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SMART ORE TRACKING SYSTEM
USING SOFT SENSOR TECHNOLOGY**

1. Introduction

Traditionally, a mining operation has been perceived as two distinct stages: (1) mining and (2) mineral processing. The mining stage involves extraction of valuable minerals from the ground, and the processing stage includes the conversion of the minerals into a marketable end-product. However, mining and processing are intimately linked, particularly in terms of comminution, when reducing particle size of ore. The relationship between ore mineralogy and downstream processing is well known in the mining industry. In fact, the very definition of a mineral deposit as an ore body depends on its susceptibility to processing in an economical manner. With the advanced capabilities of state-of-the-art mine control systems, it is possible to combine the knowledge of the mineralogy of different ore types and other characteristics, to achieve an improved level of control in mineral processing and to allow optimization of the mine processes on a real-time basis [1].

This concept was described by Robertson and Sehic as early as, and is often discussed by mine and mill operators 1993 [2]. Unfortunately, it is difficult to accomplish simply for two reasons: (1) mining processes, including drilling, blasting, loading, and transporting, may allow for segregation of mined ore by composition, mineralogy, or other characteristics important in subsequent processing, (2) processing facilities may not allow segregated storage of ore, at least not to the extent that might be used in an optimized operation. Both these limitations could be overcome to some extent by a method of tracking the ore types in terms of individual blocks and volumes of ore. If the ore type can be tracked, the information of

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each ore type such as hardness, grade and density, gained during exploration and mining operation, could be used as input data to the mine control system. This would allow the real-time optimization of ore processing. A typical mineral processing is shown in Figure 1, which generally consists of various process units including primary crushers, secondary crushers, tertiary crushers, separators, scrubbers, screens, feeders, belt conveyers, stockpiles, storage bins, etc.

Ore mined from different ore bodies has different characteristics, including ore grade, ore hardness, ore density, etc. Different operational strategies are required to control a mine production when different types of ore are mined and treated. When the ore varies in hardness, for instance, different ways of operation should be applied to mining and processing, namely, deferent drilling and blasting in mining and deferent control requirements for various crushers, screens and separations. Without appropriate control, a crusher may then be either underutilized or over utilized. An underutilized crusher results in reduced production, and an over utilized crusher is running with many trips caused by high current, which stops the crusher and results in production losses. The throughput of a crusher may slow down tremendously when treating the ore with high clay content, which makes the ore sticky or slippery and consequently have a lower feed rate. If an ore with higher density is treated, a higher yield of dense media separation will be encountered, particularly when the ore has large amount of heavier inclusions, which may increase the production load on the downstream recovery units and to such extent the increased feed may excess the production capacity designed for the recovery units.
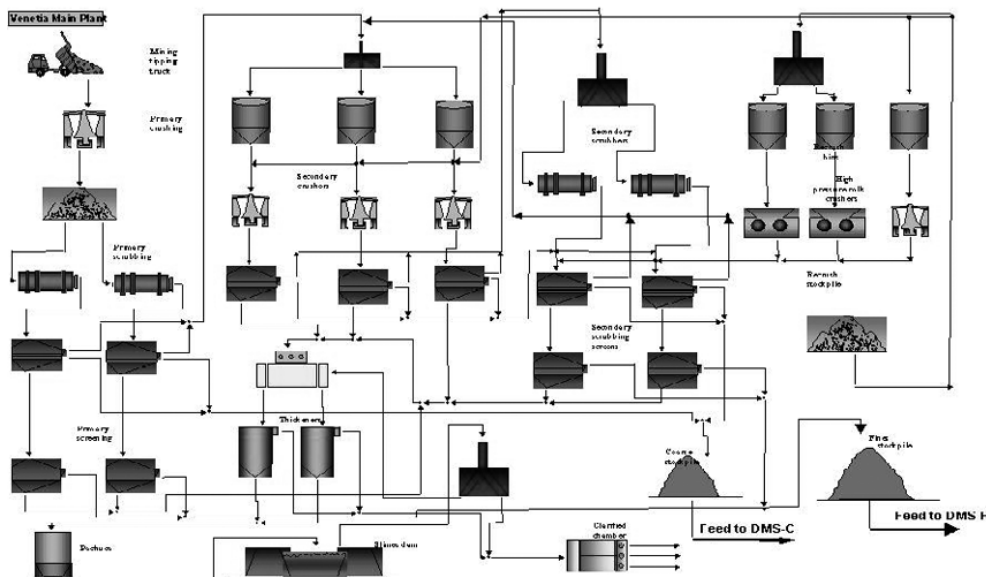

Fig. 1. Flowsheet of a mineral processing plant, including crushing, screening, scrubbing, dense media separation and stockpiles

Because of its importance to have ore types monitored in a mine, various work has been done to develop an ore tracking system based on the usage of tracers, including odd meter [3], and mobile computer with smart cards [5].

Due to the difficulty to deal with ore blending, all above mentioned applications of ore tracking are limited in tracking the movement of trucks used to transport ore at a mine. No industrial application has been reported to track ore continuously through the entire down stream processes, such as crushing, screening, dense media separation, stockpiles, etc.

2. Development of ore tracking system

A smart ore tracking system was developed using soft sensor technology [4]. CSense software (CSense Systems, part of General Electric Company) was used to develop the ore tracking system. After tested, the ore tracking system was deployed at a diamond mine in 2006.
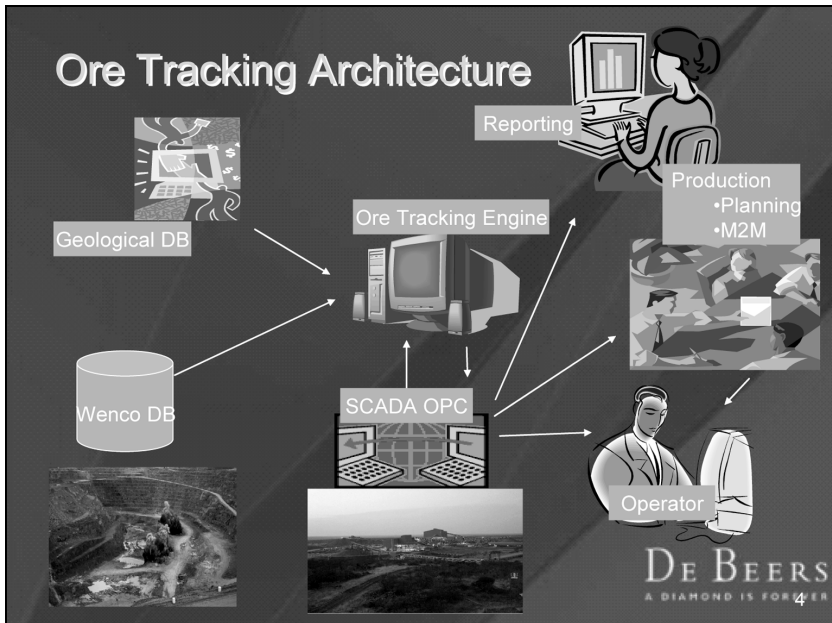
Fig. 2. Architecture of smart ore tracking system with mine database, geological database, ore tracking engine, OPC connectivity, GUI, email dispatch and reporting systems

The architecture of the ore tracking system, see Figure 2, consists of the following components:

— Mine real time database (Wenco database);
— Geological database;

— Ore tracking engine (CSense);
— OPC connectivity;
— SCADA graphic user interface (GUI);
— Email alert function;
— Reporting System.

Wenco database, a real-time, truck dispatch system, is used to provide real time mining information, including truck loading position (via truck's GPS), ore tonnage loaded and the time when the ore is dumped in a primary crusher.

Geological database is used to provide the information of ore that is dumped at the primary crusher, such as ore type, ore grade, ore hardness and density, etc.
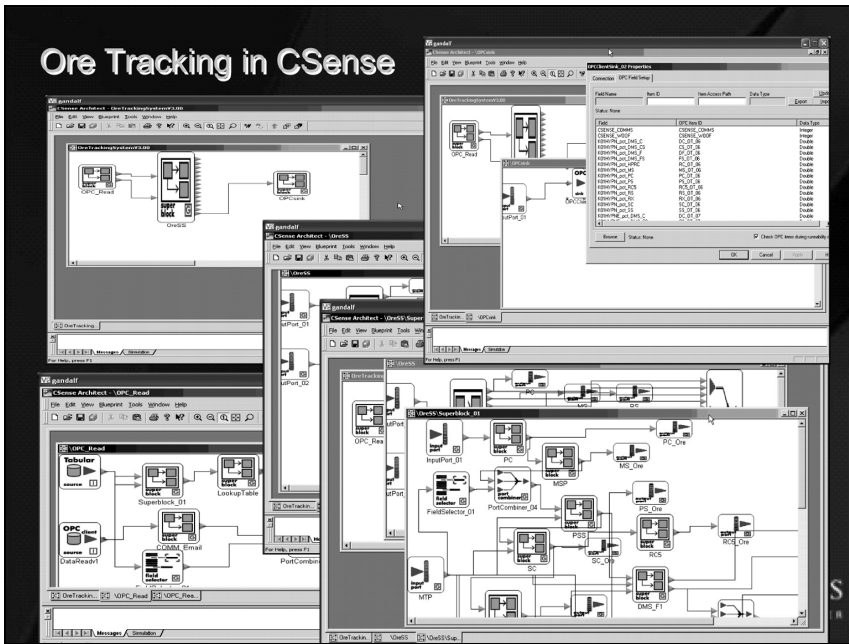

Fig. 3. Smart ore tracking engine developed using CSense software

Ore tracking engine is developed using CSense software, see Figure 3. It includes the following functions:

— ODBC connection to Wenco real time database (read only);
— OPC communication with real time SACAD (both read and write);
— CSense heart beat to monitor the communication between CSense and SCADA;
— Email function to send alert messages.

The ore tracking engine is used to do various calculations, such as the time delay factors, percentage of mixed ores, the grade and density of blended ores at each process units where they are treated.

3. Function and requirement of smart ore tracking system

3.1. Communication System

Data is required from the mining Wenco database by the ore tracking engine using the ODBC protocol. The ore tracking enguine also reads data from the SCADA systems using the OPC protocol, namely the bin and stockpile levels as well as feed rates in the plant. Using its internal models, it then calculates the rate at which the ore moves through the plant, and the percentage of each ore type that is currently passing through each process units, if the ore is mixed.

The ore type information is written to and presented by the SCADA system using the OPC protocol. Operational staff can view the ore type information using the SCADA mimics. The ore type information can also be used by reporting systems, such as Ampla and Crystal reports for inclusion into the analysis of plant operational efficiencies [5–8].

3.2. SCADA Requirement

The ore type information being provided at the various process stages can be displayed on a SCADA system in two ways:

1) An instantaneous view — by colour coded pie charts. One pie chart for each process;
2) A historical view — a trend chart that shows the percentage of each ore type over time, for a particular process unit.

The instantaneous view consists of a single SCADA mimic page, accessible from the standard menu. Historical trends can be accessed by clicking on the pie chart of the respective process area — i.e. as a drill-down.

Each ore type is given a unique colour, where the "problem" ores should be in shades of red for easy visual identification. About 500 tags in total are required in the SCADA system.

4. Implementation of smart ore tracking system

The smart ore tracking system in a SCADA system is illustrated in Figure 4, which is easily accessible to operators at the central control room, production section heads, engineers and technicians at the mine. The smart ore tracking provides the ore type information for each important process units.

Those process units include:

— Primary crusher;
— Main stockpile;
— Re-crusher stockpile;
— Coarse stockpile of dense media separation;
— Fines stockpile of dense media stockpile;
— Primary scrubber and screen;
— Secondary scrubber and screen;
— Secondary crushers;
— High pressure roll crushers (HPRC);
— Coarse module of dense media separation;
— Fines module of dense media separation;
— Concentrate of dense media separation;
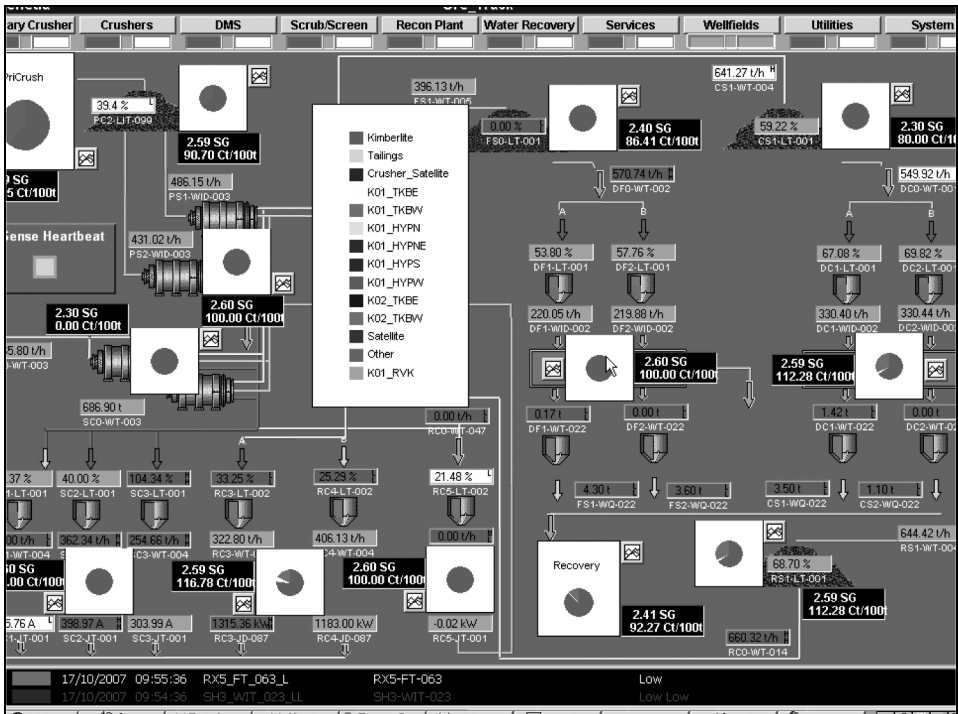— Feed to recovery plant.

Fig. 4. Graphic user interface of smart ore tracking, displaying ore grade, density and blended percentage at all process units at a mineral processing plant, including crushing, screening, separation, de-watering, and stockpiling

In a stockpile, ore may mix and has a long residential time. Therefore the behaviour of ore in a stockpile has the profound impact on the accuracy of the ore tracking system. In order to gain a better understanding and help estimate the residential time and the mixing characteristics, a detailed modelling investigation on a main stockpile was conducted using DEM software from Itasca, USA [3].
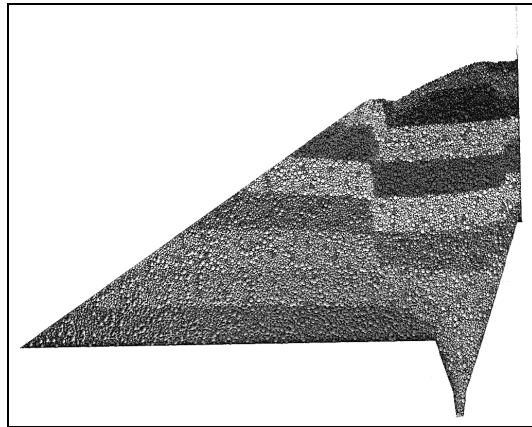
Fig. 5. Illustration of ore moving and mixing in a stockpile,
showing a stage of little or no mixing
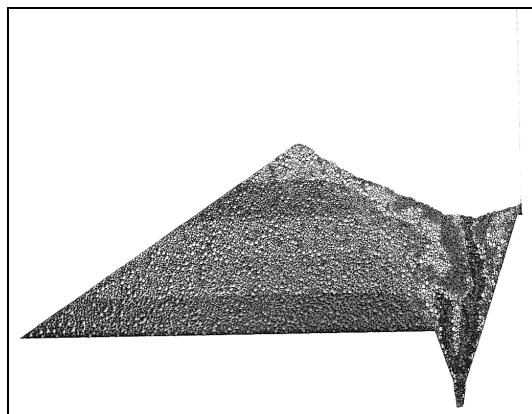
Fig. 6. Illustration of ore moving and mixing in a stockpile,
showing a stage of completely mixing

The results can be used to estimate the residential time (time delay) of different layers of the ore within the stockpile. The model shows that the discharge of the ore in different layers has taken place without major mixing, if the stockpile level is more than 60%. Normally

only two neighbour layers were mixed slightly with each other. The discharge of one of these layers is not finished before the one on the top starts flowing through the hopper at the bottom of the stockpile. From the moment when the stockpile level is less than 30%, all the remaining layers start thoroughly mixing and ore from the bottom first or second layers is discharged into the hopper from side, see Figure 5 and 6.

Using reporting systems, the ore type information can be reported daily, weekly or monthly. For instance, daily ore type information of the primary crushers and the secondary crushers can be seen in Figure 7 and Figure 8.
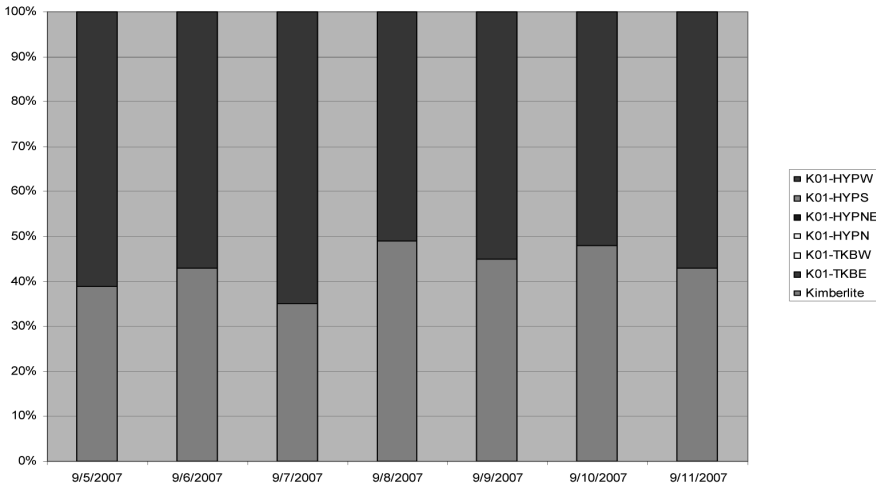
Fig. 7. Daily ore type (%) treated at the primary crusher in a period of 7 days
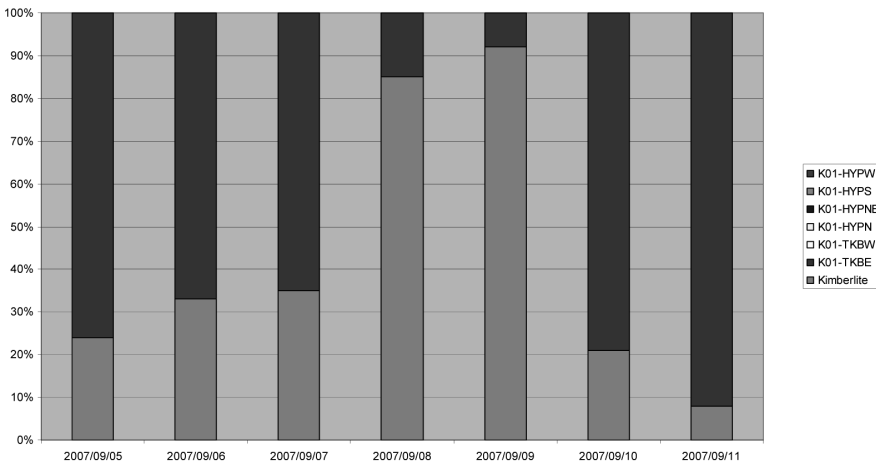
Fig. 8. Daily ore type (%) treated at the secondary crushers in a period of 7 days

5. Conclusion

A smart ore tracking system is developed by using real time information available in both mining database and SCADA system of a mine. After developed and tested, the system was implemented at the diamond mine in 2007. The system can be used to provide the ore type information through the entire processing plant, including primary crusher, primary stock pile, primary scrubbers, secondary scrubbers, secondary crushers, re-crusher stock pile, high pressure roll crushers, fines dense media separation stock pile, fines dense media separation, coarse dense media separation stock pile, coarse dense media separation, concentrate bin and feed to recovery plant. Daily weekly and monthly reports of ore type treated at any processing units can be available through reporting systems.

The smart ore tracking makes it possible to combine the knowledge of ore types, mineralogy, and other characteristics, (located in the mining system), with the advanced capabilities of state-of-the-art mine control systems, to achieve an improved level of control in mineral processing, and to allow optimization of the mine processes on a real-time basis.

The smart ore tracking system, developed originally for a diamond mine, can be used for other mines, such as iron ore, coal, chromite ore, manganese ore, etc.

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