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A case study of 54 mm ropes operating on a double drum rock winder

Summary

In mid November 2004, Lonmin Platinum at their Marikana Operations, northwest of Johannesburg, installed two 1100 m long 54 mm diameter CASAR Turboplast ropes on the Karee No. 3 Main Shaft double drum rock winder. This was the first time a rope with eight compacted outer strands and a plastic coated steel core was used by the mine for vertical shaft mine hoisting.

At the time of completion of this paper (June 2007) the ropes had completed 220,000 cycles and hoisted a total of 440,000 skips or 7.0 million tonnes of rock. The most recent magnetic non-destructive test showed that the ropes do not have any broken wires. The current operating life is approximately double the standard triangular strand rope life achieved previously on the same winder.

This paper describes the full operating history of the ropes, the lubrication system used and the general maintenance practices. Through collaboration between the mine and the rope manufacturer, it has been possible to safely increase the number of cycles between backends (drum crops) from the standard 10,000 cycles to 30,000 cycles. This change, combined with fewer rope changes, has significantly benefited production efficiency and shaft safety.

1 Lonmin Platinum - Karee No. 3 Main Shaft double drum rock winder

The rock winder is a double drum installation at Lonmin Platinum Karee No. 3 Main Shaft. The shaft, headgear and the winders were commissioned in November 1992 and are responsible for hoisting circa 224,000 tonnes per month of platinum ore which represents 21 % of the Lonmin Platinum monthly production. The most important shaft data is shown in Table 1 below. Figure 1 shows the Karee No. 3 Main Shaft headgear and Figure 2 shows the rock winder. The headgear sheaves are fitted with plastic groove inserts as in Figure 3.

Hoisting depth (m)	837
Drum diameter (m)	4.88
Sheave diameter (m)	4.88
Skip mass including attachments (kg)	11,523
Payload (kg)	16,500
Hoisting speed (m/s)	15
Type of drum coiling	LeBus

Table 1: Karee No. 3 Main Shaft rock winder data.

Figure 1: Karee No. 3 Main Shaft headgear, the top two ropes are the rock winder ropes.

Figure 2: Karee No. 3 Main Shaft double drum rock winder.

Figure 3: Polypropylene inserts as fitted to the rock winder headgear sheaves. These inserts were used for both the TSRs and the eight-strand ropes.

2 Previously used rope design

Until November 2004 the mine used triangular strand winding ropes on their No. 3 Main Shaft double drum rock winder. These ropes achieved an average lifetime of 16.7 months or 116,800 cycles, hoisting 3,737,600 tonnes from the No. 3 Main shaft. This average life is based on seven previous rope sets. The best lifetime achieved by the triangular strand ropes corresponded to 20.3 months or 141,900 cycles (283,800 skips). The reason for discarding the triangular strand ropes was mainly due to broken outer wires at the drum end of the rope due to damage at the LeBus turn and layer crossovers. Figure 4 shows a typical triangular strand rope (TSR) cross-section.

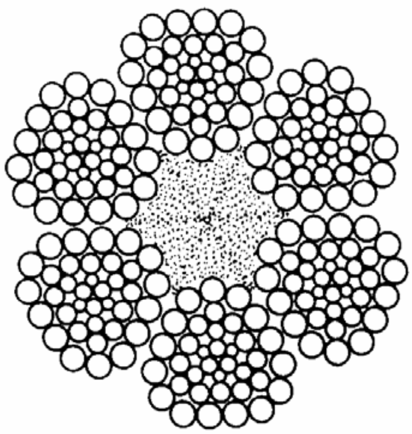

Figure 4: Typical triangular strand rope cross-section [**1**].

In this paper, a cycle is as per SANS 10294 [**2**], i.e. bank to bank for one conveyance. For a rock winder this means the number of skips hoisted per shaft compartment. For every cycle a double drum rock winder hoists two skips.

3 The new rope design concept

On the 14 November 2004 the mine installed two eight-strand winding ropes (Coil numbers EXP402727/01 and /02). The specification of these ropes as well as the previous triangular strand ropes (TSR) are detailed in Table 2 below.

Rope Construction	Turboplast	Triangular Strand
Nominal rope diameter (mm)	54	54
Rope length (m)	2 × 1100	2 × 1100
Rope lay	Right hand Lang's Lay	Right hand Lang's Lay
Tensile grade (MPa)	1770	1900
Wire finish	Galvanised	Bright
Rope terminations	Resin socket at skip, cow hitch on drum shaft	Resin socket at skip, cow hitch on drum shaft
Rope mass (kg/m)	13.13	12.47
Minimum breaking strength (kN)	2335	2182
Rope factor of safety	6.10	5.78
Rope capacity factor	8.49	7.94

Table 2: Turboplast and triangular strand rope specifications for No. 3 Main Shaft rock winder.

Turboplast ropes are characterised by eight compacted, equal lay outer strands and a fully lubricated independent wire rope core (IWRC). The core is enclosed by a plastic layer which also cushions the outer strands from one another. This plastic layer (shown in red in Figure 5a) between the steel core and the outer strands gives the rope high structural stability, avoids internal rope destruction and protects the core against corrosive environments. The plastic layer seals in the core lubricant for the life of the rope.

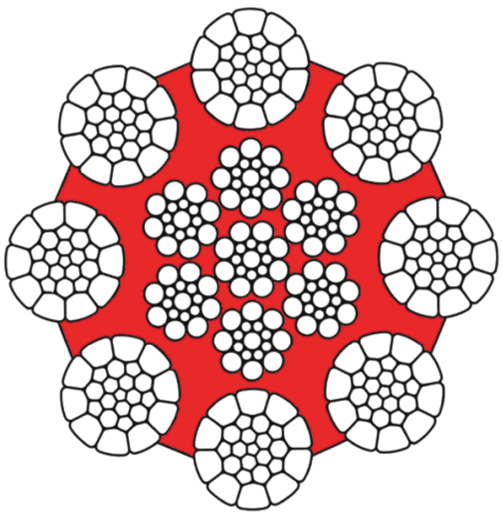

Figure 5a: Turboplast rope cross-section [**3**].

Figure 5b: Turboplast as-installed exterior.

The Turboplast rope has a very high breaking load and good resistance against drum crushing. Ropes like these with a plastic infill have been successfully used in the crane industry for more than 35 years. The first installation of these ropes in mining applications, both in Europe and Australia, dates back 17 years.

The eight-strand design provides a round wire rope cross-section. The compacted Lang's lay outer strands provide superior abrasion resistance and smooth coiling performance on multilayer drums, Figure 5b.

The plastic infill protects the steel core from moisture, gases and loss of lubricant. It also prevents metallic contact between the steel core and the outer strands, thereby reducing the risk of internal wire breaks. The plastic layer increases the torsional stiffness and stabilises the wire rope geometry.

4 New rope performance history

The rope manufacturer's service life calculation indicated a significant improvement in expected wire rope fatigue life and significant operational improvements in the form of reduced maintenance and easier rope handling.

The mine was offered a rope life guarantee of 250,000 cycles of which 220,000 cycles had been completed by end June 2007, equivalent to 7.0 million tonnes of rock hoisted by the winder. As mentioned earlier, the triangular strand ropes achieved an average lifetime to discard of 16.7 months or 116,800 cycles over seven rope sets. After 220,000 cycles, the eight-strand ropes showed no broken wires during the routine magnetic non-destructive testing. Based on their current condition it is expected that they will achieve the guarantee of 250,000 cycles.

Table 3 lists the backend (drum crops) that have been cut to date and the corresponding tonnages and cycles completed. The target number of cycles between backends is 30,000 for the eight-strand ropes. This is a factor of three increase over the triangular strand ropes (10,000 cycles). Typically 2 m of rope is cut off each rope every time in order to move the turn and layer cross-over points on the drums.

Date cut	Total tonnes hoisted by winder	Total cycles	Cycles since last backend cut
13 February 2005	668,800	20,900	20,900
26 June 2005	1,644,800	51,400	30,500
30 October 2005	2,572,800	80,400	29,000
19 February 2006	3,395,200	106,100	25,700
10 June 2006	4,211,200	131,600	25,500
22 October 2006	5,196,800	162,400	30,800
18 March 2007	6,275,200	196,100	33,700

Table 3: Backend cutting history for eight-strand ropes on the No. 3 Main Shaft rock winder.

An important point to note is that it is not strictly appropriate to compare rope life for different constructions with different backend cutting frequencies. It is in the mine's interest to maximise the number of cycles between backends so as to reduce shaft downtime and maintenance costs and improve shaft safety. Therefore, the rope life comparison that should be made is eight-strand with 30,000 cycles between backends with triangular strand ropes also run with 30,000 cycles between backends. There have been suggestions by some mining companies in South Africa to run such back to back trials with identical maintenance practices which could prove very useful in further quantifying the different performance characteristics of the rope constructions. Clearly rope maintenance practices will have a significant effect on rope life.

5 New rope stretch during skip loading

Another advantage in changing to the new rope design has been significant reductions in rope stretch during loading of the skips. This has the benefit of reduced spillage at the shaft bottom and a more efficient loading process. It recognised that in deeper shafts the benefits of reduced rope stretch would be even more significant. The observed stretch data for the eight-strand ropes on the No. 3 Main Shaft rock winder are listed in Table 4.

Rope construction	Turboplast
Nominal rope diameter, d (mm)	54
Tensile grade (MPa)	1770
Rope metallic area (mm^2)	1517.8
Rope metallic area / d^2	0.521
Number of ropes per skip	1
Rope suspended length (m)	837
Change in total load, during loading (kN)	177
Rope stretch due to change in load (m)	0.80
Average rope modulus E (GPa)	**121.7**

Table 4: Observed stretch data for the eight-strand ropes on the No. 3 Main Shaft rock winder.

6 Cost benefit relationship for new rope technology

For the mine, the decision to purchase the more expensive eight-strand ropes needed to be justified through an expectation of considerably longer rope life. A rope life guarantee was offered by the rope manufacture of 250,000 cycles (equivalent to 8,000,000 tonnes hoisted by the rope set). Table 5 lists the data required to determine the cost benefit relationship for both rope types. This shows that it is 56 % more expensive per 1000 tonnes hoisted for the mine to operate the triangular strand ropes compared to eight-strand ropes. Based on the guaranteed rope life for the eight-strand ropes, the mine has saved Euro 44,200 per year of operation. Over the circa 3 year guaranteed life of the eight-strand ropes the savings which they generate constitute a significant proportion of their initial purchase costs (81 %). The calculations in Table 5 assume that the eight-strand ropes only reach their guaranteed life to discard. If the actual lifetime turns out to be greater than 250,000 cycles then the savings compared to the triangular strand ropes will increase further.

	Turboplast	TSR
Rope life to discard, guaranteed and average (cycles)	250,000	116,800
Rope life to discard, guaranteed and average (months)	35.7	16.7
Total rock hoisted by rope set at discard (tonnes)	8,000,000	3,737,600
Backends done every (cycles)	30,000	10,000
Number of backends done in rope life	8	11
Direct cost of one backend (Euro)	5,000	5,000
Total cost of all backends for rope life to discard (Euro)	40,000	55,000
Direct installation cost (Euro)	10,000	10,000
Direct lubrication material cost over rope life (Euro)	21,400	3,300
As delivered cost of one rope set, mid 2004 (Euro)	163,400	102,900
Total direct cost of one rope set (Euro)	**234,800**	**171,200**
Rope cost (Euros per 1,000 tonnes hoisted)	**29.35**	**45.80**
Relative rope cost per 1,000 tonnes hoisted	**1.00**	**1.56**

Saving per annum compared to TSR (Euro)	**44,200**
Saving over life of rope set compared to TSR (Euro)	**131,600**
Saving over life of rope set compared to TSR (% of rope cost)	**81%**

Table 5: Cost benefit relationship for eight-strand compared to triangular strand ropes.

In the analysis Table 5, only the direct costs of running the ropes have been taken into account. These include the as-delivered cost of one rope set, rope installation cost, cost of all backends to discard and the lubrication material cost over the rope life. It has been very cost-effective for the mine to invest in this new rope technology.

7 Rope maintenance collaboration and practices

The mine and rope manufacturer worked closely together in installing, inspecting and maintaining the eight-strand ropes. The objective of this collaboration was to maximise rope life and thereby minimise rope cost per 1000 tonnes hoisted for the mine.

Care was taken after installation to double down with full skips to ensure that the load on the dead turns on the drum was at least 50% of the maximum rope operating load. Figure 6 shows the general arrangement for doubling down in the shaft. This is critical to prevent premature failure of the wires in the dead turns due to secondary bending of the wires caused by the rope layers above. After every backend cut, Table 3, the ropes were again doubled down with full skips.

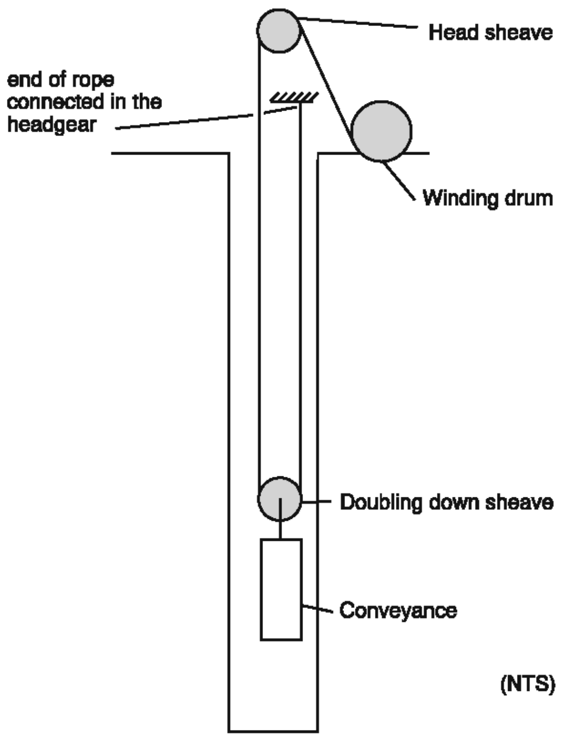

Figure 6: Doubling down arrangement for ensuring proper tension in the dead turns on the drum.

Based on operating experience with eight-strand ropes in Australia on similar winders, the target number of cycles between backends was set at 30,000 (60,000 skips for the winder). Regular inspections of the turn and layer crossover regions were done at intervals of 10,000 cycles during the first six months of rope operation to ensure that damage was accumulating at the crossovers at the expected rate. Figure 7 shows a typical pattern of deterioration at the LeBus layer cross-over area after circa 20,000 cycles. This can be compared to the undamaged rope in Figure 5b.

Figure 7: Typical layer crossover area plastic wear after circa 20,000 cycles.

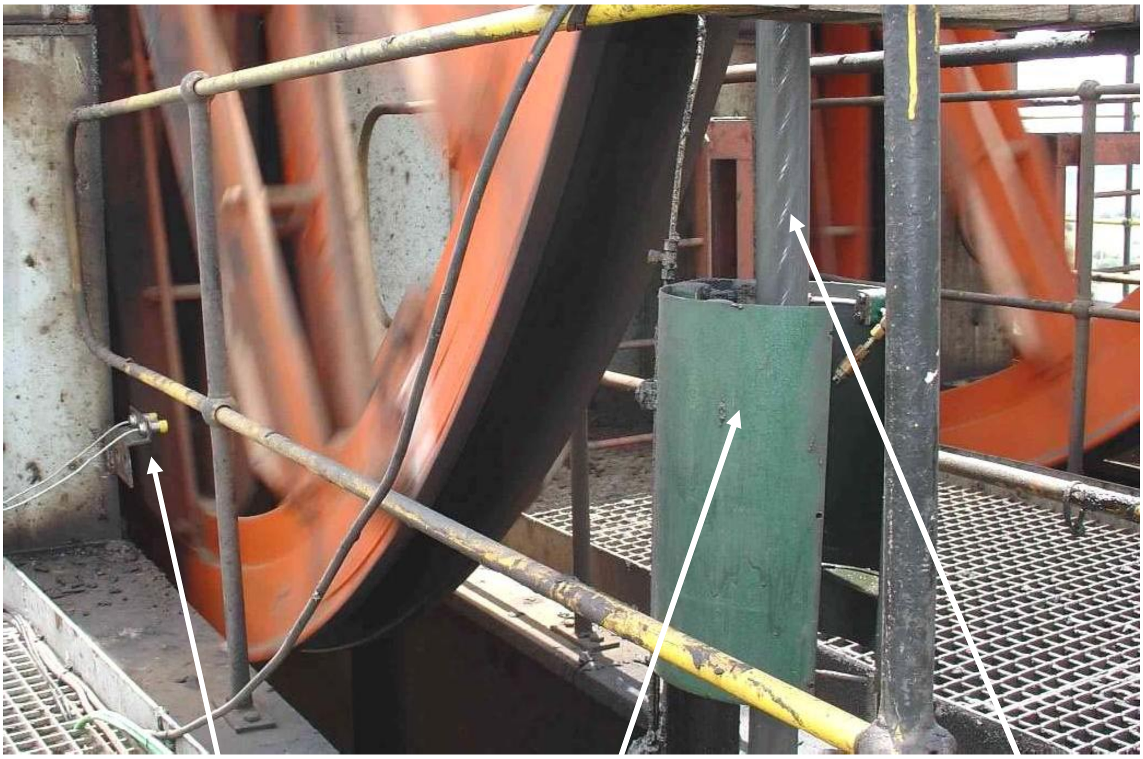

Figure 8: Permanent automatic rope lubrication system mounted in headgear, below the sheaves. This system was only used for the eight-strand ropes and not for the TSRs.

A key difference in the maintenance practices compared the previous triangular strand ropes was the installation of a fully automatic spray lubrication system. Figure 8 shows the arrangement of this below the headgear sheaves. A four nozzle spray arrangement was controlled based on the number of cycles completed by the ropes. The ropes were dosed with ELASKON Spray Oil 200 circa every 300 cycles over the operating rope length. The cost of the lubrication over the guaranteed life of the eight-strand ropes is given in Table 5 and has been taken into account in the cost benefit analysis. The use of the automatic spray lubrication system reduces shaft downtime and ensures that the correct amount of lubrication is always applied to the ropes. In the past, the triangular strand ropes were lubricated every two months with standard bitumen based wire rope dressing.

The rigging personnel at the shaft have reported that the eight-strand ropes are easier and safer to handle than the triangular strand ropes as they show very little rotation when being disconnected from the skips and drum during maintenance procedures. The reason for this change in behaviour is a more stable and torsionally stiff construction. The plastic layer between the core and the outer strands makes a significant contribution to the rope stability.

8 Rope discard criteria

Prior to installation of the new ropes, the mine and rope manufacturer examined SANS 10293 “Code of practice for the condition assessment of steel wire ropes on mine winders” [**4**] and concluded that this standard applies to the new ropes. In the case of the 54 mm eight-strand rope the mine could work safely on a maximum of not more than four broken wires in one strand in one lay length as this represents less than 40% of the outer wires in the strand and 1.8 % of the total steel area. This keeps the rope discard state within the bounds of SANS 10293, Section 5.5.1. Outer strand outer wire specifications for the 54 mm eight-strand rope are given in Table 6.

Nominal rope diameter (mm)	54
Total metallic area of rope (mm^2)	1517.8
Mass of rope (kg/m)	13.21
Diameter of outer wire (mm)	2.95
Area of one outer strand outer wire (mm^2)	6.83
Number of outer wires in each outer strand	12
40% of outer wires in one outer strand (wires)	4.8
One outer strand outer wire as % of total metallic area	0.45
Four outer strand outer wires as % of total metallic area	1.8

Table 6: Discard criteria calculations for 54 mm eight-strand rope.

At the time of writing this paper the two ropes on the No. 3 Main Shaft rock winder had no broken wires. This has been determined by traditional magnetic inspections which are conducted by an external testing company every 3 months (circa 21,000 cycles). It is anticipated that eventually broken wires will form at the drum end of the ropes due to the plastic wear type damage that occurs as a result of the LeBus turn and layer crossovers. Once four broken wires in one strand in one lay length are detected the ropes will be discarded.

9 Conclusions and future objectives

This paper has shown that it has been cost effective for the mine to change from the traditional triangular strand rope design for drum winders to an eight-strand construction with a plastic coated steel core. The eight-strand ropes have completed 220,000 cycles as of June 2007 and show no broken wires. It is expected that the ropes will at least reach their guaranteed life of 250,000 cycles (500,000 skips / 8,000,000 tonnes of rock from 837 m) by mid November 2007 based on the current shaft production rate.

Experiences in Australia on double drum rock winders have shown that Turboplast and Duroplast [**3**] ropes are capable of delivering rope lives up to 400,000 cycles (11,000,000 tonnes) at backend cutting intervals in excess of 30,000 cycles in shaft depths up to 1000 m. The Duroplast construction is very similar to Turboplast except that it has larger outer wires which are even more tolerant to damage on the drum.

The mine is currently considering various techniques to extend the life of the present eight-strand ropes which include the possibility of end for ending them. The rational here is that the front half of the rope is in an almost new condition. By placing this portion of rope on the drum a more even distribution of damage along the rope length could be achieved with extended rope life. Generally end for ending is not recommended for triangular strand ropes as they show relatively large changes in lay length from the manufactured condition and some of these changes are plastic after extended periods of operation. The observed variations in lay length for the No. 3 Main Shaft eight-strand ropes are small enough (20 mm to 25 mm from skip to drum) that this should not cause a problem when the ropes are turned around.

The mine has also ordered a replacement set of eight-strand ropes for the No. 3 Main Shaft rock winder which will be installed once the current set has been discarded.

10 References

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2 SANS 10294 *Code of Practice: The performance, operation, testing and maintenance of drum winders relating to rope safety*, Edition 1, South African National Standards, Pretoria, 2000, ISBN 0-626-12600-2, pp. 1-43.

3 CASAR *Special Wire Ropes Catalogue*, CASAR Drahtseilwerk Saar GmbH, Kirkel, 2006, pp. 14-17.

4 SANS 10293 *Code of Practice: Condition assessment of steel wire ropes on mine winders*, South African National Standards, Pretoria, 1996, ISBN 0-626-10929-9, pp. 1-36.