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THE PROCESSING OF TUNGSTEN ORES. PROCESSES AVAILABLE — CHALLENGES — A CRITICAL REVIEW

Problems encountered during the processing of lean and finely disseminated tungsten ores by the gravity separation and flotation are discussed. The need to develop proper technologies for the recovery of fine particles in the range of 0-10 μm by any physical method and further improving of the existing processes for the 10-20 μm particles is described.

Introduction

As the world's supply of mineral raw materials diminishes, lower grade, finely-disseminated ores will have to be sought as new sources of metal and minerals. It need not be emphasized that in the years to come, advanced mining and size-reduction techniques will be needed to deal with the problem of finding ways to reduce unnecessary fines. To meet the increasing energy, environmental and economic constraints of present-day society, the need for continued, ever-expanding research in fine particles characterisation and processing will grow.

The problem of processing fine particles poses an immense challenge today to researchers both in mining and mineral processing areas. With the increasing demand for minerals and continiously diminishing grades of ores, it is necessary to mine and process a larger tonnage of ores. Consequently, ever-increasing tonnages of fines are also being produced.

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Ideally, one would like fines to be produced only for the purpose of liberating valuables from gangue minerals. However, large amounts of fines are generated at the mine site itself. Advances in mining techniques that would reduce the production of fines, is one area which needs to be explored. Also, the occurrence of valuable minerals in a finely-disseminated form necessitiates fine grinding for liberation and subsequent physical separation. To avoid unwanted fines, grinding and classification circuits have to be made more efficient. This is another area where improvements could help to reduce the problem of fines. Most importantly, the processing of fine particles requires extensive research. Because of the losses of mineral and metal values in the fine size range, considerable interest is growing in developing new processes and in improving old processes for the recovery of fine particles. One of the most widely-used mineral processing techniques is froth flotation.

Due to the extremely complicated physico-chemico-mechanical conditions existing in the flotation process, the problems associated with the presence of fine particle are most pronounced in flotation processing.

Challenge: The efficiency of the flotation process is much less for particles in the range of 0 to 10 microns. The same holds true for gravity separation technology as well. The challenge posed to research scientists is to develop a proper technology for the recovery of fine particles in the range of 0 to 10 microns by any physical methods of separation. The recovery of particles in the range of 10 to 20 microns is also to be improved further by existing processes.

Processes and their limitations

Reasearch and development projects must be timely and economically exploitable.

For the concentration of tungsten ores, the available processes and their limitations are as follows:

Table 1

Sl. No.	Process	Size applicable
I.	OLD TECHNOLOGY	
	a) Conventional Processes	
	1. Jigs	upto 10 mesh
	2. Tables	20 to 200 mesh
	3. HMS	5" to 10 mesh

cont. Table 1.

Sl. No.	Process	Size applicable
	4. Spirals	20 to 200 mesh
	5. Flotation	35 to 400 mesh
	b) Pneumatic Concentration	
	1. Jigs	upto 10 mesh
	2. Tables	28 to 200 mesh
	3. HMS	10 to 65 mesh
	4. Sluices	10 to 100 mesh
II.	NEW TECHNOLOGY	
	a) New Processes	
	1. Bartles Mozley Concentrator	100 to 5 microns
	2. Pre Concentration and Sorting	10 mm to 20 mm
	3. HMS	upto 1/4"
	4. DWP	2" to 65 mesh
	5. Heavy Madia Cyclones	upto 40 mesh
	6. Triflo Separator	upto 40 mesh
	7. Jigs	20 mesh
	8. IHC-Jigs	to still fner sizes
	9. Sluices	upto sand sizes
	10. Moving Belt Separator	Fine material 35 mesh to 100 mesh
	11. Rotating Cone Concentrator	20 to 200 mesh
	12. Denver Buckman Tilting Concentrator	upto 20 microns
	13. Rocking Shaking Vanner	Minus 20 mesh
	14. Bartles Cross Belt Concentrator	5 to 150 microns
	15. Reichert Cones	100 to 30 microns
	16. Duplex Concentrator	upto 100 microns
	17. Yuba Richards Mineral Jig	1/2 to 200 mesh
	18. Flotation	upto 20 microns
	19. Shear Flocculation	40 to 1 micron
	20. Rotating Tube	..
	21. Nelson Separator	..
	22. Centrifugal Jig	..
	23. American Balanced Jig	..

In mineral processing, most of the losses of minerals and metal values are in the fine size ranges, and considerable work has been done in recovering these values by modifying earlier process models.

cont. Table 1.

Sl. No.	P r o c e s s	Size applicable
	b) Advanced Technology for specific cases ; Modified versions of earlier models	
	1. Jigs	
	2. Tables	
	3. Spirals	
	4. Pre Concentration Technology	
	5. HMS	
	6. Flotation Reagents	

Problems in Processing

Mineral processing technology has to change to keep up with the demand for cheaper processing methods, contend with environmental constraints and reduce energy requirements in order to treat the lower and poor-graded disseminated ore types economically.

With the increasing demand for minerals and the continuously diminishing grade of ores, mining larger tonnages has become a necessity which in turn increases the production of fines and slimes. As much as 1/3rd of Florida phosphate, roughly 1/5th of world's tungsten and 1/2 of Bolivian tin are lost in slimes due to a lack of suitable separation technology. Diminishing raw material resources have necessitated the recovery of mineral values from finely-disseminated ores. Thus research in fine particle processing methods is urgently needed.

Considerable interest is being shown in the development of a suitable process technology for the recovery of values in the fine size ranges. The most pressing problem of the mineral processing industry these days is the recovery of valuable minerals from slimes. The difficulty is due to small mass, low momentum, colloidal coating, hetroaggregation, high surface area, increased surface energy and also increased pulp viscosity.

Ore grades have dropped. Energy costs have risen. Metal prices have fallen, and the treatment of lower ore grades means a higher tonnage must be treated for the same metal recovery. Energy costs are becoming a greater percentage of overall costs. Lov metal prices demand cheaper milling processes.

The major problems in processing are;

1) Tungsten ores are the disseminated type and need fine grinding for complete liberation.
2) Since tungsten mineral are fragile, slime production is greater in comminution.
3) In Gravity Separation Concentration, the other associated heavy minerals (garnet, topaz, iron-oxides and sulphides, etc.) join tungsten minerals and thus dilute the concentrate.
4) The presence of calcite is a problem in scheelite flotation.
5) When the tungsten minerals are scheelite and wolframite, concentration is a problem as different methods are required for these two minerals.
6) Recovery of the fine and slime tungsten is problematic.
7) An effective scheme for the flotation of wolframite is yet to be established.
8) In the cases of disseminated ores, the recoveries are far from satisfactory.
9) The removal of garnet and tourmaline from wolframite is not fully successful.
10) Recoveries of wolframite values in the size ranges of 0 to 20 microns are poor both by gravity and flotation methods.
11) Changes in processing practices and the introduction of new and better equipment have been rather slow.

Major problem areas in flotation & gravity separation

The processing of fine-grained ores frequently results in the production of ultra-fine particles, which respond poorly to conventional physical separation techniques. These ultrafine particles, commonly called slimes, are often rejected from circuits fllowing comminution. They represent major losses of available minerals that are mined but not recovered during primary processing.

(A) Flotation

Wolframite flotation is most broadly and throughly studied in China, which is the world's largest producer of tungsten. Wolframite is characterized by its tendency to form fines and slimes. In wolframite flotation, three types of flow-sheets and reagent systems can be used. For simple ore, flotation in weakly basic or neutral pulp with oleic acid, toluol arsonic acid or benzol ethylene phosphonic acid is applied. These acids are sometimes combined. For more complex ores, bulk concentrate flotation is used. Collective concentrate is separated in a recleaner section into a sulphide product and a tungsten containing product. Wolframite final flotation proceeds in neutral or weakly alkaline pulp. Complex and hard - to - treat ores are floated in strongly acidic pulp in the presence of fluosilicates after sulphide flotation. A combination of arsonic and sulpho succinamic acid, phosphonic acid are used as collectors. In this way, a concentrate containing 17-18% WO_3 is obtained from ore feed having 0.59% WO_3, with a recovery of about 75%. Another collector system uses 8 hydroxyquinoline which forms chelates with iron and manganese in the wolframite lattice, with neutral oil at pH 8.5. A concentrate containing 15.7% WO_3 is obtained from ore feed containing 0.57% WO_3, with a recovery of 94%.

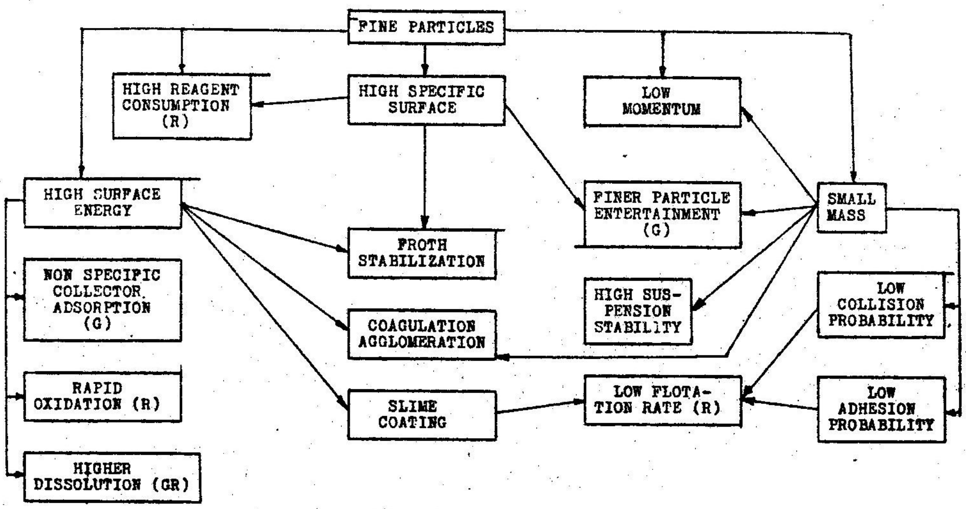
The third method is based on roughing with oleic acid. The rougher concentrate is upgraded by reverese flotation of the gangue minerals using amine as a collector. A concentrate containing 74.3% WO_3 is obtained from a feed with 0.46% WO_3, with a recovery of 61.6% in the concentrate and 18.4% in middlings. The difficulties encountered in wolframite flotation are eliminated in the roughing section by splitting the feed into several branches.

It is a well-known fact that the efficiency of flotation diminishes with a decrease in particle size. The reasons are numerous complex. As particles gets smaller as a result of increasingly fine grinding, the surface properties of the individual minerals tend to lose their crystallographic individuality because the outer layers become amorphorous. Under these conditions, partial coverage of the particles by collectors that are not too highly specific towards given ions can easily occur both in the case of valuable minerals and gangue. The flotation of all the mineral species present thus occurs indiscriminately. Furthermore, the very fine particles tend to adhere to the coarse grains as a results of mechanisms similar to those involved in flocculation, again in an unselective manner.

The figure on the next page gives a schematic presentation of the relationship between the physical and chemical properties of fine particles and thier behavior in flotation.

The major constraints in flotation are:

1) The efficiency of flotation is very poor for particles below 10 microns. There is no evidence of equitable size below which particles become unflotable.
2) Slimes float very slowly. The rate of flotation decreases with the particle size from 10 microns downwards.



Physical & chemical properties of fine particles & their behavior in flotation

A schematic diagram showing the relationship between the physical and chemical properties of fine particles and their behavior in flotation. (G) and (R) refer to whether the phenomena affects grade and/or recovery. The arrows indicate the various factors contributing to a particular phenomena observed in flotation of particles. (After D.W. Fuerstenau, Fine Particle Flotation, in.: Fine Particles Processing, Proc. Inter. Symp., Las Vegas, 1980, v. 1, 669-705).

3) Investigations into the reasons for the slow flotation of fines have had limited success. The attachment of particles to the bubbles appears to be a major contributing factor.
4) The unsuccessful flotation of fine particles can be chiefly attributed to the lower rate of collision with the bubbles and low particle momentum, limiting the chances of adhesion.
5) The selectivity of the attachment of desired particles with the bubbles is very poor, thus resulting in poor grades of concentrates. Slime coatings also contribute in the noneffective flotation of fines. The successful methods of flotation of slimes use neutral oils and also flocculation of fines before flotation.
6) A suitable environment for the flotation of particles of, say, 10 to 200 microns is not necessarily suitable for fine particles.

(B) Gravity separation

Gravity concentration techniques are capable of beneficiation a number of ores and minerals in a wide size range. Lately much attention has been foccussed on processing in fine size ranges (for example 85%

cassiterite in the world is produced by gravity methods, as this is one of the most difficult minerals to float). As a result, the Bartles Mozley Tables, Cross Belt Separators and Reichert Cones have been developed and successfully employed in the industry.

Mineral values carried in slimes

The most pressing current problem of the mineral industry is the difficulty of recovering valuable minerals from slimes. The main causes are small mass, low momentum, colloidal coating, hetroaggregation, high surface area, increased surface energy and also increased pulp viscosity. After a lapse of about 50 years, caused by the tremendous success of flotation, there has recently been a renewed interest in gravity concentration. The reasons are increasing reagent costs, environmental pollution and the limited success that flotation has had with oxide minerals. The slime gravity equipment considered includes the Bartles Mozley Separator (or Mozley's frame), the Bartles Cross Belt Concentrator and the latest unit Duplex Concentrator. Slime gravity circuits are at present found in many plants treating Sn and W. Other areas where such circuits can be potentially utilized are Ta, Cr, Pt, Pb and beach sands of fine sizes. Modern units of such circuits are capable of recovering heavy particles as fine as 5 microns. Two plants with slime gravity circuits are Geevor Tin Mines Ltd. and Berni Lake Tantalum Mining Co. Slime recovery by gravity methods, with or without other methods such as high intensity magnetic separation, flotation, etc., is a promising route allowing flexible circuits and economical treatment of very low-grade feeds. It is worth probing all the possibilities of successfully employing such a circuit, wherever possible.

The degree of efficiency of separation for material which is close to ±0.1% of separation is presented in the following table:

Table 2.

The efficiency of gravity techniques

Degree of difficulty of separation; for the wt% of material with ± 0.1% of separation

Wt% within ±0.1% Gravity of Separation	Degree of difficulty expected	Gravity process recommended	Type
1	2	3	4
0-7	simple	almost any process - High tonnage	SLUICES JIGS
7-10	moderately difficult	efficient process - high tonnage	TABLES

cont. Table 2.

1	2	3	4
10-15	difficult	efficient process - medium tonnage - good operation	DWS CONES SPIRALS
15-20	Very difficult	Very efficient Process - low Tonnage - Expert operation	DWS
20-25	exceedingly difficult	Very efficient Process - low Tonnage - Expert operation	DWS
Above 25	Formidable	Limited to a few exceptionally efficient processes Tonnage - Expert operation	DWS close control

Conclusion

Most people in the mining industry are optimists - they have to be. The mining engineer is always thinking that he can find a way of coping with bad ground; the mineral processor is sure he can improve concentrate grades and recoveries; the metallurgist is always looking for higher process yields and better thermal efficiency. In times of low prices, everyone seeks to outwit the martet, cut their costs and keep going.

For the most part, rich ores are being exhausted, and the ores now being mined are all disseminated and require fine grinding to liberate the mineral values. While attempting the liberation of mineral values, a lot of fines and slimes are inevitably produced. In mineral processing, every process has a size limit up to which the process works efficiently. Today, the processes available to satisfactorily recover mineral values in the range of 0 to 20 microns are limited. Research scientists are eager to develop both flotation and gravity processes to recover fine values otherwise lost in slimes.

Recognition of the need to develop gravity separation equipment for the recovery of fine materials led to the development of Frue Vanner, the buddle, the cornish round frame and the strake before the turn of the century. Later on, the wet shaking table, the Denver Buckman tilting frame, the Burch Shaken Helicoid and, more recently, the Bartles Mozley Concentrator, Bartles Cross Belt Separator and Reichert Cones were developed.

The grade of ore mined and processed will depend upon a number of factors, where lower grades are treated in larger tonnages and rich grades are treated in lower tonnages. The mill feed grade at which a mine can work profitably depends upon economies and investment policies. Factors which are vital to the selection of ore grade include the characteristics, size and location of the deposit; financial aspects such as investment requirements, available capital and the costs of borrowed capital; the mine costs depend upon the type of mining; the development costs of all auxilliary services, like power supply, water, and waste disposal; the amenability of ore treatment, process flowsheet, operating costs, concentrate grade and recoveries, by-product recoveries, taxes, royalty payments, metal prices and concentrate value at mine site.

Challenge;

Although the Mozley, Cross Belt Separator and Reichert Cone can recover particles in the range of 10 to 100 microns, the efficiency of these separators is limited in the range of 10 to 20 microns and very poor for particles in the range of 0 to 10 microns. The efficiency of flotation is also poor in this range. Research and development projects need to place great emphasis on the development of a new technology or the modification of existing ones to tackle the problem of losses in the slimes, i.e., the 0 to 20 micron size range. This problem exists in the processing of all ores and minerals, not only tungsten ores, and poses a challenge to every research scientist.

STRESZCZENIE

Rao G.M., Satyanarayana K., 1987. Krytyczny przegląd metod przeróbki rud wolframowych. Fizykochemiczne Problemy Mineralurgii 19; 183-193.

W pracy przedyskutowano problemy występujące podczas wzbogacania ubogich drobno rozproszonych rud wolframowych metodami wzbogacania grawitacyjnego i flotacji. Wskazano na potrzebę rozwoju odpowiednich technologii dla odzysku ziarn rudnych (w zakresie 0-10 μm) metodami fizycznymi i dalsze ulepszanie istniejących procesów dla ziarn w zakresie 10-20 μm.

СОДЕРЖАНИЕ

Г.М.Рао, К.Сатьянараяна, 1987. Критический проссмотр методов обогащения вольфрамовых руд. Физикохимические вопросы обогащения, 19; 183-193.

В работе обсуждены проблемы, выступающие во время обогащения бедных и мелко рассеянных вольфрамовых руд методами гравитационного обогащения и флотации. Указана необходимость развития соответственных технологий для обогащения мелких рудных зерен /в пределе 0-10 мк/ физическими методами и дальнейшее улучшение существующих процессов для зерен в пределе 10-20 мк.