

Wear Analysis of Transfer Chute Liners

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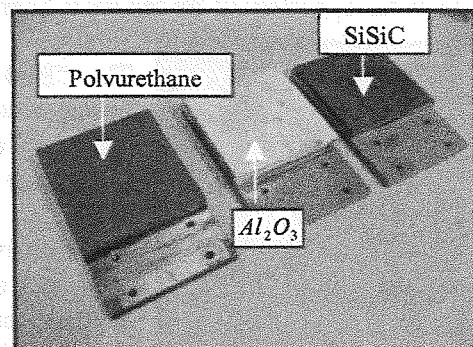
Abstract

The primary aim of the project entitled "Wear Analysis of Transfer Chute Liners" is the identification and analysis of wear mechanisms occurring on the liners of a transfer chute due to ore slurry movement. Specific wear mechanisms (such as abrasion, erosion and gouging) are trialled on three differing chute liners; Polyurethane, Silicon Carbide Ceramic and Alumina Ceramic. This examination acts to compare the reactions and wear rates experienced by the three liner types due to differing input conditions and forced wear mechanisms. The comparison is conducted with the intent of identifying an optimal wear liner for implementation within the chute system.

1.0 Introduction

Numerous differing types of wear liners are used within the mining industry to enhance the lifespan of machinery and equipment. These liners have the specific purpose of reducing rates of wear and protecting a systems infrastructure, this protection can amount to savings of millions of dollars over the entire lifetime of any one plant. Through implementation of effective wear liners, labour, replacement and research costs can be significantly reduced.

Polyurethane (Poly), Silicon Carbide Ceramic (SiSiC) and Alumina Ceramic (Al_2O_3) are three of the primary wear liners in use at Pilbara Iron's Tom Price mine site, (see figure 1). This project is aimed at analysing each liner's effectiveness in minimising wear due to mechanisms of abrasion, erosion and gouging. These are the predicted wear mechanisms occurring on the disperser component of a rock box transfer chute due to ore slurry movement.



(Figure 1, Poly, SiSiC and Al_2O_3 samples)

A "Bulk Particle High Stress Abrasion Test Rig" and "Impact Wear Test Rig" developed by Michael Skinner and Saurabh Das, a "Rubber Wheel Test Rig" developed by Leanne Mac Adams and a "Fine Particle High Stress Abrasion Test Rig" supplied by Concord Engineering are utilized to assist the wear liner analysis.

2.0 Methodology

Wear is dependent on several critical parameters: contact geometry, surface roughness, microstructural features, grain sizes, fracture toughness, velocity, force, temperature, duration, environment conditions and lubrication. The primary wear mechanisms occurring with the chute system due to ore slurry movement are abrasion (high stress abrasion and gouging) and erosion. (Stachowiak, 2001).

High stress abrasion occurs when contact stresses are sufficient to fracture abrasive particles (ore). This fracture can cause fresh sharp edges to be formed on the particles surface structure (increasing wear rates) or cause particles to loose existing sharp edges and “roll” or “round off” (reducing wear rates). (Stachowiak, 2001).

Gouging or “gouging abrasion” occurs when particles impact an object and plastically deform the surface structure of a material. Macroscopic grooves in the material surface are often visible. If a particle impacts a sample with enough energy, material will be sheared from the overall surface structure. This can significantly reduce a wear materials effective lifetime. (Tomlins et al. 1995).

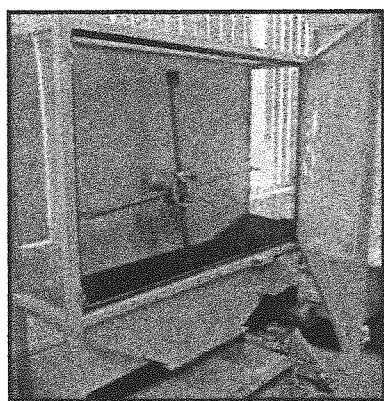
Erosive wear is caused by high velocity fluids, with or without entrained solids passing over a systems surface (Tomlins et al. 1995). The velocity and momentum of the particles impinging on the surface structure are the primary factors determining the severity of wear.

3.0 Test Rig Development and Associated Wear Mechanisms

Four test rig systems were developed and or utilised to simulate the differing mechanisms of wear occurring within the real life environment. Each test situation allows for precise control of the critical system inputs mentioned above in 2.0 Methodology.

3.1 Bulk Particle High Stress Abrasion Test (6.3mm – 31.5mm Particles)

The “Bulk Particle High Stress Abrasion Test Rig” was developed to simulate the mechanism(s) of abrasive wear experienced by the wear liners within a chute system.



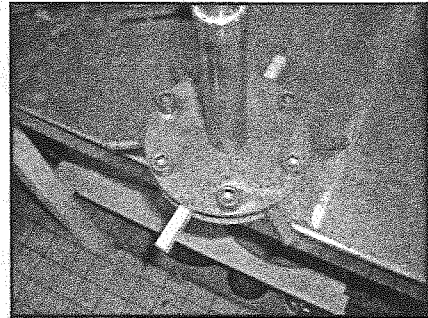
(Figure 2, High Stress Abrasion Rig)

The “Bulk Particle High Stress Abrasion Test Rig” (Figure 2) drives wear liner samples through a pre-determined amount of stationary ore within a hopper, causing high stress abrasive wear at the surface level.

The abrasive wear mechanisms occurring within the rig system are used as a comparable model to that of the abrasive contact forces experienced between the ore slurry and wear liners within the transfer chute. In order to further increase the accuracy of simulation, inputs such as velocity, ore type, ore quantity and testing duration were variable within the test system.

3.2 Fine Particle High Stress Abrasion Test (Fine grit – 5mm Particles)

A “Fine Particle High Stress Abrasion Test” provided by Concord Engineering is utilised to compare the wear rates of the 3 liners (Poly, SiSiC and Al_2O_3 , see Figure 3) due to high stress abrasion from fine particle slurries. Three slurry types are tested, Ore/Water, Ferro/Water and Ore/Ferro/Water. The test rig horizontally rotates the test samples through slurry at a speed of 850rpm, for a testing time of 30min – 1hr.



(Figure 3, Fine Particle Test Rig Samples)

3.3 Impact Test

The “Impact Test Rig” was developed to investigate the mechanism of gouging. The “Impact Test Rig” uses a simple pendulum system with a sharpened tip to impact a wear liner sample normal to its surface. The depth of the groove made, and the energy absorbed from impact is used to grade how each liner with stands gouging at the surface level. Impact testing will take place at a later date.

3.4 Rubber Wheel Test

The “Rubber Wheel Test” uses abrasive 300 micron rounded quartz sand at a flow rate of 320-340g/min for a running time of 30mins to investigate how each liner reacts to abrasive wear at its surface due to fine particles. The test does not attempt to duplicate the exact field conditions experienced on site but rather grade a liner’s ability to resist fine particle abrasion.

4.0 Experimental Procedure

Wear data is collated and analysed in numerous forms. These include:

- Individual samples normalised wear (depth loss per given time frame), $((mm^3 / mm^2) / hr)$,
- Changes to a surface topography (SEM imaging),
- Ore spike parameter quadratic fit (SPQ).

To obtain such data accurately, stringent experimental procedures must be developed to reduce possible inaccuracies and sources of error.

Liner samples are initially sandblasted to remove all bulk excess material, such as dirt and grit. The samples are scrubbed and ultrasonically cleaned with warm soapy water to remove any remaining fine particles. Solvent (Hydrocarbon X55) is used to cleanse any remaining grease. Samples are dried with compressed air, weighed to, $\pm 0.01g$. Note: Without proper cleaning excess grit/particles may collect on a sample surface causing a misrepresentation of the samples weight.

Each test conducted by the “Bulk Particle High Stress Abrasion Test Rig” and the “Fine Particle High Stress Abrasion Test Rig” uses mild steel datum as a reference. The datum is implemented as a reference to ensure the test is run under standard control parameters for each sample set. This is aimed reducing the possibility of errors occurring between sample tests due to varying inputs and or environmental conditions.

5.0 Results

Wear normalisation is used to provide an accurate indication of each liner's wear minimisation ability. Normalisation of the wear data to the form $\text{mm}^3 / \text{mm}^2$ takes into account the density of each material, and provides an average depth of wear per sample over a given time frame.

Where density:

$$\rho = m / V$$

Equation 5.0a

Normalised Wear or Average Depth Loss is given by:

$$\text{Normalised Wear} = \frac{(m / \rho)}{A} = \frac{V}{A} = \frac{\text{mm}^3}{\text{mm}^2}$$

Equation 5.0b

Where: ρ = Density, m = Mass, V = Volume, A = Area

Normalised wear rates are given by $(\text{mm}^3 / \text{mm}^2) / \text{hr}$. Due to the order of magnitude of the wear data (0.001 mm/hr) a high degree of accuracy and precision is required during testing. Thus, standardised test conditions must be maintained for each sample set:

Test Conditions: 6 x 10L Buckets of 5 – 50mm graded ore.
8 hrs testing period, with 2 hourly interval weight measurements.
Standardised cleaning and weighing procedure, see heading 4.0.
600 rotations of each sample through graded ore per hr.

Analysis of the normalised wear rate provides detail information on how each liner reacts due to abrasive wear over a given time frame. Tables 1 and 2, and Figure 4 depict the average normalised wear rate $(\text{mm}^3 / \text{mm}^2 / \text{hr})$ and the percentage difference in wear of each liner sample, during 8 hrs of testing in the "Bulk Particle High Abrasion Test Rig",

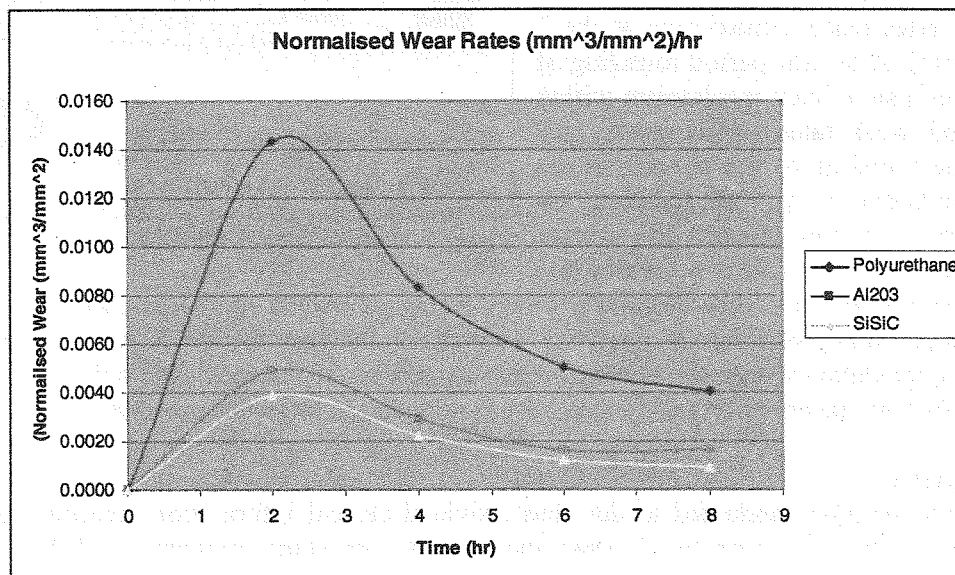
Normalised Wear	Polyurethane	Al2O3	SiSiC
0	0.0000	0	0.00
2	0.0143	0.0049	0.0039
4	0.0084	0.0029	0.0022
6	0.0050	0.0016	0.0012
8	0.0041	0.0016	0.0009
TOTAL WEAR	0.0318	0.011	0.0082

(Table 1)

Percentage Difference (8 hour test)	Polyurethane	Al2O3	SiSiC
Polyurethane	n/a	71.05	74.21
Al2O3	n/a	N/a	25.45
SiSiC	n/a	N/a	n/a

(Table 2)

Preliminary tests indicate that the polyurethane samples tested in "Bulk Particle High Abrasion Test Rig" have a significantly greater quantity of wear than the two ceramic samples over the same time frame. The Polyurethane samples had an average normalised wear of $0.0318 \text{ mm}^3/\text{mm}^2$ over the 8 hour test; up to 74.21% more than any other sample (see table 1 and 2). The SiSiC samples wore an average of $0.0082 \text{ mm}^3/\text{mm}^2$, up to 25.45% less than the $0.011 \text{ mm}^3/\text{mm}^2$ of wear experienced by the Al_2O_3 liners (see table 1 and 2). Figure 4 indicates that the reduction in $(\text{mm}^3/\text{mm}^2)/\text{hr}$ of the two ceramic samples decreases equally at a uniform rate from 2 to 8 hours of testing. Thus an early possible hypothesis/conclusion can be made; in that the decrease or increase in rate of wear of the two ceramic samples is uniform, and that this decrease in wear rates is primarily due to the degradation of ore particles within the hopper, (see heading 6.0 Ore Degradation).



(Figure 4, Normalised Wear Rates (3 Test Sets))

The rate of normalised wear of the polyurethane samples decreases dramatically between the 2-4 hour time interval, this decrease is significantly greater than the decrease in wear rate experienced by the two ceramic samples between the same interval. The primary factor identified for this decrease is the degradation of the ore structure, (see heading 6.0 Ore Degradation).

6.0 Ore Degradation

The size, shape and physical properties of the ore within the system have a direct impact upon the wear mechanisms and the wear rates associated with each liner. The abrasive and erosive ability of a particle increases proportionally with the ratio P^2/A (Perimeter²/Area). Numerical parameter "Spike Parameter Quadratic Fit" (SPQ) have been developed using this ratio. The spike parameter of a particle is used as a measure of sharpness, and abrasive potential.

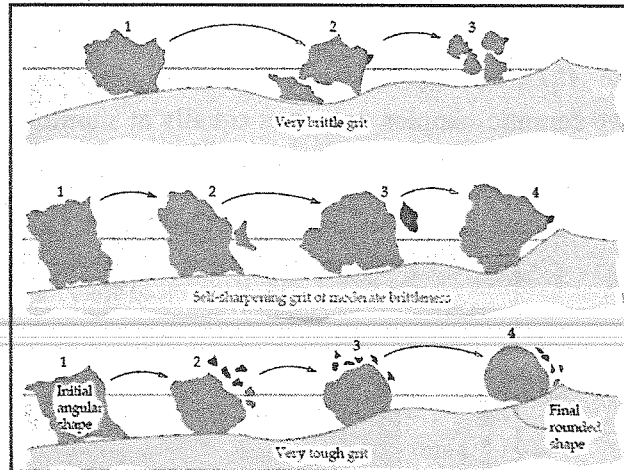
Ore particles with a large SPQ values have the potential for gouging greater amounts of material from a samples surface, and thus causing greater quantities of wear. The SPQ of an ore sample alters through the testing process; a particle will either become more or less abrasive over time.

Brittle particles have the potential to break down into small sizes and develop new cutting faces, thus causing an increase in wear rate. Tough particles will generally “round-off” and become less abrasive thus reducing rate of wear, (see figure 5).

The wear rates of the three samples (Poly, SiSiC and Al_2O_3) reduce over the 8 hour time period of testing. This is primarily attributed to the “rounding” degradation of the ore within the test.

This degradation progresses over the entire test period. Wear rates reach a maximum at the 2 hour time interval. After this period rounding of the ore becomes a significant mechanism within the system and wear rates are reduced. (see Figure 4). The rounding of the ore within the test rig is vindictive of the degradation the particles experience within the real life system at the Tom Price mine site. Ore is subjected to

numerous procedures (such as crushing and grading) during its processing lifetime, this acts to cause such degradation. Future work into an analytical comparison between the ore degradation within the test rig versus degradation within the mining system should be conducted. This will act to identify the wear rates that are experienced within the chute system due to degraded ore slurry.



(Figure 5, Stachowiak 2001, Ore Degradation)

7.0 Conclusion

The comparative analysis conducted to date has provided critical information regarding the wear rates and reactions that occur on the 3 wear liners due to ore slurry movement. SiSiC (Silicon Carbide) experienced the lowest rate of wear within the test system. Polyurethane experienced the highest rate of material loss under the same environmental conditions and system inputs. Further testing will be used to deduce how samples behave and degrade due to additional mechanisms of wear, such as fine particle abrasion and gouging. The data collected will form the basis for a comparison between the test systems and real life environmental system on site. This comparative data will ideally lead to the identification of an optimal wear liner best suited for implementation within the Pilbara Iron's transfer chute system.

8.0 References

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