

# **Polymer Wear Materials—The Right Product for Different Applications**

...One Size Doesn't Fit All

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## **ABSTRACT**

Wear is the result of material loss due to impingement, impact, scuffing, and the sliding of particles across the material surface. Add to that the many other variables which affect the wear rates such as pressure, temperature, velocity, and particle size just to name a few. With that being said wear is very application specific. There are a few standard tests such as the National Bureau of Standards (NBS), DIN and the Taber Abrasion that provide guidance, but often specific field tests must be conducted to determine the best material. This presentation describes the relationship between lab data and field results with various types of cast polyurethane systems. In the end, experience in various operating environments is often needed in order to select the proper polyurethane system for the specific wear service.

## **IRACORE INTRODUCTION**

Iracore International, LLC and its' subsidiaries, Irathane Systems and Industrial Rubber Applicators, have provided engineering solutions for abrasion and corrosion in the mining industry for over 50 years. Iracore has specifically designed polymers including rubber, polyurethane, polyurea, and neoprene to solve premature wear and failure of critical assets caused by abrasion and corrosion. Iracore customers achieve a return on their investment through immediate increases in production uptime, lower maintenance costs, and reduced health, safety and environment exposure.

Iracore operates manufacturing facilities in Minnesota, sales offices in Calgary, AB, and sales/service in Ft. McMurray, AB. To date, Iracore has lined over 2 million feet of pipe and hundreds of millions of pounds of elastomer lined products with a primary focus on the hard rock mining industry. In recent years, the oil sands industry in northern Alberta has installed over 350,000 feet of Iracore lined pipe to transport bitumen/sand slurry for the regions tailings and hydro-transport operations.

## **WEAR / ABRASION MECHANISM**

Wear behavior is a very complex phenomena which involves a variety of operational variables. Wear is defined as removal or deformation of a surface due to mechanical action. The mechanical action comes in many forms and the most typical in mining operations involve erosive wear: particle impacts on the material surface, abrasive wear: a hard or rough surface particle sliding across a softer surface, and corrosion / oxidation wear: a chemical reaction between the material and corroding medium (e.g., Rabinowicz 1995; Stachowiak et al. 2005). Thus, operational conditions such as particle size, impingement angle, particle surface characteristics, transport media, and velocity to name a few are important variables to consider when examining wear behavior.

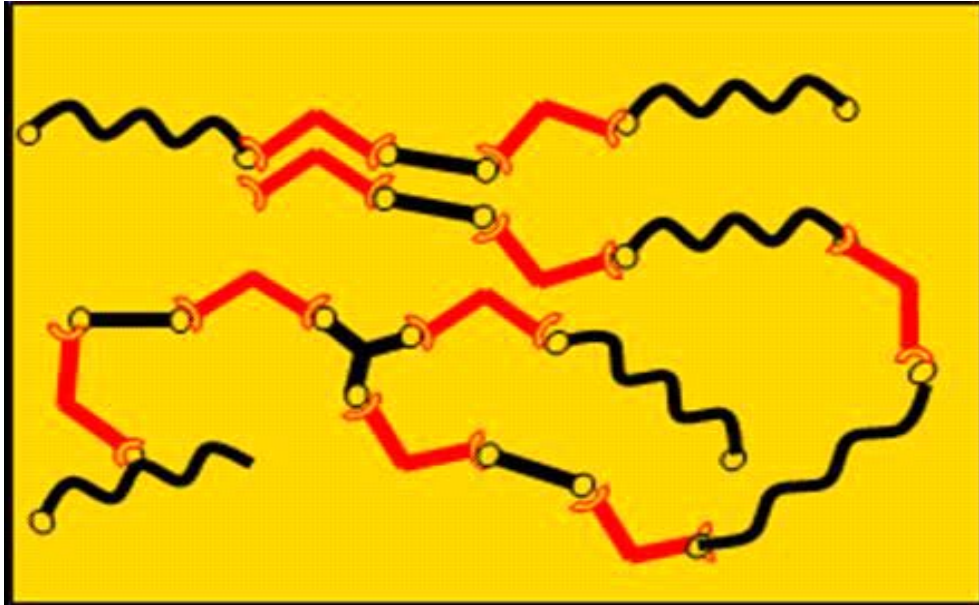
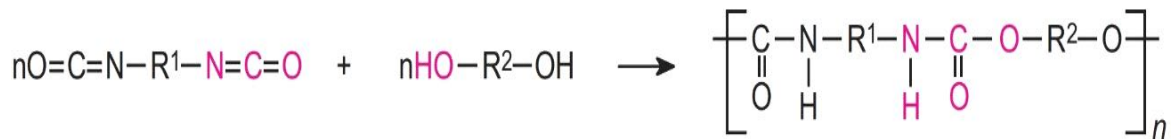
In mining operations, the transportation of the ore is the primary cause of wear. The transportation mechanism of the ore is dependent on the process of the mining operation which can vary from shovels digging the ore from the ore body to piping systems used to convey the ore from one process in a plant to another. It comes without saying that most processes in mining operations are susceptible to wear in some type of form.

In order to optimize the wear behavior, the material must be designed specifically for the application or process. An effective method to reduce erosive or abrasive wear is to design the material surface to be harder than the transport media. Materials such as ceramics, hardened steel alloys, or weld overlays fit into the high surface hardness category. However, an equally effective method is to increase the material surface elasticity in order to absorb the impact of the transport media. Polyethylene, rubber, and polyurethane are examples of materials with elastomeric properties. Both material design methodologies are effective, but ultimately wear performance depends on the specific operational conditions.

## **SELECTING THE PROPER ELASTOMER**

Elastomers have been the material of choice in many mining applications over the past few decades with a proven track record of protecting critical assets from wear and corrosion. Two of the most prominent elastomers utilized in the industry are natural gum rubber and polyurethane. However, the selection of the optimal material for a given application is more complicated than just picking a particular class of material such as a rubber or polyurethane. For instance, natural gum rubbers come in a variety of choices depending on the service conditions. Rubber can be supplied in various durometers (hardness), blends with synthetic rubbers for various chemical environments, or various colors such as black, tan or red.

In the case of polyurethanes, the choice of materials and the resulting mechanical properties is endless. To understand these choices, a basic understanding of the chemistry is needed. The basic building blocks of polyurethane are shown in Figure 1. There are 3 main components of polyurethane: isocyanates, polyols, and cross-linkers/chain extenders. With the exception of the isocyanate family which only comes with a few choices (MDI, TDI, and aliphatic), the polyol and cross-linker/chain extender family have hundreds of possible choices. The combinations of these building blocks result in millions of possible variations and a unique set of physical properties for each design. It comes with no surprise that polyurethanes are used in such a wide variety of industries such as soft foams, insulation, automotive parts, coatings and adhesives to name a few.



**Figure 1. Polyurethane building blocks**

Experienced manufacturers are able to custom design material properties to meet specific service conditions. For wear applications, physical properties of the material are an important first step in the material selection process. Physical properties such as tensile strength, elongation, tear strength, resilience, and durometer (hardness) must be optimized. While service conditions such as temperature, chemical environment and expected part life must also be considered.

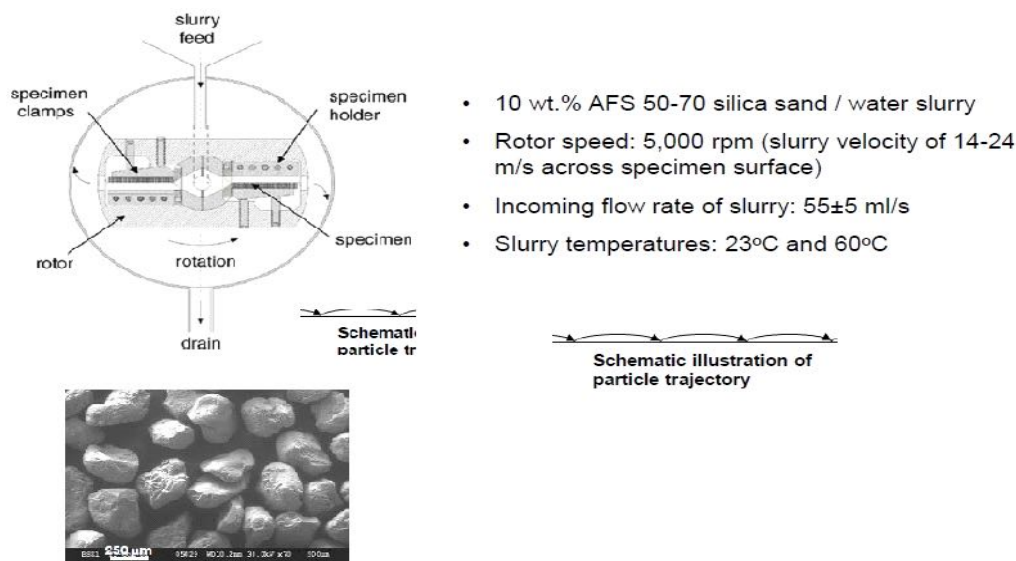
Many polyurethane suppliers purchase pre-formulated kits from large chemical manufacturers for use in industry. Iracore has remained a leader in the industry by manufacturing custom polyurethane materials designed for specific applications. As field knowledge has been accumulated over the decades, many formulations have been fine tuned to meet rigorous operating conditions. The current polyurethane product suite for the cast parts business are shown in Table 1. As you can see, the products vary greatly in the physical properties; however, each material has its' best suited applications.

One of the key properties variables visible from Table 1 is the differences in durometer. The materials range from a 70 durometer with a very resilience (high elasticity) to a harder 92 durometer with a low resilience (low elasticity, high toughness). Another product difference which stands out is the variability in properties of 3040 versus 2140. Both materials have roughly the same durometer, but vary in all other properties listed. The major difference in these two materials is within the polyol backbone. The 2140 material is formulated with an ether base polyol while the 3040 is formulated with an ester base polyol. Ester polyol base materials are known to be less stable in water environments over periods greater than 1-2 years. Ether polyol base materials are known for their stability in water for decades of possible service life in the right conditions.

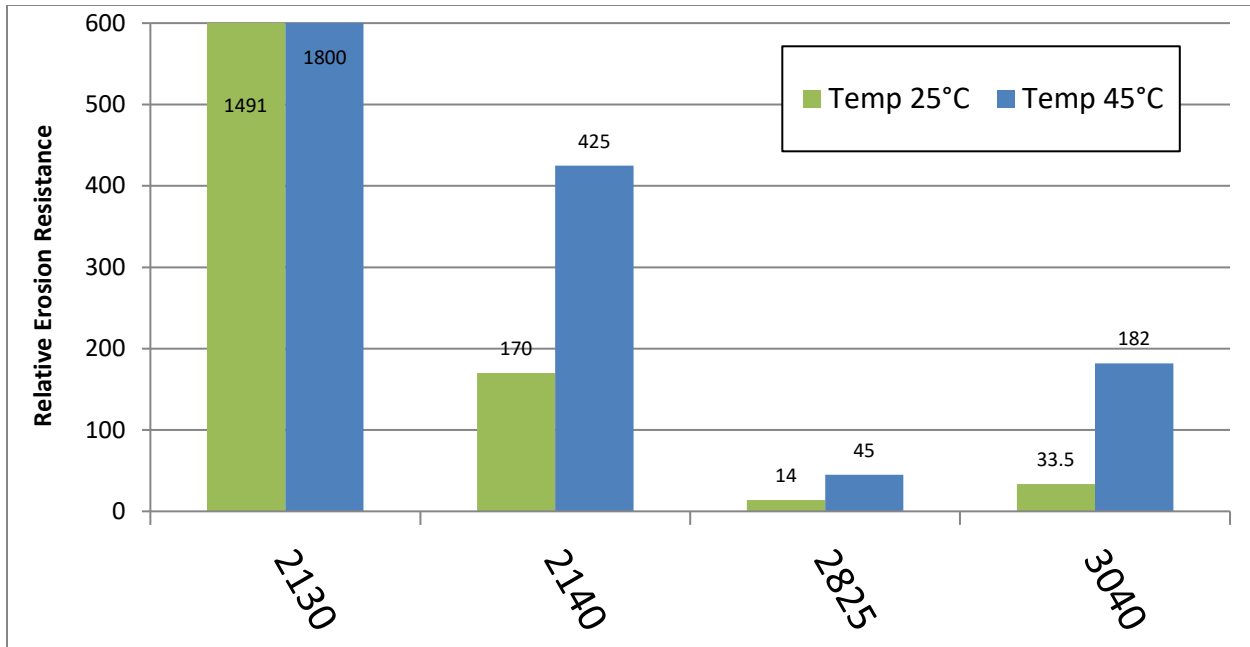
**Table 1. Iracore castable polyurethane physical properties**

Castable	2130	2140	2825	3040
Durometer (Shore A)	68	85	92	82
Resilience (% Rebound)	70	55	30	25
Tensile Strength (PSI)	3500	5000	5500	6800
Elongation (%)	550	500	250	550
Tear Strength (PLI)	40	90	55	125
General Application	Pumps, Cyclones	Flotation, Sheets, Mill Liners	Bridge Pads, Spray Nozzles	Screens, Mixer Liners, Dry Abrasion

Although knowing the physical properties of the material is an important piece of the puzzle to help in selecting the proper material, a lab scale abrasion test is often needed to gain assurance a particular material can perform in field environment. There are many lab scale abrasion tests such as Taber, DIN Abrasion, and ASTM G65 which can provide feedback on how one material can perform versus another. However, when the primary wear mechanism is slurry based, there are two abrasion test which have become industry standards in ranking materials in similar material families. The National Research Council Canada (NRC) in Vancouver, BC (e.g., NRC 2016) have been accumulating wear data based on a multitude of abrasion tests with the Slurry Jet Erosion (SJE) and Coriolis apparatus emerging as the backbone for slurry based applications. Figure 2 shows the basic test set-up for the Coriolis which uses AFS 50-70 silica sand (mesh size of 210 and 300 µm) as the abrasive media. Figure 3 provides the Coriolis results of the various Iracore castable polyurethanes. The best wearing material in the test has highest relative erosion resistance as the data is correlated to 1018 steel which has a relative erosion resistance of 1.



**Figure 2. NRC Coriolis erosion test apparatus**



**Figure 3. Iracore castable polyurethane Coriolis results at different temperatures**

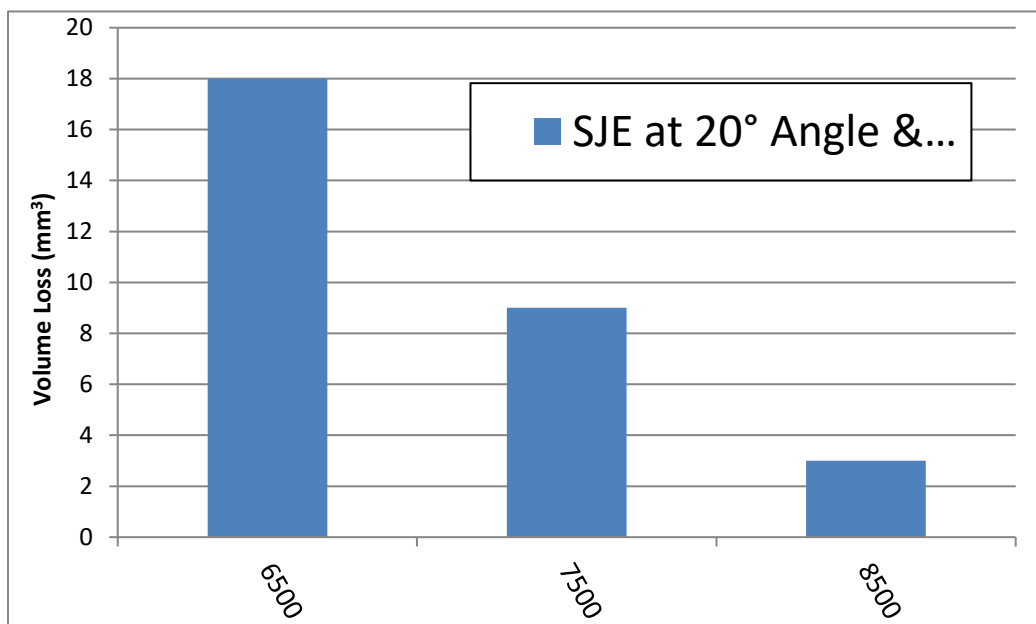
The relative rank of erosion resistance in Figure 3 follows the resilience ranking in Table 1 where the higher resilience equates to better erosion resistance. The results of the Coriolis is not surprising given that the definition of resilience is the measure an objects ability to retain its' shape after deformation. The Coriolis apparatus function is to create small angle impacts (2-10° impingement angle) of the sand particles across the material surface.

The other high value abrasion test is the SJE. The basic test setup is shown in Figure 5. This particular SJE test uses silicon carbide (SiC) as the erodent media which is a much harder and rough surface compared to the AFS sand in the Coriolis test. However, the relative rank of material for the SJE test is very similar as compared to the Coriolis test where the more resilient material has better erosion resistance. An example of these results are shown in Table 2 and Figure 4.

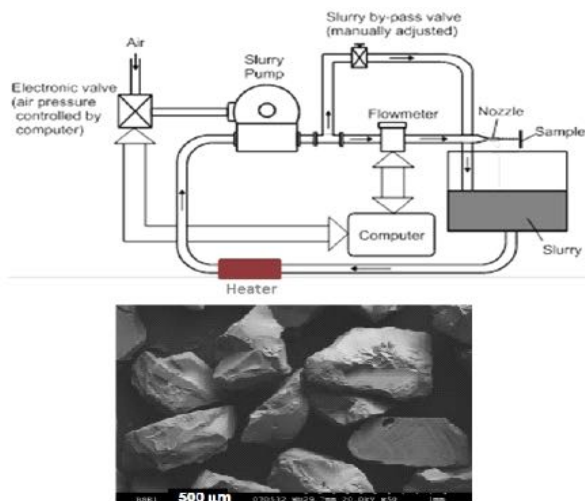
The SJE results are measured in volume loss of the base material during the test. Therefore, the lower value equates to a more abrasion resistant material. Two interesting features of the SJE apparatus are the ability to change the impingement angle and/or slurry temperature which allows the tester to more closely mimic a particular field conditions. The 20°, 45°, and 90° impingement angles are the most popular for testing. The SJE testing in Figure 4 were conducted at 45°C which is the typical operating temperature of the tailings lines in the oil sands of northern Alberta. The 6500 material has been the commercial lining material of choice for over 10 years. Through Iracore's extensive field experience and R&D testing, the 7500 and 8500 have been developed to bring another level of wear performance to the oil sands customers.

**Table 2. Iracore polyurethane pipe lining physical properties**

Pipe Lining	6500	7500	8500
Durometer (Shore A)	92	89	80
Resilience (% Rebound)	20	44	52
Tensile Strength (PSI)	4500	3800	4000
Elongation (%)	250	320	450
Tear Strength (PLI)	50	50	50



**Figure 4. Iracore pipe lining polyurethane SJE results**



- Slurry: SiC and water at 1:10 weight ratio
- Test duration: 4 hours
- Jet velocity: 16 m/s
- Slurry temperatures: room temperature
- Impingement angle  $\alpha$ : 20° and 90°



**Figure 5. NRC slurry jet erosion apparatus**

The downside of lab scale testing is the test can never fully mimic every condition in operating environments. A very important factor in understanding the cause of wear performance is the physical characteristics of the particle. Most lab tests use only one type of abrasive media in order to have consistency in measuring. The physical characteristics such as particle size, shape, roughness, speed, and impact all have an effect on the wear performance. For this reason, there is a need to use all the data from lab testing which includes physical properties and lab scale abrasion testing along with actual field performance to fully understand the best material design.

## CASE STUDIES

Over many years, Iracore has been able to understand best practices of using various elastomers in certain operating conditions. In numerous occasions, it has been decided to try to different materials in the same operating environments in order to understand the best material in a particular situation. The following case studies highlight a few of the lessons learned which can be used in future material selection choices.

### Trommel Panel

One particular iron ore mine uses an autogenous mill as one of the primary means of crushing the ore to very fine particle size. The basic operation of the mill is a rotating drum of ore slurry which throws the larger rocks up the side of the drum in a cascading motion which causes impact breakage of the larger rocks and compressive grinding of the small particles. At the outflow of the mill are screening panels called trommels. This particular mill has a ore feed of < 1.5 inches rock, a new ore feed rate of 400 tons per hour, and a recirculating ore feed rate of 600 tons per hour. Figure 6 shows a new versus worn trommel with a screen size of 0.16" x 1". Two Iracore castable polyurethanes have been tested in these mills with one material clearly outperforming the other. The 2140 compound which has good overall resilience and a good tear strength and the 3040 compound with excellent toughness (high tensile and elongation), lower resilience, and very high tear strength.

The 3040 had an operating life of 9-11 months while the 2140 had an operating life of 4-5 months. Clearly, the wear mechanism is more abrasive (sliding) than erosive (impact) as the high toughness and high tear strength 3040 material prevailed versus the more resilient 2140.

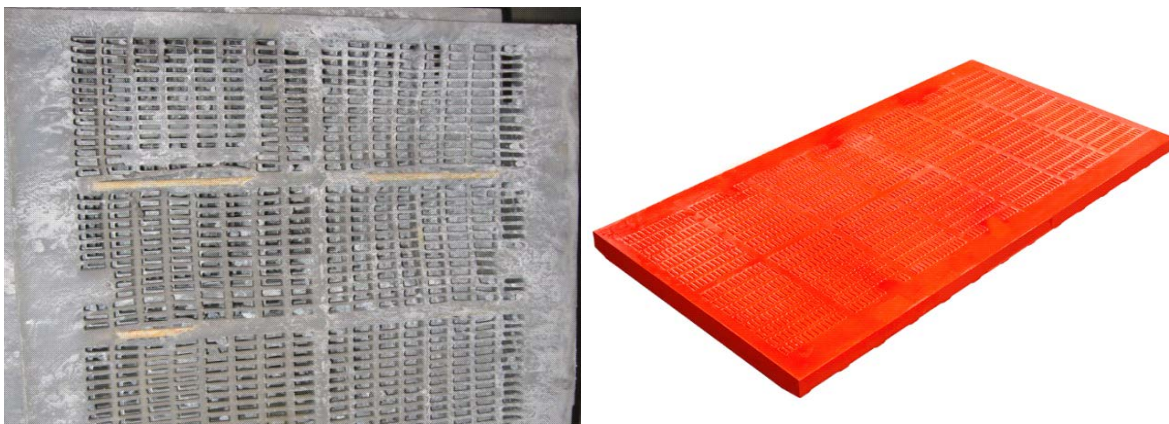


Figure 6. Worn trommel panel on the left and a new trommel panel on the right

## Slurry Pump Liners

Mining operations regularly use slurry pipe to convey the ore from one process to another. Slurry pumps are an asset to this operation and polyurethane pump liners are utilized to increase the pump service life. Figure 7 shows the appearance of a new polyurethane slurry pump liner versus a worn polyurethane slurry pump liner. Table 3 represents a case study comparing polyurethane liner performance of Iracore 2130 versus 2140 in three various mine operations. All three slurry types have similar particle characteristics. The main variable controlling the material performance appears to be particle size. For these slurries, a particle size of less than ¼” seems to favor 2130 while particle sizes ¼” or greater favor 2140. Even though the resilience of 2130 is higher than 2140 which would indicate a better wear performance in erosive wear conditions, the ¼” particle size indicate tear strength and toughness of the material as the critical property over the resilience. Over course, velocities of the slurry lines will also play an important variable and perhaps at slower velocities the 2130 would perform closer to 2140 at ¼” particle size.

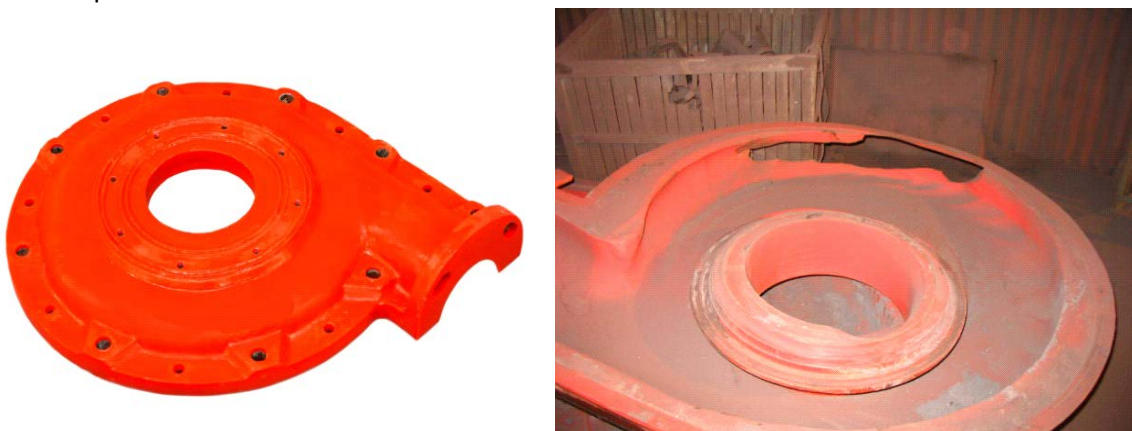


Figure 7. New slurry pump liners on the left and worn slurry pump liner on the right

Table 3. Slurry pump liner performance for 3 different operating environments

Slurry Type	Feed Line	Pump Size	Particle Size	2140 Life	2130 Life
Iron Ore	Hydrocyclone	14” x 12”	500µm	1,200 Hrs	3,000 Hrs
Molybdenum	Hydrocyclone	14” x 12”	¼”	6 Months	2 Months
Soda Ash	Tailings	6” x 4”	¼”	4 Months	0.5 Months

## SUMMARY

Elastomers are proven leaders in wear and corrosion performance in numerous mining service conditions. With so many elastomeric products on the market, choosing the correct material for a particular operating environment requires the gathering of data in order to make informed decisions. The operator must consider both the physical properties of the erosive media and the physical properties of the selected materials. If lab-scale abrasion testing is available, the abrasion data can serve as a useful screening tool; however, the abrasion test must closely mimic the operating conditions to be valuable. In the end, a field trial or past field experience may still be needed to properly understand the wear mechanism and ultimately select the proper material.

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