SLEIPNER transport systems – advantages and problems of operation

Summary: Results of research of the Sleipner transportation system for mining excavators. Economic benefit for the undercarriage of the excavators. Abnormal load on the structure of the excavator, mainly on the upper carriage and the slew ring. Overload on the slew ring due to dislocation of the centre of gravity of the excavator outside the slew ring. Inadmissible hoist of the chassis by hooking the ropes on the teeth of the bucket when wires of the rope are exposed to kink. Extreme overload of the braking and pulling forces of the dump truck.

Keywords: economic benefit, abnormal loads on dump truck and excavator, kink the ropes when hoisting the chassis, inadmissible load on bucket teeth.

A. Introduction

“We were born in North. In Cold. In tough conditions. Miners’ blood in our veins. We never gave up, whatever the task in front of us.

But we were different. We did not want to continue doing things like we were told to do – like our fathers did. We were rebels - We wanted to save resources: time and money. We wanted to make things easy and smart. Sleipner was born.

Our vision is to change the world of moving track equipment. Moving faster than anybody – like we our native Finnish heritage is demanding from us.”

This is the main slogan of Sleipner.

“For global mine operations and contractors who want to optimize their track equipment moving tasks in demanding conditions, who are open minded for changes and requiring highest return for their investment, Sleipner brings to it user easy-to-use and innovative solutions, made to last”.

That is the promise of Sleipner for the operators of open-pit mines hydraulic excavators:

The Sleipner System “Simply Ride and Roll”

Highlight the mobility
Simplicity – ease of use
Always visualization required.
Easy to remember: Rock’n Roll – Simply Ride and Roll.

Sleipner Campaigns Slogan: “Get more out of your mines”.

Encourages mine operations to challenge their current thinking.
Promising high returns which needs to prove to customer – in their own operations.  

The above promises and intentions of Sleipner for open-pit mines hydraulic excavators are the presuppositions to analyse the benefits of Sleipner but also the disadvantages, handicaps and risks of operating Sleipner hydraulic excavators transport systems. The entire influence of Sleipner to maintenance, repairs, fuel and transport time savings and risks for personnel, excavators and trucks are subject of this research.

B. The technology of Sleipner

Picture 1. Komatsu PC4000 pulled by a dump truck

Sleipner is a transport system where dump trucks are used to move hydraulic excavators on two chassis – one for each track of the excavator. The range of types of Sleipner starts with chassis for 20 t excavators and ends with chassis for 550 t excavators.

The choice of the right dump truck to pull the excavators is done as follows:

- There is a fix relation between the bucket size of an excavator and the dump truck it loads. This relation bases upon the ratio of 4 to 6 buckets loaded to a dump truck. This ratio is the most effective interaction between excavators and dump trucks.
- Concluding, an excavator of an approximate weight 200.000 kg and a bucket size of about 12 m³ (viz. 25.000 kg weight) effectively loads a dump truck with a payload of 100.000 up to 120.000 kg.
- Subsequently following the considerations of Sleipner, this truck is able to pull half the weight of the 200 tonnes excavator.  

The Sleipner chassis are built up of a frame with stop ridges, a strap brake to park the chassis, axles and bearings, a hoist rope and high pressure tyres. All components are simple mechanical parts without power unit, hydraulics, electrics, and electronics.
The Sleipner chassis is patented, the patent was granted in 2003. The patent gained recognition to protect an idea that never was realized before, not a technical innovation.

The operation of pulling an excavator with the Sleipner system starts with the placement of both chassis in front of the tracks of the excavator. To place the chassis the hoist rope has to be used, hooking the rope on the teeth of the bucket.

After having placed both chassis in front of the tracks, the excavator climbs upon the chassis with its tracks and the dump truck can be allocated in front of the excavator. The excavator driver puts the bucket on the dump body of the truck. Before this operation two buckets of pebble, gravel or similar material must be loaded to prevent the bucket to slip over the load floor of the dump truck.

Upon having finished this operation the transport can be preceded. The maximum speed of the dump truck – excavator unit can be about 15 km/h and the maximum slopes a safe transport is guaranteed could amount up to 15 %. The haul roads in any case must conform to the worldwide instructions of open-pit mine roads.

The excavator always has to be transported with switched on engine and all power systems in active mode. The reason for this is the possibility to lower the tracks in case of emergency stops and to compensate reflow of hydraulic oil during the transport.
In contrast to the speed of about 1 km/h of an excavator moving on own tracks, the speed of the dump truck – excavator unit can exceed 15 km/h.

C. Economic advantages

Sleipner uses a benefit calculation to demonstrate the effects of its transport system.

Of course, the transportation of an excavator by Sleipner saves unproductive time due to the 10 times higher transport speed. Fuel consumption will be saved, too. Even due to the fact that the operation of a Sleipner transport involves two machines with fuel consumption, on account of the much higher speed fuel use will be reduced.

A more important issue is decrease of needs of spare parts, maintenance and repair time.

As result of the mentioned savings, the production time also increases. A payback period of less than one year – from 4 to 11 months - is promised.
Mining excavator manufacturers of any brand refuse warranty when the time an excavator moves on its own tracks more than 7% of the entire operation time – i.e. approximately 1 km per working day. The board computers of all mining excavators easily show this percentage. This may make it worth to consider the use of a Sleipner system to transport an excavator.

Subject of this article is the research whether it is possible to transport excavators by using other types of machines operated in open-pit mines.

**D. Problems of operation – Reasons to operate Sleipner systems or not**

1. **Hoist ropes**

The chassis of a Sleipner unit are equipped with hoist ropes to lift and put them in front of the excavator tracks. Doing this, the ropes were hooked on the teeth of the bucket.

In all engineer standards and rope and bucket teeth supplier manuals the fact is fixed that such an operation is not allowed. Reasons for this prohibition are:

- **Bucket teeth**
  - Bucket teeth are made of high-alloyed steel which is very wear-resistant but refractory and brittle and there is no guarantee that they can bear the weight of the chassis. The load rating of load handling devices has always to be verified by appropriate strengths calculations which is never done for bucket teeth.
  
- **The extreme load to the teeth**
  - The extreme load to the teeth illustrates as an example the weight of one of the chassis of the Sleipner E550 with a weight of 42 tonnes. This is not a load that teeth can bear without causing dangerous situations. The use of teeth as loading device can result in breaks causing incidents and physical injuries with evil consequences. But the greatest hazard is that wires of the rope are exposed to kink and thus their load rating is inadmissibly decimated.

Thus the use of bucket teeth is not allowed in any country.
2. Stop ridges

As mentioned above the frames of the chassis are equipped with welded stop ridges. The target of these stop ridges is to hold the tracks tight to the frame during transport operations and to prevent the excavator from slipping off of the frame. Due to the fact that nearly all of the mining excavator types use different designs of the tracks, a frame with its welded stop ridges can be used only for this special kind of an excavator the frame was manufactured for. This makes the economic benefit quite doubtful when different brands of excavators with nearly the same weight are operated in a mine and every brand requires its own Sleipner. The same problem applies to different track plate widths.

Furthermore, these stop ridges are exposed to extreme wear and tear because before going fixed to the ridge stops the tracks of the excavator have to pass them. That makes them very liable to wear and after a couple of operations the stop ridges could be worn out in a way that they cannot fulfil their function and do not guarantee a proper form closure.

Thus in some countries there is no permission to operate Sleipners due to this fact.
3. Weight balance between dump truck and chassis

Picture 9 shows the weight balance between the dump truck and the chassis for a 570 tonnes excavator. About 60% of the weight of the excavator lies on the chassis and 40% the dump truck has to bear. Depending on the geometry of dump truck and excavator, the balance can differ from a ratio 70%/30% (excavator/truck) to 50%/50%.

Regarding picture 9 the dump truck will have a load of two buckets of pebbles – 68 m³ = 136 tonnes and 40% of the weight of the excavator – 228 tonnes. Thus the summary weight will be 364 tonnes. Sleipner recommends dump trucks with a payload of minimum 240 tonnes and maximum 320 tonnes for a 570 tonnes excavator. Simply to see that all recommended trucks are overloaded, the minimum truck by 50%. Thus the threat of overloading and hence damaging the trucks is predictable.

The problem in the weight balance is the displacement of the centre of gravity of the excavator. The centre of gravity of an excavator always must be located inside the slew ring. The slew ring is dimensioned in this manner. Any displacement of the centre of gravity outside of the slew ring is a factor of extended wear or break of the slew ring.

Not alone the overstress to the slew ring and the damages that can arise, the load on the attachment and the slew ring during the transport is 168% higher than the load during digging operation – 228 tonnes to 136 tonnes.

Additionally the transport of excavators on the Sleipner systems generates high dynamic forces. Vibration is not the problem because vibration has an impact on the steel structure only when the vibration forces exceed a certain level of force, so-called destructive force. Shocks during digging are drastically higher than those when it moves on own tracks. Destructive vibrations impacting on the life time of the slew ring occur due to the deflection of the tyres of dump truck and chassis.

As result of the examination of the weight balance, this kind of transport operation cannot be permissible. Similar considerations are valid for the entire range of Sleipner transportation systems.
4. Driving downhill and retarding

How all this balance will look like when the dump truck – excavator unit moves downhill?

The below diagram shows the continuous retarding chart of a 562 tonnes excavator, a dump truck with a Gross Machine Weight (GMW) of 570.678 kg recommended for the 562 tonnes excavator.

The weight of the empty truck is 257.678 kg plus 313.000 kg payload – 570,7 tonnes. It can be maximally overloaded for a period of 10% of the operation time with 20% above payload. Thus the maximum weight of the overloaded truck is 633,3 tonnes. With this weight the maximum continuous retarding force is achieved.

The weight balance of the truck plus two buckets plus the weight of the excavator plus weight of the corresponding Sleipner E550 summarizes up to 755,2 tonnes. The retarding force is exceeded. Down speeding is only possible by using the brakes.

Due to worldwide safety regulations and recommendations of dump truck manufacturers the maximum slopes in open-pit mines should not exceed 10%. Sleipner recommends a maximum slope of 15%. The brake force of the dump truck with normal payload accounts for 657,806 kN. The brake force for the complete Sleipner unit is 870,5 kN.

The combination of a CAT795F dump truck or even any other brand of a dump truck with a payload of 300 to 350 tonnes is an absolutely improper and dangerous action. Especially when the truck is equipped with an electric drive. An operation with such an overstress is absolutely not admissible. The entire braking or slow down operation has to be done by the braking system because the retarding doesn’t work at this overload.
5. Dump truck traction force and pulling uphill

Not only driving downhill and retarding is a huge problem for the trucks that brings excessive wear and overload to the power and braking units of a truck. When the Sleipner transport unit moves uphill the dump truck has to carry its own weight plus the weight of the pebble but additionally the weight of the excavator (see above). Reviewing the example of point 4 the truck has to generate an engine power to pull a weight of 870,5 tonnes. The weight of the truck with normal pay load amounts to 755,2 tonnes.

In accordance to the simplified calculation of the traction force the amount for the truck including pay load is 657,8 kN. For the transport unit this traction force arises up to 870,5 kN.

Between bucket on top of the gravel in the truck body is only friction connection. Any change of direction (e.g. going around corners etc.) must be done under extreme caution with a very low speed.

The floor of the truck body is not specially designed for the point load contact created by the excavator bucket. This heavy point load results in deformation of the truck body structure.

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**Picture 11. Continuous retarding (CAT795F)**

**Picture 11. Transport unit driving uphill and point load**

Entire weight Sleipner unit 755,2 tonnes
6. Tyre life

As described below, the forces impacting on the components of excavator and dump truck are extremely higher than the accepted design data. Tyres at the dump truck are one of the most sensitive parts of this equipment. They are very expensive, very high-wear parts and subject to oftentimes maintenance and replacement. Since the entire productivity of the open-pit mine is up to the working capacity of the trucks, is absolutely relevant to the tyre life.

The normal inflation pressure of dump truck tyres accounts to 7 bar. Dump truck tyres are a very special kind for high load at minimum soil pressure at less than 50 N/cm². To use existing tyres for the Sleipner chassis, the impact tyre pressure has to be increased up to more than 10 bar (9.5 – 10.3 bar).

Only this measure alone excerpts an extreme effect on the life of the tyres. But also the described above over-stress to the load capacities have a negative effect on the tyre life.

![Graph](image)

**Picture 5. Influence of load increase on tyre life**

**Conclusions**

Sleipner transport systems have existed for about 16 years and less than 150 units have since been sold. My research found out that about 58 units are in operation until now.

- According to the economic benefit, Sleipner systems have a positive effect on saving of fuel, reducing maintenance and repair costs for the undercarriage of hydraulic excavators, increase the productivity time. This makes these systems interesting for open-pit mines where excavators have to be transported over long distances frequently.

- From the point of view of strain, load and wear but also under safety perspective, Sleipner systems show disadvantages, some of them have to be accounted as non-acceptable:

  - Hoisting the Sleipner chassis by hooking them to the bucket teeth is not permitted in technical normatives and recommendations of manufacturers. The weight of a single Sleipner chassis can arise up to 42 tonnes. But the greatest hazard is that wires of the rope are exposed to kink and thus their load rating is inadmissibly decimated.
Stop ridges cannot guarantee a safe fixation of the excavator to the frame of the Sleipner chassis. Form closure of the excavator to the frames cannot replace a safe mechanical connection like it is given by a force closure. During the operation period of Sleipner frames they are exposed to high loads by moving the tracks of the excavator over them and thus there is a huge wear that makes this kind of closure very unsafe.

The weight balance between dump truck and excavator illustrates an extreme overload not only to the truck but also on components of the excavator. The centre of gravity is displaced outside of the slew ring – what is not permissible if the initial function and life time of the slew rings should be retained as foreseen by the design considerations. Additionally, the load impacting on the attachment and the slew ring of the excavator and the components of the dump truck exceed amounts of up to double the normally acceptable load of trucks, attachment and slew ring of the excavators.

Driving the Sleipner transportation unit downhill overstresses the dump truck braking system at a progressive rate caused by overstraining the retarding system. The overstress is unacceptably high.

Pulling uphill decreases the speed of a Sleipner transportation unit to a speed below 10 km/h. Of course, this speed is much higher than the speed of an excavator on own tracks but the dump truck is exposed to overload.

Due to the high load on the tyres of the frames of the Sleipner units the lifetime of tyres can be supposed to be low. Additionally the increased pressure of the tyres of more than 10 bar will negatively effect on its lifetime.

The undercarriage of excavators with tracks is supposed to high load and high stress. Therefore their lifetime, depending on the conditions of operation, is quite limited and repairs are expensive. Finally concluded, the transport of excavators makes sense for huge distances inside a mine and from one mine to another. In cases of a Sleipner transportation unit consisting of a dump truck as the traction device an excavator and Sleipner chassis, a huge part of the wear caused by the transport operation is displaced from the excavator to the dump truck. Additionally, the excavator has to bear loads on the upper carriage, mainly on the slew ring, which are absolutely too high. Furthermore, the use of Sleipner entails safety problems that make some operations inadmissible.

**Literature:**

1. Presentation Sleipner Brand Promise; Sleipner Finland OY, 2013
2. Sleipner Towing Equipment; Sleipner Finland OY, 2011
3. The Sleipner Benefit Calculation; Sleipner Finland OY, 2012
4. Lifting rope versus bucket teeth; Sleipner Finland OY, 2011
5. Komatsu PC2000 versus Liebherr R9250 track details; Sleipner Finland OY, 2011
6. Example – weight distribution during transport; Sleipner Finland OY, 2011
7. CAT Global Mining: Booklet CAT 795; 2010
8. CAT Global Mining: Circular letter to global dealership; 2013
9. Савочкин В.А.; Тяговый расчет тягачей, МГТУ "МАМИ", Москва 1997
10.