Classifying best access points for return of external flows into flowsheets

Pejman Oghazi ¹, Bertil Pålsson ¹, Kent Tano ²

Luleå University of Technology; SE-971 87 Luleå, Sweden ¹,

LKAB, SE-983 32 Malmberget, Sweden ²

Contact Author:

Full name: Pejman Oghazi

Position title: PhD student

Organisation Name: Luleå University of Technology

Address: Luleå University of Technology, 971 87 Luleå, Sweden

Phone: +46-920-491692

Fax: +46-920-97364

Mobile: +46-736878623

Email: Pejman.Oghazi@ltu.se

ABSTRACT

External flows are process streams that come from auxiliary processes or events. They are re-routed into the ordinary flowsheet, since they are thought to be too valuable to be sent to any tailings pond. External flows come from multiple sources, e.g., drainage sumps, spillage thickeners, depleted products etc. Therefore, external flows may fit or not fit into an existing flowsheet depending on several factors like, flow rate frequency, dilution ratio variation, chemical and mineralogical composition, particle size or particle morphology.

By using Particle Texture Analysis (PTA) to investigate external flows and compare them with existing ordinary flows, it is possible to pin-point from a process mineralogy point of view to what extent the external flow in question fits into the ordinary processing flowsheet. Results from this category of information helps to reach a higher quality of process knowledge and control for every step in the concentrator.

Result from analyses show that some re-routed flows that are reconnected to the main flow are not connected to the best point. A side effect of the analysis is that it indicates that some flows may be sent to later grinding stages. Thus, decreasing the load on the primary mill, and increasing its retention time.

Keywords: Process optimisation, mineral processing, particle morphology

INTRODUCTION

To select the best process for a plant is a vital task for a process engineer. In doing so it is important to have full knowledge of the variables that will affect the decision such as mineralogical and process data or simply to know what sort of material that flows into the plant.

In a process industry there are numerous processes and flows that are connected to each other, so that a minimum of the raw material that is used in the process goes to waste. What is often the case in a mineral processing is that flows are lumped together and it is important to check when this is the best solution for the process. In this context, external flows are the flows that come from auxiliary processes and re-routed into the ordinary flowsheet. A detailed knowledge of these flows that moves around in the flowsheet is often missing.

The purpose of this study is to try to understand the difference between the external flows that are connected back to the ordinary flow. By formulating the topics in different research questions, they would be:

- What are the specific characteristic methods that can be used to classify different flows?
- Is it possible to pin-point any decisive mineralogical factor for rerouted flows that are to be reconnected to the main process flow?

THEORETICAL FRAMEWORK

Process mineralogy

Firstly it is imperative to explain the mineralogy of the material that is coming into concentrator. The iron ore minerals are both magnetite and hematite but the magnetite is more common of the two. The important gangue minerals of the ores are: apatite and feldspar (microcline), since they are quality issue for the produced iron ore pellets. Furthermore, the final circuit concentrate should have a total gangue content < 1.5%. In the concentrator, ball mill grinding is used in three following steps and with wet low intensity magnetic separators in between, for more details of the process cf. Kvarnström et al. (2008).

Secondly, to understand the fundamentals of the mineral processing it is important to understand and link every single stage in the process chain. It is the mineralogy and the properties of an ore that determines the conditions for the further processing. To meet these challenges an efficient process can be designed and the mineral treatment may be optimized. (Sutherland, Gottlieb et al. 2000).

Process mineralogy is a useful tool for flowsheet development and selection of the optimal process for the specific plant. Process mineralogy explains the characterization of minerals according to how they behave during specific treatment, and gives us useful information such as grain size, mineral association, liberation and also trace element content that affect the process (Zhou et al. 2008).

All mineral companies struggle to have as high recovery as possible and to do so information that characterises the minerals is vital. In the present case, Particle Texture Analysis (PTA) is used for getting information on the process mineralogy.

Particle texture analysis

The Particle Texture Analysis (PTA) system is developed at the Norwegian University of Science and Technology (NTNU) (Moen, 2006). The scanning electron microscopy produces Back Scatter Electron (BSE) images that can be analysed based on grey levels and every grain of interest is also analysed by X-rays. All analysed particle size fractions were imported to the PTA software; where images analyses are done offline to process and evaluate if grains occur as liberated or in composite particles.

Standard queries can be done on the output results in a new database that contains information on the mineral liberation of any mineral, mineral association of any mineral and miniature images of particles of a certain texture category. PTA gives also useful information of modal mineralogy, which shows how many percentages of minerals, is found in the analysed samples. This information is vital for knowing what kind of material is moving in the external flows.

EXPERIMENTAL

It is important to realise that the raw material comes from several ore bodies that are mixed in the process and this means there will be ores having different Fe-content and levels of contaminants (Martinsson and Wanhainen, 2000).

Samples from nine different points in the concentrator were taken. Most samples are from flows that are to be re-routed into the main process flow mainly from thickeners and magnetic separators. In Table 1 are all the sample points presented. Samples point 1-8 are chosen to cover all the recycled material that is going back to the main stream, sample point 9 is a reference sample from the final magnetic separator that gives information on the material that leaves the concentrator.

Figure 1. Scheme over sample points in the section for pre-concentration and dewatering of external flows.

Table 1. Sample points with explanation and information.

Samples point	Sample explanation	d_{80} (μm)	%<45 μm
1	Underflow thickener # 2 Sample contains a mix from section 1-3, mostly hematite with a large variation.	120 μm	22 %
2	Underflow thickener # 4 Contains waste from wet cobbing plant section 4-5, also tails from magnetic separators section 3 and section 6.	210 μm	18 %
3	Underflow thickener # 5 Thickener #5 parallel to #4	210 μm	22 %
4	Concentrate from magnetic separator. Feed is spillage from secondary mill section 1.	110 μm	11 %
5	Concentrate from magnetic separator. Coarse particles from classifier.	380 μm	14 %
6	Concentrate from magnetic separator. Fine particles from classifier.	111 μm	32 %
7	Concentrate from magnetic separator. Fine particles from classifier.	105 μm	37 %
8	Concentrate from magnetic separator, feed is combined flows material collected from the re-routed flows.	211 μm	22 %
9	Concentrate from magnetic separator, from tertiary mill in grinding section 6. Used as reference.	75 μm	23 %
Feed Mill #1 section 5	Primary mill feed. Used as reference.	4780 μm	3 %

All the samples were dried and cut by a Jones splitter into suitable proportions in the laboratory at Luleå University of Technology (LTU). The dry material was sieved with a Ro-Tap shaker down to 75 μm and wet sieved further to 38 μm . Samples 53-38 μm were sent to NTNU, Norway for particle texture analysis.

RESULT AND DISCUSSION

Modal mineralogy is a convenient way to understand the content of different flows. This type of analysis can be used to:

- Identify what sort of material is pumped to the grinding section
- Optimise the process
- Reduce any overloading in any process-step
- Improve the final product

The modal mineralogy from Figure 2 shows that in thickener number two (sample #1) there is mostly magnetite while in thickeners four and five (sample #2 and #3) there is around 25-30% magnetite and the rest is gangue minerals. The material that is sent to the thickeners four and five is the tailings from the wet cobbing separators and that contains mostly gangue minerals. The modal mineralogy for samples #2 and #3 looks almost similar to each other, the reason is that feed material for both thickeners is the same and is distributed between the thickeners. The d_{80} is also approx. the same for both thickeners. Sample #4 in Figure 3 shows the same result (high magnetite content) as sample #1. Therefore, these streams would be better sent to the tertiary mill in the main grinding section. It is unnecessary to grind them much because of high content of the magnetite, and they are also much more finer compares to samples # 3 and 4.

Figure 2: Modal mineralogy from samples 1-3, taken from thickener underflows.

Figures 3 and 4 shows the modal mineralogy from the concentrates of magnetic separators that are used the recirculation circuit, except for sample number 9 which is taken from the final magnetic separator after the grinding stage. Sample #9 is here the reference, representing the desired product that all other samples are compared with. The concentrate from the concentrator (in this case sample 9) goes to next process step, which is the pelletising plant. As seen in figure 3, the gangue content in sample 5 is almost the double compared to sample #6 or #7, while the last mention samples are almost identical. Materials in sample #5 are the coarse discharge from two spiral classifiers. The overflow from the same spiral classifiers that contains fine particles and enters the magnetic separators represented by samples #6 and #7. In Table 1 can be read that the d_{80} for sample #5 is much coarser compared to sample #6 and #7, and should so be. From figures 3 and 4 is shown that there is more gangue minerals in the discharge of the classifiers, which is logical.

Figur 3. Modal mineralogy from samples 4-6, taken from magnetic separators.

All re-routed flows go through a magnetic separator (sample #8), and from this the material is pumped to the primary mill in section 5. By comparing the existing feed entering the primary mill with the material in sample #8 that is sent to the primary mill, it shows that sample #8 contains over 96% magnetite and a particle size distribution with a d_{80} around 200 μm . But, the feed to the primary mill has 86% magnetite and a d_{80} is around 4800 μm . Therefore, sample #8 does not match with the feed to the primary mill. To obtain a better process the concentrate (sample #8) should bypass the primary mill, and preferably be sent to the secondary mill since the material properties are similar. The reason for not sending it to the tertiary mill is that there is one coarse intermittent flow entering before sample point #8. Could this coarse flow be treated separately, sample #8 might be sent directly to the tertiary mill.

Today this material is sent to the primary mill, but it is too fine for the primary mill. It will only create an unnecessary volumetric load and reduce the retention time in the primary mill.

Figure 4. Modal mineralogy from samples 7-9, taken from magnetic separators.

The modal mineralogy in Figure 4 shows that there is mostly magnetite in sample #9 (final concentrate); however, it also contains few particles of gangue minerals. One of the advantages with modal mineralogy is the possibility to exactly know how much of a certain mineral that exists in the sample. Counting the particles in the final concentrate, gives that of totally 4513 particles there were 31 gangue mineral particles and the rest of it was magnetite. Thus, the material that leaves the concentrator contains 99 percent magnetite, Nevertheless, it is interesting to look into what kind of minerals that are following with the magnetite leaving the concentrator.

Figure 5 shows the mineral associations to quartz and feldspar in the thickener underflows. Most of the quartz and the feldspar are liberated. However, around 10 percent of them are associated to magnetite. This means that these mixed particles need some regrinding, otherwise they will increase the SiO₂ content of the final pellets.

Figure 5. Mineral association to Quartz and Feldspar in thickeners.

Figure 5 and 6 shows the association of minerals to quartz/feldspar and apatite. Sample #1 was shown earlier (Figure 1) to contain mostly magnetite but there were small portions of other minerals as well. Figure 6 demonstrate that none of the magnetite in sample #1 is associated to apatite. The similarities between sample #1 and sample #4 are shown once again in in Figures 6 and 7. This result further substantiates the recommendation to by-pass to send these streams to the secondary or tertiary mill in the grinding section. For samples 4-9 there were not much of quarts and feldspar associations in the samples, therefore these analysis is not presented in this paper. However, there were some (4%) in sample #8, but that most likely comes from samples #2 #3.

Figure 6. Mineral association to Apatite in thickeners.

Figure 7. Mineral association to Apatite in concentrate from magnetic separators.

Analysis from samples #5-8 shows that there are some apatite mainly associated to magnetite, sample #8 shows clearly that over 25% of the apatite is associated to magnetite. On other hand in

Figure 4, the modal mineralogy for sample #8 shows that the sample contains mostly magnetite so it is expected that any association should be with magnetite. There were few apatite grains in sample #9, which is the final concentrate. Figure 8 shows that these are not associated to magnetite or any other minerals.

Figure 8. Mineral association to Apatite in concentrate from magnetic separators.

CONCLUSIONS

The modal mineralogy and mineral associations is one way for collecting total information on how each unit is operating and what sort of material that is recycled to the main flowsheet. The ideal case is when complete information from each external flow that is added to the main streams is analysed and then joined to an optimal position in the main flowsheet. Some of these circulating flows are today not returned to the best process point and it puts an unnecessary load on some units.

The result from modal mineralogy shows that there were some gangue minerals in the streams from the thickeners, and also some in intermediate streams. Most of them are gone after the re-treatment section. Based on gangue content and particle size this combined flow should by-pass the primary mill.

Minerals association analysis on these samples is a more informative and important way to pinpoint how mixed gangue minerals occur in these streams. If the gangue minerals are locked with magnetite they will ultimately end up in the final concentrate, since current low-intensity magnetic separators pick any particles with small magnetic volumes. Therefore, mineral association analysis is the most important tool in deciding where to send re-routed flows.

FUTURE WORK

Next step will be to use the data from the PTA and investigate it with Multivariate Data Analysis to see in detail to what degree the particle morphology is affecting the process. Even here, a comparison of main stream flows with recycling flows to check for relationships is done, but with the added benefit of an un-biased analysis.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support by LKAB. They are also grateful for the assistance during sampling at LKAB, Malmberget. We would also like to thank Prof. Terje Malvik and Dr. Kari Moen, NTNU, Norway for supervising and helping with the process mineralogy analyses.

REFERENCES

- Kvarnström, B. and Oghazi, P. (2008). "Methods for traceability in continuous processes- Experience from an iron ore refinement process", *Minerals Engineering* 21(10) pp. 720-730.
- Martinsson, O. and Wanhainen, C., 2000, "Excursion Guide, GEODE work shop" Retrieved 1 October, 2007, from <http://www.gl.rhbnc.ac.uk/geode/KirunaGuide.pdf>.
- Moen, K. (2006). "Quantitative measurements of mineral microstructure", Department of Geology and Mineral Resources Engineering. Trondheim, Norwegian University of Science and Technology. Doctoral thesis, ISBN 82-471-8163-0, ISSN 1503-8181 pp. 1-120.
- Sutherland, D. N. and Gottlieb, P. (1991). "Application of automated quantitative mineralogy in mineral processing", *Minerals Engineering* 4 pp. 753-762.
- Tano, K., Pålsson, B., and Alatalo, J. (2006) "Validation of a computer simulated circuit design at the LKAB Malmberget concentrator", 11th European Symposium on Comminution, Budapest, Hungary.
- Zhou, J. Gu, Y. and Zhou, H. Y. (2008). "Process mineralogy and applications in mineral processing", Proceeding of XXIV International mineral processing congress, Beijing China, Volume 1 pp. 107-117.