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Combined Mining Systems for Open Pit Mines

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Summary

Production rates in opencast mines will have to be increased in the future, especially in the energy sector. Reasons for this development are an increased demand for coal, oil-sand and oil-shale, the steadily growing share of opencast mining operations as opposed to a decreasing share for underground mining, and the increase of the overburden to pay mineral ratio.

Mining systems can be classified into discontinuous operations (for small to medium mass movements) and continuous operations (for medium to very high mass flows). Due to the cost advantages of continuous systems, a tendency towards the application of combined mining systems becomes obvious, in which loosening and loading is executed by discontinuous methods whereas transport and dumping of the spoil is effected by continuously operating equipment.

The various possible combined opencast mining systems are presented and explained by practical examples.

1. Introduction

The energy sector occupies with 49 % a dominant position in todays total mass movement (including overburden) of world mining operations which can be estimated to be around $27 \cdot 10^9$ t. Other important fields are sand, gravel and aggregates (31 %), iron-ore mining (9.5 %), and copper mining (5 %), whereas the rest such as phosphate, bauxite, uranium, heavy minerals etc., only amounts to 5.5 %.

Concerning the growth rates which can be expected for the years to come, data from various sources indicate that there will be hardly any growth in the field of sand and gravel. All estimates made during the last years and decades for the iron ore industry have proven to be too high. The development in copper mining cannot be predicted with any certainty. The absolute volume of mass movement for phosphate, uranium and bauxite will surely increase, but considering their low share, this increase will not create a real challenge for the future.

A completely different situation can be found in the energy sector. Based on the world energy consumption of the year 1980, i.e., $7.9 \cdot 10^9$ t bituminous coal units (conversion of the consumption of all primary energy carriers to the equivalent consumption of bituminous coal), the actual estimates predict an increase of 2.5 % p.a. (i.e., about 50 % of the consumption increase between 1965 to 1973). This figure considers both a considerably lower growth rate of the gross national product and also the recognizable tendency that an increase in GNP will, in the future, go in hand with a considerably lower increase in energy consumption.

According to estimates the total consumption for the year 2000 will be around $19 \cdot 10^9$ t bituminous coal units. The share of oil will decrease while natural gas and water power will remain constant. The share of nuclear power is estimated to rise from 2 % to 10 %. The share of coal will increase slightly from 26 % to 28 %, and the share for synthetic energy, i.e., oil-sand and oil-shale, will rise from about 0 % in 1980 to 4 % in 2000.

In order to permit a calculation of the masses which must be moved in open pit mines of the energy sector in the year 2000, the following assumptions were made:

Share of open pit bituminous coal mining:

1980 = 38 % 2000 = 49 %

Overburden to coal ratio for bituminous coal:

1980 = 10:1 2000 = 16:1

Overburden to coal ratio for lignite:

1980 = 3:1 2000 = 5:1

Share of open pit synthetic energy mining:

1980 = 100 % 2000 = 60 %

Overburden to oil shale (oil sand) ratio for synthetic energy materials:

1980 = 1:2 2000 = 1:1

Based on these assumptions an increase in exploitation of pay minerals in the energy sector from $1.86 \cdot 10^9$ t in 1980 to $6.09 \cdot 10^9$ t in the year 2000 can be forecast (growth factor 3.2 = 6 % p.a.) The increase for overburden removal will be from $11.1 \cdot 10^9$ t in 1980 to $42.25 \cdot 10^9$ t in 2000 (growth factor 3.8 = 7 % p.a.). These figures prove the importance of opencast mining operations for the future.

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In the following the main mining methods, i.e., discontinuous and continuous systems will be discussed and the advantages of combined systems will be explained by analyzing several planned or already operating open pit mining systems.

2. Discontinuous Mining Systems

The individual mining operations are executed by the following equipment (Fig. 1):

Loosening	Drilling rig blasting
Loading	Hydraulic excavator rope shovel wheel loader
Haulage	Off-highway trucks
Dumping	Off-highway trucks
or alternatively by	
Loosening	Drilling rig blasting
Loading, Transporting, Dumping	Dragline

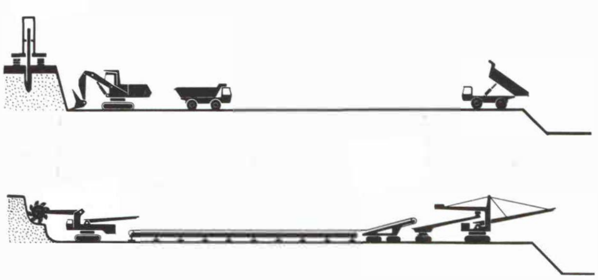

Fig. 1: Discontinuous (top) and continuous mining system

Typical applications for this system are:

- Mines with small to medium mass movements (100 — 7,000 t/h per haulage chain)
- Minerals to be mined: Lignite, bituminous coal, iron-ore, copper-ore, phosphate etc.
- Type of overburden: Unconsolidated, inhomogeneous formations, semi-consolidated and hard rock (cemented conglomerates, shale, clay, sandstone, limestone etc.)

3. Continuous Mining Systems

The individual mining operations are executed by the following equipment (Fig. 1, lower part):

Loosening, loading	Bucket wheel excavator bucket chain excavator
Transporting	Belt conveyor system (shiftable and stationary) conveyor bridge
Dumping	Spreader (stacker)

Typical applications for this system are:

- Mines with medium to very high mass movements 1,500 — 35,000 t/h per haulage chain
- Minerals to be mined: Lignite, bituminous coal (soft), chalk (soft), gypsum (soft)
- Type of overburden: Soft soil and unconsolidated formations (sand, gravel, loam, loess, clay, slightly cemented conglomerates).

4. Combined Mining Systems

Worldwide, discontinuously operating mining systems predominate. The extremely high costs of transportation and haulage, which have increased during the last 10 years from about 45 % to 60 % of total investment and operating costs for discontinuous systems, has led to the evaluation and introduction of combined mining systems. In these systems the operations "loosening" and "loading" are executed discontinuously, whereas the operations "transportation and haulage" and "dumping" are effected by continuously working equipment.

This tendency is also a consequence of an increase in mass movement due to higher production rates also in hard rock and semi-consolidated rock mines, an increase of mining depths (the present limiting depth is about 300 m, planned for the future are 600 m). Of major importance are also the increasing thicknesses of overburden and especially the disproportionate rise of the price of diesel fuel and tires.

In the following the various combined mining systems are discussed in detail:

4.1 Combined Mining Systems with Intermediate Truck Haulage

4.1.1 Direct feeding onto conveyor (Figs. 2 & 3):

Excavator — heavy truck — storage trench — reclaimer — conveyor

In order to be able to use conveyor belt transportation in a certain mine area of a Canadian oil-sand mine of Suncor, in which oil-sand is mined with rope shovels, Mannesmann Demag supplied, in 1979, a trench reclaimer with subsequent belt conveyor system.

Fig. 2: Combined mining system with intermediate truck haulage and storage trench reclaimer

The oil-sand has an approximate oil content of 14 % and is interbedded with individual large boulders. This material has to be blasted during the winter months due to the prevailing permafrost conditions with a freezing depth of several meters. In the winter time, oil-sand has to be transported in large, sharp-edged lumps and in the summer time the oil-sand has the consistency of softened asphalt.

Fig. 3: Storage trench reclaim system at Suncor, Canada

The intermediate transport to the 1,100 m³ storage trench is accomplished using 120 t trucks. The trench, serving mainly as an intermediate storage for equalizing the material flow, is supported by sheet piles on the dumping side only and was dug by the trench reclaimer itself. The bucket wheel reclaimer with a guaranteed capacity of 4,000 t/h is of the luffing boom type with which the oil-sand in the trench can be reclaimed in 4 cuts. Operation of the machine can be automatic or manual. Special design features can be found in the following areas:

— Design of the bucket wheel and the buckets. Boulders with an edge length of up to 1 m have to be reclaimed and oversize material must be rejected.
— Design of chutes, belt conveyor system and transfer points. The chutes can be sprayed with Kerosene as well as heated. The lumpy material required special impact idlers at transfer points.
— Easy erection and dismantling must be possible as the machine has to operate at different positions in the mine.

This combined mining system works successfully and might serve as a model for other operations involving direct feeding onto belt conveyors.

4.1.2 Grading prior to feeding onto conveyor (Fig. 4)

Excavator — heavy truck — grizzly — conveyor

An installation supplied by Kawasaki for a mine of the Kobe Development Board (Myodani, Japan) represents a good example of a system including truck transport, grading and feeding onto a belt conveyor. This plant has a capacity of 2,500 t/h and is fed by trucks of relatively low payload, dumping at short cycling times at 6 dumping points located side by side, in order to obtain the desired equalizing effect for feeding the conveyors. The material slides over a grizzly where the minus 200 mm material passes directly onto the belt conveyor. Oversize material (approximately 16 %) slides onto a second conveyor after having been slowed down by a chain curtain. This second conveyor discharges into a crusher with a throughput of 400 t/h, with subsequent feeding onto the main conveyor. The height difference between dumping level and lower belt is 12 m.

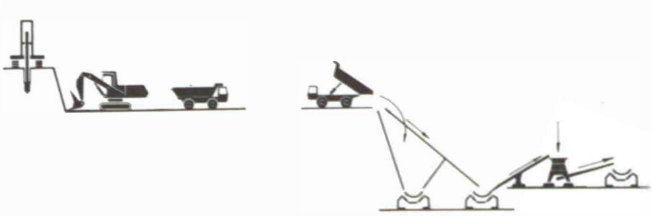

Fig. 4: Combined mining system with intermediate truck haulage and grading of material prior to loading onto belt conveyor

This considerable height difference and the lumpy material require special design features for the discharge conveyor, which was supplied by Bando under the name Rock Belt. The belt width is 2,000 mm, the thickness of the steelcord belt is 40 mm, with 20 mm top cover and 10 mm bottom cover. The special strengthening corresponds to a class St 3000 belt. This belt is said to be extremely resistant to impact. The non-troughed belt is supported on intermediate frames which carry the spring supported impact idlers of 250 mm diameter with 350 mm spacing, and which are themselves supported by the main structure via spiral springs. The belt speed is 0.5 m/sec.

Experience so far allows an estimate of useful life of approximately 3 years. The belt was turned after about 1.5 years, since it was worn out on one side due to the irregular impact of the material.

4.1.3 Crushing prior to feeding onto conveyor (Figs. 5 & 6)

Excavator — heavy truck — mobile crusher — conveyor

A suitable model for the operation of a semi-mobile (in-pit) crusher fed by heavy trucks and connecting to a continuous transport and dumping system is the overburden mining system at Sishen, an iron-ore mine of ISCOR (South African Iron and Steel Corp. Ltd.).

Fig. 5: Combined mining system with intermediate truck haulage und mobile crusher

Fig. 6: Discontinuously working dragline feeding material via hopper car onto belt conveyor

This installation was built by Krupp Industrie- und Stahlbau in early 1980 and represents the biggest and most modern plant ever as far as throughput is concerned. According to the Tender Specifications it comprises three major sections:

1. Heavy trucks feeding a crusher and crusher discharge
2. Belt conveyor system for transport out of the pit
3. Belt conveyor system on the spoil pile and spreader.

A gyratory crusher with a throughput of 6,000 t/h, positioned in a trench between two retaining walls, is fed from two sides by heavy trucks of 155 t payload dumping material into the 170 m³ feed hoppers.

A Nordberg crusher which can accept lumps of 1.2 m diameter and "fishes" of 2.4 m length discharges into an outlet hopper of 150 m³ content. A discharge conveyor transfers the material onto the 1,800 mm belt conveyors running underneath the crusher and effecting the transport out of the pit. These conveyors are positioned in two sections of 500 m length each. They can be considered as quasi-stationary. The belt conveyor line can be extended on the crusher side when the crusher is relocated at intervals of several years, depending on the advance of the mining operations.

The dumping installation on the spoil consists of two 1,800 mm belt conveyor systems located at right angles to each other (one shiftable and one extendable section), one tripper car and one crawler-mounted spreader with a boom length of 56 m connected with the belt conveyor system via a 30 m long conveyor bridge.

A transport crawler with 1,000 t carrying capacity is an important component of this system and serves to relocate the crusher with supporting structure designed as a 3-point supported ring girder. Other parts, such as feed hoppers, service cranes etc. have to be dismantled and transported separately. Retaining walls and foundations have to be removed.

This installation represents a completely new concept as far as design and size are concerned.

4.2 Combined Mining Systems Without Intermediate Transport

4.2.1 Direct feeding onto conveyor (Fig. 7)

Dragline — hopper car — conveyor

For the combined opencast mining systems without intermediate transport by trucks one example is given here of an installation with direct material feeding onto conveyors, without grading or crushing.

The Fortuna opencast mine of the Rheinische Braunkohlenwerke, Germany, uses the continuous mining method with bucket wheel, belt conveyor and spreader. However, a dragline operation can be found on the deepest level of this mine where the coal formation is influenced by several faults. On this level a bucket wheel excavator has been working for several years, with an output of 1,040 bank m³/h in a 20 m high cut, as well as a Ruston Bucyrus RB-480-W dragline with an effective capacity of 600 bank m³/h. The dragline with a 66 m boom length is equipped with a 15 m³ bucket and has a digging depth of 40 m. With a deadweight of 775 t this machine is lighter and cheaper than a bucket chain excavator of identical capacity and digging depth.

Fig. 7: Semi-mobile crusher at ISCOR, South Africa

The dragline transfers the material — and this is the critical operation — into the 100 m³ crawler-mounted hopper car with a hopper opening of 7.5 m by 6.4 m. Despite these dimensions it is sometimes difficult to position the bucket above the hopper. Discharge from the hopper is by means of an apron feeder running at 0.2 m/sec. The service weight of the hopper car is around 400 t. It became obvious that the belt conveyor system should have a width of 1,600 mm due to the lumpiness of the material which is naturally considerably larger than if mined by a bucket wheel excavator. The belt speed can be relatively high, i.e., 5.2 m/sec if catenary idlers are used.

4.2.2 Grading prior to feeding onto conveyor (Figs. 8 & 9)

Excavator — grizzly — hopper belt wagon — conveyor

A real simple solution for combining discontinuous and continuous transport systems was presented by Mannesmann Demag at the Mining Exhibition Bergbau '81 in Düsseldorf, Germany. This system comprises two hydraulic excavators Type H 241 and one so-called hopper spreader HS 5000-56, i.e., a hopper belt wagon with a very long feeding boom, which can operate as a spreader and dump material directly into the mined out pit areas, similar to the operation of a dragline.

Fig. 8: Grading by hopper belt wagon prior to feeding onto conveyor

In another and considerably more interesting alternative the feeding boom establishes the connection to a shiftable belt conveyor system which in this special case is fed via a small hopper car running on the shifting rails of the conveyor system.

The hydraulic excavator H 241, especially developed for mining operations, has already been in operation for two years in several installations with very good results. These excavators were supplied as diesel-hydraulic and electro-hydraulic versions with a drive power rating of 1,000 kW. Their service weight is 270 t. The excavators can be equipped with buckets of 10 m³, 14 m³ (for overburden) and 21 m³ (for coal). It is envisaged that two excavators will alternately feed into the hopper belt wagon (at approximately 30 sec intervals) via a hydraulically collapsible grizzly with a 400 mm mesh width. The hopper can take the contents of two buckets.

A discharge conveyor with an infinitely variable discharge speed of maximum 0.5 m/sec controls the loading of the 1,400 mm wide boom belt which runs at a constant speed of 4.5 m/sec.

The maximum outreach of the 56 m boom (rotating center to center discharge pulley) guarantees sufficiently long time intervals between shifting of the bench conveyor line.

Lifting and lowering of the boom is effected by two hydraulic cylinders; the boom itself is a latticed tubular construction. The crawler assembly with 7.5 m gauge and 7.5 m centre to centre tumbler length permits a low ground pressure of 8 N/cm² with a service weight of the machine of 300 t. Drive motors of 700 kW as well as hydraulic motors and pumps are, as far as possible, part of the hydraulic excavator program.

In order to avoid off-center belt run during unfavourable ground conditions, the total superstructure is tiltable around the longitudinal axis (boom direction) by means of hydraulic cylinders.

The equipment combination of H 241 and HS 5000-56 has found considerable interest since its presentation at Bergbau '81.

Fig. 9: Model of Mannesmann Demag "hopper spreader" HS 5000-56

4.2.3 Crushing prior to feeding onto conveyor (Fig. 10 & 11)
Excavator — mobile crusher — conveyor

The presentation of application examples will be completed with an installation supplied by PWH (PHB Weserhütte),

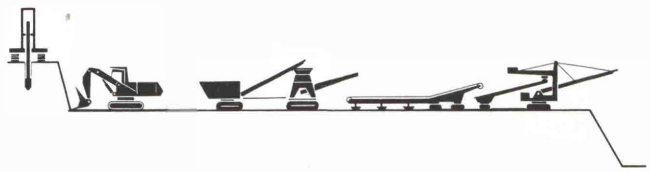

Fig. 10: Crushing by in-pit crusher prior to feeding onto conveyor

Germany to the Grooteluk coal mine in South Africa. Here a mobile crusher with intermediate bridge and belt conveyor system is used for the transportation of the overburden. The total mass movement is around 32 million t/year with an overburden share of 8 million t. The overburden thickness varies between 15 to 20 m, it consists of 85 % shale and 15 % sandy soil and is blasted, excavated by P+H 2300 rope shovels and discharged into a mobile crusher on walking pads. The mobile crusher with a weight of about 1,000 t follows the rope shovel at 25 m intervals.

The total material passes through a gyratory crusher and is transferred via a 23 m long boom onto a crawler-mounted 110 m long conveyor bridge transporting the material to the bench conveyor system. The subsequent belt conveyor system consists of 4 sections with a total length of 3,600 m. The 1,400 mm wide belt runs at a relatively low speed of 2.7 m/sec. Considering the characteristics of the crusher, the belt system with max. 3,000 t/h is oversized compared to the required nominal rating of 1,800 t/h.

Crushing of the material is required due to the fact that the overburden has to be mixed in a subsequent stockpile arrangement with waste material from the coal processing plant, which still contains about 25 % carboniferous material, in order to avoid self-ignition.

Several alternatives to this total system were analyzed and compared with respect to investment and operating costs. Since the individual cost figures in Rand/ton are not significant, the comparison was related to a pure shovel — truck system (100 % value). The following data were worked out:

1. Heavy trucks + stationary crusher outside the pit + conveyor system — 75 %
2. Heavy trucks + mobile crusher outside the pit + conveyor — 75 %
3. Heavy trucks + mobile in-pit crusher + conveyor — 66 %
4. Selected solution — 42 %

Fig. 11: Mobile crusher with intermediate bridge at Grooteluk coal mine, South Africa