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Revamp of Diesel LHD to Battery LHD for Minimising Operational Cost in Underground Metal Mines

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Abstract

In underground mines, haulage vehicles are routinely employed to move ore from subterranean loading stations to the surface. It's occasionally possible for descending empty cars to stop in a passing lane and wait for moving, heavier vehicles to pass. This is how traffic moves downhill. The number and placement of passing bays affect the haulage productivity of a mine. The operational expenses of the battery LHD and the diesel LHD have been contrasted in terms of gases released, diesel costs, and charging costs. According to our data, using a rechargeable LHD can cut operational costs by 90%.

Keywords: *Battery LHD, Cost, Diesel LHD, Productivity, Underground Mines Optimization*

1.0 Introduction

As mining depths rise, operational efficiency becomes increasingly important since longer transit times, greater stresses, seismicity, energy consumption, ventilation requirements, and distances will all contribute to higher operating costs. To address the myriad issues of the future, automation, flexibility, and the transition from diesel to electric technologies need to be given more thought.

A conventional deep underground mine uses both horizontal and vertical systems. Among the most popular unit operations in material handling are drilling, blasting, loading, transporting, and elevating the material. The material is usually moved with subterranean rubber tire loaders, including Load-Haul-Dump (LHD) equipment, across short distances away from the face. For more than 50 years, these devices have been utilized to transport waste from the point of origin to the disposal sites. Wagner (now Epiroc), Teletram, and Scooptram built the first loader in 1959 by Chadwick, J[1]. Nowadays, LHDs are used by more than 75% of underground metal miners.

Three crucial elements determine their selection in the mine design process: production capacity, tire life, and tunnel clearance. Diesel engines are currently used to power the majority of LHDs due to their remarkable efficiency, durability, and adaptability by Pronk *et al*[2]. However, the air in the mine is contaminated by harmful or excessive gases produced by diesel-powered gear, leading to a large increase in ventilation costs. Replacing outdated diesel equipment with more modern equipment could not be sufficient because of the stringent ventilation criteria (outlined in regulations), significant environmental effects, and high running expenses. It might be required to use a different power source.

Using electric equipment is one alternative; it may save a lot of money on ventilation costs and is also more environmentally friendly and compliant with regulations.

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Mine air quality and carbon dioxide emissions regulations are getting stricter by Chadwick J.[1], Paraszczak *et al*[3]. Technologies that can quickly adjust to changing environmental rules and the dynamic nature of the mining environment are essential for mining operations. Mining may become carbon-free and ventilation systems simpler by switching to battery-powered vehicles. Thus, an attempt is made to compare the gas emissions and operating costs of battery LHD with diesel LHD in this article.

2.0 Literature Review

LHD (Load, Haul, and Dump) loaders were designed to tackle the most challenging hard rock mining operations with dependability, safety, and overall production efficiency in mind, much like conventional front-end loaders. They are remarkably resilient, agile, and extremely prolific. More than 75% of underground metal miners worldwide employ LHD to handle the trash from their excavations.

Concerns regarding the harmful consequences of diesel engine use on health have grown since the mining industry started utilizing them extensively in the 1960s. Several groups, notably the Manufacturers of Emission Controls Association and the Diesel Emissions Evaluation Program, are now looking at the problems associated with diesel emissions. Consequently, several innovative technologies have been created, including hybrid freight trucks, zero-emission subterranean cars, and catalytic diesel particle filters.

Fuel impurities and incomplete combustion cause diesel engines to produce Diesel Particulate Matter (DPM). Significant changes have occurred in the health risks related to DPM in the past year. The World Health Organization classified DPM as a Group 1 carcinogen as of June 2012. This is supported by data showing a connection between exposure and a higher risk of lung cancer (IARC 2012). According to a survey, underground miners are exposed to the greatest concentrations of DPM of all jobs, which makes sense given that these health consequences are more severe underground.

There are currently no legislative restrictions on the amount of DPM that can be present in underground mines in Western Australia, despite the fact that some actions have been taken in response to the IARC's most recent findings. Furthermore, the allowed exposure limits (0.1 mg/m^3 and 0.07 mg/m^3 of elemental carbon over 8 hours and 12 hours, respectively) are Total Weight Average (TWA) limits, which do not account for brief episodes of intense exposure. With the known detrimental effects on health and the constraints on the environment, one can predict that more stringent DPM laws are likely to be implemented soon. Battery LHD has the greatest versatility of the three options (diesel LHD, electrical LHD, and battery LHD), but it also has the highest weight and needs to be recharged more frequently. A study by Greenhill and Knights (2013) found that LHDs could only run for two to three hours at a time since they required 1-2 tonnes of batteries. A 50% unfavorable vehicle availability resulted from the anticipated 2-hour recharge period. A battery switch mechanism has been suggested as a solution for this. Overhead power line trolley systems may be feasible for haul trucks with long-haul, predictable routes, but they are impractical for light-duty trucks (LHDs) because to their high maneuverability requirements. Nowadays, an umbilical trailing mine is the most practical way to power a mine.

Although diesel is typically used to power LHDs, electric LHDs are starting to appear more frequently (Paterson and Knights 2012). These zero-emission vehicles will produce less heat, vibration, and noise, which will improve working conditions for employees by Paraszczak *et al*[3]. The potential cost reductions on fuel, ventilation, consumables, maintenance, regulatory inspections, and inspections provide additional financial motivation to consider LHDs by Miller[5], Paterson and Knights[4]. Nevertheless, there are a lot of drawbacks to the limitations that trailing cables impose by Miller[5], Paterson and Knights[4]. Among these include less mobility, decreased adaptability, cable issues, and relocation worries.

2.1 Objectives

The main objective of this project is to reduce the emission of gases, heat, and noise levels produced by the Diesel Load Haul Dumper by replacing the Battery Load Haul Dumper to reduce manpower and improve productivity.

Table 1. Specifications of SANDVIK LH204

Tramming capacity:4000kg
Speed with load forward and reverse:15km/h
Fuel tank capacity:150 litres
Average fuel consumption:14.5 l/h
Total operating weight:13,300 kg
Total loaded weight:17000 kg
Total length:7766mm, Width:1600 mm, Height with canopy:2127mm

3.0 Case Study

The HGML Mallapa shaft transports ore and commodities using a Diesel Load Haul Dumper (LHD), which emits fumes, makes noise, and generates heat. Therefore, one of the means for transporting ore and materials in underground mines is the task undertaken to remodel Diesel LHD and replace it with battery-powered LHD. The primary drawback when operating the diesel load haul dozer in my mind is the increased exhaust gas emissions, noise, and heat.

Battery-supplied drives don't require special maintenance apart from the charging of the

Table 2. Shows the diesel exhaust composition

Average Diesel engine exhaust composition		
Gas emitted	**Mass percentage**	**Volume percentage**
Nitrogen (N_2)	75.2%	72.1%
Oxygen (O_2)	15%	0.7%
Carbon dioxide (CO_2)	7.1%	12.3%
Water (H_2O)	2.6%	13.8%
Carbon monoxide (CO)	0.043%	0.09%
Nitrogen oxides (NO_x)	0.034%	0.13%
Hydrocarbons (HC)	0.005%	0.09%
Aldehyde	0.001%	n/a
Particulate matter (sulfate + solid substances)	0.008%	0.0008%

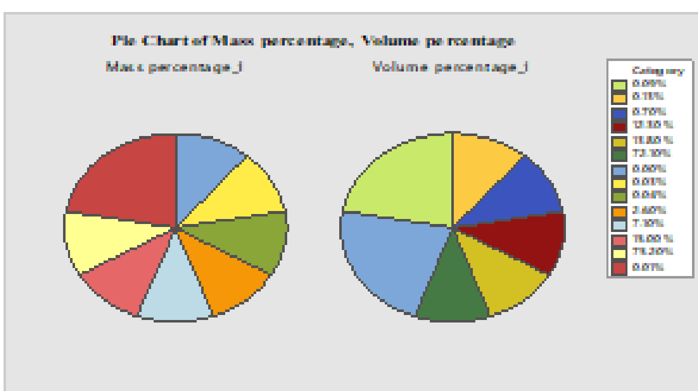

Figure 1. Gas percentage comparing with threshold limit.

Table 3. Comparison of exhaust gases y diesel and battery to threshold limit

Average Diesel engine exhaust composition			
Gas emitted	**Threshold limit**	**Diesel exhaust**	**Battery**
CO_2	0.5	0.3	0
CO	0.005	0.004	0
H_2S	0.0025	0	0
SO_2	0.0005	0.00004	0
NO	0.0005	0.00069	0
NO_2	0.001	0.00004	0

NOTE: Due to limited use of battery LHD's by the mining industry detailed information about the exhaustion of gases is currently not available, but CATERPILLER R1700 XE makes the first battery LHD platform with zero emission of gases and low maintenance cost.

batteries. Their operation duration is only by battery capacity.

The front and back portions of each LHD are joined at articulated locations. The unit includes rubber wheels on each portion that are both flame-resistant and unsteerable. The hydraulic system controls the steering, the bucket, and the brakes.

The main issue with these vehicles is the production of Diesel Particulate Matter (DPM), which, after continuous exposure, might harm the operators' health. A by-product of incomplete fuel combustion in a diesel engine is DPM.

The solid core of these particles is mostly made up of Elemental Carbon (EC), which is encircled by Organic Carbon (OC). Together, these two are referred to as the Total Carbon (TC). Numerous studies have found that human exposure to diesel exhaust fumes can result in cancer. Table 1 displays the SANDVIK LH204 specifications, while Table 2 displays the composition of diesel exhaust.

4.0 Load Haul Dumper

The first trackless rubber-tired loader for underground mines was created in 1959. Teletram and Scooptram were then built in 1962 and 1963, respectively (Chadwick, 1996)[1]. Figure 2 depicts a typical LHD used for face hauling in underground mining. Because of LHDs' consistently rising productivity, flexibility, and success

Figure 2. Diesel LHD used in underground metal mining.

in the challenging mining environment, their utilization is expanding must be able to fit into the apertures in the underground and the mine infrastructure, the choice of LHDs is regulated by ventilation requirements and minimal working clearance (minimum one-meter operating clearance between vehicle and sidewalls) (Dubois *et al*., 2007). In order to prevent the wheel from spinning in the event that the hydraulic breakout force is too high, it is crucial to balance the static and hydraulic breakout forces when choosing an LHD. Accordingly, breakout force is the sum of the forces applied to the machine's boom by the operator's hydraulic breakout force and the machine's own weight (static breakout

Figure 3. Battery LHD used in underground metal mining.

force – tipping capacity). The loose density (weight/m^3) of the material to be carried determines the appropriate bucket size. Accordingly, the bucket sizes range from 3 to 11.6 m^3.

A battery is a type of power generator that has the capacity to store chemical energy and transform it into work. As mining corporations dig deeper underground mines in quest of higher-grade ore and bigger reserves, battery-powered vehicles have become more and more common. Ventilating diesel fumes, and heat, and keeping the drive air-conditioned for worker safety and comfort is one of the main difficulties with digging further into the earth. Table 4 displays the gasoline and current expenses.

4.1 Advantages of Battery LHD

- Low noise production (Battery LHD 85 dB compared to 105dB for Diesel).
- Lower heat emission.
- Reduced capital cost on ventilation, cooling, and mine design.
- Reduced fog and better visibility due to less exhaust particles.
- Reduced ventilation and cooling operating costs.
- Less fuel and oil delivery, less waste oil handling.
- Reduced maintenance costs.
- Lithium Iron Phosphate battery system for fast charge, high performance, and improved safety.

5.0 Results and Discussions

As per our observation, it was found in Figure 4. Shows the comparison study is made to minimize the cost

Table 4. Consumption cost of diesel and current for LHD period of one year

MONTH	Diesel cost (Rupees)	Battery cost (Rupees)
APR	321375	3600
MAY	321375	7200
JUN	337875	10800
JUL	354375	14400
AUG	357000	18000
SEP	362875	21600
OCT	368875	25200
NOV	381875	28800
DEC	378750	32400
JAN	389125	36000
FEB	389125	39600
MAR	389125	43200
APR	392000	46800

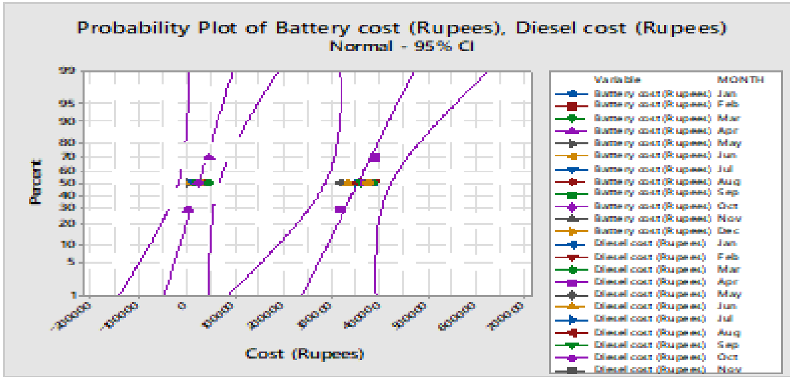

Figure 4. Comparison between diesel LHD and Battery LHD.

incurred on the renovation to diesel to battery LHD. It was observed that diesel cost was found 53,562 per day and for a month it was found to be 3,21,375 per month considering

25 days working and per annum, the cost was estimated about 47,43,375.00 (Forty seven lakh forty three thousand three hundred seventy five only). As it was planned to the diesel LHD to Battery LHD, the initial cost of the battery purchased may be the highest investment. In services for charging 100 volts battery of 3 numbers found to be 15 units (per unit cost is Rupees 16 only). Approximately 30 minutes to charge and no need to replace or change the battery. The cost incurred in battery charging annually is 3, 27, 600. The formula for calculating the percentage.

PERCENTAGE SAVING =

$$\frac{Total\ diesel\ annual\ cost\ - Total\ Battery\ Charging\ annual\ cost}{Total\ diesel\ annual\ \ cost} \text{x}100$$

$$\textbf{PERCENTAGE SAVINGS} = \frac{4743375-327600}{4743375} X100 = 90\%$$

Overall 90% SAVINGS in operational cost, when compared to Diesel LHD.

6.0 Conclusion

Without drastically altering production, switching to battery power is possible. The operation of the diesel and battery LHDs is comparable. Battery adjustments would reduce the amount of effective time. Without substantially decreasing the amount of useful time, the battery substitutions might be done during breaks. Gas emissions, noise, and heat production can all also be decreased and managed by converting to battery-powered LHDs. The initial cost for changing the battery will be higher after the battery LHD is switched from diesel LHD. It was discovered that the battery LHD's running and maintenance costs are drastically lower than those of diesel LHD, with savings of up to 90%. Consequently, in this work, a suggestion is offered to safe environment and cost on ventilation.

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