A HISTORY OF ISAMILL PROGRESS AT THE TECK RED DOG MINE

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Abstract

In December 2011, Teck's Red Dog Operation commissioned two 1.5 MW M3000 IsaMills as part of a project to improve their zinc metallurgy. This paper examines the history, including initial performance, characterization of a feed that has managed to be both abrasive and viscous at the same time, reviews improvements to the mill flexibility through an operating vessel size upgrade and the optimization of the internal component configuration for improved wear life. Red Dog has also completed a program for grinding media optimization. Recently, Red Dog finalized testwork and design on a value improvement project (VIP#2) that will install the world's first M15000 IsaMill in 2019 into their grinding circuit to ensure throughput and grind size targets are maintained as harder ores are processed in the near future.

Keywords

IsaMill, regrind

Introduction

The Teck Red Dog Operation in Alaska has been running two IsaMills in the zinc circuit since 2011. These two IsaMills replaced seven smaller vertical tower mills. The circuit is shown in Figure 1. One IsaMill treats the zinc rougher concentrate while the other treats the feed to the zinc retreat circuit.

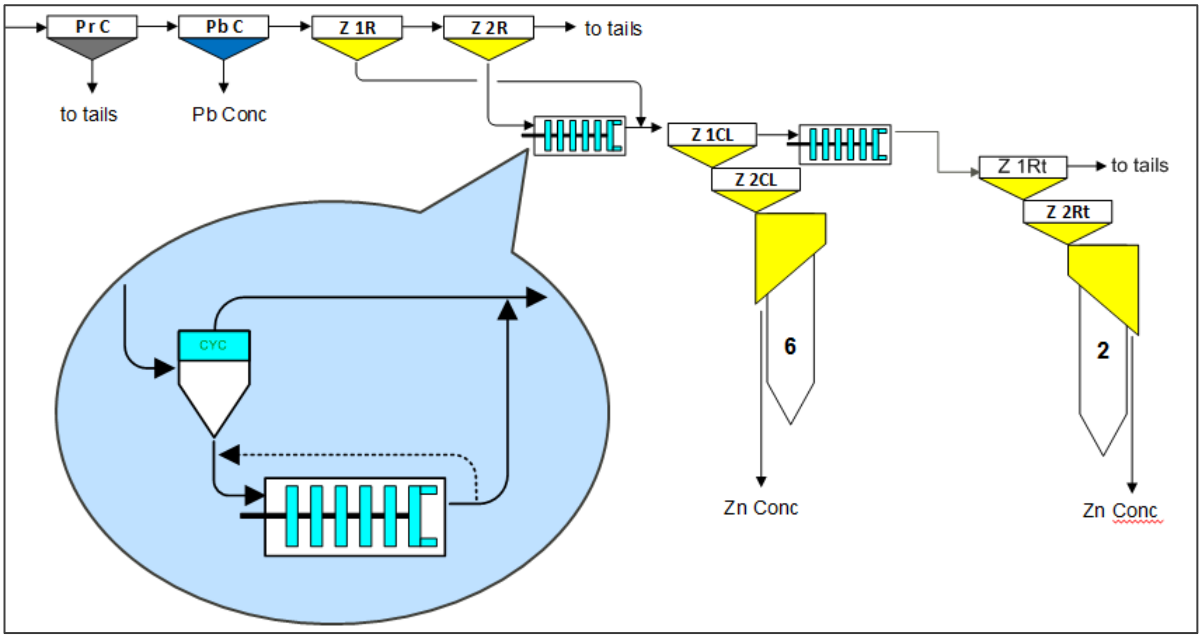

Figure 1 – Teck Red Dog flotation and regrind flowsheet (Lacouture, 2013)

The following will attempt to explain the methods involved in optimizing the wear and reliability of the two Red Dog IsaMills. The focus of this was not to optimize the grinding performance, but to improve the runtime, stability, and internal component wear of the two mills. This was a more demanding project, in that in a typical IsaMill operational challenge, either abrasive wear or viscosity will be an issue. Red Dog has both. The general operating conditions of the two Red Dog IsaMills are shown in Table 1.

This optimization program turned out to be a complex process involving flow, mixing, viscosity, grinding media, internal components, and the entire shell liner. Thermal imaging and regular viscosity measurements would prove to be critical tools in this process.

Table 1 – Teck Red Dog IsaMill feed and operating parameters (Lacouture, 2013)

Parameter	Zn Rougher	Zn Retreat
Cyclone U/F (µm – Malvern)	90 – 120	50 – 70
Discharge (µm Malvern)	45 – 65	3 – 50
Recombine (µm Malvern)	28 – 37	20 – 30
Power (kW)	1000 – 1200	900 – 1100

Parameter	Zn Rougher	Zn Retreat
Power (kWh/t)	11 – 13	14 – 17
Feed Flowrate (gpm/m^3/h)	500/115	400/90
Feed Density (%)	53 – 60	47 – 55
Feed Viscosity (cp)	20 – 40	20 – 40
Feed Silica (%)	17 – 27	35 – 55
Feed Barite (%)	7 – 12	8 – 15

Discussion

DISC SIZE AND THERMAL IMAGING

From January 2012 (one month after startup) to June 2012 Glencore Technology and Red Dog experimented with different disc configurations in the rougher IsaMill to minimize disc and shell liner wear. This was aided with the use of a thermal imaging camera to track media movement and compression in the mill. The thermal imagery has proved to be a useful indication of the initiation and development of wear areas within the mill, particularly on the shell lining.

Initially the rougher mill was operated at around 1250 kW with excessive wear found towards the feed end of the mill on both the discs and shell liner. The thermal imaging in Figure 2 (Anderson, 2012) shows the concentration of media towards the feed end of the mill resulting in higher heat generation and wear on the shell liner.

As an initial step to address this, smaller diameter discs (SDD) were installed into the mill. Initially the maximum of seven were installed from the feed end, leaving a single normal-diameter disc in front of the rotor. The SDDs rotate at the same shaft speed but at a lower tip speed due to the reduced diameter. In addition, the smaller diameter creates a larger gap between the disc tip and the shell that allows for reduced compression and a more fluidized media pattern at the shell liner, as well as a reduced media impact speed on the shell liner. Upon startup under this configuration, the mill was limited to a power draw of 650 kW. Thermal imaging of the shell in Figure 3 (Anderson, 2012) showed the media had shifted towards the discharge end of the mill. The reduction in power was a direct result of the smaller disc diameter drawing less power per disc and also drawing the media further down the mill overcoming some of the pumping action of the rotor.

To improve the pumping action and distribution of the media within the mill, the rotor was reconfigured with a rhomboidal finger design in place of the standard square design. Adjustment of the rotor finger configuration allows for changes in the pumping volume of the rotor, the volume pumped by the rotor when operated at a fixed rotational speed. The disc configuration was left as seven SDDs. The resultant thermographic image is shown in Figure 4 (Anderson, 2012), clearly illustrating that the change in the rotor configuration had allowed the media to be pushed back towards the feed end of the mill. In addition, the overall power drawn by the mill was able to be increased to a maximum of 900 kW under these conditions. This configuration stabilized the wear on both the discs and shell liner in the mill. The disc wear can be seen from both the feed and discharge end in Figure 5.

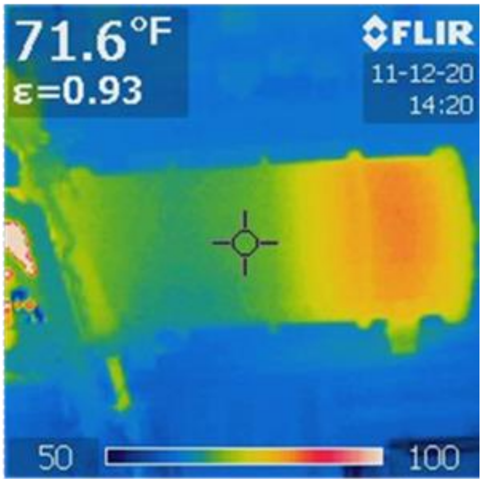

Figure 2 – IsaMill thermal image – gouging

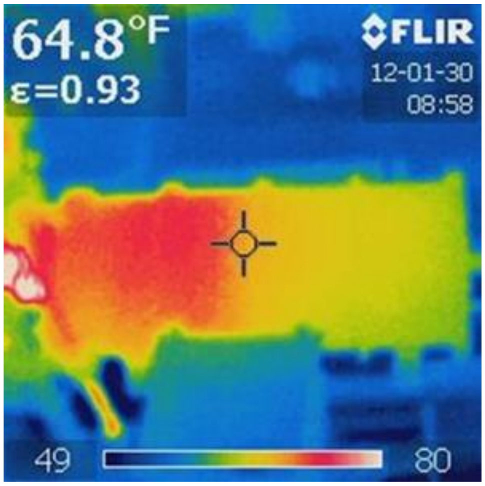

Figure 3 – IsaMill thermal image – media at discharge (left side)

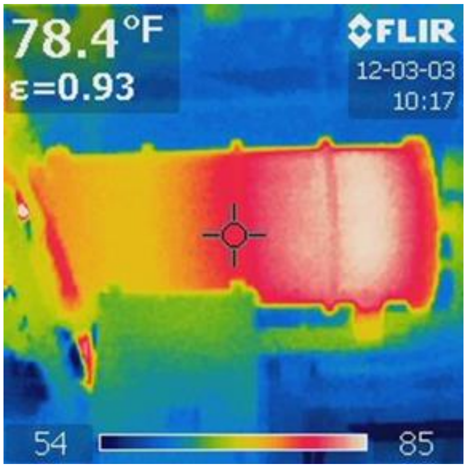

Figure 4 – IsaMill thermal image – media at feed end (right side)

Figure 5 – IsaMill small diameter disc installation from discharge (left picture) and feed (right picture) ends

SHELL LINER

In order to increase the power draw on the mill under stable wear conditions it became apparent that the Red Dog IsaMills could benefit from a retrofit in shell sizing. Though the original IsaMills in operation at Mount Isa and McArthur River Mine were 3,000 litre (L) shells, a 5,000 L shell had recently been designed for non ultra-fine grinding duties with larger ceramic media. This shell would allow for a larger gap between the shell wall and the grinding discs, thereby reducing wear while allowing for a higher power draw. The disc-to-shell ratio of the M5000 with the normal diameter discs would replicate the use of the SDDs in the M3000. This extra space allows the media to properly fluidize and mix between the discs and the shell wall, rather than packing and gouging the rubber. In September of 2012 Glencore Technology converted both mill shells from 3,000 L to 5,000 L. This allowed the use of full-size discs and a return to +1000 kW operation without the previous wear issues.

GRINDING MEDIA

When the Red Dog IsaMills were first started, the retreat mill utilized 2 mm ceramic media and the rougher mill 3.5 mm ceramic media. The original IsaMill grinding theory was to use the smallest media possible. This was valid when the mills were first introduced in the industry given the approximately 7-micron (µm) target regrind sizes from an already fine feed, and limited selection of grinding media at the time. However, with improvements in grinding media and a better understanding of the IsaMill grinding process it became clear that the original theory was flawed, and that in many cases larger media would be beneficial to both the grind and internal wear properties of the process. By utilizing larger media, the coarser particles present in the flotation regrind feeds can be broken down quicker, so they do not accumulate at the front of the mill and prematurely wear those rubber components at the feed end of the mill.

To prove this point, Red Dog contracted ALS Metallurgical in Kamloops, BC, to run a media comparison trial on the zinc retreat feed in March of 2012. ALS tested graded charges of three different media top sizes, 2, 2.8, and 3.5 mm. These energy signature plot results are shown in Figure 6.

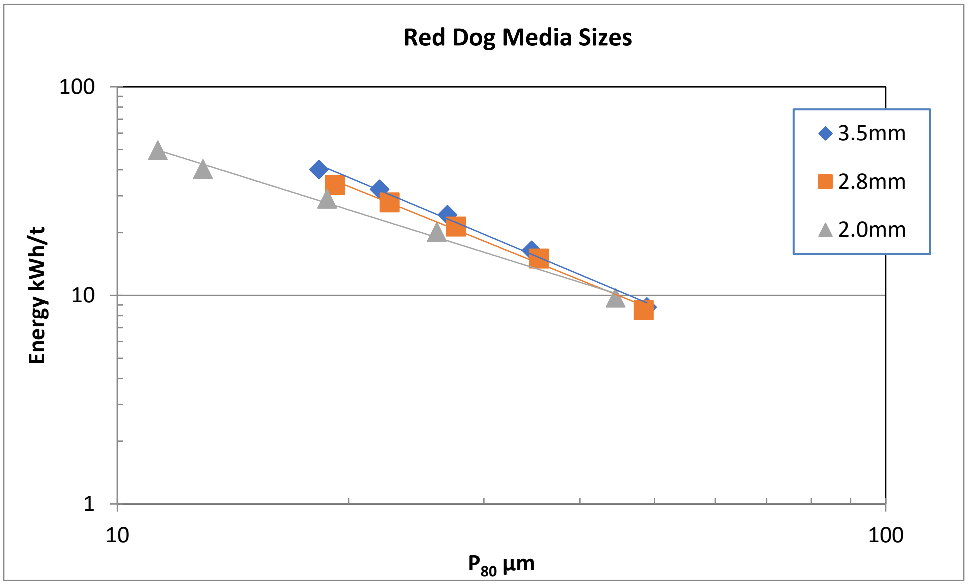

Figure 6 – IsaMill laboratory media sizing comparisons, retreat feed (Mehrfert, 2012)

The 2 mm results would indicate better performance, but what Figure 6 does not show is that the 2 mm test was holding in the coarse material, indicated by a higher motor power-draw — that insight is in the full test report.

As a result of this testwork, grinding media size was adjusted from 2 to 3 mm in the retreat. At the same time the rougher mill was switched from 3.5 to 4 – 5 mm. These changes also coincided with a change in supplier. This was brought on by availability of sizes, wear performance, and shape of worn media. The newer media was found to maintain a round shape longer than the original media, which would also contribute to improved component wear. As an added benefit it is thought that the relatively larger media with bigger gaps between packed pieces is impacted less by viscosity.

SEPARATOR

The discharge end of an IsaMill contains a centripetal separator that provides internal classification for the mill. This also provides the backflow necessary to keep grinding media and coarse particles in the mill. Typically, the fingers on this separator are a square or hexagonal shape. The Retreat IsaMill was experiencing higher than normal wear at the feed end flange, indicating a concentration of material in this area. To remedy the problem, some of the separator fingers were rounded (Figure 7) to make it less aggressive and reduce back flow.

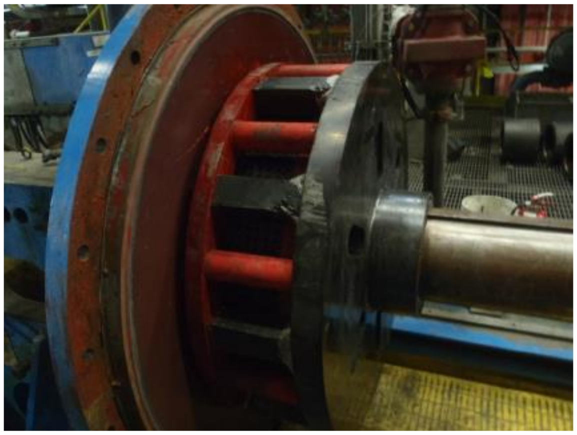

Figure 7 – IsaMill separator retrofitted with round fingers (Lacouture, 2013)

VISCOSITY

If viscosity were regularly measured at all IsaMill installations, it would be likely that Red Dog would rank at the top of challenging rheology. In this case, over the normal operating density range of 50% to 55% solids for the rougher mill, the viscosity increases by over 50% from the low to high point (Figure 8).

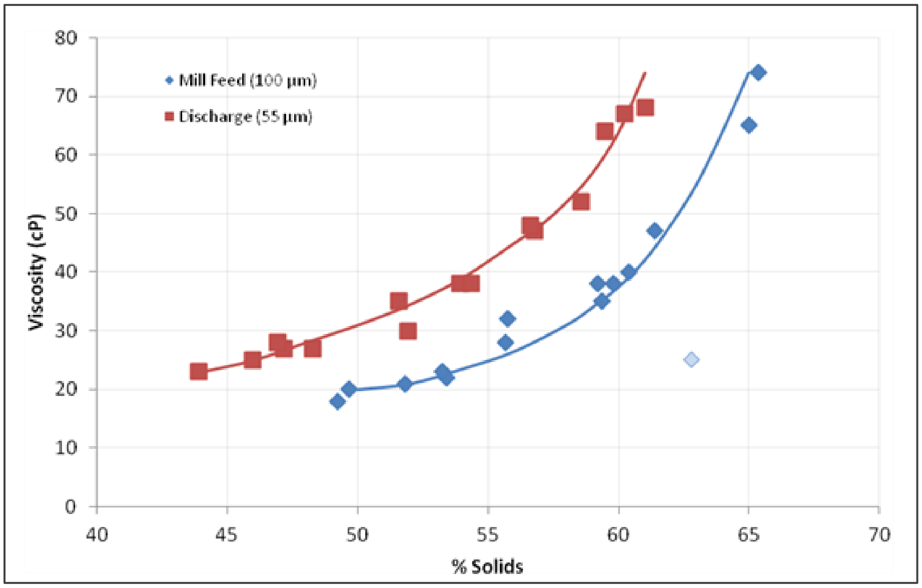

Figure 8 – Rougher IsaMill feed and discharge viscosity at variable densities (Merritt, 2012)

The mineralogy of barite, sphalerite, and silicates ground fine has resulted in some unique challenges to mill operations. The general power trend of this variable viscosity feed is shown in Figure 9. This is a good example that had been previously theorized for IsaMill operations but rarely demonstrated with actual plant data. As the feed solids and viscosity increase, the power draw increases, eventually past a point of optimum operation. As the viscosity continues to rise, the power draw will eventually drop off as the mixing of the mill decreases and the discs begin to rotate freely without agitating the charge adequately.

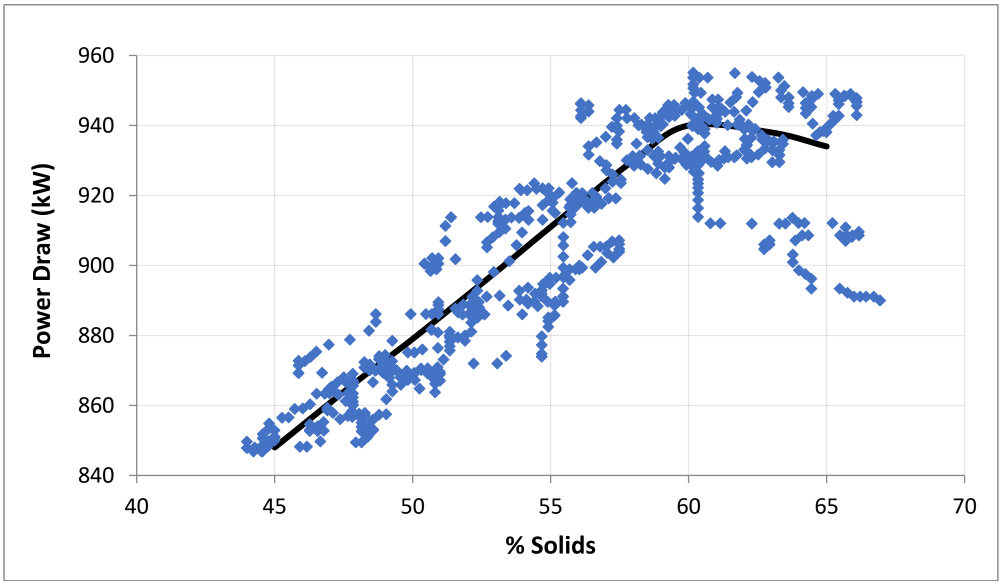

Figure 9 – Effect of density on power draw (Merritt, 2012)

One option to reduce viscosity was to reduce the amount of recycle directed back to the mill feed. The recycle is primarily used to maintain constant flow into the mill, but there was room to reduce this. This was preferred over reducing density, as it has historically been shown that operation at dilute density also increases the component wear in the mill. All else being normal, it is usually recommended to operate an IsaMill at about twenty percent solids by volume. Across sites this has been a good starting guide to regulate surface area present.

One interesting product of this work is the beginnings of a rheological model based on surface area of the solids in slurry. A series of samples were taken in the Red Dog plant and from laboratory grinding. The plant samples included feed and product from both IsaMills and the laboratory samples were ground for varying lengths of time in a laboratory rod mill. These were analyzed in a Malvern laser sizer for a full-size distribution. Each individual particle size was assumed to be a sphere for simplicity, and then assigned its given surface area. Given the solid specific gravity (SG) and slurry density the total number of each particle size and then the total surface area per unit of volume was calculated. This was plotted against the viscosity of each sample as measured in the Red Dog laboratory (Figure 10). In general, there will be some differences based on method of grind (and resulting particle shape) and slurry stream mineralogy, but overall this looks like it could potentially be a start to a guide to viscosity characteristics if ever necessary.

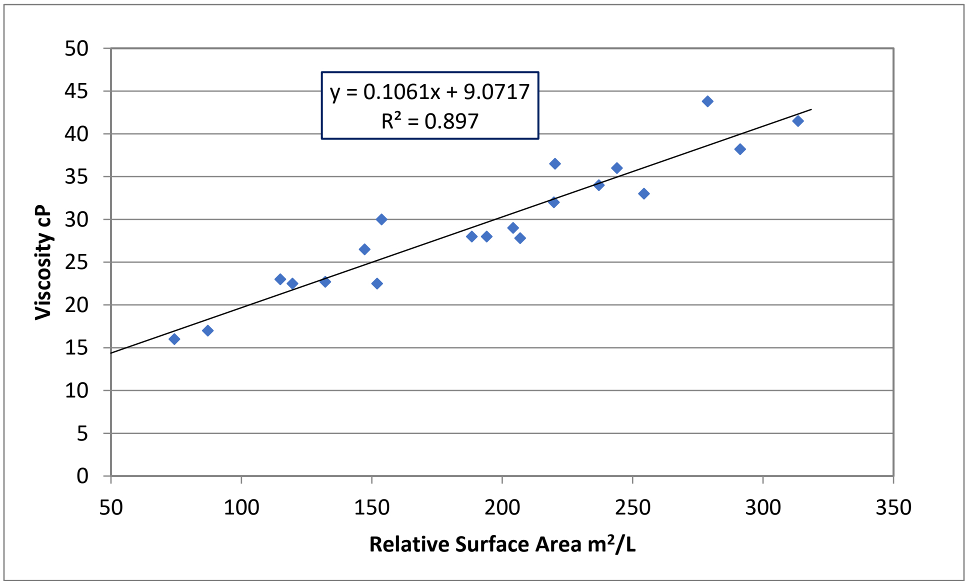

Figure 10 – Surface area vs. viscosity (Larson, 2012)

IsaMill Grind

A series of surveys was completed in June of 2013 to review the two IsaMills' performance. Figure 11 and Figure 12 show typical examples of mill breakage performance for the zinc retreat and rougher mills. In this case the rougher IsaMill ground from an F_{80} of 105 µm to a P_{80} of 42 µm at 10 kWh/t. The retreat IsaMill ground from an F_{80} of 45 µm to a P_{80} of 30 µm at 12 kWh/t.

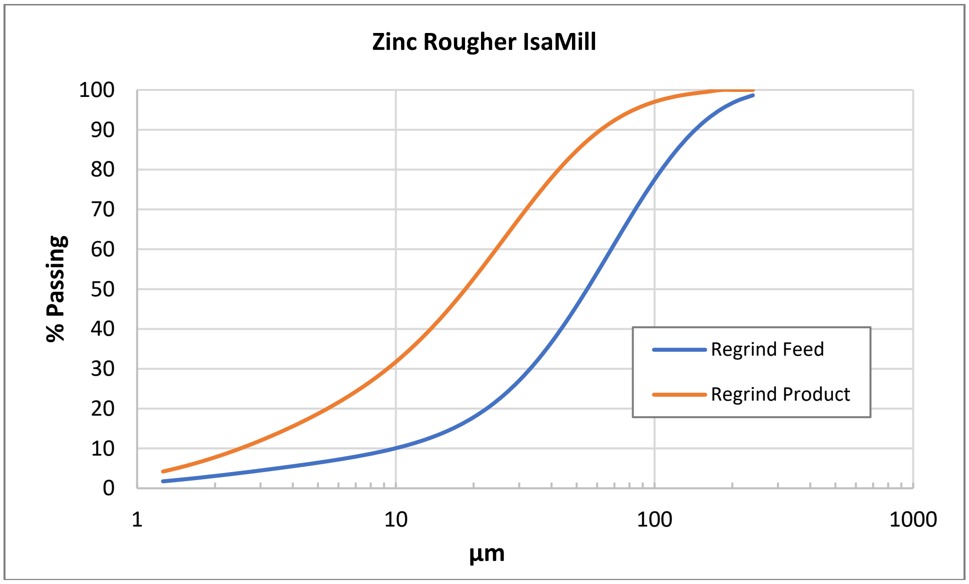

Figure 11 – Rougher IsaMill performance at 10 kWh/t (Larson, 2012)

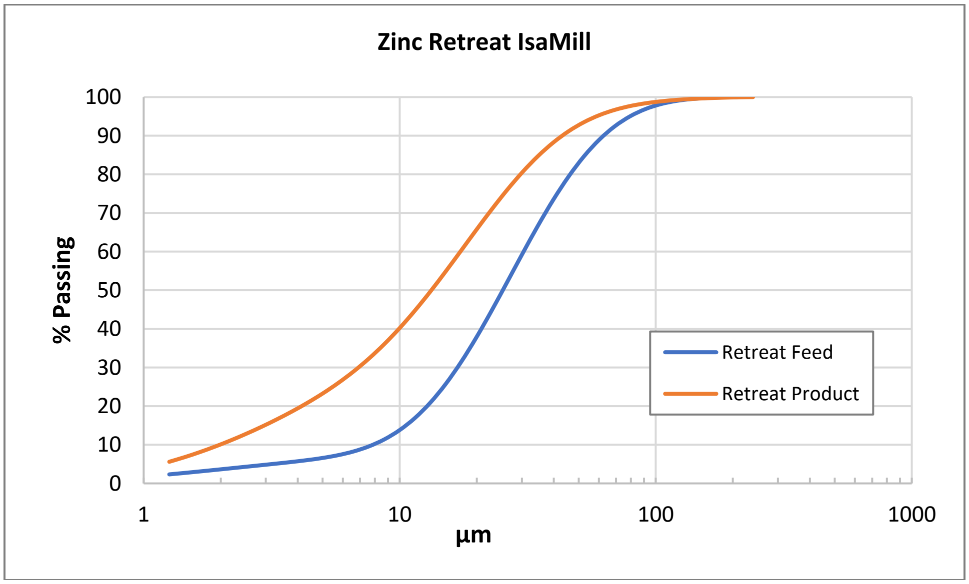

Figure 12 – Retreat IsaMill performance at 12 kWh/t (Larson, 2012)

M15000

In 2019 Red Dog will commission a new M15000 IsaMill as part of Red Dog's latest mill upgrade. The mill will treat the prefloat tailings, grinding the material from a feed of 150 µm down to a product of 65 µm to feed the lead flotation circuit. The M15000 was chosen over the M10000 due to the larger gap between the discs and shell liner, along with a capability to process a higher feed flow than the M10000.

Conclusions

Given the complexity of the issues around the Red Dog Zinc IsaMills and the relative quickness with which they were addressed, this program should be considered a success. Less than eight months after commissioning, the mill had been adjusted both in internal components and media sizing to reduce wear and internal instability. Within one-and-a-half years Red Dog gained an understanding of the effect of viscosity on their mills that should be the envy of any number of researchers. This has resulted in more than seven years of reliable operation of the first two IsaMills at Red Dog and has given the team the confidence to install the first ever M15000 IsaMill to maintain mill throughput with harder ores.

Acknowledgements

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