

Improved Wire Rope Lubricator Design for a Mine

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Abstract

The study explored aspects of effective mining wire rope lubrication with regards to minimizing common failures. Thus the work looked at coming up with a design which sought to improve the safety of the wire rope facility and increase production in local Zimbabwean mines through reducing excessive labor cost and unnecessary cost associated with undue replacement of ropes. It is this regard that this work devised a wire rope lubricator that reduced labor allocated to lubricating of wire ropes by more than 50%, as well as achieving high lubricant penetration and cleaning the rope prior the process. The design would reduce the cost of wire rope maintenance by more than 42%.

Keywords

Rope failure, lubrication, cost effectiveness, loss reduction, lube penetration

1. Introduction

Some effort has to be made to deal with challenges that prevent maximum mass production in local mines. The study has the objective of coming up with a more efficient method of lubricating wire ropes as well as reducing the cost of wire rope cleaning and maintenance in a more sustainable, and economic manner. Wire ropes are used in mines for transmitting mechanical power in mine hoists and cranes. Mine hoists are the fundamental mode of transport of workers and goods into and out of the mine shafts. A wire rope without proper lubrication also causes wearing of the sheaves, this would require re-grooving and replacement with time costing a mining company thousands of dollars in addition to down time during replacement. When a wire rope has reduced its strength by 10% it is recommended to be discarded. Wire rope lubrication extends the wire rope life by about 60% (Draka Elevator Tech Tips 2013), saving the mining companies replacement costs. Currently, most mines in Zimbabwe use methods of wire rope lubrication such as heating the lubricant and applying the lubricants using hands, rags or brushes. It was established that such methods are ineffective, costly and pose a health risk to workers. The wire rope needs to be cleaned before new lubricant is applied to remove foreign particles and old lubricant from the strands, and the spaces between the outer wires. Practically, use of hands to lubricate a 760 m of wire rope would be time consuming and results in poor lubricant penetration to protect the rope. The same practice would increase incidence of waste of

lubricants through spillages, which in some cases would require more attention in terms of extra housekeeping. There is no consistence in the amount of lubricant applied throughout the wire rope when applied by hand.

For effective lubrication the lubricant should penetrate to the core of the wire rope to prevent moisture within the core of the wire rope as this will lead to corrosion of the wire rope from inside. When this corrosion continues unnoticed this would lead to unplanned failure of the wire rope during service leading to accidents which could possibly be fatal. Poor lubrication causes wearing of sheaves as well as the wire ropes would be costly to the mines through replacement. On a safety note, lubricant spillage creates an accident risk working environment because it would make floors slippery, which may be a hazard to shop floor workers. The current methods have very poor dust removal capacity from the wire ropes. Dust stuck on wire ropes increases friction as the wire ropes slide over the sheaves causing more wear thereby reducing rope diameter in the process. In terms of personal hygiene, over exposure to petroleum solvents such as grease may cause skin irritation and inflammation called dermatitis. Also, sweating inside gloves for a long period of time may lead to over-hydration resulting in skin cracking. In summary the methods being used are time consuming and require more human labor. Thus labor is wasted in of duplication of duties instead of it being deployed elsewhere in the mine, and increase productivity. The local mining sector contributes over 8% to the Gross Domestic Product (GDP) according to Ministry of Mines and Mining Development 2012 report. This work seeks to come up with a design of a self-lubricator which scraps off dust, cleaning the wire ropes prior lubrication and improve on lubricant penetration with less effort. Such a gadget would save time and money on unnecessary labor for lubrication and housekeeping. This must see wire rope life in service significantly extended.

2. Wire Rope Application

2.1 Mining Wire Ropes

Wire ropes are used over other methods of transmission of power such as chains or belts because they can transmit power over longer distances, they offer more silent operation, and can withstand shock loads. Wire ropes should be examined and tested during their service life to supervise the deterioration so that rope can be removed from service before becoming a hazard to safety. Operating hoists with wire ropes that are in the discarding state are dangerous. Wire ropes deteriorate with time hence require checking for defects before failure and also reduces premature replacement when the rope is in good condition hence incurring unnecessary costs. There are two major classifications of wire rope testing and examination, these are destructive testing (in Zimbabwe it is done by Ministry of Mines after a period 6 months) and non-destructive testing done at the mine every 3 months (Mironenko 2013)

2.2 Wire Rope Construction

Heat treated and cold drawn wires of high tensile strength ranging from 1200 MPa – 2400 MPa of different grades are twisted together to form a strand. A strand is made of 7, 19, 36 or 37 wires twisted together by a special machine. 6 or 8 of the strands are twisted into a single wire rope with a core at the centre made from a fiber core (in case of mining hoisting wire). The fibre core improves the flexibility of the wire ropes on sheaves and it is saturated with lubricant to protect the rope from rouging from inside. A wire rope on average has an average life of 2 years. The mine is required to do internal inspection of wire ropes at the mine periodically after every 3 months using non-destructive methods such as visual inspection for broken wires, ultrasonic tests or magnetic inspection which is capable of detecting inner wire breaks. When a wire rope has reduced its strength by 10% it is recommended to be discarded. Safety factor of a wire rope is based on the ultimate strength of the wire rope

$$f = \frac{s}{w} \dots\dots\dots (1)$$

where

s = Manufacturer's rated breaking strength of rope

w = maximum static load on the wire rope and rated load at any position in the hoist way

The sheaves which guide the rope are made of cast iron or steel castings, and are normally mounted on fixed axles on antifriction bearings or bronze bushings. The diameter of the sheaves should be large enough to reduce bending stresses in the wire ropes as it goes over the sheaves. A larger sheave is more efficient and more economic as it does not damage the wire rope.

2.3 Wire Rope Failure

Wire ropes during their service may undergo degradation by different causes some which are preventable whilst others are not. Ways in which wire ropes fail include fatigue, corrosion abrasion and mechanical damage.

Fatigue - When ropes move over sheaves or drums, they subjected to repeated bending cycles and bending stresses, and they end up developing cracks in the wires. This leads to reduction of cross sectional area and hence increase in stresses that would cause premature failure when overloaded (Weischedel 2005).

Wire rope wear -Wear is the degradation of material due to mechanical causes such as friction, abrasion and chemical means such as corrosion. The rate of wear is proportional to the surface area in contact and load per unit area. The larger the area, the lower the load per unit area and hence lower the rate of wear. The two main classes of wear are adhesive and abrasive (Mechanical Engineering Hand Book).

Erosive Wear - Material loss from a surface due to contaminated fluid with foreign particles between the surfaces in relative motion.

Corrosion Wear - This is chemical caused wear by oxidation due to moisture, poor quality lubricant or contamination causing pitting or weakening surfaces.

2.4 Wire Rope lubrication

Lubrication is a process of introducing a fluid film to control and reduce wear of surfaces in contact with each other or with relative motion. It separates the relatively moving parts of machinery with a film of mater to reduce direct rubbing of the surfaces. Most of the causes of wire rope failure can be minimized or eliminated by lubrication. Hydrostatic lubrication method most recommended for wire ropes. This enables full film lubrication under very high load and very slow speed conditions for wire rope operation. A wide range of oils and greases are used as lubricants for wire ropes. Fluid lubricants are penetrating, while grease are coating. Penetrating lubricants help protect the wire rope from inside the core of the rope. Coating lubricants are corrosion resistant and wash proof to protect the outer layer from frictional wear. New developments are being made to produce biodegradable wire rope lubricants to protect the environment (Mercator Media, 2015). A number of lubricant application methods exist such as swabbing, application of lubricant on sheaves, continuous bath and pressure grease lubrication. In the literature, the existing lubricator concepts are grease drop lubricator, dipping lubricator and conical lubricator:

Grease drop lubricator

The lubricator operates on the sheaves by taking advantage that when the wire rope goes over the sheave (pulley), it slightly spreads out the strands allowing melted grease to penetrate the rope to the core. The grease is melted by heaters during winter season or on cold days thereby allowing it to flow as drops.

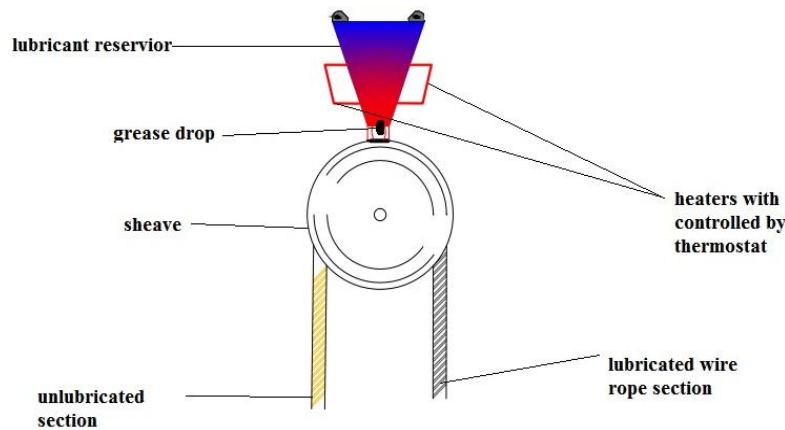


Figure.1 Grease drop lubricator

The lubricator is only usable on sheaves hence if the installed sheaves have no enough space to place it, adjustments have to be made. Usually in mines the sheave is at a higher level accessible using a ladder, this would require using a ladder for installation and refilling lubrication. The operator has to take extra caution to avoid accidents. The design concept has a high risk of burning the operator when they come into contact with the device while still hot. Although the cost of the device is low, the amount of lubricant applied is not controllable hence the objective to reduce wastage of lubricant is not solved.

Dipping lubricator

The lubricator consists of a removable scraper located on the outside of the lubricating column that removes dust, old lubricant, debris and water particles before lubrication. The device lubricates the wire rope as it moves around the pulleys, the rope bends and the strands have a slight opening up. When this happens this allows the lubricant to penetrate into the rope ensuring sufficient lubricant penetration to prevent corrosion from inside.

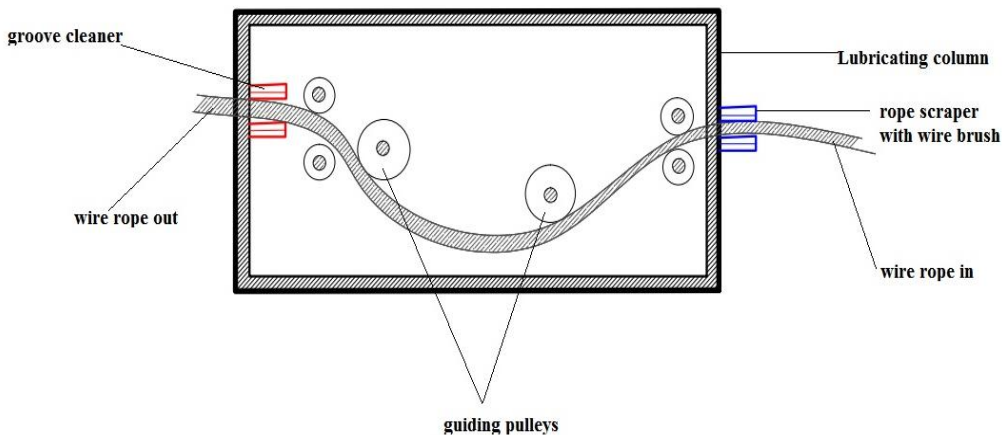


Figure. 1 Oil dipping lubricator

The lubricator concept has good lubricant penetration and good wire cleaning ability. It works best when horizontal therefore it cannot lubricate the vertical section of the wire rope. The device has to be very large as the rollers have to be big enough to reduce fatigue in the rope due to bending over the rollers. The other inadequacy is need for frequent refilling because the rope cannot use the lubricant in the corners. Due to the high tension and fluctuating loads in the roller shafts as the rope moves around the rollers, there is high risk of failure on the shafts.

Grease conical lubricator

The lubricator device is made up of two half cones are assembled to form a full conical collar surrounding the wire rope. Grease is loaded into the conical collar, as the wire rope moves down using gravity it is lubricated. As the wire rope leaves the cone a scraper removes excess grease and forcing the grease into the rope for better penetration. A wire brush scraper ring is attached at the top to remove dust and old lubricant from the rope.

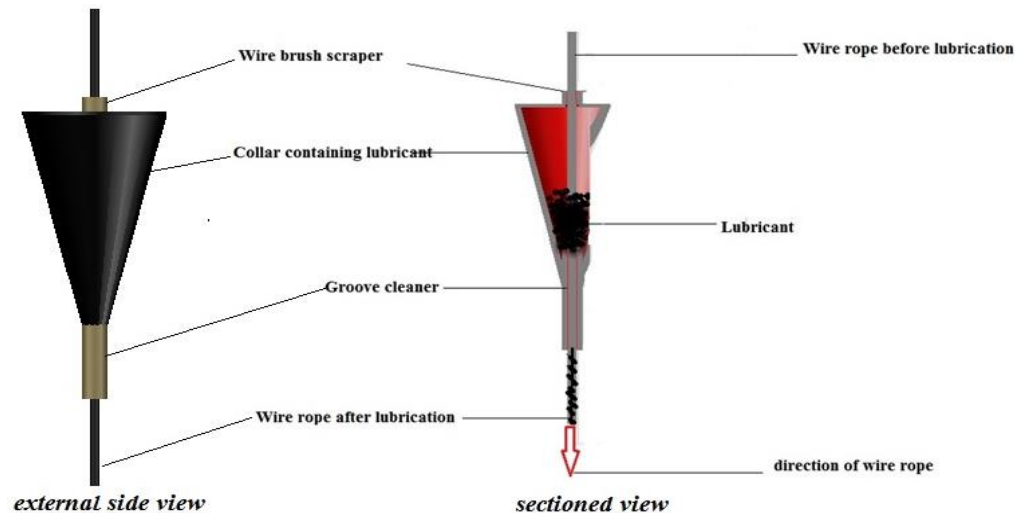


Figure. 3 Grease conical lubricator

The lubricator works using the simple principle of gravity however during the cold season when the grease is highly viscous it might not flow as desired. The device may not give a desired lubricant penetration due to the high viscosity under these conditions. The device works well on when perfectly vertical to ensure smooth flow of lubricant. When the device has an inclination this would reduce the force of gravity working on the lubricant, hence poor and inconsistent lubrication. The design concept has few removable parts making it safe to work underneath it. However the layout of the device requires using a ladder during installation and lubricant refilling where rope is the vertical. The lubricator is made up of components that are relatively cheap making the overall cost of the device favorable. The two grease lubricators – the grease drop and the grease conical, by using grease as the lubricant with some heating at times, it means at times the rope is not adequately lubricated. While the dipping lubricator, other than being massive it only operates in the horizontal position and not for vertical wire ropes. It is because of this argument that this study seeks to come up with a universal liquid pneumatic lubricator which is effective regardless of the wire rope inclination. It has also to be robust and reduce lubricant wastage to the environment (Bimba Manufacturing Company, 2012)

3. Methodology

The researchers worked closely with a gold mine based in Zimbabwe. A cost analysis and expenditures on wire rope installation, operation and maintenance at this mine was done. The analysis showed that a lot of money was spent on the maintenance of wire ropes and time consuming methods were used to lubricate the ropes that could be reduced by this study initiative. The researchers weighed out the various possible solutions for the wire rope lubricator. The optimum possible solution was selected using weighting method, and the design details were done using calculations for key parameters. Detailed drawings and assembly drawings of components were made using AutoCAD 2014 and Solid Works software respectively. Computer simulations on final designs were done and analyzed for verification of efficiency of the device. Effort was also made to do the economic analysis of cost for the design and manufacturing of the prototype of the device, as well as drawing the bill of quantities.

4. Process of Designing

The design concept was developed around need to provide effective lubrication of wire rope so as to reduce wire rope failures during mine operations. This entailed that the wire rope lubricator enabled cleaning of wire rope prior lubrication and that lubrication itself is done with better rope core penetration.

Pneumatic liquid lubricator concept .

The design option consisted of two semi cylindrical sleeves assembled around the wire rope to form a collar. The collar would have an inlet hole for fluid lubricant into the collar, with a hose connected from a pneumatic pump to the collar inlet as shown in the schematic diagram in Fig 7.0 below. The lubricant would be pumped into the collar at a required rate depending on the speed of the wire rope, with the high pressure to ensure sufficient lubricant penetration.

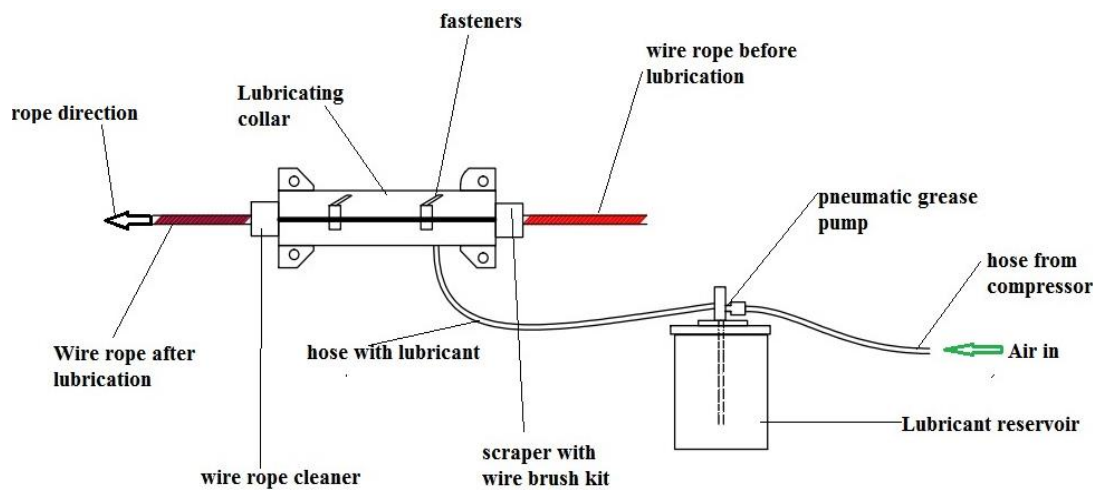


Figure. 4 Fluid pneumatic lubricator

The selected concept uses high pressure pump to ensure the desired lubricant penetration is achieved, as well as optimizing the amount of lubricant applied to reduce wastage of lubricant. The device would be portable, easy to operate, and could be moved to various sections of the rope with different orientations. Components such as the compressor and pneumatic pump would be relatively expensive making the overall cost of the installation high. However considering the amount of money lost by a mine during down time, through wasted lubricant and due to unnecessary, it would be better to spend 10% of it on a device that would save thousands of dollars.

Lubricator design specifications

- Good wire rope core lubricant penetration
- Reduce lubrication time
- Reduce reported wire rope related down time by 80%
- Reduce wire rope lubricating labour input hours by at least 50%.
- Portable for varying rope orientations
- Life span of at least 10 years
- Simple parts and easy to maintain
- Maximum cost of USD 1 200
- Maximum weight of 25 kg
- Lubricant leak proof

Key components of lubricator prototype model

- Design lubricating collar
- Selection of compressor

Selection of pump
Pipe sizing

Design of lubricating collar

The lubricating collar would consist of outer steel casing with rollers welded onto them. The function of rollers would be to bend the wire rope as it would move over them hence opening the strands slightly allowing for lubricant penetration. The wear resistant rubber seal would spread the lubricant on the outer surface as well as scraping off excess lubricant from the exit wire rope. Excess lubricant would be collected through the gap in the rubber and tapped off to a reservoir for reuse.

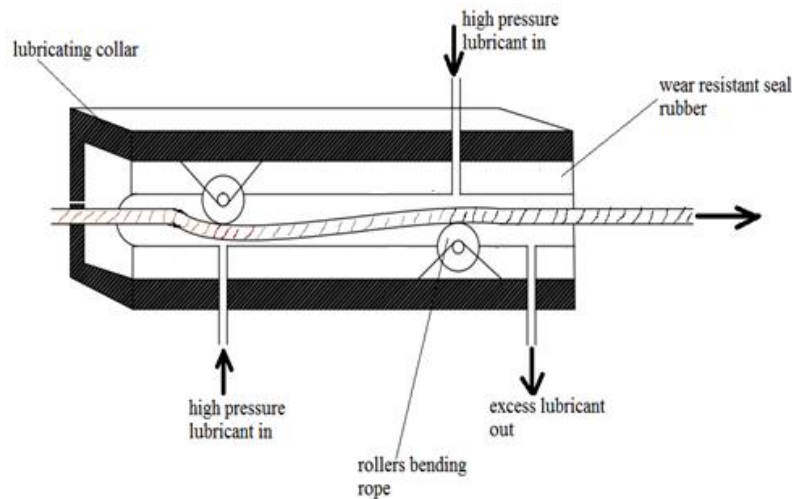


Figure.5 Lubricating collars

Finished wire rope lubricator

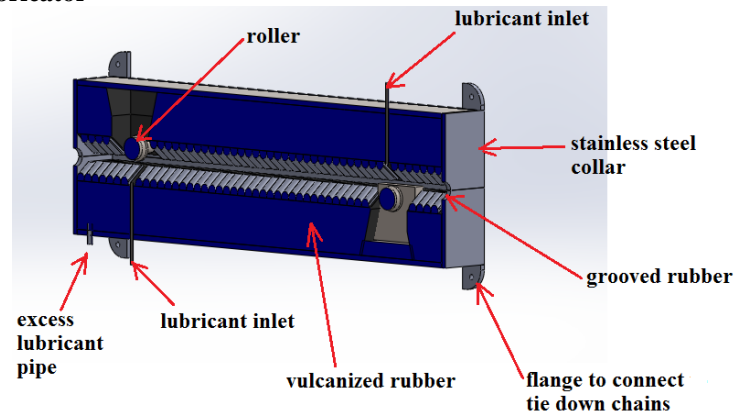


Figure.6 Cross section of designed wire rope lubricator

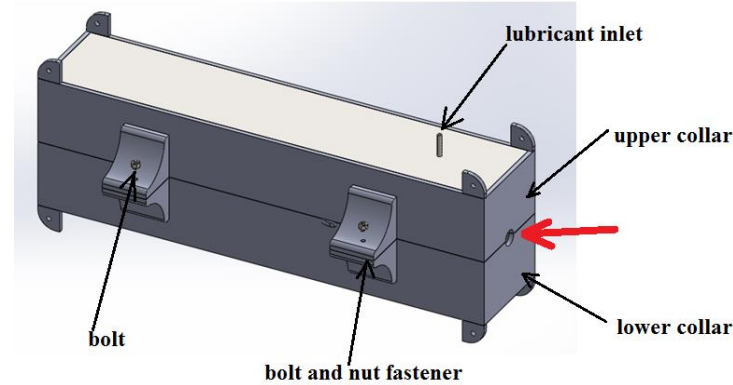


Figure.7 Isometric 3D view of lubricator

5. Recommendations

The size of the collar could be changed by using a stronger and lighter material (high strength to weight ratio) instead of cast iron or mild steel whose selection was based on material availability. This would reduce the size and weight of the collar and improve the portability of the device. The current use of semi-solid grease (Noxal Super 8) required some heating to make its application to the ropes easy. This messy and cumbersome practice could be replaced by use of a fluid lubricant with low viscosity which could be easily pumped and penetrate rope core effectively to reduce wire failure. Thus this study recommends the use of a solvent based lubricant such as Grippa 33S. It is easier to apply since it does not require heating and has a lower viscosity hence can be pumped by a pneumatic pump with great ease. Other advantages of using such a lubricant are its Molybdenum Sulphide (MoS_2) additive which makes it water wash resistant in underground mine environment and it is also biodegradable making it environmental friendly in case of incidental leakage. This lubricator device can be further improved by incorporating other accessories like the spiral wire scraper in Fig 17.0 below to clean the wire rope before lubrication. Tie down chains or a securing bracket for fixing its position during lubrication may be required, as well as a carrying case to keep the device clean. A compressor with the following specifications: Power 3hp, Pressure 125psi and 10 gallons, was also recommended.

6. Conclusion

The design study managed to come up with a wire rope lubricator that was simulated using Solid Works for functionality and feasibility. The device could achieve the required key design objectives of lubricant penetration and time saving from 4 hours to about 1 hour 40 minutes according to the design calculations. The design for manufacture drawings were provided for fabrication of the prototype model. Further improvements of device could be done by adding pressure control valves and pressure regulators on the system for safe operation in the plant.

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Biography

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