International Journal of Mining Science (IJMS)
Volume 1, Issue 1, June 2015, PP 1-9
www.arcjournals.org

Technical and Economic Aspects of the Sleipner System in Real Use

Philipp HARTLIEB[1], Erik Horst Carl ERKENS[2]

[1] Chair of Mining Engineering and Mineral Economics, Montanuniversitaet Leoben, Austria; corresponding author

[2] Heidelberg Cement Group

Abstract: *The Sleipner system is composed of a pair of wheels for hydraulic excavators. It is used in combination with a dump truck and allows for quick relocation of the excavator in one mine or between different mine sites of one company. Customers are offered a broad range of benefits starting from quicker transition times to increased availability and reduced down-time and maintenance costs. We show that the benefits are largely depending on the way of application and geometry of the specific mine site where the system is in use. In extreme cases an increase of availability of 79 %, significant reductions of fuel consumption and increased maintenance intervals (factor 1.5) of the undercarriage and the chain of the hydraulic excavator are reported.*

Keywords: *sleipner, selective excavation, availability, flexibility*

1. INTRODUCTION

Selective excavations and mining at different positions are major challenges for the flexibility of the applied mining machinery. On the one hand side large distances between single draw points can be most efficiently covered with wheel loaders. On the other hand chain driven hydraulic excavators are superior in terms of productivity, way of application and space consumption at the specific draw point. The sleipner system tries to combine the positive aspects of both types and therefore increase the flexibility and mobility of chain driven excavators.

The sleipner System Solution contains a pair of the sleipner shoes, the hydraulic excavator with chain undercarriage and the normal or articulated dump truck. With these sleipner shoes it is possible to relocate the excavator inside one or between two mines or quarries similar to a semi-trailer with dump trucks or dumpers. Each sleipner shoe consists of a welded massive steel base frame in form of a shell, enclosing the end of the chain undercarriage, with one or more non-driven wheels on each side depending on the model (Figure 1). The wheels are mounted to welded stub-axels on the outer side. To keep the sleipners in place when parked in uneven areas (up to 15 % inclination) they are fitted with automatic safety brakes on the inside of the rim.

The usage of the sleipner system by chain driven hydraulic excavators is done in several easy steps: The starting position for a complete cycle of relocating the excavator is defined at that point, where the digger operator has finished the loading of raw material at point A and needs to get to the next excavation site called point B.

First, the bed of the dumper used for the relocation is loaded with one or two shovels of material to prepare it for the later reception of the supported bucket and to prevent damages. Subsequently, the excavator operator drives forward into the sleipner shoes (Figure 2) to control the drive in and the correct fitting of the sleipners from inside the cabin. Meanwhile the release of the automatic safety brakes is caused by the chain chassis pushing the brake mechanics. If the sleipners are in incorrect position for driving into them, the operator can displace them by the attached steel cord with his bucket teeth to the right position.

Figure1. *Base frame and stub axels of asleipner shoe.*

Figure2. *Hydraulic excavator pulling into a pair of sleipner shoes.*

If the sleipners are correctly installed the upper carriage is turned around and the excavator boom is lifted up to allow for the following connection with the dump truck. After driving the dumper backwards under the lifted excavator boom the boom is lowered into the prepared dumper bed. By pushing the boom lower the chain chassis is lifted into a horizontal position so that the excavator is now only resting on the dumper and on the two sleipners. The load distribution amounts about 20 percent weight onto the dumper and 80 percent on to the sleipners. The dumper is now capable to haul the excavator on the free rolling sleipners to the next digging point B (Figure 3).

Figure 3. *Hydraulic excavator resting on the dump truck and the sleipner shoes while moving.*

At point B the operator now raises the excavator boom to get back onto the ground with the chain chassis and to release the dumper. At last the upper carriage is turned again about 180 degrees to control the correct rear pull out. After that the excavator is now able to continue with the normal loading cycle with the already prepared dumper. Because of the automatic safety brakes the sleipners remain at that position, where the operator pulled out and wait for the next operation. During the whole process of relocation the dumper operator and the excavator operator remain seated in their cabins.

Apart from a significant reduction of travelling time and thus increased productivity of the hydraulic excavator further improvements like longer service intervals, especially of the undercarriage, reduced maintenance costs and a reduction of fuel consumption and CO_2 – emissions are expected when using the system.

The goal of this paper is to assess whether these promises are valid and to provide an overview of the functional principles of the sleipner system in real use.

2. Data Acquisition and Methods

The sleipner system is in use in a wide variety of mining companies all over Europe. Five of those mines have been chosen according to their application of the sleipner system and their willingness to provide data on the use of the system in their operations. The requested data can be summarized in 5 large groups being: Equipment, Procedure, Maintenance, Mine Planning and Costs. Data was collected via questionnaires and personal interviews with the persons in charge for the respective companies. An overview of the provide data can be seen in Table 1.

In the chapter *equipment* all parameters and data were recorded that are linked to the usage of the sleipner shoes, like the type of the used machines and their power and weight classes, to be able to see relationships and correlations between the combinations of sleipners, dumpers and excavators.

In *procedure* all the important comparable times including distances and height differences / changes in altitude have been collected in order to get a general overview about the operating conditions and the geometry of the mine site.

Maintenance first includes the question about the place of the servicing of the hydraulic excavator. It is important to know if service takes place in the mine or in a workshop and which distances have to be covered to and from the workshop. It is of interest to know about the possible change of maintenance intervals or type of maintenance at the undercarriage, the crawler tracks or the driving chains. Additionally it is important to investigate the maintenance of the sleipner system itself and not only the one of the excavator.

Whether or how the usage of the sleipner shoes does impact the mining plan and management or if they effect a more selective extraction was asked in the chapter *mine planning.*

In order to assess the financial component of the use of the sleipner system the section *costs* investigates whether the use of the sleipner system has any influence on the cost structure or spendings of the investigated companies.

Table 1. *Overview of mines, equipment, use of sleipner and maintenance*

			Mine 1	Mine 2	Mine 3	Mine 4	Mine 5
Overview	Company		Mine 1	Mine 2	Mine 3	Mine 4	Mine 5
	Sleipner (type)		E120-700	E70-800	E90-600	E90-600	E90-750
	Excavator (type/weight)		Komatsu SP1250; 125 t	3x Liebherr R944C; 45 t	Liebherr R954; 87 t Hitachi 670Z; 70 t	Liebherr R974; 80 t	Caterpillar 390D; 90 t
	Loader (type/power)		3x Komatsu 785; 1000 PS 7x Komatsu 985; 1200 PS	4x Volvo A30; 340 PS	3x Caterpillar 775F; 800 PS	Caterpillar 773; 680 PS Komatsu HD 605; 740 PS	4x Caterpillar 775D; 800 PS
	In use from/to		May 2012 - today	November 2007 - today	2006 to 2011	Jan 2008 - today	January 2012 - today
Operation	Process		In pit	Between quarries	Between quarries	In pit	In pit
	Usage/month	[1]	4-12	4-8	14-16	8-9	50-75
	Distance [km]	[km]	4-6	1-6	1.5-3	1.5-2	1-2
	Height difference	[m]	400	~200	Max 150	~100	150
	Required time (wS)	[min]	60-90	30-120	90-120	90-100	30-60
	Required time (S)	[min]	20-25	5-25	40-60	10-15	5-10
	Pull in/out	[min]	1	0.5	2	0.5	1-2
	Operating/month	[h]	300	2x 120	300	120	160
Maintenance	Workshop/ working face		Workshop	At working face	Workshop	Workshop	Workshop
	Distance	[km]	~4.5	- - -	Max 1.2	0.3-2	0.7-1.25
	Height difference	[m]	400	- - -	Max 100	20-80	Max 100
	Required time (wS)	[min]	60-70	- - -	50	15-100	25-40
	Required tims (S)	[min]	20	- - -	20	2-15	2-5
	Maintenance Sleipner		Lubricate, adjust brakes	Lubricate, adjust brakes	Lubricate, adjust brakes, little cracks welding	Lubricate	Lubricate, adjust brakes
	Reduction maintenance chain		Specified by manufacturer	Yes	No	Yes	Yes
	Percentage of reduction		No information	No information		No information	No information
	Maintenance interval chain		Every 500 h	3000 h	After inspection plan	No information	No information
	Extension of interval		No information	1.5 x longer	No	Yes	No information
Mine Planning	More flexible mine planning		No information	No	No	No	No
	More flexible mine management		A bit	Yes	No	No	No
	More selective extraction		No information	Yes	No	Yes	No
	Other comments		Used for narrow benches	Used for narrow benches			Same flexibility like wheel loaders but higher tensile forces
	(S)...using the Sleipner system						
	(wS)...without using the Sleipner system						

3. Data Analysis

The extent of the collected data at the plants allows combining several individual groups of data for comparison and analysis of different relationships. It is possible to calculate the reduction of time spent while travelling on tracks from one point of extraction to the other or from one quarry to another and a relative change can be estimated.

As a result, it is possible to derive the different speeds of the different sleipner - excavator - dumper´ combinations. Similarly, the indication of the resulting better fuel economy and depending lowered emissions is possible to be shown in detail. The individual statements of changes in the maintenance procedures are also comparable.

3.1 Travelling Time

The required times given by the companies for the relocation of the excavator with and without the sleipner system with their corresponding pull in and pull out times are extrapolated to the total monthly time spent travelling and shown in Table 2. With this data the effective as well as the relative differences between sleipners and the conventional system are calculated. The result of that examination of the timespan needed for the relocation of the excavator, shows that the total duration of relocating per month can be reduced from 54 % up to a maximum of 85 % by using the sleipner system. Considered individually, these are reductions from up to 18 h of relocating down to only 5 h at Mine 1, from maximum 16 h down to just 3.4 h at Mine 2, from 33 h at Mine 3 down to less than 16.5 h, from a maximum timespan of 15 h down to just 2.3 h at Mine 4 and from impressive 78 h relocation timespan per month without using the sleipner system down to just 12.5 h with the sleipners at Mine 5.

Table 2. *Overview of times spent for travelling with and without sleipner system*

		Mine 1	Mine 2	Mine 3	Mine 4	Mine 5
Usage/month		4-12	4-8	14 - 16	8-9	50-75
Required time (wS)	[min]	60-90	30-120	90-120	90-100	30-60
Required time (S)	[min]	20-25	5-25	40-60	10-15	5-10
Pull in/out	[min]	1	0.5	2	0.5	1-2
Total travelling time/month (wS)	[h]	4-18	2-16	21-33	12-15	26-78
Total travelling time/month (S)	[h]	1.0-5.0	0.4-3.4	9.8-16.5	1.4-2.3	5-12.5
Decrease of travelling time	[h]	**3-13**	**2-13**	**12-16**	**11-13**	**21-65**
Relative decrease of travelling time	[%]	**66-71**	**82-79**	**54-49**	**88-85**	**81-84**

(S)...using the Sleipner system
(wS)...without using the Sleipner system

3.2 Stand-Up Time

The monthly operating times of the hydraulic excavators provided by the mines with and without the sleipner system with their corresponding pull in and out times were used to calculate the change of the standup-times in total and relative values. Table 3 demonstrates the difference in machine availability with and without the use of the sleipner system.

Inspecting the results of the standup-times of the different quarries significant differences are recognizable: At Mine 1 the increase of the standup-time of the hydraulic excavator is only 0.9 to 4.6 %, corresponding to a total increase of 2 hours and 40 minutes up to 4 hours and 36 minutes. That is attributed to the only small proportion of the travelling time even without using the sleipner system of a maximum of 6 % with 18 hours travelling of the 300 monthly operational hours. Even though the time spent travelling on tracks can be decreased between 66 and 71 % this only leads to an increase in the availability of between 0.9 and 4.6 %.

At Mine 2 an increase of standup-time of between 0.7 and 5.7 % is measurable. These values are a result of the proportion of a maximum of 3.4 % travelling time of the total 240 hours of operation per month. Although the travelling time can be decreased up to 82 % the stand-up time is not influenced as significantly.

At Mine 3 the standup-time increases between 4.2 and 6 %, because of the 49 to 54 % decreased time spent travelling on tracks that have been a maximum proportion of 10.8 % without using the sleipner system.

The increase of the standup-time at the Mine 4 is between 9.9 and 12.2 %, because the 85 to 88 % decreased travelling time had a maximum proportion of about 12.5 % of the total operational time without using the sleipner system.

At Mine 5 the increase of the standup-time can be improved between 15.5 up to a maximum of 79 %. The proportion of the total operating time travelling on tracks is about 48 % without using the sleipner system and that time can be decreased about 81 to 84 % by using the sleipner system.

If the same proportion of time of the availability of the excavator (standup-time) is used for production by using the sleipner System Solution as using the conventional system for relocation of excavators, the production can be increased about the same percentage as the Standup-time. It is therefore possible to achieve a real increase in the productivity by using the sleipners.

Table 3. *Standup-times with and without using the sleipner system*

		Mine 1	Mine 2	Mine 3	Mine 4	Mine 5
Usage/month		4-12	4-8	14-16	8-9	50-75
Required time (wS)	[min]	60-90	30-120	90-120	90-100	30-60
Required time (S)	[min]	20-25	5-25	40-60	10-15	5-10
Pull in/out	[min]	1	0.5	2	0.5	1-2
Operating/month	[h]	300	2x 120	300	120	160
Total travelling time/month (wS)	[h]	4-18	2-16	21-33	12-15	26-78
Total travelling time/month (S)	[h]	1-5	0.4-3.4	10-16.5	1.4-2.3	5-12.5
Total standup-time/month (wS)	[h]	296-282	238-224	279-267	108-105	134-82
Total standup-time/month (S)	[h]	299-295	240-237	290-283	119-118	155-148
Increasing of standup-time /month	[h]	**3-13**	**2-13**	**12-16**	**11-13**	**21-65**
Increase of standup-time	[%]	**0.9-4.6**	**0.7-5.7**	**4.2-5.9**	**9.9-12.2**	**15.5-78.8**
(S)...using the Sleipner system						
(wS)...without using the Sleipner system						

3.3 Speed

The average speed of the chain driven hydraulic excavators while travelling with the sleipner system or on their own chains is calculated by considering the average transport distances given by the companies and the associated needed time span for travelling the same ways with and without the sleipner system and their corresponding pull in and out times.

The calculated velocities with and without sleipners differ in the increase of speed of the self-driving excavators with chain undercarriage to the relocation of the same with the sleipner system, as well as in the driven speed, between the different companies, itself. The increase of speed of about 200 to 360 % at Mine 1 from 4 to 12 km/h is significant. Here the roadway in the quarry just consists of a few straight lines of about 200 to 300 m, but has many 180 degree turns with slopes up to 10 %, where the speed advantage of the sleipner system can only be used partially. The calculated average speed at Mine 2 increases from 2 to 3 km/h at the self-driving excavator up to 12 to 14.4 km/h by using the sleipner system, representing an increase of speed of 380 to 500 %. That increase results from the driven route of the relocation, which is characterized by many straights but just a few tight bends and only partially short slopes of up to 25 %. The increase of 100 to 125 % by the self-driving excavator with a speed of 1 to 1.5 km/h to a speed of 2.25 to 3 km/h by relocation the excavator with the sleipner system at Mine 3 shows that, due to the routing and design of the quarry, the system cannot fully exploit its advantages concerning the average relocating speed. Mine 4 reaches an average speed of 8 to 9 km/h when moving with the sleipners representing an increase of 566 to 800 % compared to the self-driven excavator without sleipners. This average relocation speed is the result of the typical travel distances of 1.5 to 2 km and their corresponding pull in and out times and the combination of a 80 texcavator to a 700 hp dumper.

At mine 5 the average relocation speed increased by using the sleipner system is about 500 %. The self-driving excavator reaches an average speed of 2 km/h while travelling on chains from one mining face to another; whereas up to 12 km/h can be driven using the sleipner system for relocation. Those values are the result of the favorable route design of mostly straight sections with slope of only 8 % and only one 180 degrees turn per action.

Table 4. *Average speed of movement of hydraulic excavator with and without the use of sleipner system*

		Mine 1	Mine 2	Mine 3	Mine 4	Mine 5
Distance	[km]	4.0-6.0	1.0-6.0	1.5-3.0	1.5-2.0	1.0-2.0
Required time	[min]	60-90	30-120	90-120	90-100	30-60
Required time (S)	[min]	20-25	5-25	40-60	10-15	5-10
Pull in/out	[min]	1.0	0.5	2.0	0.5	1.0-2.0
Velocity (wS)	[km/h]	**4.0**	**2.0-3.0**	**1.0-1.5**	**1.0-1.2**	**2.0**
Velocity (S)	[km/h]	**12.0-14.4**	**12.0-14.4**	**2.25-3.0**	**9.0-8.0**	**12.0**
Increasing velocity	[km/h]	**8.0-10.4**	**10.0-11.4**	**1.3-1.5**	**8.0-6.8**	**10.0**
Increasing velocitiy	[%]	**200-360**	**500-380**	**125-100**	**800-566**	**500**
(S)...using the Sleipner system						
(wS)...without using the Sleipner system						

3.4 Fuel Consumption

The calculation of fuel savings due to the use of the sleipner system is based on a lot of different data that need to be compared and combined with each other. The data of the fuel consumption per kilometer of the excavator while travelling on tracks and also the data of the sleipner system combination of the excavator, the sleipners and the dumper per kilometer are combined with the number of relocations of the excavator per month and the average distance per operation to take them onto a monthly basis. With the information about the fuel consumption of the excavator while digging and the data about the monthly standup-times with and without using the sleipner system it is possible to calculate the total fuel consumption of digging time on a monthly basis. The sum of the monthly fuel consumption for digging and the monthly fuel consumption while travelling on tracks or with the sleipner system gives the total fuel consumption of the whole operation with and without using the sleipner system. On that basis it is possible to calculate the total fuel savings per month and also the percentage savings of the system compared with the conventional method of relocating the hydraulic excavator. Details are shown in Table 5

Table 5. *Calculation of fuel consumptions of hydraulic excavators with and without using the sleipner system.*

		Mine 1	Mine 2	Mine 3	Mine 4	Mine 5
Usage/month		4-12	4-8	14 - 16	8-9	50-75
Distance	[km]	4-6	1-6	1.5-3	1.5-2	1-2
Used Fuel/km trav. (wS)	[l]	81.6	11	20	20	25
Used Fuel/km trav. (S)	[l]	13.6	3.5	6.2	6.2	7.5
Safed fuel while travelling	[%]	**83.33**	**68.18**	**69**	**69**	**70**
Fuel/month trav. (wS)	[l]	1305-5875	44-528	420-960	240-360	1250-3750
Fuel/month trav. (S)	[l]	217-979	14-168	130-297	74-111	375-1125
Standup-time/month	[h]	296-281	237-223	278-267	107-104	134-82
Standup-time/month (S)	[h]	298-294	239-236	290-283	118-117	155-147
Fuel/month exc. (wS)	[l]	31393-29893	7853-7390	13927-13373	5398-5248	10062-6187
Fuel/month total (wS)	[l]	32699-35768	7897-7918	14347-14333	5638-5608	11312-9937
Fuel/month total (S)	[l]	31610-30872	7867-7558	14057-13671	5472-5359	10437-7312
saved fuel/month	[l]	**1088-4896**	**30-360**	**289-662**	**165-248**	**875-2625**
saved fuel (%)	[%]	**3.33-13.69**	**0.38-4.55**	**2.02-4.62**	**2.94-4.43**	**7.73-26.42**
(S)...using the Sleipner system						
(wS)...without using the Sleipner system						

The calculated total fuel consumptions and savings by using the sleipner system show, that the relative reduction of used fuel is different in each quarry. It is remarkable that the larger the hydraulic excavator is the greater the potential savings during the relocating are. Distances and frequencies play a bigger role in the view of the total potential fuel savings of a quarry, demonstrated by Mine 5 with a saving of over 7 to about 26 %. The remaining plants are almost all in a range of 2 to 5 % of fuel saving by using the sleipner system, except for Mine 1 where the maximum potential savings are nearly 14 %. Compared to the relative savings the effectively saved liters of fuel vary significantly between the investigated plants. This is due to the different sizes of excavators in use and their respective consumption.

Please note: The calculated reductions in fuel consumption refer to the same loading capacity per month. In real use the measured total fuel consumption per month by using the sleipner system would be unnoticeable lower or in the extreme case slightly higher compared to the conventional method of relocating the excavators. This is due to the fact that while using the sleipners a higher loading capacity can be achieved resulting from increased stand-up time.

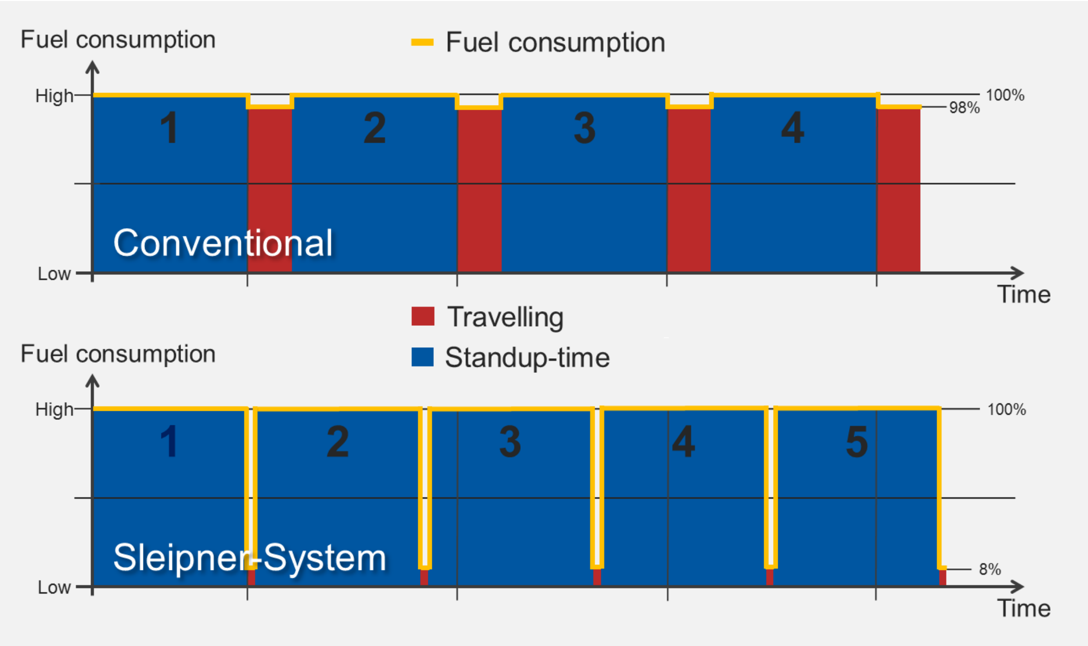

Figure 4. *Schematic representation of fuel consumption of a hydraulic excavator when digging and travelling with and without using the sleipner system.*

Figure 4 shows a schematic representation of the fuel consumption of a hydraulic excavator. Three different modes are identified: digging (standup-time), travelling on tracks and travelling with sleipners. The height of each blue marked block represents the fuel consumption while excavating at one single location, the width represents the timespan of excavation at that point. The height of the red blocks in between the blue ones represents the fuel consumption while travelling from one point of digging to another on tracks or with the sleipners, depending on the diagram. The width of the red blocks represents the time spent travelling on tracks or on sleipners. The total fuel consumption seems to be higher at the same time span using the sleipner system. However it is important to notice that in the same timespan the Excavator is able to excavate 5 blue units, while the conventional system is only able to excavate 4 blue units.

3.5 Emissions

CO_2 is considered as being the major climate-relevant greenhouse gas. However, with the use of certain fuels such as Diesel also other greenhouse gases are emitted. These additional gases are transferred into CO_2 – equivalents in the respective balance sheets. E.g.: 1 liter of Diesel emits 2.63 kg of direct greenhouse gases and 0.42 kg of indirect CO_2-equivalent gases resulting in total emissions of 3.15 kg of CO_2-eqivalent gases (Bayerisches Landesamt für Umwelt 2015) . This corresponds to a volume of 506 l or 0.506 m³ of CO_2.

It is easy to realize, that the emissions of CO_2 are directly depending on the fuel consumption. These values are accordingly the same compared to those explained in section 3.4. The absolute values of the saved CO_2 volumes show that with increasing share of the travelling time the potential savings of CO_2 emissions are also increasing when using the sleipner system.

4. Discussion

The result of this study shows benefits and saving throughout the whole process in the operational chain of hydraulic excavators and dump trucks in open pit mines where hydraulic excavators are in use as direct mining equipment or as assistive equipment.

To classify these results into a holistic view of the economic benefits within a mineral resource operation need to be set in relation to the other process modules of production.

According to Lurf (2008) 38 % of open pit mining costs are actually spent for the production of valuable minerals, 11 % are spent for infrastructure and service, 30 % for tailings handling and 21 % are spent for all other procedures. Of the 68 % of costs spent for production and tailings handling 9 % are spent on drilling, 12 % on blasting, 25 % for loading and at least 53 % are spent for haulage (Niemann-Delius and Fedurek 2004; Lurf 2008; Choi et al. 2009).

The life cycle costs of diesel fuel powered machinery are distributed to 40 % staff costs, 12 % energy costs, 21 % capital costs, 20 % maintenance costs, 4 % cleaning costs and the rest to downtimes and recycling costs (Grote 2014).

Due to the implementation of the sleipner system at Mine 1 averaged savings of 4.4 % of the life cycle costs of a hydraulic excavator can be determined, resulting in savings of approximately 3 % (1 % loading and 2 % haulage) at the total costs structure of the production and the tailings handling. Referring to the production costs of an entire mining operation total savings of approximately 2 % are expected divided in 1 % savings in production and 1 % savings in tailings handling.

The effect of an increased availability of the excavator by 3 % while decreasing the time spent travelling on tracks by 70 % and a reduction of fuel consumption by 13 % related to the total operation leads to a reduction of the production costs of the entire open pit mine of about 2 %.The cost share of the production of the valuable mineral can thus be reduced to a total amount of 37.6 % and the cost share of the tailings handling to 29.7 %. The cost share for infrastructure and service as well as for others accordingly amounts 11.2 and 21.4 %.

Other companies investigated in this study are expected to have an even higher effect on the cost structure by using the sleipner system. The example of Mine 5 shows that availability of the hydraulic excavator can be increased by 78 % by reducing the time spent travelling on tracks - which amounted to almost 50 % of the total operating time - by 80 %. A significant impact on the production cost structure of this mine is therefore expected.

The possible reduction of CO_2 emissions have not been accounted for in these considerations. However, they can be reduced by an average of 10 % and a maximum of 26 % when using the sleipner system.

Unfortunately the investigated mines did not document the service structure and maintenance carefully enough to draw major conclusions. Most of them kept the standard service interval for the excavator and its undercarriage despite the possible extension due to the usage of the sleipner system. Only Mine 2 monitored the wear of the driving chain. They could extend the service interval for the chain by a factor of 1.5 from 3000 to 4500 h. This only gives an idea of how large the possible positive effects of using the sleipner system on maintenance and service might be.

5. CONCLUSIONS

The sleipner system combined the benefits of a hydraulic excavator with the flexibility of a wheel loader. It could be demonstrated that depending on the setup of a mine several possible ways of improvement and increase of productivity can be achieved. The system offers savings especially for small companies, operating at different draw points or mine sites where the relocation of the hydraulic excavator can be done quickly and efficiently with the help of this system. Long straight roads with only few turns are most favourable for a significant increase in productivity by reducing the time spent travelling up to 80 %. This study could not sufficiently clarify the influence of using the sleipner system on maintenance, wear and service of the hydraulic excavator. This is mainly due to the fact that companies did only look for increased flexibility of their operations but did not control the real wear and adapt the service schedule accordingly.

ACKNOWLEDGEMENTS

We appreciated the help of all responsible persons who provided us with data and insights into their companies in order to investigate the performance of this system.

Mr. Jaakko Lipsanen and Mr. Teijo Höylä of sleipner Oy are thanked for valuable discussion and financial support for this study.

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