and manufacture of the helical static mixers, twelve of them were implemented in column cell No. 2 during the overhaul period of the copper concentrating plant. In accordance to the static mixer replacement, several changes and modifications had to be made on the selected operational parts of the column cells such as air flow rate setting, wash water system optimization, and new piping. As mentioned earlier, there was a backing flow from the concentrate lander into the cleaner cells before the static mixer change. The problem is being hauled by implementation of a vent pipe on the concentration transportation path from cleaner to recleaner. As known, air consumption in helical static mixers is lower than that in elliptical static mixers. Based on a precise computation, it was decided that the air volume used was significantly reduced in the column cell No. 2 (by 40%). The primary observations indicated that the changes resulted in more stable operational conditions in column cell No. 2 compared with column cell No. 1 during the initial performance period.

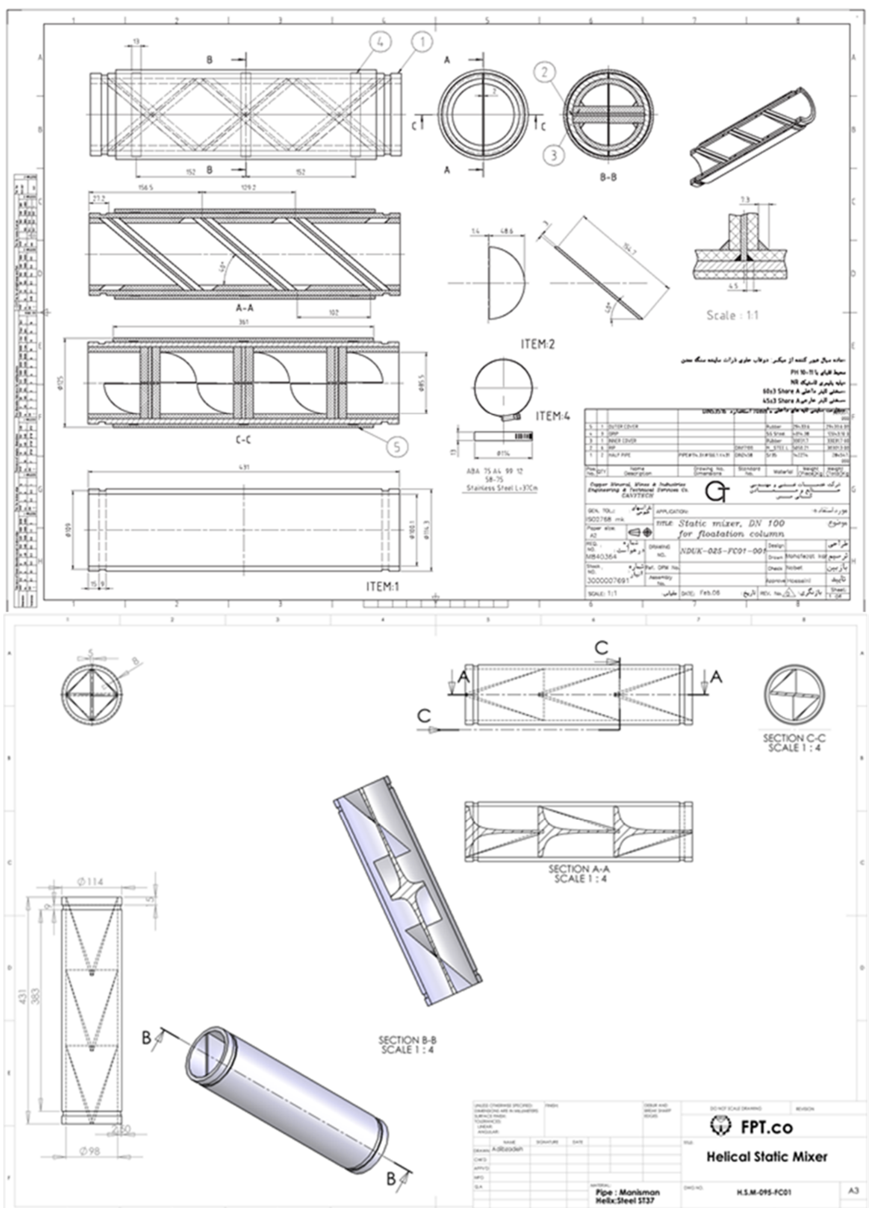

Figure 1. Technical design of elliptical (left) and helical (right) static mixers.

3. Result and discussion

3.1. Proper froth generation

As Figure 2 proves, the finer bubbles are generated in the column cells equipped with helical static mixers in comparison with the bubbles produced in the former elliptical column cells. The finer bubbles aided by wash-water flow provided significantly the proper conditions for the flotation process, producing concentrate with a higher grade through entrainment reduction and proper control of gangue transportation in the froth phase. The exerted changes in the froth generator type led to production of finer bubbles with uniform distribution in the depth and surface of the column cell No. 2. In addition to the advantages, finer bubbles having more stability could increase valuable mineral recovery in the collection zone. More stable bubbles led to more froth depth, and consequently, more wash water flow rate had to be used. From the flexibility overview and grade-recovery subject, the metallurgical performance of the helical column cells was improved significantly due to the mentioned changes.

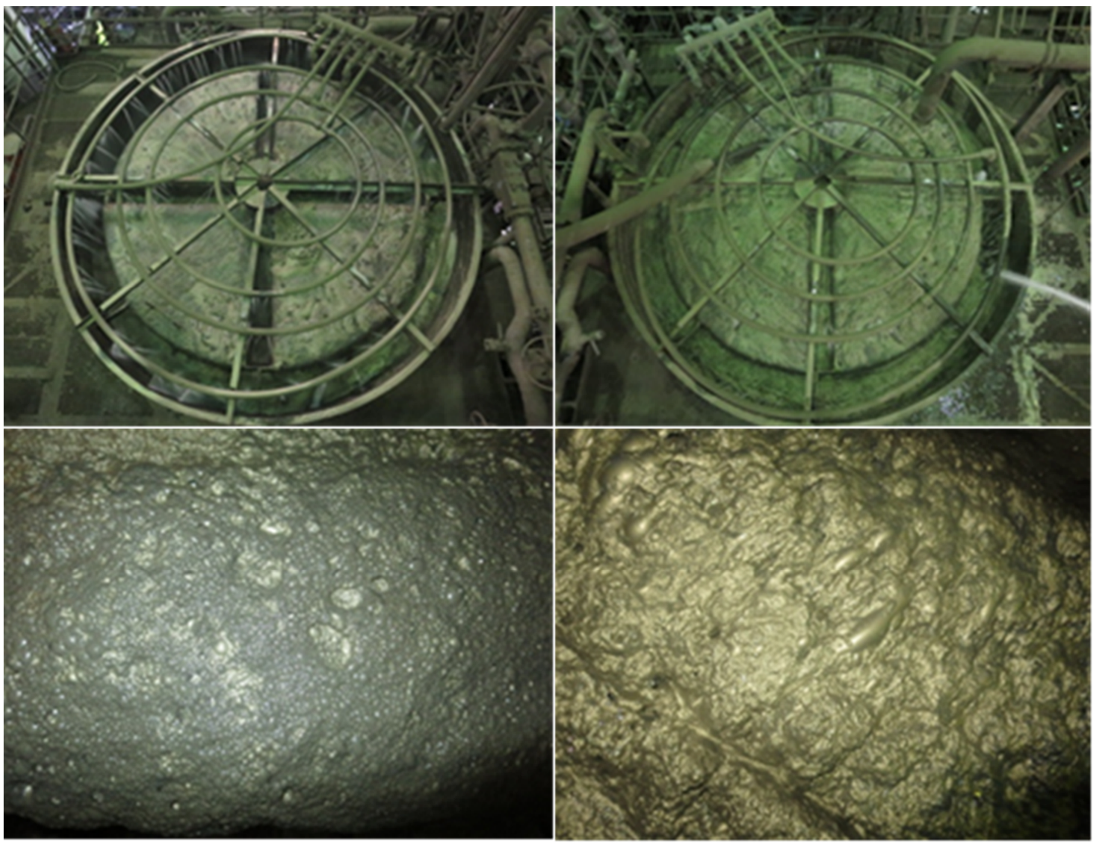

Figure 2. The froth generated in elliptical column cells (right) and helical column cells (left).

3.2. Influence on air consumption and wash water system

After 60 days continuous monitoring and data collection related to air consumption of column cell No. 2, the helical column cells consumed compressed air about 40% less than the elliptical column cell (Figure 3). The air consumption decrease after helical static mixer installation resulted in a reduction in the air compressor operation time, and then a fair energy and cost saving. In spite of the lesser air consumption in the helical column cell No. 2, the froth depth of the column cell was more than that in the elliptical column cell as the most important achievement of the static mixer replacement (Figure 4).

Regarding the problems in the elliptical static mixer column cells such as coarse bubble production, burping cells, and pulp overflow in concentrate landers, the wash water system lost its positive performance, while the problems were solved to produce a high-grade concentrate by changing the static mixer type, modifying the bubble generator system and stabilizing the column cell flotation performance.

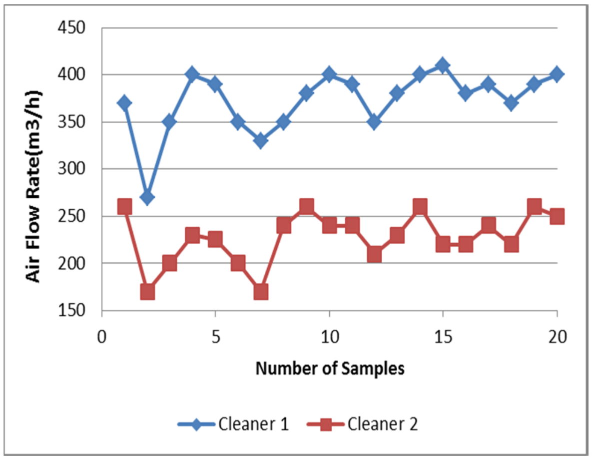

Figure 3. Air flow rate variation during 60 days continuous monitoring.

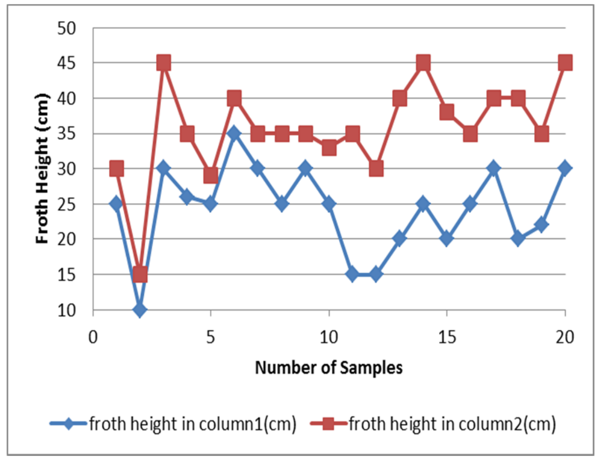

Figure 4. Froth depth in helical column cell *vs.* elliptical column cell during 60 days continuous monitoring.

3.3. Burping column cell problem solution

The burping problem has arisen from mixer chocking and uninformed distribution of air in the column cells. The problem resulted in the overflow of a low-grade concentrate to concentrate lander and domination of non-selective flotation mechanism with a negative influence on the column cell metallurgical performance. This observation indicated that the burping problem was eliminated in the helical column cell No. 2 (Figure 5). The results obtained reconfirmed the fact that spargers had a main role in the column cells operation without the burping problem, producing the required bubbles with more uniformity [28].

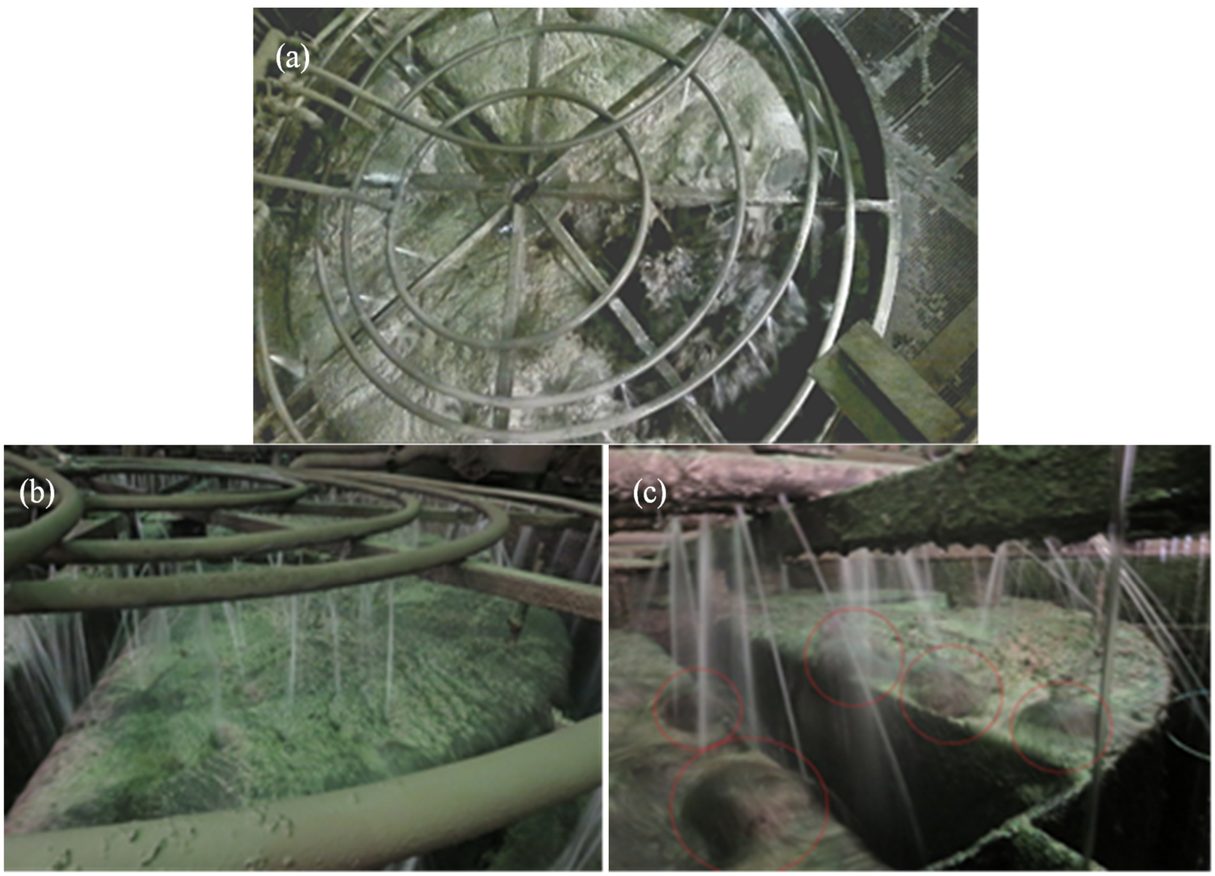

Figure 5. (a and b) burping elliptical column cell. (c) helical column cell No. 2 with uniform air destitution.

3.4. Static mixer life improvement

As known, the elliptical static mixers and helical static mixers have different designs, and then it would be expected that the sparger replacement would influence the mentioned parameters in the column flotation. In order to test the influence of the changes on the service time, the helical static mixer chocking status was checked using the sonic method in column cell No. 2 every week during 60 days monitoring. The results obtained uncovered that there was no chocked helical static mixer increasing the static mixer life time having a positive effectiveness on the operational cost and economic issues (Figure 6). The life time improvement can be attributed to the fact that the negative influence of clay minerals responsible for chocking problems is reduced due to the helical static mixer implementation owning to their especial design.

Figure 6. Static mixer of elliptical type (above) after 5 day with chocking and helical type (below) after 3 months without chocking.

3.5. Concentrate grade increase

Regarding the improved metallurgical performance in the helical column cell, the flow rate of the concentrate stream was increased, minimizing the high-grade circulating load. The accurate sampling of the concentrate streams in the elliptical and helical column cells proved that copper and molybdenum grade was increased in the helical column cells due to the modified conditions in the column cell flotation process by the static mixer replacement (Figure 7). The proper contact conditions between bubbles and particles, uniform distribution of bubbles and reduction in the bubble size can increase the grade of concentrate in column cell No. 2, as cited before [2, 8, 23, 29, 30]. As expected, due to the finer bubble generation in column cell No. 2 (Figure 2), the grade of column cell No. 2 has to be increased. The results obtained also proved that the sparger type changes had more influence on the molybdenum concentrate than the copper concentrate, whereas Cu grade in the concentrate of cleaner No. 2 increased by about 18.7% from 16.8% (11%) in cleaner No. 1, and molybdenum grade increased by about 511.1 ppm from 263 ppm (94%) after helical static mixer replacement. Thus it can be concluded that the effectiveness of finer bubble generation on grade improvement is not the same for all the minerals involved in the flotation, and depended on the mineral hydrophobicity. In addition to grade, recovery of copper and molybdenum was increased by about 1.5% and 0.2%, respectively.

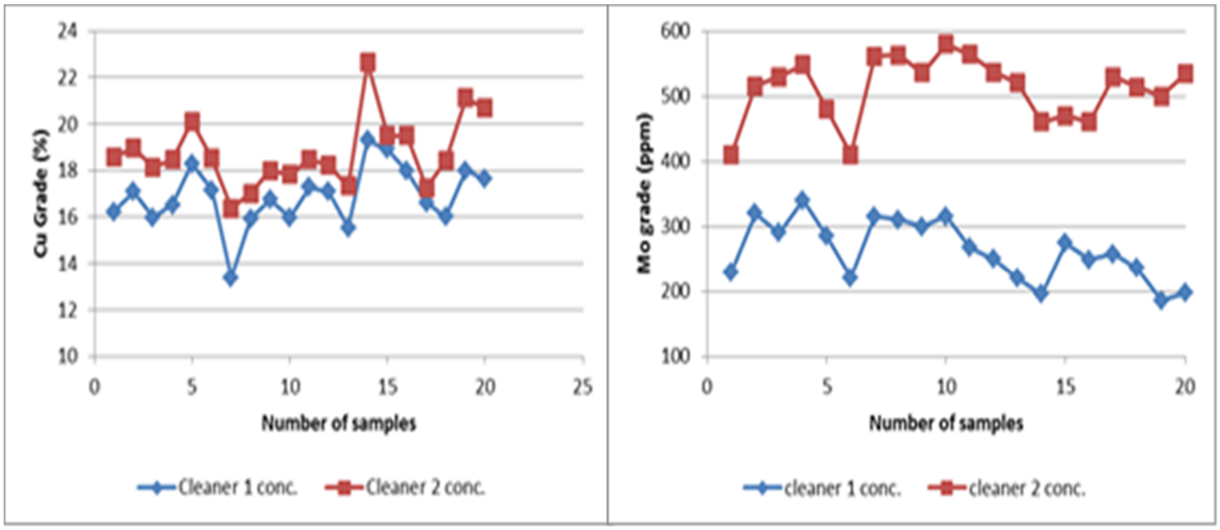

Figure 7. Concentrate grade comparison in column cells of No. 1 and No. 2.

4. Conclusions

As a main achievement, the chocking problem in the column cells used in the cleaner step was solved through replacement of the helical static mixers instead of the elliptical static mixers. In addition, the change in the static mixer type improves the flotation process, as follows:

- The compressed air flow rate was reduced by 40%, resulting in 30% air compressor capacity to be saved.
- The flotation process improved as circulating load of high-grade concentrate from the cleaner step to the recleaner step, and consequently, from there to scavenger cells was reduced. The improvement led to a decrease in the final tail grade and recovery.
- The grade and recovery of copper in the helical column cells increased by 11% and 1.5%, respectively. The same as copper, using the helical static mixers, the grade and recovery of molybdenum increased by 94% and 0.2%, respectively.
- The static mixer life (operation without chocking) was increased from 20 days to 5 month.
- The solid percent increase in the final concentrate of the flotation process improved the thickener operation by reducing the flocculants agent dosage from 25 g/ton to 21 g/ton.
- The effectiveness of finer bubble generation on grade improvement is dependent on the mineral hydrophobicity.

References

[1]. Wheeler, D.A. (1966). Big flotation column mill tested, E & MJ. 167: 98-99.

[2]. Rubinstein, J.B. (1995). Column Flotation Processes: Designs, and Practices, Gordon and Breach Science, Moscow, Russia.

[3]. Laskowski, J. (2001). Coal Flotation and Fine Coal Utilization, Elsevier,Vancouver, BC, Canada.

[4]. Finch, J.A. and Dobby, G.S. (1991). Column flotation: a selected review. Part I. Int. J. Miner. Process. 33: 343-354.

[5]. Finch, J.A., and Dobby, G., (1990). Column Flotation. Pergamon Press, Oxford.

[6]. Han, O.H., Kim, M.K., Kim, B.G., Subasinghe, N. and Park, C.H. (2014). Fine coal beneficiation by column flotation, Fuel Process. Technol. 126: 49-59.

[7]. Banisi, S. and Finch, J.A. (2001). Testing a Flotation Column at the Sarcheshmeh Copper Mine, Miner. Eng. 14: 1177-1182.

[8]. Rabha, S., M. Schubert, Grugel, F., Banowski M., and Hampel, U. (2015). Visualization and quantitative analysis of dispersive mixing by a helical static mixer in upward co-current gas–liquid flow, Chem. Eng. J. 262: 527-540.

[9]. Hobbs, D.M. and Muzzio, F.J. (1998). Optimization of a static mixer using dynamical systems techniques," Chem. Eng. Sci. 53: 3199-3213

[10]. Chen, R.C. (1994). Analysis of homogeneous slurry pipe flow, J. Mar. Sci. Technol. 2: 37-45.

[11]. Rahmani, R.K., Keith, T.G., and Ayasoufi, A. (2006). Numerical study of the heat transfer rate in a helical static mixer. J. Heat. Ttrans-t. ASME .128: 769-783.

[12]. Jones, S.C., Sotiropoulos, F., and Amirtharajah, A. (2002). Numerical modeling of helical static mixers for water treatment. J. Environ. Chem. Eng. 128: 431- 440.

[13]. Zidouni, F., Krepper, E., Rzehak, R., Rabha, S., Schubert, M. and Hampel, U. (2015). Simulation of gas–liquid flow in a helical static mixer, Chem. Eng. Sci.137: 476-486.

[14]. Chang, K.T., Jang, J.H., Lai, T.C. and Chen, J.N. (2011). Experimental and numerical study on the flow visualization in a tri-helical static mixer, J. Mar. Sci. Technol. 19: 392-397

[15]. Bakker, A., LaRoche, R.D., and Marhsall, E. M. (2000). Laminar Flow in Static Mixers with Helical Elements, The Online CFM book at http://www. bakker.org.

[16]. Byrde, O. and Sawley, M.L. (1999). Optimization of a Kenics static mixer for non-creeping flow conditions, Chem. Eng. J. 72: 163-169.

[17]. Kumar, V., Shrike, V., and Nigam, K.D.P. (2008). Performance of Kenics static mixer over a wide range of Reynolds number, Chem. Eng. J. 139: 284-295.

[18]. Lin, C.T., Chen, K.D., and Chang, K.D. (2007). Static mixer along with its helical mixing device, PRC Patent No. ZL 200720126548.

[19]. Rahmani, R.K., Keith, T.G., and Ayasoufi, A. (2005). Three-dimensional numerical simulation and performance study of an industrial helical static mixer, J. Fluids Eng. 127: 467-483.

[20]. Rahmani, R.K., Keith, T.G., and Ayasoufi, A. (2006). Numerical simulation and mixing study of pseudoplastic fluids in an industrial helical static mixer, J. Fluids Eng. 128: 467-480.

[21]. Thakur, R.K., Vial, Ch., Nigam, K.D.P., Nauman, E.B., and Djelveh, G., (2003). Static mixers in the process industries-a review, Chem. Eng. Res. Des. 81: 787-826.

[22]. Maldonado, M., Desbiensa, A., Poulin, É. Del Villar., and R., Riquelme A. (2015). Automatic control of bubble size in a laboratory flotation column. Int. J. Miner. Process. 141: 27-33.

[23]. Pyecha J., Lacouture, B., Sims, S., Hope, G., and Stradling, A. (2006). Evaluation of a MicrocelTM sparger in the RED Dog column flotation cells, Miner. Eng. 10: 748-757.

[24]. Brake, I., Eldridge, G., Luttrell, G., and Yoon, R.H. (1996). The design of industrial Microcel™ sparging systems. In: Proceedings of the International Symposium on Column Flotation. COLUMN 96, Montreal, Quebec, Canada. 13-24p.

[25]. Filippov, L.O., Joussemet, R., and Houot, R. (2000). Bubble Spargers in Column Flotation: Adaption to Precipitate, Miner. Eng. 13: 37-51.

[26]. Kracht, W., Gomez, O., and Finch, J.A. (2008). Controlling bubble size using a frit and sleeve sparger, Miner. Eng. 21: 660-663.

[27]. Somnuk, K., Soysuwan, N., and Prateepchaikul, G. (2019). Continuous process for biodiesel production from palm fatty acid distillate (PFAD) using helical static mixers as reactors, Renew. Energ. 131: 100-110.

[28]. Kohmuench, J.N., Mankosa, M.J., Wyslouzil, H., and Luttrell, G. H. (2009). Column and Non-Traditional Flotation, in: P.T. Deepak Malhotra, Recent Advances in Mineral Processing Plant Design. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc. (SME). 220-231p.

[29]. Lakshmanan, V.I., and Roy, R. (2015). The Need for Process Innovation. In: R. R. Vaikuntam Iyer Lakshmanan, Innovative Process Development in Metallurgical Industry: Concept to Commission. Mississauga, Springer, Canada, 6-65p.

[30]. Mesa, D. and Brito-Parada, P.R. (2019). Scale-up in froth flotation: A state-of-the-art review, Sep Sep. Purif. Technol. 210: 950-962.

مقایسه عملکرد استاتیک میکسرهای نوع هلیکال و الیپتیکال سلولهای فلوتاسیون ستونی مجتمع مس سونگون

بهزاد نعمتی اخگر[1*]، احمد فتح زاده[2]، بهنام گلی زاده[2] و سیما حاجیلو[3]

1- گروه مهندسی معدن، دانشکده فنی و مهندسی، دانشگاه ارومیه، ایران
2- شرکت ملی صنایع مس ایران، مجتمع مس سونگون ، ایران
3-شرکت فنی- مهندسی فرآور پیشگام توسعه گر

ارسال 2019/8/13، پذیرش 2019/10/2

* نویسنده مسئول مکاتبات: B.n.akhgar@urmia.ac.ir

چکیده:

مدار فلوتاسیون در مجتمع مس سونگون شامل دو سلول فلوتاسیون ستونی مجهز به سیستم اسپارجر ثابت در مرحله کلینر است. رسیدن به اهداف تعیین شده در مرحله فلوتاسیون با چالش های جدی نظیر انسداد سریع استاتیک میکسرها، مشکل جوشش و پدیده آروغ زدن و سریز پالپ به جریان کنسانتره و مشکلات نگهداری و کنترل رو به رو است. به منظور غلبه بر این مشکلات، تلاش شد با جایگزینی استاتیک میکسرهای قدیمی نوع الیپتیکال با نوع جدیدتر هلیکال در یکی از سلولهای ستونی بر این چالش‌ها فائق آمد. این تغییرات موجب عملکرد مناسب سلول‌های ستونی گردید در شرایطی که به دلیل عدم انسداد مشکل آروغ زدن از بین رفت، حباب‌های ریزتری تولید شد و مشکل جوشش و سریز حل شد. همچنین عمر استاتیک میکسرها از یک ماه در سلول‌های ستونی الیپتیکال به حدود هفت ماه در سلول‌های ستونی هلیکال افزایش پیدا کرد. علاوه بر کاهش 40% مصرف هوا و افزایش 20 درصدی درصد جامد محصول نهایی، با جایگزینی استاتیک میکسرهای نوع هلیکال عیار مس و مولیبدن در مرحله کلینر به‌ترتیب از 16/8% به 18/7% (افزایش 11 درصدی) و از 263 ppm به 511/1 ppm (افزایش 94 درصدی) افزایش خواهد یافت. بازیابی مس و مولیبدن نیز به‌ترتیب در حدود 1/8% و 0/2% افزایش خواهد یافت. در انتها، نتایج بدست آمده نشان داد که تاثیر گذاری تولید حباب‌های ریز بر روی بهبود عیار به میزان آبگریز بودن کانی وابسته است بطوری که مقدار افزایش عیار Mo بیشتر از Cu خواهد شد.

کلمات کلیدی: فلوتاسیون ستونی، سیستم اسپارجر، مجتمع مس سونگون، فلوتاسیون، آبگریزی.