Plough Scraper and Tilting Device on Conveyor Belts

Mpho Cacious Makutu

Student, Department of Mechanical and Industrial Engineering Technology
University of Johannesburg
Johannesburg, Doornfontein, South Africa
cashmpipo@gmail.com

Daramy Vandi Von Kallon
Senior Lecturer, Department of Mechanical and Industrial Engineering Technology
University of Johannesburg
Johannesburg, Doornfontein, South Africa
dkallon@uj.ac.za

Abstract

South African mining industry is struggling with quick methods of structural change set ups. This is also a challenge even in temporary set ups and installation. Most mining materials are handled/moved using conveyor belts. These conveyor belts are reducing downtimes and increases operating cost due to higher maintenance and breakdowns. A study for different equipment making up a complete conveyor belt was conducted to learn more about this equipment and their behaviour. Advantages and disadvantages were noted in studying different types. Causes of failures with recommended maintenance and operating methodologies were also noted on the research made in the past. Conveyors systems can be very dangerous especially when in operations. Protective devices and methods are also noted and advised. Plough Scraper and Tilting Device are also researched as they provide a cheaper method of transferring materials or offloading a conveyor system either temporarily or permanently. History of scrapers and tilting device is also observed to further understand the background in contribution to recommending the best suitable solution to scrap off materials either in a tilted method or non-tilted scraping off from a moving conveyor. All of the equipment making up the conveyor belts including the tilting and scraping systems contributed to coming up with a very successful method of scraping or offloading a moving conveyor in a reasonable time and cost without major modifications as before this technology was discovered.

Keywords

Tilting, Plough, Scraping, Angle and Settling

1. Introduction

Exxaro is the third largest coal producer in South Africa. In November 2006 Kumba Resources Limited and Kumba coal and other assets merged with Eyesizwe coal to create Exxaro Resource Limited. It has since grown to be the largest and foremost black empowered coal and heavy mineral company is South Africa. Exxaro also has other business interest in Europe, USA and Australia. In South Africa Exxaro's portfolio include coal mining, Iron ore, pigment manufacturing, renewable energy (Wind) and residual base metals **(Exxaro Resources, 2021)**. Although more revenue and operations are in coal mining interest is also focused in expanding in these investments. Table 1 shows the operations where Exxaro has secured shares. Locations of Exxaro operates in South Africa in the province of Mpumalanga and Limpopo. Grootegeluk Coal Mine being the mine this research was developed feeds 2 Eskom Power Stations being Matimba and Medupi alone, No coal mine in close proximity to assist in case Grootegeluk is unable to. The coal is graded accordingly, crushed, screened, and washed before being supplied to different customers.

Table 1: Exxaro Limited Investments (Exxaro Resources, 2021)

Operation	Main Share Holder	Merchandise	Exxaro's Share Holding (%)
Exxaro Coal Mines	Exxaro Limited	Coal Mining	Major Share Holder
Exxaro Ferro Alloys	Exxaro Limited	Ferro Alloys	Major Share Holder
Exxaro Cennergi Power	Exxaro Limited	Renewable Power (Wind)	Major Share Holder
Mafube Coal	Anglo Coal and Exxaro	Coal Mining	50
Sishen Mine	Anglo American	Iron Ore Mining	21
Tronox Limited	Tronox Limited	Titanium Oxide	24
Black Mountain Mine	Vedanta Zink International	Zink, Silver, Lead and Copper	26

Due to high demand of power station coal in the country, decision was made to tap coal from Medupi power station conveyor line to load trains to be sold to either other power station or export purposes. Grootegeluk operation currently only has one silo to load trains but for metallurgical and export coal which are not that different in grade. Investigation was made on the cheaper and less down time method to tap coal from Medupi conveyor to the export silo so it can be transported by train. The point that had both advantages was at the intersection where Medupi conveyor (4000 tons per hour) passes above silo feed conveyor (2000 tons per hour). Medupi provides power to many South Africans and cannot stop production as South African power grid is always under pressure to supply both South Africa and local countries, it is not possible to shut down the supply for more than 12 hours at any given time. Other methods to tap from the top conveyor to bottom have been considered including to install a suffocating/flip chute. This was going to require major structural and setup changes that can take more than a week or months with delays. Tilting plough was then seen as a quick way in within he available 12 hours a week shut.

The drive for this paper is to familiarise a method of using Tilting Device and Plough to scrap off or offload material from a conveyor belt. Conveyor belts, Tilting Devices and Ploughs are designed according to SABS standards. The law enforces compliance due to safety factors that might be involved when operating and maintaining the conveyor belts. This paper entails a simple method used to offload coal mineral on top of an existing top conveyor belt (4000 tpa) into another existing lowered conveyor belt (2000 tpa). This is one method of saving too much capital and complicated design that results in big construction cost involving traditional transfer towers. It focuses more on method used in Exxaro Grootegeluk Mine to off load power station coal from a running belt to another means of production line tap without redesign and reconstruction of the existing systems. This also details the method used and the results there of after construction. Part of this paper includes more studies on Tilting Device, Plough and Conveyor Belts being a major part of this system.

Raw stone material handling is a method used to move materials from one point to the other. Stone handling specifically needs conveyors or surface mobile equipment to move any quantities from one point to another. Bigger particles are mostly handled by surface mobile equipment to be crushed on the nearest crusher mostly jaw (primary crushers) to conveyable sizes. After the primary crushing, conveyors then become economical and efficiently used. Diesel purchase and maintenance prices for surface mobile equipment makes it difficult to use the surface mobile equipment anywhere unless if no choice is available on the set up. Conveyors are very economical and easy to operate but not in extremely longer distances. Materials from one conveyor is transferred to the other using a chute of either single or flip if wanting to transfer to multiple conveyors or feeds. Traditional transfer towers with chutes requires major structural change and more time to install, and this does not become practical on busy conveyors servicing high demanding organisation like Eskom generation power stations. Systems like the tilting device and plough are not familiar in the industry. Tilting plough does not require extensive structural change and huge down times. Installation can be done during routine shuts of about 8-12 hours. A typical conveyor belt set up is shown in Figure 1.

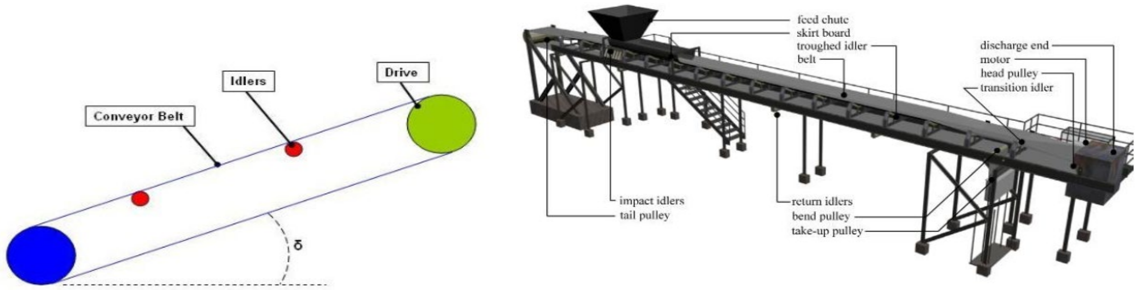

Figure 1: Typical Conveyor Set Up **(Lucas, et al., 2007; Lucas, et al., 2007)**.

1. Literature Review

2.1. History of Tiling Devices

Tilting devices come a long way with the first design being in train waggons (Schneider, 1998). This need to develop a tilting device was driven by the need to optimise rail transport due to its economical and reliability advantages. Most of the bulk material is received from the source being the mine is transported by train to the end user or next line of transport (Shah, 2019). This mechanised way of offloading was derived by the huge quantities received. There are two types of wagons used being BOXN and BOBRN wagons (Shah, 2019). Material is discharged from the top on BOXN type while in BOBRN is discharged from the bottom. A system consisting of wagon tipplers is used for BOXN type wagons whereas unloading system for BOBRN wagons consists of track hopper (Shah, 2019). The wagon gets dismantled from the train, lined up on the tilting device. It is then attached to the tilting device to tilt and spill the material in a dedicated bin/chute. Put back in place for the next wagon to be done the same. Figure 2 shows a typical train waggon tilting device used to offload minerals from the trains.

Figure 2: Typical Train Wagon Tilting Device (Anon., n.d.).

This then became more standard and preferred by most countries especially the mining and mineral processing plants (Schneider, 1998). The first wagon tilting device was developed in 1943 in Talgo (Spain) (Schneider, 1998). In 1998 Europe had 13 countries that were using the same wagon tilting device already. Fiat in Italy was investing more applications and improvements in 1988 with an application of 381 units since 1973 (Schneider, 1998). This has been having increasing requirements and the market kept asking for more powerful and more friendly solutions (Schneider, 1998). Generally, a tippler or tilting device contain table for positioning the wagon, wagon holding mechanism, gears, pinions for rotation and drive units.

The most commonly tippler/tilting devices are random models. It required the train waggons to be disconnected from each other (Tellier & Matthias, 2015). There are 2 types of rotary tipplers being the C and O type (Tellier & Matthias, 2015). C-type has an opening to the one side for the waggon to pass through the tipplers unchecked (Tellier & Matthias, 2015). This type rotates 135^0 up to a maximum 160^0 to discharge materials (Tellier & Matthias, 2015). If using an O-type tippler, the wagons need to be pushed into and out of the tippler from further up or down (Tellier & Matthias, 2015). This type rotates 180^0 with the minimum of 160^0 to discharge material (Tellier & Matthias, 2015). There is a small-time savings associate with a C-type tippler because the positioner can operate closer to the wagons being pushed into the system (Tellier & Matthias, 2015). Before any tippling action the waggon needs to be accurately in position before clamping to tilt to pour off the material. Hydraulic or gravity clamping can be used but the most popular in South Africa is the gravity one (Tellier & Matthias, 2015).

2.2. General Arrangements and Origin of Conveyor Tilting Ploughs

The first conveyor was documented in 1868 during Lyster descriptions to the British. The intent was to convey the materials any how being vertically up and down or from a higher or lower level. (Velmurugan, et al., 2014). Depending on the requirement you will have either flat or troughed conveyor. The popular ones are troughed as they control the spillages of what is being conveyed (Velmurugan, et al., 2014). Flat belt type will have a flat surface being used to convey bags, blocks, packages material or something that is not likely to fall off the belt. They normally self-balanced to maintain their position (Velmurugan, et al., 2014). Troughed ones are for any shape of material like crashed stone or soil or unpackaged material that is more likely to roll or fall of the belt (Velmurugan, et al., 2014). Conveyor performance is dependant of the service attention given to it. Poor maintenance and design can also lead to accidents or incidents during operation and maintenance (Velmurugan, et al., 2014). Impacts are also experienced where a conveyor gets loaded or to where it discharges. Liners and skirtings are also required where there is wear possibility to avoid wear to the actual conveyor structure (Velmurugan, et al., 2014). Conveyors are classified in grades according to the British standards being A, B and C. A being used in strongly abrasive or cutting applications, B in normal moderate abrasion or cutting applications (Velmurugan, et al., 2014).

2.2.1. Conveyor Belts

A typical conveyor consists of a drive unit, pullers idlers, take up, skirt boards, conveyor belt and other units. Conveyor belts are used to transport materials from one point to another. This is the most efficient way and easy to use especially in process plants. All process plants in the world will have some sort of conveyor if not many unless if they process does not allow. All mines in the whole world have conveyor belts in their mining and process plants. Different kinds of conveyors are untreated cotton canvas belts, the impregnated cotton and canvas belts, coated belts, covered belts, reinforced belts, integral cleat belt and white finishes belts.

Studies shows that costs of storing and transporting bulk materials are always high hence the importance of designing and operating material handling with cost reduction in mind (Roberts & Harrison, n.d.). Some advantages of using conveyor belts as compared to road transport is conveyor has high load carrying capacity, large length of conveying path, simple design, easy maintenance and high reliability, long life, does not have noise easy to operate (Ananth, et al., 2013). Some of the important information required when designing the conveyor belt is belt speed, belt width, absorbed power, gear box selection, drive pulley shaft, material to be conveyed, material size, capacity (tons per hour), conveyor length and environmental conditions like temperature (Ananth, et al., 2013). The conveyors that are widely used in various industries, including the mining, construction, and manufacturing industries, to transport materials from one place to another are textile-reinforced conveyors (Lemmi, et al., 2021). A lot has changed since when the first conveyor was used in the 19th centuries including the invention of vulcanized rubber by Charles Goodyear in 1839 and the introduction of thermoplastic fibres to the market in the mid-20th century has meaningfully positively contributed to the development of a textile–rubber reinforced conveyor belt production that is in use to date [13, 14]. Recent research discovered that disinfecting or using disinfections on conveyors affects the material characteristics including material hardness, elasticity, and static and dynamic loading. This could result in mechanical damage to the rubber parts of the conveyor belt resulting in premature failures (Dragonova, et al., 2021).

2.2.2. Drive Unit

The drive unit consist of electric motor, coupling, gearbox that connects output shaft with conveyor pulley to run the belt. A crucial object in this subsystem is gearbox. 13-17% of the gearboxes even if correctly maintained they fail (Velmurugan, et al., 2014). It is still advised to follow correct maintenance practices to have a long gearbox life. About 50% of the failure on the gear box are caused by geared wheels (Velmurugan, et al., 2014). Another critical failure is the input shaft of the gearbox. It is to be noted that failures are also caused by controlled things like overloading, rough loading and input problems hence frequent maintenance is always advised (Velmurugan, et al., 2014). Figure 3 shows popular conveyor drive set up used by most operations (Velmurugan, et al., 2014).

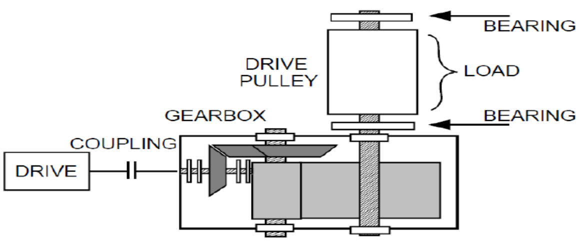

Figure 3: Typical Drive Unit Set Up (Velmurugan, et al., 2014; ZIMROZ & Krol, 2009).

2.2.3. Pulleys

Pulleys are generally made of steel, and some wrapped in lagging. Lagging increases the friction and grip between the belt and the pulley. The pulley will have a support at each end with bearings for a smooth rolling action. Figure 4 shows a set up in the tail end of every conveyor.

Figure 4: Typical Tail pulley Set Up (DRCrollers, n.d.).

Most failures in pulleys are in bearings assemblies. Research shows that 43% of the bearing failures are caused by moisture and dirt as they degrade the lubricate being grease in most instances (Visic, et al., 2020). Once the grease or lubricant is degraded the is increased rolling resistance that puts too much pressure on the bearing, and it fails due to that. Grease or lubricant provides good protecting against dust and corrosion and is also easy to use. Grease has limited serving life and gets mostly affected by increased temperatures (Visic, et al., 2020).

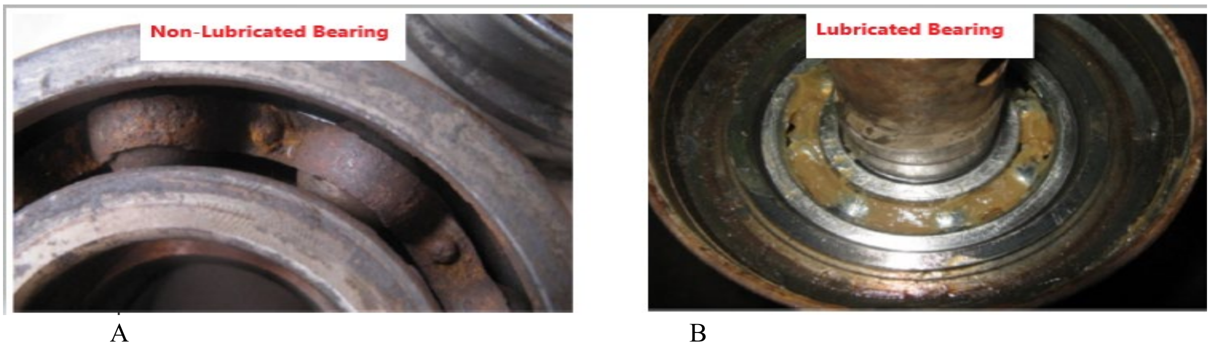

Figure 5: Non-Lubricated and Lubricated Bearings (Visic, et al., 2020).

Figure 5A and 5B clearly shows the difference between a non-lubricated bearing and a lubricated one. Figure 5 being a non-lubricated bearing with rust and increased changes of failing (Visic, et al., 2020). Figure 8B being a non-rusted bearing that is well greases and will run smooth and longer if installed. Lubricated ones are protected from failures and corrosions thus increasing the life span of the bearing. The rolling balls are the main items to be protected for a less resistant pull or push of the conveyor (Visic, et al., 2020).

2.2.4. The Idlers

Idlers are of the same design as a pulley but small with anti-friction bearings to eliminate lubrication requirements. Different idlers will include toughing idler- to tough the belt, toughing trainer- to train the belt, return idler- to balance the return section of the belt as it circles, return trainer- to train the return section of the belt, impact idler- to absorb the impact especially in the loading sections of the belt (Sust, 2013).

Figure 6: Idler with Bearing Assembly and a New Seal in Accordance with the Invention of the Central Mining (Sust, 2013)

Figure 6 shows the shell and inside of the idler. The shaft is run on a bearing that is installed at each end of the idler drum. Main purpose of the idlers is to provide right shaping required, support and protect the conveyor from touching the structure parts that might cause damage, reduce resistance caused by motion. Their life span normally depends on the construction, engineering and operational factors or conditions. Most failures are caused by bearings that jammed (Figure 7) or seized which is normal wear and tear as much equipment (Sust, 2013). With the wear on idler shown in Figure 7 the conveyor can be cut or scratched which could cause the conveyor premature failures due to scratches or cuts from a worn idler as shown in Figure 7.

Figure 7: Jammed Idler Worn by Running Conveyor (Skecon, 2021)

According to studies done on laboratory and operational practices, their quality of most manufacturers standards idlers is lower than the average durability expectations (Sust, 2013). It is normally around 1 year life (Pytlik, 2013). This was tested according to requirements in PN-M-466606:2010 which confirmed that they do not meet the minimum requirements when manufactured at factories (Pytlik, 2013). This was also confirmed by studies conducted by Department of Mechanical Devices Testing- the Central Mining Institute (GIG) (Pytlik, 2013). Expects from University of Technology in Gliwice were leading by monitoring the work of idlers in operations to conclude that (Antoniak 2007) the damages and symptoms of idlers where either demonstrated by an increase in temperature, noise, and vibration. Temperature was the most contributor in both (Sust, 2013).

Engineering failures analysis also indicated that the studies conducted in 6 months proved that most failures were caused by plastic deformation in the form of gabs (42.3%0 and corrosive wear (30.7%). Fault tree analysis diagram can be used by engineers to buy new idlers. Bearings and idlers are the most loaded segments of the conveyor system therefore the performance of the blet is dependant of their proper functioning. Failures my develop with no visible signs in some instances.

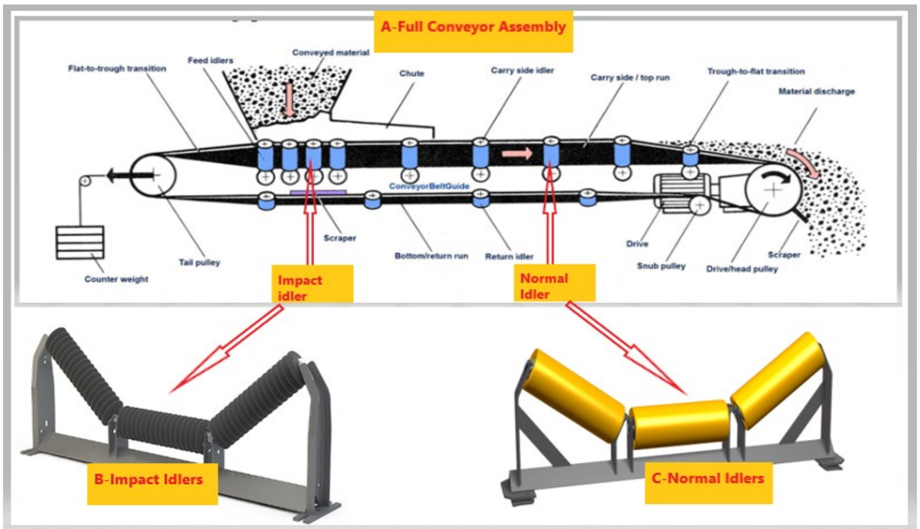

Figure 8: Full Conveyor Assembly (A), Impact Idler (B) and Normal Idlers (C) (Crusher Rand Parts, 2021).

The Figure 8 (A) shows a typical conveyor set up with different idlers, pulleys, drives, chutes, counterweight, and material. Also Figure 8 (C) shown a normal idler and impact idlers (B). On the impact sections, impact idlers mainly covered with rubber to absorb the impact are used while on non-impact areas uses normal idlers not covered with rubber. Idlers can either be plastic (modern ones) or steel made (mostly used and older preference). Each idler has two bearings on the mountings. Bearing manufacturers mostly preferers SKF brand, other manufacturers used are FAG-INA (Herzogenaurach, Germany), TIMKEN (North Canton, Ohio, USA), GPZ (Krivoy Rog, Ukraine), NKE (Steyr, Austria), FERSA (Zaragoza, Spain), NTN (Osaka, Japan), KG (Delhi, India), KOYU (Osaka, Japan), ZKL/ZVL (Brno, The Czech Republic) (Visic, et al., 2020). The operational resilience of a roller is determined by factors like design, roller set parameters (the spacing and the angle of bevel) and the operating conditions (Robert, 2017).

2.2.5. Take-ups

Take-up structure or system is to keep the conveyor in good tension and allow extension or reduction in length during different temperatures and loading pressures as per Figure 9. Longer belts cannot work properly if not having take-up section to control the tension and slack absorption required in conveyor belts. Almost every belt has a take up system. Take up system can be in different designs but are serving the same purpose. The application and plant set up does contributes to which design is best for a belt design.

Figure 9: Take Up Pulley (Lucas, et al., 2007)

Types of takes-ups mostly used are:

- Screw takes up of which the tail pulley bearings are riding on guides. The bearing mounting are moved manually by single screws so that the tension on the belt can be wide-ranging appropriately.
- Vertical gravity take-ups of which is the common type of self-controlled take-ups. The take up pulley bearings are usually riding on a yoke which moves vertically up and down along two posts guides. Weights are added to the take-ups as to maintain the belt tension. Weights are calculated custom for each belt to ensure the right tension on the system.

2.2.6. Skirt Boards

Skirt boards are used to guid the material during loading and discharge section. They mostly have rubber or some sort of a liner to absorb the shock and wear on the frame

2.2.7. Belt Cleaning Scraper

Belt scrappers were developed from the theory of power scrappers used to scrap material underground. The first power scrapper was for moving muck by Bukner Hill and Sillivan mining companies in Kellogg from 1898 (Guy, 1950; Van Barneveld & Charles, 1924). Scrapers are installed at the strategic section of the belt preferable at the discharge pulley to clean the material carry backs on the belt to avoid damages to the system caused by this dirt. It is basically to clean the return belt after discharge. The material sometimes gets stuck on the return belt and causes lot of housekeeping problems and damages to the belt, structure and other equipment that are sensitive to the material that is carried back. Research also shows that lack or inadequate scraping to prevent carry backs contributes to idler, pulley and belt failure contributing to downtimes and safety concerns. Materials carry backs sticks on the belt, then to the return idlers and pulley. Carry backs also makes it difficult to train the belt. This will also cause spillages along the belt length as stuck materials fall off throughout the length. The amount of carry back is dependent on material type, material size, belt speed, system capacity, moisture presence/amount and belt speed. This then means belt scraping improves belt availability, reliability, and organisational profit. It reduces safety hazards as there will be less spillages and less damage to equipment. A 1.2m belt running at 1.6m/s will carry back approximately 1.04 tons of coal per hour (Shortt & Nel, 1999). It is also possible to have primary, secondary and tertiary scrapers, if necessary, in one line, this will eliminate the carry backs even more efficiently in material that are stickier (Ariff, et al., 2015). The first scraper was just a piece of wood placed between the belt with a smaller clearance not to wear the belt as per Figure10 (A). This was replaced by counterweighted arms as per Figure 10 (B) which is self-adjusting to prevent too much or less of scrapping force. This is now more advanced that different materials that have less wear to the belt are used with consideration of rubber or springs to self-adjust the scrapping force as per Figure 10 (C).

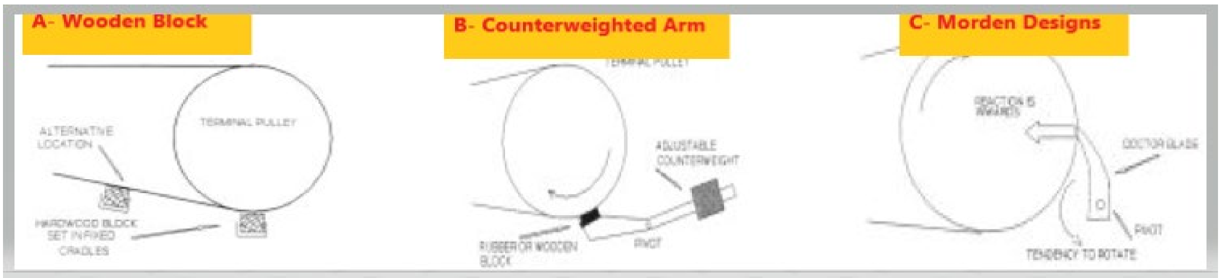

Figure 10: Wooden Block (A); Counterweight Arm (B) and Morden Design Scraper (C) (Shortt & Nel, 1999)

Ensuring belt is scraped and cleaned very well keeps the belt and area clean but also improves efficiency by providing the following (Marting Engineering, n.d.).

- Increased profitability - Eliminating carryback reduces fugitive material and minimizes the cost of compliance, Safety, cleanup, and maintenance.
- Less material loss - By scraping the belts clean at the head pulley, belt cleaners eliminate carryback and keep bulk materials moving in the right direction through transfer points or into containers.
- Longer lasting conveyor equipment - Material that is carried back under the belt often ends up inside the conveyor system and can damage rollers and idlers while causing belts to wander and fray.
- Lower energy costs - When material sticks to the belt beyond the head pulley, the added weight of the material stuck to the belt makes the equipment work harder so it uses more energy.
- Safer work environment - When fugitive material accumulates under the belt, workers can easily slip and fall trying to walk through the mess. Plus, uncontained dust can cause health problems when inhaled and can ignite causing a deadly explosion.
- Reduced dust problems - Fugitive dust is frequently a by-product of material that falls from under the belt on the return trip.

Lot of mines are losing materials due to carry backs especially the coal mining industry (Merchant, 1992).Take the example of a coal conveyor traveling at a speed of 3.5m/s and carrying 3000 tons per hour with a moisture content of 8% (Merchant, 1992). If 0,05% of the material conveyed were carry backs, it means 1,5 tons per hour would be material lost along the length of the conveyor (Merchant, 1992). It this is not cleaned regularly the belt might end up not even running or access temporarily forfeited. It therefore if carry backs are eliminated or reduced substantial costs savings can be achieved by reducing potential damage to belts, idlers, structure and avoiding clean-up costs with increased compliance and safety adherence (Merchant, 1992). Importance is to note that besides cost saving there is a safety factor with this coal spillage hazard (Merchant, 1992). This carry backs can cause friction, spark, spontaneous combustion which could destroy the plant, equipment, and injuries/fatalities to personnel. Materials conveyed throughout the country vary in consistency from dry powders to wet slurries. Types of materials range from phosphates, coal, and iron ores to chrome ores with a corresponding variance in densities. One can readily see that these materials each have their own unique properties in relation to belt cleaning and great consideration has to be given to the types of belt cleaners employed. Only recently are scrapper installation made provided for in the chute design. Modification and plans had to be made previously resulting in additional cost to redesign, fabricate and install so scrapers can be accommodated (Merchant, 1992).

2.2.8. Basic Conveyor Belt Structure

Conveyor belt set up or structure contains minimum two pulleys. A belt has one or more drives to drive the conveyor depending on power requirements. The pulley that is not driving is called non-drive/idle pulley and the driving one being called the drive pulley. Pulleys on the structure are used for different purposes including to turn the belt or to create more friction required to drive the belt. The belt and other control devices are installed in the conveyor structure. The structure will have steel members that are designed to keep itself standing and safe to work/work on. The structure is also designed to carry the load of the material and other structured or equipment's on the belt structure (Velmurugan, et al., 2014).

2.3. Conveyor Wear/Failure During Scraping

Conveyor wear is the most experienced factor when continuously scraping materials from the moving conveyor. This is due to the scraping force of the scraper to conveyor and carry back of materials. Most wear is experienced on the top layer of the belt as is where the scraping force is always applied. It is advice to consider thicker or more layers on the side being scraped. Consideration to consider scraper that will have low friction to the kind of conveyor or vice versa before applying scrapers on conveyors is advisable. Conveyor speed, scraping force, material being scraped, position of the scraper and material that the scraper is made of are to be determined carefully before scraper application is selected. Abrasion, fatigue and roll formation are lead wear mechanisms that are driven by load, velocity, hardness and friction itself (Hakani, et al., 2017). Connections between persuasive parameters and their outcome on rubber wear was researched in detail. The equation of Archard does not work well for rubber wear but in other material wears (Hakani, et al., 2017). The detailed research being referred to does give good results in this regard (Hakani, et al., 2017).

In coal mining conveyance, conveyor failures are normally impacted by impurities including sharp, foreign, or hard objects or rocks (Ly, et al., 2021). This will be prone to longitudinal tear in the belt, the same tear will expand along the direction of operation resulting in belt failure (Ly, et al., 2021). Belt failure causes lot of material spillage and equipment damage if not detected in the early stages. This damage will obviously result in economical or financial impacts to the company. Longitudinal tears are the failures that most research is focused on and will be a focus area on the future as the most contributors to belt failures (Ly, et al., 2021). The Figure 11 (A) shows the belt scratches before they become tear as in Figure 11 (B). Figure 11 (B) shows a longitudinal failed belt due to scratches as of Figure 11 (A).

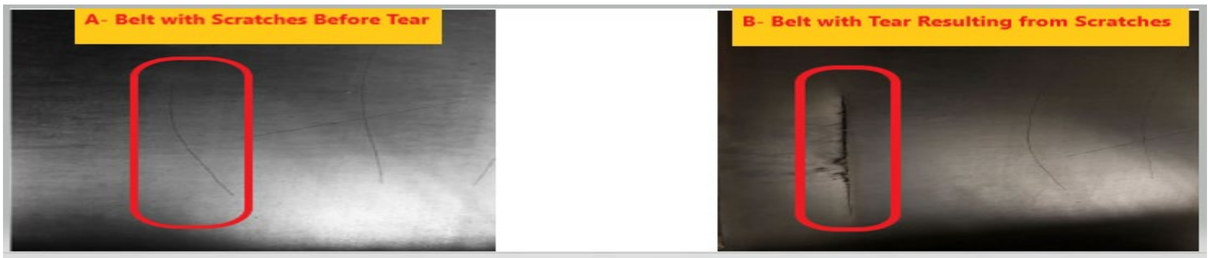

Figure 11: Belt with Scratches Before Tear (A) and Tear Resulting from Scratches (B) (Ly, et al., 2021)

2.3.1. Further Research Notes on System Failures

The following are further research notes and failures experienced in the market (Velmurugan, et al., 2014).

- Some sticky materials on the return belt exist as carry back.
- More than one scraper system on strategic sections like the head pulley work effectively if scrappers are installed there.
- Liquid preferable water spays also work effective to remove this carry back or sticky material.
- Pulleys mostly fail on bearings, lagging and shells due to material carry backs.
- 50% of gearbox failures is due to gears which is the main components in the gearbox system. Bearing failures in gearbox are not that popular than in pulleys.
- If overload is frequently uncontrolled shafts normally fail if designed to the minimal factor of safety.

3. Good Performance and Safety in Conveyor Belt Systems

More focus should be put in proper operating and maintenance philosophies as recommended by the original equipment manufacturers or engineers. Qualified personnel are also crucial to do the right thing at the right time. This could increase production profitability's to survive in these competitive times.

4. Belt Intelligence and Design

Conveyor belt in and advanced mining area has lot of intelligence mainly for safety, reliability, and reporting purposes (Zhang, et al., 2021). This intelligence depending on the advancement of the mine and designer. This intelligence includes the determination of its running state of self-awareness, self-learning using sensors and cameras and real time status of operational parameters (Zhang, et al., 2021).

A typical conveyor belt contains a multilayer flat composite on both the bottom and top parts. Careful attention was paid in research that shows that when changing the physical and mechanical properties of the belt layers either by traying to make it more robust or increase its advantages contributes to changing the rigidity and flexibility of the belt itself (Czaplicka, et al., 2003). Design of the belt is divided into minimum stages as follows (Czaplicka, et al., 2003):

- Structure design- This includes the selection of material, analysing and selection of layers or reinforcement

- Selection or analysing the requirements- Consistent with the assumptions of another user. This will include the destruction criteria on the design.
- Composite design and optimisation
- Presentation of explainer material. This is the first attempt that can further be improved if need be.

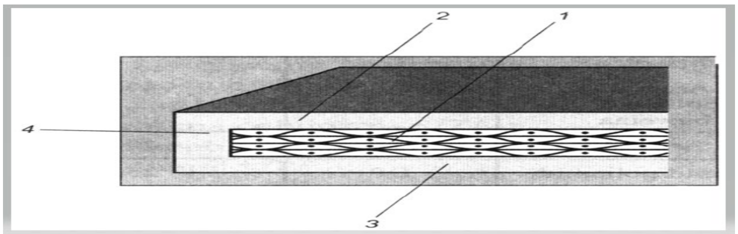

Figure 12: Typical Conveyor Belt Structure (Czaplicka, et al., 2003).

Figure 12 shows 1 being the core or reinforcing of the belt. 2 Carrying covering or top layer, this is normally multilayer. 3 is the running coverage or bottom layer, it could also be a single or multi layered depending on the application. 4 being the rim.

5. Fire Proofing/ Prevention During Belt Scraping

It is to be noted that the scraping action creates lots of friction between the belt and the scraper. Effort is to be applied to ensure the scrapping plate and conveyor being scraped does not cause fire hazard especially when scraping coal as is highly flammable. There are lot of conveyor material that are easily flammable. The non-flammable ones are to be considered as part of fire proofing in coal mines. Rubber textile conveyor belts used in underground coal mines require strong and standardized fire-resistant properties to guarantee the safety of the human beings and equipment's. The purpose of this is the optimization of the rubber ingredients used in the conveyor which are the main contributors of fire hazard in the belts (Dushi, et al., 2013). The ingredients include but not limited to Sb2O3 (X1), chlorinated paraffins (X2) and clay (X3) (Dushi, et al., 2013). The experiments were designed using central composite rotatable design (CCRD) of second order, according to the mathematical model of desirability functions. The fitted responses for flammability were Spirit Burner test (Y1), Surface resistance test (Y2), and Limit oxygen index, LOI (Y3). The preferred solution minimum X1 = 0.2889; X2 = 0.39 and X3 = -0.832. Composite appeal is minimum 0.932. This is well-organized rate for appeal (Dushi, et al., 2013).

6. Belt Safety Devices

Safety devices normally incorporated in the belt conveyor systems includes anti-roll back devices, speed limit switches, skew sensors, no speed switches, interlock protection switches and overload notifications

7. Conclusion

The objective was to acquire more information on the challenges, recommendations from past researchers and best ways to avoid failures on system equipment of Tilting Device and Plough Scraper. This included the history and other Plough Scrapers and Tilting Devices previously used and any other similar method to remove material from a moving conveyor into a new line or destination. The method of using Tilting Device and Plough Scraper was proven to be efficient and cost effective before and after being put into practice in Exxaro Grootegeluk Mine. Improvements can be made to adjust some smaller grey areas on the system. It can also be rolled out as it works better comparing to the effort and cost of using the traditional transfer tower method. More research can assist in improving this set up. Because the Tilting Device is rarely used, results obtained are good for a scarce system of this nature. This is less complicated and more ideal for the mining environment since complexity is not ideal. Ease of maintenance and operation is also evident on this Tilting Device and Plough Scraper. The only maintenance will be on the scraper of the plough, liners on the plough and flattening rollers on the tilting device. Time taken to design and install the system is also effective and economical. It takes lesser time to design and install this system with no alternative supplies or penalties to consider when installing this system. The customers remain undisrupted during this construction. The opportunity that rose to supply power station coal to other mines other than the ones currently supplied via directs belts was solved without an impact. Now coal is supplied to other users for additional income. This can open the market to supply even more customers for better profit. With this operational the mine does not depend on the current bigger customers being Eskom Matimba and Medupi. Some contracts can emerge from the ability to supply more from the current system. The scraper suppliers are to be involved when designing this kind of system. Scraper suppliers might not have supplied this kind of systems but have supplied a return belt scraper on the conveyor belts. Return belt scrappers work similar as this but they will just focus more of this kind of objective. Carry back scraping experience gives better insight to contribute to this kind of system as scraping force is similar, just on different quantity and purpose for this set up. Plough also works fine without the Tilting Device. It is evident that the Plough without Tilting Device also produces good material transfer if the belt is flattened.

References

Ananth, K. N., Rakesh, V. & Visweswarao, P. K., Design and Selecting the Proper Conveyor-Belt. *International Journal of Advanced Engineering Technology,* 4(2), pp. 43-49. 2013.

Anon., n.d. *Train Wagons Tipler Picture (on Images).* [Online] Available at: https://www.google.com/search?hl=en-ZA&gbv=2&biw=1519&bih=723&tbm=isch&sxsrf=AOaemvK1fbeg7zw3MBaoTjZ-WUD3-JT7rg%3A1639987195181&oq=&aqs=&q=train+wagons+tipler+picture [Accessed 2021 12 2021].

Ariff, T. F., Jusoh, M. F., Parnin, M. & Azenan, M. H., Improving Efficiency and Enhacing Productivity in Transporting Fertilizers by Using Conveyor Belt Cleaners. *Advanced material Reseach,* Volume 1082, pp. 505-510. 2015.

Ciesielski, A., *Introduction to Rubber Technology.* Shrewsbury: Rapra Technology Limited Shawbury. 1999.

Crusher Rand Parts, *Crusher Rand Parts.* [Online] 2021. Available at: https://www.crusherandparts.com/types-of-conveyor-idlers/ [Accessed 21 12 2021].

Czaplicka, K., Gornictea, G. & Gwartow, P., Eco-Design of Non-Metallic Layer Composites with Respect to Conveyor Belt. *Material and Design,* 24(2), pp. 111-120. 2003.

Dragonova, K. et al., Influence of Disinfectants on Airport Conveyor Belts. *Sustainability 13,* 13(19), p. 10842. 2021.

DRCrollers, n.d. *DRC.* [Online] Available at: https://www.drcrollers.com.au/product-category/conveyor-pulleys?__cf_chl_f_tk=PdFp75CxjxBGRNIwnotadONWFGVUK8hddWMb.6RovTU-1640057575-0-gaNycGzNB30 [Accessed 21 12 2021].

Dreyer, E. & Nel, P. J., *Best Practices:Conveyor Belt Systems,* s.l.: Safety in Mines Reseach Advisory Comitee. 2001.

Dushi, A., Kongoli, F., Mcbow, I. & Rizaj, M., Sustainability and Mineral Processing. *2FLOGEN Technologies Inc,* pp. 377-384. 2013.

Exxaro Resources, *Mining Opratation, Mining.* [Online] 2010. Available at: https://www.exxaro.com/operations/#where-we-operate [Accessed 10 7 2021].

Exxaro Resources, *Exxaro Resources Campany Profile, Mining Industry, Exxaro.* [Online] Available at: https://www.exxaro.com/about/company-profile [Accessed 10 12 2021]. 2021.

Exxaro Resources, *Portfolio.* [Online] 2021. Available at: https://www.exxaro.com/operations/portfolio [Accessed 10 12 2021].

Giraud, L., Masse, S. & Schreiber, L., Conveyor Belt Safety. *ASSE Profesional Safety,* pp. 21-22. 2004.

Guy, R. K., *A Study of Mine Scraper Efficiency on Materials of Different Gravities,* s.l.: Scholars Mine. 1950.

Hakani, A., Pramanik, N., Ridgway, A. & Basak, K., Development of Rubber Material Wear in Conveyor Belt System. *Tribology International,* pp. 148-158. 2017.

Lemmi, T. S., Barkurski, M. & Frukacz, K.,. Effect of Vulcanization Process Parameters on the Tensile Strength of Carcass of Textile-Rubber Reinforced Conveyor Belts. *Materials 14,* 14(24), pp. 1-15. 2021

Lucas, J., Thabet, W. & Worlikar, P., *Using Visual Reality (VR) to Improve Belt Safety in Surface Mining.* Maribor, s.n., pp. 431-436. 2007.

Lucas, J., Thabet, W. & Worlikar, P., Using Vitual Reality (VR) to Improve Conveyor Belt Safety in Surface Mining. *NIOSH Grand #1 R01 OH008716-01 Virtual Environment (VE) Applications to Improve Mining Health and Safety Training,* pp. 431-438. 2007.

Ly, Z., Zhang, X., Hu, J. & Lin, K., Visual Detection Method Based on Line Lasers for the Detection of Longitutional Tear in Conveyor Belts. *Measurements,* Volume 183, pp. 1-5. 2021.

Marting Engineering, n.d. *Marting Engineering Webside.* [Online] Available at: https://www.martin-eng.co.za/content/product_category/2227/conveyor-belt-cleaners [Accessed 11 12 2021].

Merchant, B., *CHute Design for Belt Cleaning.* s.l., s.n. 1992.

Pytlik, A., Durability Testing of Idlers for Belt Conveyors. *Jounal of Sustainable Mining,* 12(3), pp. 1-7. 2013.

Robert, K., Studies of The Durability of Belt Conveyor Idlers with Working Loads Taken into Account. *IOP Conference Series:Earth and Enviromental Science,* 95(4). 2017.

Roberts, A. W. & Harrison, A., n.d. *Recent Reseach Developments in Belt Conveyor Technology,* s.l.: s.n.

Schneider, r., Pantograph for Tilting Trains. *IEE Seminar Current Collection for High-Steed Trains,* pp. 1-24. 1998.

Shah, K. P., *Construction, Working and Maintanance of Equipment for Unloading Bulk Materials,* s.l.: Practical Manintanance. 2019.

Shortt, G. & Nel, P., Belt Cleaning-A Designer's Point of View. *AAPG Internationl Conference and Exhibition Birmingham,* Volume 1, pp. 1-10. 1999.

Skecon, *Skecon Culk Material Handling System Solution Supplier.* [Online] Available at: https://www.skecon.com/news/conveyor-knowledge/35.html [Accessed 21 12 2021]. 2021.

Sust, J., 2013. Durability Testing of Idlers for Belts. *Journal of Sustainable Mining,* 12(3), pp. 1-7.

Tellier, L. & Matthias, G., *Waggon Tipplesr for More Efficient Unloading.* [Online] Available at: https://www.thyssenkrupp-industrial-solutions.co.za/Images/184_Sept-2015-Mechanical-Technology-thyssenkrupp-supplies-wagon-tipplers-for-more-efficient-unloading.pdf [Accessed 2021 12 11]. 2015.

Van Barneveld & Charles, E., Mechanical Underground Loading in Metal Mines. *Missouri School of Mines and Metallugy Technical Bulleting,* 7(3), pp. 210-212. 1924.

Velmurugan, G. et al., Bulk Material Handling. *IJEERT,* 2(3), pp. 1-30. 2014.

Velmurugan, G., Palaniswamy, E., Virjayakumar, R. & Sakthimuruga, T., Conveyor Belts Troubles (Bulk Material Handling). *IJEERT,* 2(3), pp. 21-30. 2014.

Visic, M., Stojanovic, B. & Blagojevic, M., Failure Analysis of Idler Roller Bearing in Conveyor. *Engineering Failure Analysis,* Volume 117, pp. 1-9. 2020.

Zhang, M., Zhang, H., Yu, Y. & Zhou, M., 2021. Deep Learning-Based Damage Detection of Mining Conveyor Belt. *Measurements,* Volume 175, pp. 1-15.

ZIMROZ, R. & Krol, R., Failure Analysis of Belt Conveyor Systems for Conditioning Monitiring Purposes. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej,* 128(36), pp. 256-270. 2009.

Biographies

Mr. Mpho Cacious Makutu is a South African born with a B-Tech in Mechanical Engineering from the University of Johannesburg, South Africa obtained in 2012. He had earlier graduated with a National Diploma in Mechanical Engineering from University of Johannesburg, South Africa obtained in 2011, and Government Certificate of Competency (Factories) obtained in 2019. Mr. Makutu is a candidate technician with the Engineering Council of South Africa, South African. Mr. Makutu had wide experience in mining, smelting, pulp and paper production.

Dr. Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD degree obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT. At the start of 2014 Dr Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 he transferred to the University of Johannesburg as a full-time Lecturer and later a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology (DMIET). Dr Kallon has more than twelve (12) years of experience in research and six (6) years of teaching at university level, with industry-based collaborations. He is widely published, has supervised students from Master to Postdoctoral levels and has graduated seven (7) Masters Candidates. His primary research areas are Acoustics Technologies, Mathematical Analysis and Optimization, Vibration Analysis, Water Research and Engineering Education.