Large Surface Miners - Applications and Cost Calculations

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Abstract

Surface miners find their natural applications in projects where drilling and blasting is prohibited or where selective mining of mineral seams, partings and overburden is required. Besides they offer further advantages as for example:

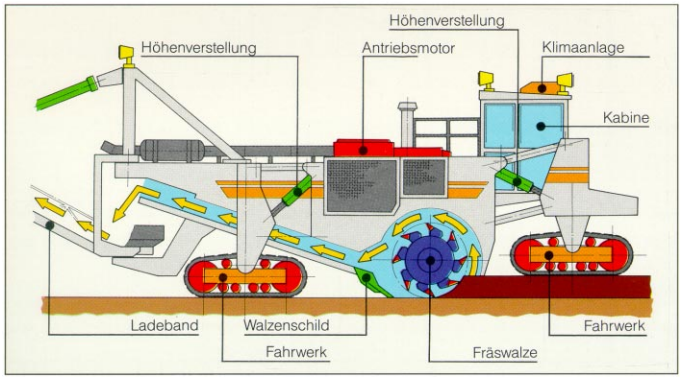
- Less coal loss and dilution.
- Improved coal recovery especially in areas sensitive to blasting.
- Less stress and strain on trucks due to minimum impact of the excavated material.
- Primary crushing and fragmentation of coal.
- Reduced capacity requirements for coal washing/preparation plants.

In this paper the development of the large Surface Miners within the last two years, their possible applications and the costs of such a system are explained by giving a number of examples.

1. General description of surface miners

Basically three types of surface miners are available on the market today :

- *machines with middle drum configuration*



Pic.1 : Schematic drawing of machine with middle drum configuration

Pic.2 : Example of machine with middle drum configuration

- *machines with front boom cutting drum*

Pic.3 : Example of machine with front boom

- *machines with front cutting wheel*

Pic.4 : Example of machine with front cutting wheel

General Technical Data

	middle drum	front cutting boom	front cutting wheel
cutting width [mm]	250 - 4200	5250	7100
cutting depth/height [mm]	0 - 800	1000/5500	0 - 2900
capacity	for all machines output is related to material characteristics		
weight [t]	40 - 190	135	540
installed power [kW]	450 - 1200	750	3340
Manufacturer	Wirtgen / Bitelli / Huron /	Voest Alpin	Krupp Fördertechnik

Table 1: Technical data of Surface Miners

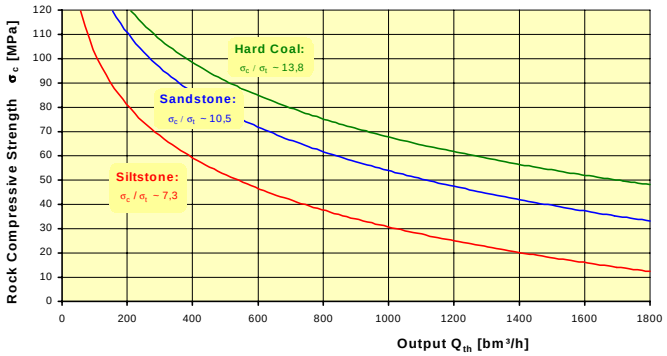
Of these three types of machines the machines with middle drum configuration (the SM type machines from Wirtgen) find the widest range of applications specially in small scale operations below 1000 t/h required output.
The KSM type machine from Krupp Fördertechnik is three times bigger than the largest SM type machine and specially designed for large scale operations in overburden and coal.
The following chapters are therefore only dealing with this type of machine and in the text the abbreviation KSM is used as name for the machine.

2. Description of Large Surface Miner with Front Cutting wheel - KSM

The KSM is a mobile, continuously operating open cast mining machine. It is suitable for the mining of compacted soils and rocks up to a compressive strength of approx. 70 - 80 MPa without drilling and blasting and loading of the mined masses on downstream transport systems.
The application of the KSM offers advantages whenever the following conditions have to be met:

- Mining of huge masses
- Selective mining of changing rock layers with thickness exceeding 0.5 m
- Selective mining with a high separation accuracy
- Production of lump sizes suitable for belt conveying with less fines
- Use of cost-beneficial belt conveyors.

In view of the applied mining technology, the KSM is not suitable for the mining of soils with plastic consistency such as clay or loam, whose natural water content exceeds the plastic limit.
The output of the KSM amounts to 1400 bm³/h in continuous cutting operation
under nominal conditions. The output changes in relation to the compressive strength, brittleness, jointing and abrasivenes of the rocks (for detailed output calculations see Graph.1).



Graph 1 : Capacity of KSM in relation to compressive strength and tensile strength

The KSM digging process starts by turning the bucket-wheels, which are equipped with point-attack-picks and slowly and continuously advancing the machine, the face in front of the bucket-wheels is mined. The maximum dimensions of the cut are 0.6-times the bucket-wheel diameter by the width of the four bucket-wheels.
The KSM 2000 attains its nominal capacity in rocks with a compressive strength of up to 40 MPa (6000 psi). At reduced capacity, it can be operated in rocks of up to 80 MPa (12000 psi), in special cases like small lenses and/or thin layers of up to 120 MPa (18000 psi).
The spectrum of mineable materials ranges from soils with semi-solid consistency such as compacted clay and loam to claystone, marl, siltstone and medium-solid sandstone.
Pay minerals such as lignite and hard coal or limestone can also be mined.

3. Design and functional description

The machine itself consists of five main assembly and functional groups with following main data :

- Undercarriage with 2-crawler assembly
  - Length 9183 mm
  - Track pad width 1300 mm
  - Travel speed when cutting 0.37 - 3.0 m/min
  - Travel speed when relocating up to 31.9 m/min
  - Possible Inclinations :
  - longitudinal 6.0°
  - transversal 5.0°
- Superstructure
- Bucket-wheel head
  - Number of bucket-wheels 4
  - Number of buckets per bucket-wheel 20
  - Diameter of cutting circle 4860 mm
  - Cutting speed at cutting circle 1.53 m/s
  - Total width of bucket-wheel head 7100 mm

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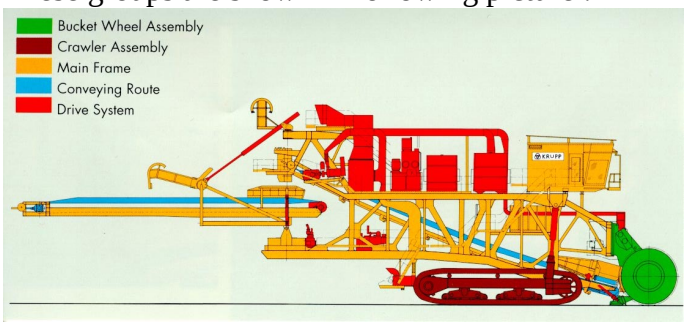
- Conveying route
  - Conveyor belt width 1600 mm
  - Belt speed 3.8 m/s
  - Length discharge boom 15.6 m
- Drive system
  - Number of diesel engines 2
  - Rated engine output ea. 1,667 kW
  - Fuel tank 12,000

These groups are shown in following picture :



Pic. 5 : Main assembly groups

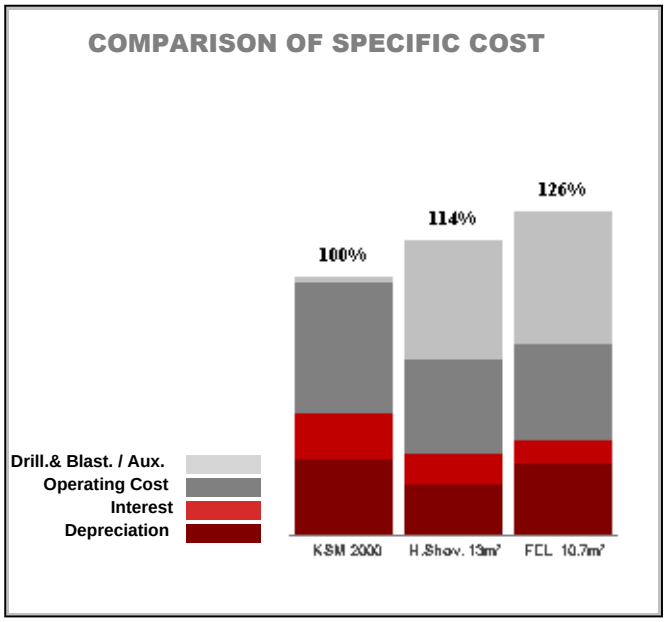
4. Possible applications of large surface miner

The KSM can be used in discontinuous and continuous open cast mining systems. The most common type of application is probably a system that uses trucks for transport of the material. Direct combinations of KSM with conveyor systems are also possible, as well as mixed systems where the trucks are used on short cycles to transport the material to a semi-mobile loading station for further conveyor transport.
The following sections describe in detail some example applications.

4.1 KSM - discontinuous transport with trucks

The operation between the KSM and trucks is similar to an open cast mining system operating with rope shovels or wheel loaders. For optimisation of the KSM-open cast mine system, the following points should be considered during operation.
During loading, the trucks are positioned parallel to the KSM. The truck traffic should be organised in such a manner that the trucks arrive and depart parallel to the KSM without shunting, turning or backing up.
The capacity of the truck body should be chosen in such a way that during normal operation, the truck stands still while the KSM moves forward and loads the truck uniformly over the whole length. A uniform loading of the trucks ensures minimum operating costs.

The most favourable operating conditions for the KSM are a relatively long and even bench. At the end of the bench, sufficient space should be available for turning and ramping in and out of the cut.
A situation frequently encountered in open cast mines is the mining of inclined seams or partings. Such an adaptation to the deposit is easily possible up to an inclination of 6° in the longitudinal and 5° in the transverse directions.
For all this type of operations the economics of the KSM - system have to be compared with either shovel or wheel loader systems which could perform the same job.
Such a calculation has been done exemplary for a mine in India :



Graph 2 : Graphical comparison of specific cost

		KSM	Hydr.Shove	FEL
Equipment Type		KSM 2000	H.Shov. 13m³	FEL 10.7m³
Operating weight	tonnes	540	230	89
Operation Life	years	10	10	5
Annual oper. time	eff hrs	4 300	4 100	4 100
Hourly Productivity	t/h	3 370	1 410	1 020
av.Benchheight	m	3-5m	3-5m	3-5m
Material: Waste				
Compr.strength	MPa	30	30	30
Specific gravity	t/bm³	2.20	2.20	2.20
Wages	US$/h	1.12	1.12	1.12
Fuel Price	US$/l	0.32	0.32	0.32
Interest rate	%	10%	10%	10%
O & O COST		100%	114%	126%
DRILL.& BLAST. / AUX.		2%	41%	42%
Operating Cost		51%	32%	30%
Interest		18%	10%	7%
Depreciation		7%	17%	22%

Table 2 : Data for comparison of KSM / HS / FEL

India has been selected as exemplary country because it has relatively low wages, and average costs for fuel and explosives.

This economy cost calculation shows clearly the tendencies for application of the surface miner. The machine is advantageous in mines where drilling and blasting is required and where this costs have a sufficient amount within the total mining system.
Two figures which are also decisive for surface miner applications have not been considered within this calculation because they will vary very much within different mine sites:

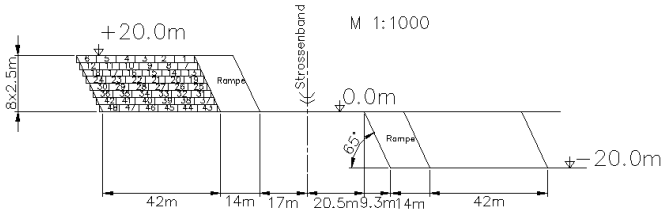
- the costs for crushing of pay mineral and
- the additional benefits which are gained from the selective operation itself, specially the higher yield of product, less dilution of product compared to blasting and less creation of fines.

Two short exemplary calculations shall show how important these factors may be.

Example A :
In a mine which produces approx. 1 million tons of coal from a multiple seam operation the higher coal output in the selective surface miner operation may add up to approx. 30.000 to 50.000 tons product without additional investment.
With an exemplary coal price of 8 US$/ton this adds up to an additional income of 240.000 to 400.000 US$ per year.
Example B:
If the operation is in pay mineral which has to be crushed, the application of a surface miner will reduce the primary crushing costs. If e.g. 5 mio tons of mineral are mined with a surface miner and the primary crushing costs are conservatively estimated to be only 5 cents per ton the utilisation of a surface miner will give savings of approx. 250.000 US$ per year.

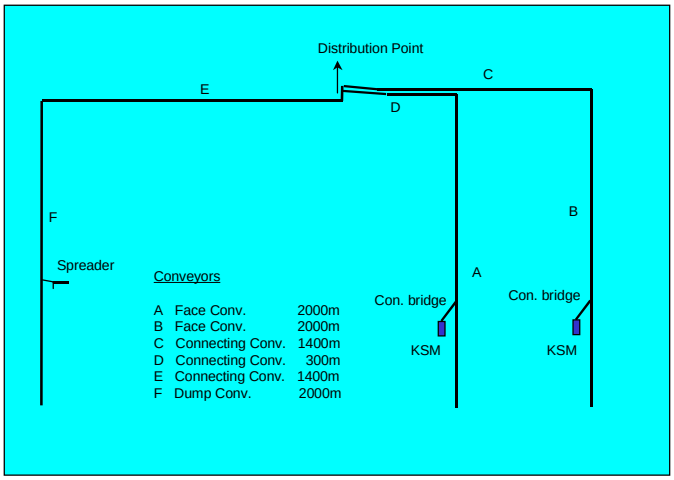
4.2 KSM application in combination with conveyor transport

A continuously operating open cast mining system with KSM requires a bench conveying system and a mobile link, such as a belt wagon or a conveyor bridge for connecting the KSM to the bench conveyor. A careful planning of the open cast mine ensures a continuous and economic operation. Compared with the combined discontinuous / continuous operation, this system is more cost-beneficial in the long run, as the intermediate truck transport is not required.
The following example shows the operation of the KSM and the Receiving Conveyor Bridge on Crawlers when working in the high- and deep block mode, i.e. above and below bench conveyor level.
Both the high and deep block are subdivided in 8 slices comprising 6 cuts each, i.e. a total of 2 x 48 = 96 cuts. Considering the dimensions of the cuts with 7 m width and 2.5 m height, the full block is 42 m wide and 20 m high.



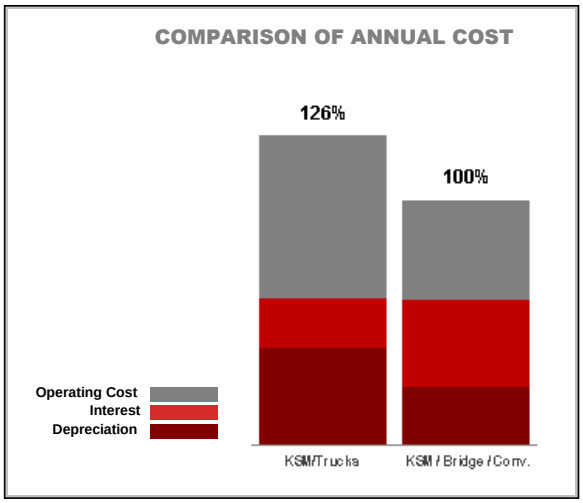
Pic. 6 : Highblock

One actual project for such a system in Russia looks as follows :



Pic. 7 : General layout of KSM project in Russia

Two KSM will be applied in an 80 m overburden removal operation. The overburden is excavated by the surface miners and loaded via two belt bridges on to two face conveyors. The two face conveyors lead to a conveyor distribution point. Here the material can be transfered either to the overland coal conveyor or to a conveyor leading to the dump site. On the dump site the overburden is spread by one spreader.
An economic cost calculation for such a system in Russia looks as follows :



Graph 3 : Graphical comparison of specific cost

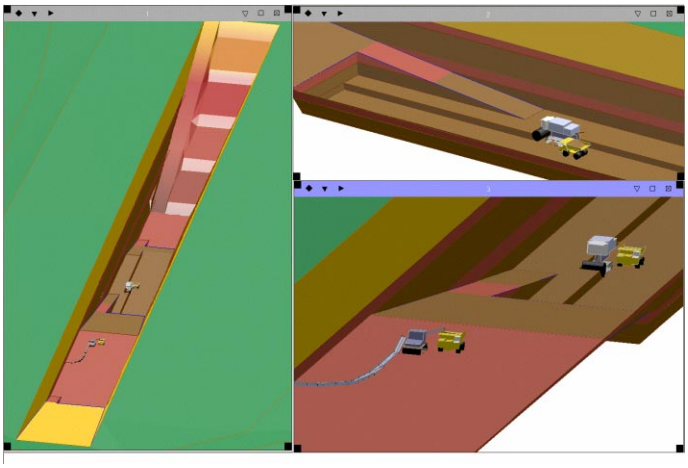
		KSM 2000 / Trucks		KSM /System
Equipment Type		KSM 2000	Cat 789B	KSM / Bridge / Conv.
Operating weight	tonnes	540		306
Operation Life	years	10	7	20
Unit Price	M US$	13.6	1.6	27.2
No of units		2	18	2
Annual oper. time	eff hrs	4 300		4 300
Hourly Productivity	t/h	3 060		3 060
Overburden	M t / a	29.0		29.0
El.power	US$/kWh		0.015	
Fuel Price	US$/l		0.20	
Wages	US$/h		2.00	
Interest rate	%		10%	
O & O COST		100%		79%
Operating Cost		53%		41%
Interest		16%		36%
Depreciation		31%		23%

Table 3 : Data for comparison of KSM / Conveyor system

In this case which compares the KSM / truck system with a KSM / conveyor system the clear advantage of the conveyor transport system with it´s low operating costs is shown.

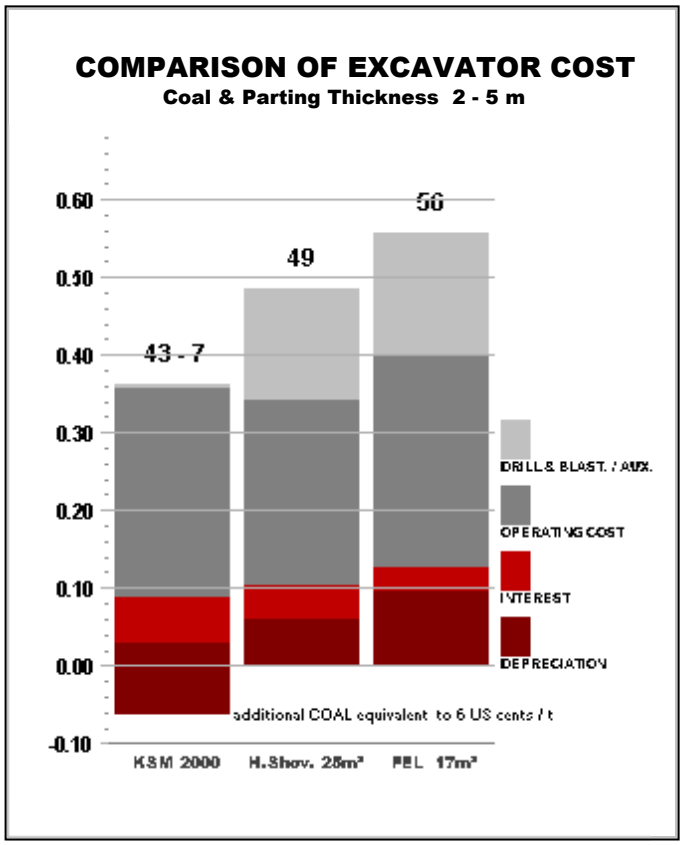
4.3 KSM application in a trench / high wall mining system

Auger mining is sometimes employed to recover any additional coal left in deep overburden areas that cannot be reached economically by further contour or area mining. A highwall mining system consist of a flexible conveyor system behind a
continuous auger miner. The mining system with the KSM, Auger miners and trucks works without drilling and blasting. This system assures a very clean coal production with a high recovery rate because neither the KSM nor the auger touch interburden during their cutting process in coal.
The physical layout of a trench is shown in the attached picture no. 8. The trench itself is approx. 1000 m long and 50 m depth. The width on the top is 100 m, on the bottom (the third floor in this example) the trench reaches a width of 53 m.
In the example drawing, the overburden depth is approximately 20 metres and the interburden layers are 5 - 10 m thick. The three coal seams are assumed to be 3 metres each.
The coal in the trench is completely mined by the KSM with a defined separating cut between coal and waste. The share of coal mined by the KSM is over 20 % of total coal production (assuming that the auger recovers approx. 50 % of the 250 m left and right of the trench).
Trucks transport the overburden over the working floors to the waste dump using the shortest possible route. It isn' t necessary to lift the over- or interburden to the top of the trench. The haulage ramps to the waste dump are also cut by the KSM, minimising the need for road construction equipment.
The sidewalls of the trench are very stable because blasting does not affect them. This also means that the danger of falling rocks is minimised and that the stability of the high walls is great, allowing for a better coal recovery of the auger itself.



Pic. 8 : General layout of Trench / KSM / Auger Miner system

For this system the economy cost calculation looks as follows :



Graph 4 : Graphical comparison of specific cost

		KSM	Hydr.Shovel	FEL
Equipment Type		KSM 2000	H.Shov. 25m³	FEL 17m³
Operating weight	tonnes	540	490	177
Operation Life	years	10	12	5
Annual oper. time	eff hrs	4 300	4 100	4 100
Hourly Productivity	t/h	2 670	2 720	1 660
av.Benchheight	m	3-5m	3-5m	3-5m
Material: Waste & Coal				
Compr.strength	MPa	20	20	20
Specific gravity	t / bm³	1.70	1.70	1.70
Wages	US$ / h	33.55	33.55	33.55
Fuel Price	US$ / l	0.22	0.22	0.22
Interest rate	%	10%	10%	10%
O & O COST		100%	137%	157%
DRILL.& BLAST. / AUX.		2%	30%	29%
Operating Cost		63%	49%	48%
Interest		14%	9%	6%
Depreciation		22%	12%	17%

Table 4 : Data for comparison of KSM / Auger Miner system

This cost calculation takes into consideration that the possible coal recovery in the trench is higher with a surface miner system than with a system which requires drilling and blasting and where the connecting benches to the dump side have to be prepared at the sides of the trench. The calculation assumes the same overburden excavation by both systems and shows the positive effect of the additional coal recovery as a conservative figure of 7 cents per ton related to total costs of mining.

5. Summary

The new technical mining system of large surface miners with technical data of the machine, possible applications and economics of the machine has been presented. The cost calculations show that it is most beneficial to apply such a system where ever it is technically feasible.
As all other large mining equipment the large surface miners will find their use in large mines with high mineral output and high overburden handling rates. Preliminarily they offer advantages because of their high selective mining capabilities which allow for clean mineral recovery without the need for drilling and blasting. Compared to other mining systems like shovels and front end loaders we find between 10 to 25 % cost savings. Additional savings will be possible when it is feasible to apply conveyor transport behind the KSM and / or when pay mineral will be mined which has to be crushed.