Synergies and potentials of near-to-face processing – An integrated study on the effects on mining processes and primary resource efficiency

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ABSTRACT

Implementing underground processing affects a series of process steps like production, processing, backfilling and infrastructure and thus needs a proper integration into the whole underground mining process. This leads to the necessity of new holistic process models for the different underground mining methods and systems. Sound resource-to-product integration concepts hold large potentials for economic, social and environmental benefits in comparison to common underground mining systems and methods. Underground processing in combination with backfill and the reduction of pillar volume leads to higher extraction rates out of a given deposit, thus leading to a higher primary resource efficiency.

Within the European FP7 project I²Mine (Innovative Technologies and Concepts for the Intelligent Deep Mine of the Future), research activities for resource-to-product integration concepts are carried out by the Institute of Mining Engineering I, the Unit of Mineral Processing of RWTH Aachen University and TOMRA Sorting Solutions. In the following concepts and approaches to achieve the vision of deep underground processing and near-to-face waste rejection will be presented.

INTRODUCTION

It is common practice to transport the ore from underground to the mineral processing plant at the surface. Means, that are partly high costs for to transport waste material – especially given that in metal mining only a small portion of the mined ore comprises valuable minerals. Therefore, it would be beneficial to transport only the concentrate to the surface instead of the ore.

In order to comply with this request, it is necessary to prepare the ore already underground. Underground processing is not a new idea. Underground comminution and classification plants are known and quite common in the mining industry. Also underground sorting is partly applied. The motivation for underground processing often comes from external circumstances like rough climatic conditions and not from economic considerations. The reasons for this are comparatively higher investment costs to establish an underground processing plant and the associated maintenance costs.

When mining goes deeper the hoisting distances elongate and thus the operational costs significantly increase. In addition, it would be better to prepare the mined ore at an earliest possible stage of the mining process near to the working faces.

This approach will be continued in the course of the European I²Mine project. Underground processing holds large potentials for cost savings in the transport chain and the primary resource efficiency. In particular, the development of near-to-face processing solutions will be pursued.

Before delving into the task of underground processing, a brief description about the I²Mine project is presented. In the following, possible synergies and potentials of underground processing are highlighted. Subsequently, the mining system evaluation approach for implementing underground processing is explained. In this context, the development of a near-to-face processing unit is shown. This paper closes with a short conclusion.

The I²Mine Project

The I²Mine project (Innovative Technologies and Concepts for the Intelligent Deep Mine of the Future) marks the start of a series of development activities, which aiming at to realise the concept of an invisible, zero-impact mine. [1]

The involvement of and project guidance by European industry partners (notable mining companies as well as equipment suppliers) will guarantee that all development activities in the frame of the I²Mine project will only aim at reaching the particular objectives for the benefit of the entire mining sector. The partners from academia and research institutes will serve as solution providers based on their expertise and knowledge. Altogether, the I²Mine network consists of 26 Partners from 10 EU-countries. The overall budget is about 25 million Euros and research will be carried out from 2011 to 2015. The described concept will be realised by eight work packages which deal with the different goals of the project. [1]

The mine of the future, which has to exploit mineral raw materials at greater depths than today, could require a completely different mine layout compared to today's deep mines. This includes machinery for exploitation, transport and processing systems that are suitable to deal with the conditions expected at depths beyond 1,500 m. [1]

The project focuses on investigation breakthrough technologies for autonomous, highly selective mineral extraction processes and machinery based on new sensor technologies as well as innovative concepts for mass flow management and transportation. Such investigations have to be accompanied closely by rock mechanics and ground control issues as well as incorporate all the health, safety, rescue and environmental issues. An exemplary mine layout and its impacts are shown in figure 1. [1]

The vision of an invisible, zero-impact mine requires a refined process underground that selectively mines the minerals and therefore reduces waste production closer to the underground workings. Furthermore, improved near-to-face processing methods including backfill procedures need to be developed. [1]

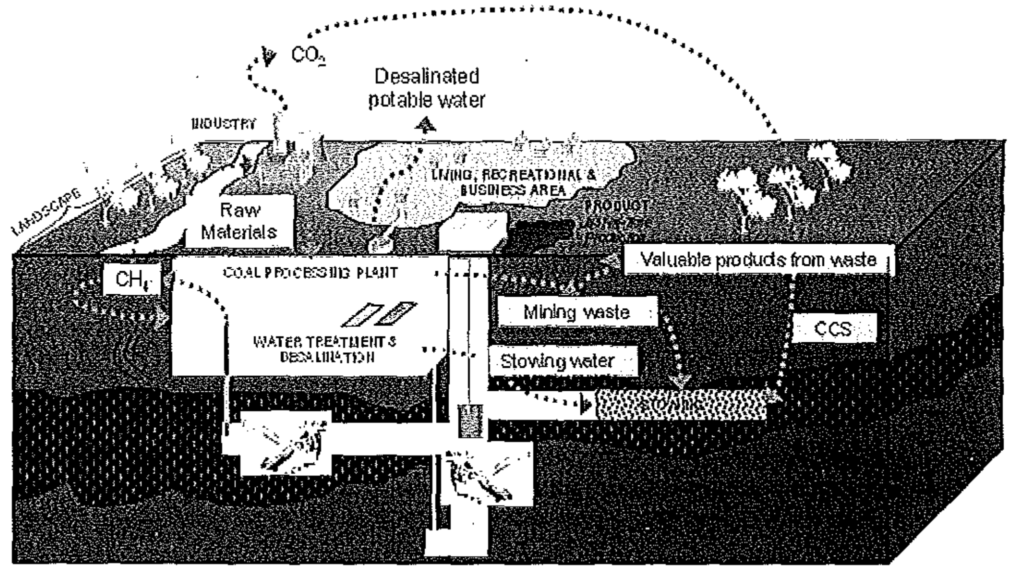

Figure 1: The underground coal mine of tomorrow (Courtesy of: GIG – Central Mining Institute, Poland) [2]

Work Package 2, called "Novel mining and underground processing methods", deals with the development of new advanced, safe and intelligent underground mining methods and systems in order to reach access to deeper deposits. Innovative mining methods for horizontally and vertically bedded deposits which are economic at depths greater than 1,500 m should be developed. Furthermore, mining methods should reach higher extraction rates than common mining methods, use more mining waste as underground backfill and move more of the primary processing underground [1]. Achieving higher extraction rates out of a given ore deposit implies a more efficient utilization of the primary resource, thus leading to higher primary resource efficiency.

In addition, the required workers underground, the production costs and specific usage of resources like energy, water and raw materials should be reduced. Besides developing new or altered mining methods the goal of this work package includes establishing new methods for prediction, monitoring and control of subsidence and it takes the requirements for backfill material and technology into account. [1]

The following chapters describe the work of the task "mine-to-mill integration" where new concepts for improved resource-to-product integration are in development to analyze the effects of the implementation of underground processing.

SYNERGIES AND POTENTIALS OF UNDERGROUND PROCESSING

In a standard underground mine, ore is transported from the mine to the mineral processing plant at the surface where valuable minerals are separated from waste rock. Especially in metal mining only a small portion of the mined ore comprises valuable minerals [3]. The waste rock is disposed on waste dumps, tailings ponds or in underground voids as backfill. Due to the fact that mining goes deeper within the next decades, the disadvantages of rising transportation costs gain impact. The extent to which underground processing can be implemented depends on equipment size, throughput, recovery at coarse grain sizes and energy consumption to name a few. In terms of valuable minerals the liberation from gangue material has to be high enough at coarse particle sizes to utilize underground processing techniques. In addition, the specific mineralogy and geology of the ore body and other logistical factors have major influence on the processing techniques [3].

The following list gives an overview of the expected potential impacts of underground processing in combination with backfill addressed in the course of this article: [4][5]

Effects on mineral reserves and thus on primary resource efficiency:

- Possibility of mining narrowing deposit parts and compensate dilution by near-to-face waste rejection
- Possibility of mining low grade deposit parts and increase of run-of-mine grade near-to-face
- Possibility of reducing the effective cut-off grade by cost savings in the mining process chain (extraction, transportation, backfilling, processing)
- Possibility of cost savings for backfill transport which is necessary for extraction rate increases
    - Pillar extraction by means of fully placed backfill
    - Pillar volume reduction by means of partially placed backfill

Effects on resource (input) efficiency:

- Less land use and environmental impact by less waste material to be stored at surface
- Less energy consumption for mass transport to surface and for grinding
- Less water consumption in the processing step by early waste rejection in combination with dry processing technologies
- Less surface subsidence via backfill placement in the mining voids

Enabling and sound implementation of underground processing – particularly near-to-face processing – in an underground mine environment hold large potentials for cut-off grade decreases by cost savings in the mining process chain [5]. In this regard, it can be concluded that underground processing has positive effects on the mineral reserves and the primary resource efficiency. Early waste rejection leads to early ore enrichment at acceptable costs. Thus, mining areas with lower ore grades could be economically mined. The same applies for narrowing parts of a deposit where selective mining reaches a limit due to the equipment dimensions. There, diluted mineral can be accepted because of the waste rejection at an early stage of the mining process [4]. In addition, as mining goes deeper, near-to-face processing is an opportunity to reduce the ore transportation costs, especially for hoisting.

When talking about underground processing, two types can be distinguished:

- Underground processing:

  Full-scale; because of its size and complexity a complete underground processing plant is a long term installation (whole life of mine or life of main level).

- Near-to-face processing:

  Small-scale; semi-mobile intended as waste rejection plant close to the mine workings.

Underground comminution before hoisting is a common technique in the minerals industry to enable or facilitate transportation. Hard rock mines in Scandinavia use different types of primary crushing aggregates like short head crushers or jaw crushers, for instance. Full-scale underground classification and in one case underground sorting are known in german rock salt mines.

For example, in 2012 the Canadian mining company Noront Resources Ltd. released a feasibility study called "The Eagle's Nest". It is planned to design and construct an underground mineral processing plant for the nickel-copper-platinum ore. The mineral processing will include standard nickel-copper processing steps like crushing, grinding, flotation and dewatering. Afterwards the concentrate is pumped to the surface for drying and transportation to the smelter. Noront Resources Ltd. plans to be in production in 2016/2017 with a daily throughput of 3,000 tons. [6]

The Andina mine of Codelco in Chile build its whole mineral processing plant underground to process 33,000 tons per day. Climatic circumstances make Codelco to put the mill into two underground stopes where one stope contains the grinding aggregates and the other the copper flotation. [3]

A mobile sorting process in the vicinity of the mine workings is named near-to-face processing. It is characterized by small construction sizes optimized for limited cross-sections, relocation depending on the extraction process and providing coarse backfill material close to the workings. Several sorting techniques are considerable due to the conditions mentioned above. Therefore suitable processing techniques for underground processing are dense media separation, magnetic sorting, electrostatic sorting, gravity sorting, size screening, coarse particle flotation and sensor-based sorting.

An example for near-to-face processing is developed by GekkoSystems (see figure 2). The so called Python plant includes options for jigging and flash-flotation and is designed to be semi-mobile [7]. Due to the low throughput of 10-20 t/h per unit it is not applicable for high run-of-mine volume commodities such as base metals, coal and salt [7]. Near-to-face processing for base metals, coal and salt implies a smaller processing unit and is intended as waste rejection plant.

Figure 2: GEKKO Python semi-mobile processing plant [7]

Especially sensor-based sorting fulfils the requirements for near-to-face processing, characterized by high throughput at coarse particle sizes between 20 mm and 300 mm (300 t/h per meter sorter width), reasonable recovery, dry or less water consumption and semi-mobile processing units [8]. Figure 3 shows the final 3D plant design of a semi-mobile sensor based sorting plant.

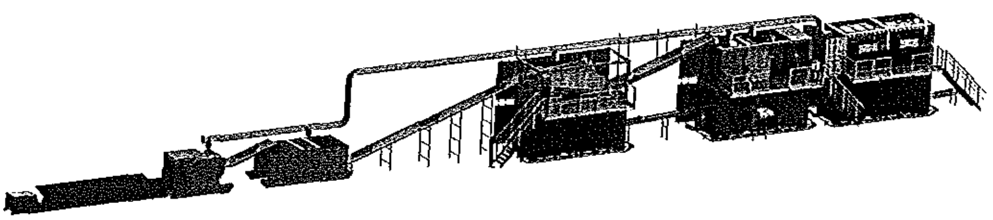

Figure 3: Iso view of a modular, semi-mobile sensor-based sorting plant (Courtesy of: TOMRA Sorting Solutions)

Further explanation concerning physical dimensions, characteristics and performances of the system will be described in the following chapters of this paper.

MINING SYSTEM EVALUATION

The implementation of a full-scale underground processing plant or a near-to-face processing unit in an underground mining system affects different mining processes like production, processing, backfilling and infrastructure. Therefore, it is necessary to develop new holistic process models for innovative mining methods and systems. In comparison to conventional mining operations the concepts of integrating underground processing offer huge potentials for economic, social and environmental benefits.

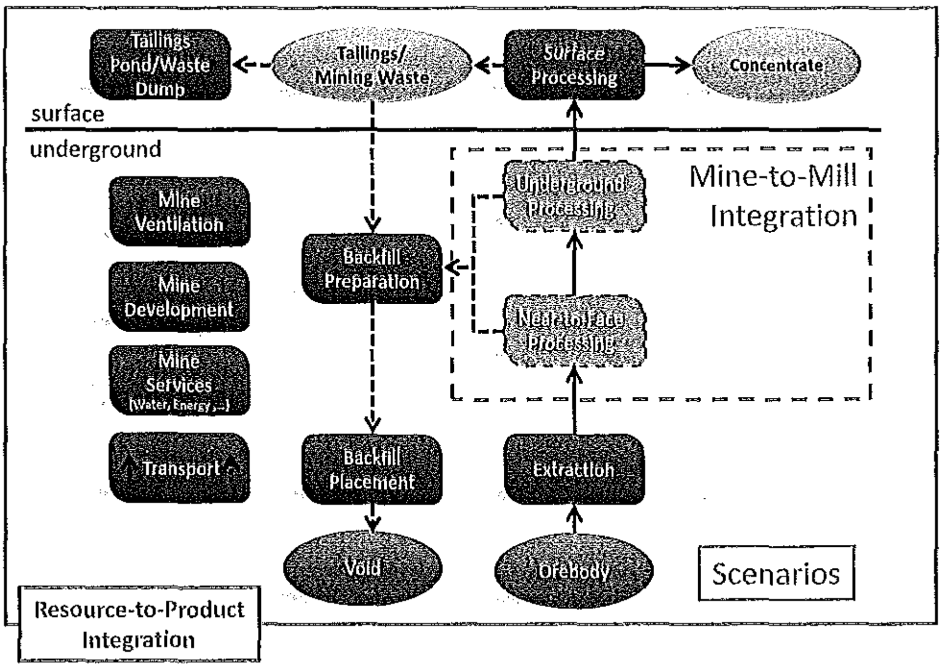

Figure 4: Structure of the mine model including several sub-processes

The aim is to model the whole mining process-chain in order to point out and analyse interactions between upstream, downstream and side-stream processes (see figure 4). Analyses of the potential for improvement in various process steps will be carried out according to different criteria.

Extraction

There is a wide range of currently used underground mining methods worldwide. With regard to Hartman's classification of underground mining methods there are eight common used methods (see table 1).

Unsupported Methods	Supported Methods	Caving Methods
Room-and-Pillar	Cut-and-Fill	Longwall Mining
Stope-and-Pillar		Sublevel Caving
Shrinkage Stoping		Block Caving
Sublevel Stoping		

Table 1: Hartman's Classification of Underground Mining Methods [9]

To figure out suitable mining methods for underground processing (especially for near-to-face processing), an assessment matrix was developed. The individual mining methods have been evaluated based on different assessment indicators related to the goals of the task mine-to-mill integration.

		Underground Mining Methods							
	Weight	Room-and-Pillar	Stope-and-Pillar	Sublevel Stoping[1)]	Shrinkage Stoping	Cut-and-Fill	Longwall Mining	Sublevel Caving	Block Caving
1 (Possibility of) using Backfill	7	2	2	2	1	2	1	0	0
2 Application in EU [%]	4	1	0	0	0	1	2	1	0
3 Potential for Automation	1	1	1	2	0	1	2	2	2
4 Potential for continuous Operations	1	2	2	1	1	1	2	1	1
5 Impact on Surface	4	1	2	1	1	1	0	0	0
6 Potential for Extraction Rate Increases	5	2	2	2	1	0	1	1	1
7 Flexibility of Mining Method	1	2	2	0	1	1	0	0	0
$\sum_{i=1}^{x} \text{Weight}_i \times \text{Points}_i$ →	Σ	37	37	31	18	25	24	12	8
	Rank	1	1	3	6	4	5	7	8

High Fulfillment (67-100 %) = 2 Points
Medium Fulfillment (33-67%) = 1 Points
None - Low Fulfillment (0-33 %) = 0 Points

1) Including variations: "Longhole Stoping", "End Slice" and "VCR"

Figure 5: Mining method selection matrix to investigate suitability of underground (especially near-to-face processing)

The possibility (or necessity) of using backfill is one of the most important criteria for the suitability of the mining method because underground processing implies backfill material occurring already underground. With increasing depth another criterion gains importance, the potential of extraction rate increases by reducing pillar volume via backfill. The impact on the surface is another assessment indicator. I²Mine focuses on deposits and mining activities within the EU, hence the amount of different specific underground mining methods in Europe is also an important indicator. For this reason a desktop/literature research was carried out in mining magazines, internet and specialist publications to build up a database to gain a detailed knowledge of the European mining industry. Indicators and results can be seen in figure 5.

Room-and-pillar, stope-and-pillar and sublevel stoping (including all its variations) reach most points. These methods will be the focus for the on-going model calculations. As a result of an online literature research a high proportion of all European mining operations are covered by these mining methods. Another benefit is that both steep dipping and flat deposits are minable with these methods.

Cut-and-fill is also interesting for further investigation because the use of backfill is an integral part of the mining system and sets it apart from the others. In general, large scale mining has the lowest operating cost but often implicates a higher dilution [4]. Small scale more selective mining decrease ore dilution but normally result in higher underground operating cost. The disadvantage of higher dilution associated with fully mechanized large scale (oversized) cut-and-fill can be compensated by near to face processing, reducing the dilution already close to the workings. This could be a promising scenario especially for mining narrow veins.

Sublevel caving and block caving are not favourable in the context of mine-to-mill integration due to lack of underground open voids which is a result of the caving process. Thus, backfill is hardly possible, which makes it necessary to transport all mined material to the surface and thus underground processing does not make sense.

Semi-mobile Sensor-based Sorting Underground

The requirement assessment conducted in the I²Mine project led to the result that the semi-mobile plant must be self-sufficient apart from electricity supply. In addition, a modular approach of smaller, transportable units was aimed at to allow for standardised transport, operation, maintenance, overhaul and replacement. The units must be shock-proof and operate in dusty and harsh environment. The temperature ranges are not as wide as for surface installations due to the buffering effect of the surrounding rock mass. Possibilities of firedamp protection are studied at the moment.

The sorting plant model was assembled on the basis of the spatial and operational constraints that the underground mining environment imposes onto the system. The above mentioned requirements resulted into an independent system that fulfils the operational requirement of being semi-mobile. During the course of the study no general dimensions for shaft transport and transport in underground roadways were found. The respective cross sections are too much a result of the geology, the operational requirements and historic developments. It was therefore decided that the sorting plant model must be as compact as possible to be suitable for as many cases as possible. Relocation, operation and plant maintenance were taken into account and a best-fit for both the mining operation and the operation of the plant itself was found. In a workshop different plant layouts were discussed. These included more vertical orientated gravity driven plants that are fed from the top and all main components are located below each other. This system has the advantage that less material handling equipment such as conveyor belts has to be used. Therefore the plant layout would actually require less volume. An alternative is a horizontally orientated plant layout where all main components are located next to each other. Diagonal systems which are widely used in fixed surface installations for mineral processing using the inclination of existing topography were also discussed.

In conclusion it was found that the horizontally orientated system offers the highest advantages in view of the requirements of a semi-mobile system. Cuboid modules that are placed next to each other require less effort for erection and transport. The cross sections of the shafts and roadways that are used for relocation of the plant need to be lower and offer thereby high cost savings. In addition, from a rock mechanical view long roadways are easier to create and maintain than more cubic stopes.

Figure 6 shows the final 3D plant design created. The layout is universal for different feed materials and sensor-based sorters. It comprises two skid-mounted crushing stages and six 6 m standard shipping containers that include all components that are essential for operation, apart from electric energy supply. The main machinery is two crushers, one screen (wet/dry), dedusting and compressor. Module 1 includes a single deck screen with two decks to ensure little height. The sensor-based sorting machine is located in module 2. The plant controls are also placed within that unit. Module 3 houses a dedusting wet scrubber as well as a fresh water buffer tank for 20 m³. Module 4 has the option for water clarification in case wet screening is needed for surface measuring technologies used for material discrimination in the sensor-based sorter. Module 5 has storage capacity for spare parts and tools. Chute-work and conveyors are also to be found in there. The compressor, a transformer and breakers are located within module 6. Connection to the mine-wide communication system, power supply and optional compressed air and water supply are all placed in module 6.

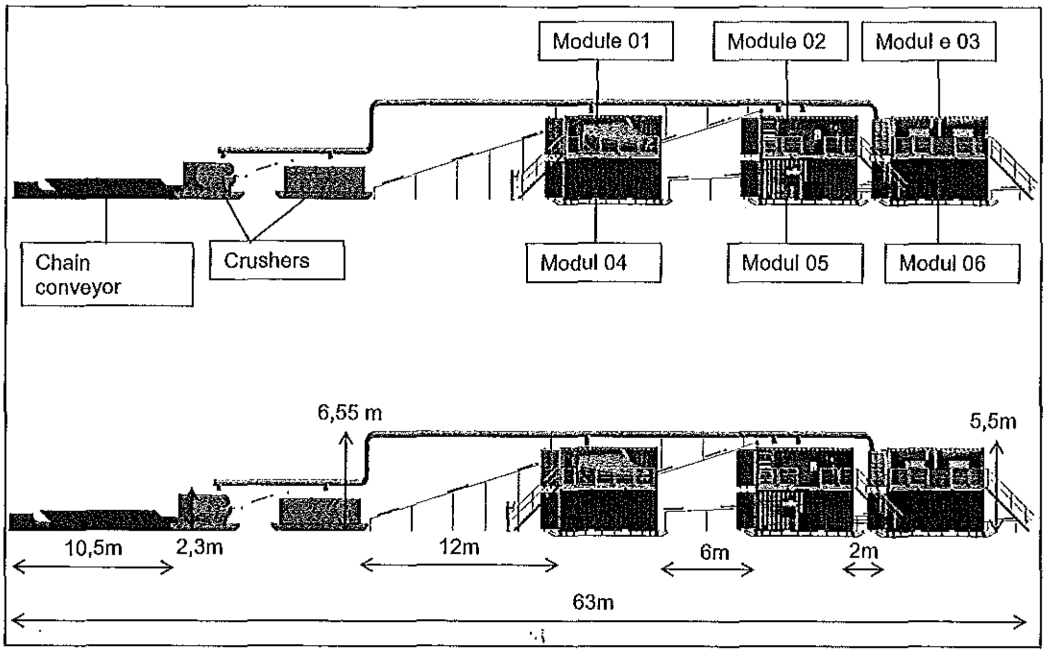

Figure 6: Side view of modular, semi-mobile sensor-based sorting plant

The total installed capacity of the installation including wet screening and the water circuit is 300 kW. Assuming a base load of 70% the base load is about 210 kW in full operation. Transformers and breakers are included in the plant design to enable a flexible integration into mine power grids with different voltages. Some 125 kW are transferred to the ventilation air as heat. The ventilation system of the respective mine must be adjusted accordingly. Ideally, especially for the operation of sensor-based sorters using surface measurement techniques, the plant must be located in intake/fresh airways.

Figure 7 shows three exemplary flow-sheets for different feed materials. This may be subject to change due to different amount of dilution, liberation of waste, sensor-based sorting specific parameters and the economic framework influencing the cut-point chosen.

The amount of backfill material rejected by the sensor-based sorter is estimated to be in the range of 10% to 20% of the feed stream.

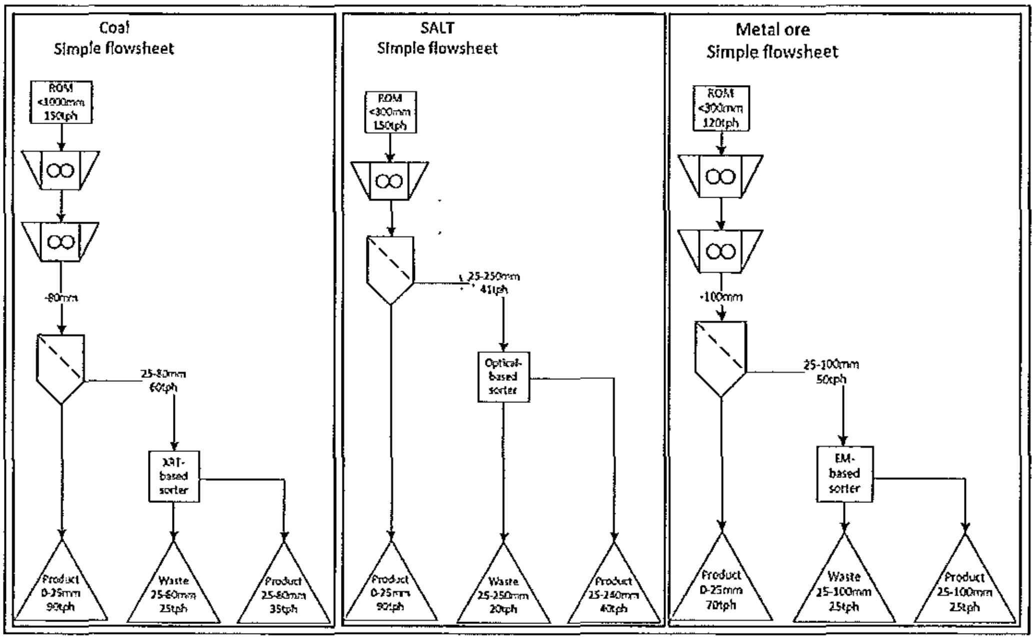

Figure 7: Preliminary flow sheets for different raw material feed streams

One requirement set by the mining system was that the sensor-based sorting plant is not releasing additional dust created by material handling and comminution into the environment. As used in many applications water sprays would be an option but would introduce more water into the environment. Water could also lead to operational problems producing caking and spillage. It can be kept in mind as an additional option. For the plant model a dedusting system using a wet scrubber has been selected as the most technically and financially viable option. It ensures that the operation is dust neutral with the environment. All major equipment is connected and the wet scrubber ensures that even -20 µm dust is filtered sufficiently. A safe environment for the operators and a protection for the equipment are ensured thereby.

The plant is designed in a way that all maintenance intensive components and such that need regular inspection are located at the front side to assure best possible accessibility. Belt conveyors are mainly positioned in the rear row within the framework structure, thus only well reachable via the space between two frames. The belt drive pulley is preferably located at the tail end of the conveyor as this area is expected easier to access. In terms of ergonomic and safe workplace design, rigging points on the framework structure are to be installed above and aside heavy components, especially when those are frequently needed to be replaced due to wear reasons. Replacement and repair works are to be recorded in detail. Long term experience will help to develop a service plan for the whole plant that specifies maintenance and replacement intervals for parts before they break uncontrolled. Such planned work tasks could be done when the plant is to be relocated, as accessibility for some components is increased when in transport mode. Within a mine, more intensive maintenance and overhaul operations are restricted by the space requirements and other environmental aspects. The plant has facilities for small tool and spare part storage. As a long term goal it has been defined that mine having multiple systems in operation could replace single modules and retreat them to a central workshop. This would ensure safe and optimal working conditions as well as maxims availability of the system.

Auxiliary equipment is needed for relocation and exchange of modules. The decision has been taken that the plant does not require crawler tracks or similar as the relocations are estimated to be conducted every 6-20 weeks. The plant is therefore to be placed on skids which can be pulled by mobile equipment already in use in the mine. To place the modules on top of each other either chain hoists attached to roof bolts or a fork attached to a wheel loader are possible. The total relocation of the plant is estimated to be around 20 hours requiring about 100 man-hours and one wheel loader. This depends strongly on the transport distance and the space restrictions. For short distances and roadways that enable the transport of two stacked modules the time decreases by about 2 hours. An optimum transport cycle has to be chosen for each and every mine taking into account space restrictions, labour costs and rock stability which translates to costs for maintenance. The plant is to be equipped with four mechanical jacks for the three lower modules (Nr. 4-6). This enables the setup on slightly levelled floors but does not require concrete foundations. For plant operation for a longer period swelling of the floor which is to be expected for openings in deep level mines can be compensated for.

The overall investment for the installation ex works is estimated to about 2.5 million €. The operating costs are estimated to about 3 € per tonne of feed and are based on 6,000 working hours per year.

Location of Underground Processing Plant / Near-to-Face Processing Unit

The location of an underground processing plant depends on the characteristics of the system and whether it is a large-scale underground processing plant or a small-scale near-to-face processing unit. Whilst an underground processing plant should be located at a central nodal point to minimize transportation cost and ensure long-term use, a near-to-face processing unit must be located close to the workings in an optimum location with regards to the mining and backfilling process.

First studies on stationary integration of sensor-based sorting underground were conducted during the early years of the last decade and resulted into two installations in German rock salt mines [5][10]. Nevertheless, stationary installations have the disadvantage of increased costs and infrastructure for waste transport to backfill areas. Two options for transport are possible: On the bottom strand of main conveyor lines or on empty runs of rubber wheeled mobile conveying equipment. The effort and costs for backfilling infrastructure can be minimized through the placement of a semi-mobile installation in strategic locations. Thereby the costs and efforts for relocations must be balanced through integrated evaluations with those for waste transport and backfilling. In most studied applications the amount of backfill is less than the product fraction being hoisted to surface. The plant would therefore be located on main haulage axis as close to the current backfill location as possible.

As already mentioned, the time for relocation is an important indicator for a semi-mobile near-to-face processing unit. The less time is needed the more relocations make sense. A general statement is not possible because practical operation time depends on the ore body dimensions, the machinery and the related throughput which is possible over a specific period. In addition, the void volumes and the lateral expansion of the production panels or stopes determine the operating lifetime at a specific point of a near-to-face processing unit. It is a relation of waste rejection ratio to void volume. The limiting factor is the backfill infrastructure and thus, the transport distances of waste material to the backfill area. In general, the more void volume is available the longer is the operating lifetime of a near-to-face processing unit at a specific location. Thus, optimum integration into an underground environment is a planning case.

Backfill

The waste material from underground/near-to-face processing must be suitable for the use as backfill. Non-chemical sorting applications – like gravity separation or sensor-based sorting – are preferred because long-term chemical reactions are not expected due to the absence of reagents. Potential for oxidation should also be taken into consideration. The backfill requirements are primarily a function of the selected mining method. Strength requirements vary with the applied mining sequence and the rock mechanical conditions of the deposit. [3]

Moreover, it is necessary to ensure that all waste material can be backfilled in the underground voids due to the volume increases of the material after extracting and processing. Based on the swell factor, every cubic meter of rejected waste requires approximately 1.7 m³ of backfill capacity [11]. If too much waste material occurs already underground a bypass or more selective mining may solve this problem.

In general, backfill requirements depend on the type or the use of backfill. This means, if the backfill is only used as waste disposal then the strength requirements are negligible. If the backfill is used as an artificial support (functional backfill) within the mining system then the backfill requirements arise, especially when talking about pillar substitution by backfill material.

Currently applied unsupported mining methods are expected to reach their economic limits at greater depth as pillar sizes increase, thus extraction rate decreases. In this context the combination of extraction, underground/near-to-face processing and backfill to reduce pillar volume perfectly fits into the vision of improved extraction rates at greater mining depth.

In particular, sensor-based sorting implies dry rock fill. Next to some strength requirements of the backfill material it is important to provide an optimal particle size distribution. The objective of particle size optimisation is to produce a fill that develops dense packing during placement and thus minimise the void ratio. The most appropriate particle size distribution that would give such dense packing is given by [12]:

$$P = 100 \times \left(\frac{d}{d_{max}}\right)^{0,5}$$

Where: *d* = *particle size [mm]*

d_{max} = *maximum particle size [mm]*

P = *percentage of rock fill smaller than size d [%]*

Figure 8 shows that an optimum (minimum) void ration only can be achieved with an appropriate combination of different particle sizes. This leads to a higher density and therefore greater strength of the backfill. [12]

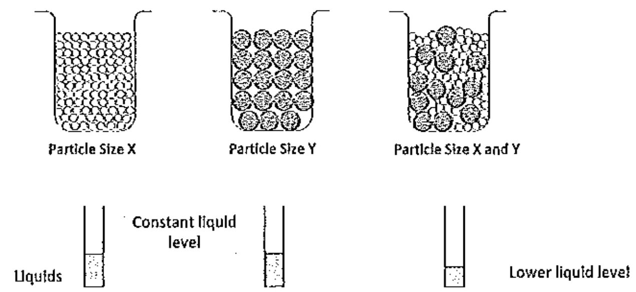

Figure 8: Demonstration of the effect of particle size distribution on void ratio [12]

Due to limited experience concerning the interaction of backfill and rock mass at greater depth a standard method to predict requirements for functional backfill is not available. Fully filled voids are the best possibility to increase the extraction rate but are associated with high costs. Partly filled voids could lead to drastically reduced backfill placement costs and simultaneously the possibility of increasing the extraction rate by reduced pillar volume. The interaction between backfill (partly filled and fully filled) and rock mass is modelled by DMT GmbH & Co. KG. On the basis of their results a method will be developed to predict the possible reduction of pillar volume in dependence of the backfill properties.

Surface Processing

The amount of valuable mineral in the run-of-mine ore is increased by underground processing or near-to-face processing. Therefore, the feed grade to the surface processing plant is increased. This could affect comminution and further processing in terms of lower grinding energy, decreased reagents consumption and total plant recovery to name a few. [3]

Comminution

Every ton of waste material rejected at the earliest possible stage of each processing step by underground processing saves specific grinding energy. Due to the higher grade in the run-of-mine ore a smaller amount of material has to be grinded per ton of concentrate. How much grinding energy could be saved depends on the waste rejection ratio of the sorting process underground and the geological conditions. It can be stated that the energy savings are much higher for hard rock as soft rock. Beside the energy savings the necessary amount of grinding media could be decreased as well. [13] [14]

Final Concentration

As mentioned before the valuable mineral content in run-of-mine ore could be increased by underground processing or near-to-face processing. Therefore the idea arises how this run-of-mine grade improvement influence the further mineral processing steps in the surface plant. This could lead to lower processing costs, increased productivity and higher recovery for the whole mineral processing chain. Interactions for single processes have to be evaluated as well in terms of, reagents and water consumption or dewatering to name a few. [13] [14]

CONCLUSION

The European FP7 project I²Mine (Innovative Technologies and Concepts for the Intelligent Deep Mine of the Future) aims at meeting the challenges of future European mining through innovative methods, systems and technologies. To achieve the vision of the invisible, zero-impact mine one focus is the development of integrated mining, processing and backfilling processes. Available studies show that integrated mining and waste rejection processes close-to-face have high potentials for deep underground mining. The methodologies and concepts in development enable the evaluation of potential benefits before going into costly case studies.

Enabling and sound implementation of underground processing – especially near-to-face processing – in an underground mine environment hold large potentials for cut-off grade decreases by cost savings in the mining process chain. In this regard, it can be concluded that underground processing has positive effects on the mineral reserves and the primary resource efficiency. The proposed systems result into higher resource exploitation through reduction of pillar volume enabled by the application of functional backfill. In addition, energy is saved in transport and further processing. Furthermore, specific water consumption by processing as well as through tailings emissions is decreased. The storage of coarse waste in combination with fine tailings underground further reduces surface impact and presents a step towards the vision of the invisible mine.

An integrated approach for the evaluation of synergies and potentials is in progress including analysing the impact on all processes of underground mining and mineral processing activities. Semi-mobile waste rejection near-to-face enables the earliest rejection of barren waste before transport, treatment and costly disposal processes. Sensor-based sorting is a well suited technology for early waste rejection because it is applicable for rock-type separation for all commodities using a variety of detection technologies.

The project has shown that a full and self-reliant semi-mobile sorting plant for waste rejection near-to-face can be accommodated in relatively small space. A horizontal oriented plant design was chosen assembled of standardised modules in the size of standard 6 m shipping containers. The throughput of the installation is case dependent but estimated at about 120-150 t/h. Nevertheless, a case specific evaluation including sensor-based sorting test work is necessary.

The applicability of semi-mobile waste rejection for different mining methods is evaluated using an integrated assessment matrix ranking the mining methods mostly applied in European mining. The analysis revealed that room-and-pillar, stope-and-pillar as well as sublevel stoping are most suitable. In addition, cut-and-fill is advantageous because backfill is an integral part of the operation.

Backfill created with rejected waste can be placed as rock-fill or cemented rock-fill. The integration of backfilling activities and the backfill properties have direct impact on the mining system applied. The positive impact of coarse waste in combination with fine tailings on the extraction rate is topic of the on-going research.

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