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Improving IsaMill™ Energy Efficiency Through Shaft Spacer Design

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Abstract

The IsaMill™ was specifically developed to address the energy efficiency issues associated with grinding to fine and ultrafine sizes. It has been doing this successfully for more than 20 years in over 120 installations.

Recent efforts by Glencore Technology to further improve the energy efficiency of the IsaMill™ have resulted in the development of a new IsaMill™ shaft spacer design. The spacer was developed through laboratory, pilot and full scale testing prior to being commercialised. Full-scale results indicate that the new configuration was able to reduce the specific energy consumption by 13-17% in an M1000 gold application grinding to a P_{80} of 18 microns. The spacers were also shown to have no adverse impact on the shape of the product particle size distribution.

This paper discusses the development process of the new spacers through lab, pilot and full scale trials, operating results and processing implications.

Key Words

IsaMill™, fine grinding, energy efficiency, inert media

Introduction

It is well known that comminution energy consumption is a major concentrator operating cost. As a result there has always been a strong focus at mine sites to reduce energy consumption where possible to minimise operating costs – this has become increasingly important in the current economic environment. Increasingly, there are also political and social pressures to reduce overall energy consumption and associated carbon footprint. However, as orebodies become more complex, finer liberation sizes are required in order to produce saleable concentrates, driving up the specific energy required to produce each tonne of saleable concentrate.

The IsaMill™ was developed in the 1990's by Mount Isa Mines (MIM, now Glencore) and Netzsch Feinmahltechnik, to specifically address the requirement for fine grinding down to a P_{80} of 7µm for the further development of MIM's McArthur River deposit and Mount Isa Pb/Zn ore bodies. The IsaMill™ addressed the two major issues of energy efficiency and the resultant downstream metallurgy, primarily through the use of small stirred, inert grinding media. The first 1.1 MW IsaMill™ using inert media was commissioned at Mt Isa in 1994 and four 1.1 MW IsaMills™ became the enabling technology for the McArthur River project in 1995. The early development and implementation of the IsaMill™ is well described by a number of authors including (Enderle, Woodall, Duffy, & Johnson, 1997), (Harbort, Murphy, Vargas, & Young Michael, 1999), (Johnson, Gao, Young, & Cronin, 1998) and (Pease, Curry, Barns, Young, & Rule, 2006).

Since its inception, the IsaMill™ has been successfully used to grind metalliferous concentrates to P_{80} product sizes from 7µm to 60µm for over 20 years in over 120 installations and proven to be significantly more energy and metallurgically efficient than conventional ball mills and tower mills (Larson, Young, & Morrison, 2008) and (Larson M. , Anderson, Morrison, & Young, 2011).

Ongoing efforts by Glencore Technology to further improve the energy efficiency of the IsaMill™ have resulted in a new IsaMill™ shaft spacer design. The new spacer was developed through laboratory, pilot and full scale testing prior to being commercialised and has shown operational specific energy reductions of 13-17% in a production scale gold concentrate regrind application. This paper discusses the development, plant performance and processing implications of the new spacer design.

Grinding Mechanism and Conventional Spacer

A conventional IsaMill™ configuration uses a cylindrical spacer to separate the grinding discs at the required distance. Figure 1 shows the conventional spacer on the shaft of an M1000 IsaMill™

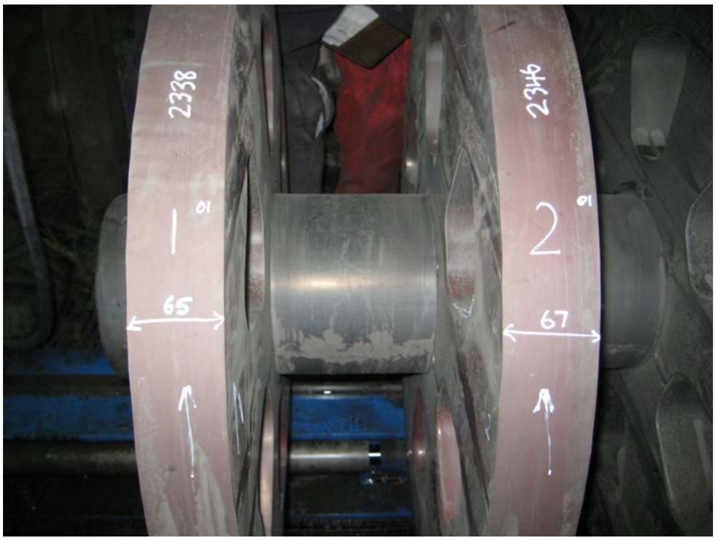

Figure 1 - Conventional Shaft Spacer between two Grinding Discs for an M1000 IsaMill™

Figure 2 illustrates the grinding mechanism within the IsaMill™. The IsaMill™ typically operates around 70% media filling volume. As the shaft rotates, the grinding discs agitate the media such that it is drawn out along the face of the discs towards the shell liner. As it reaches the shell liner, the media is turned around and directed back towards the mill shaft area. This happens on the face of each disc, where there is sufficient media present and sets up a chamber of agitated grinding media between each of the grinding discs. Slurry to be ground enters opposite the shaft end cap at one end of the IsaMill™ and must pass through each of the agitated grinding chambers in series before it can exit, making it virtually impossible for any material to short circuit the IsaMill™. At the discharge end of the IsaMill™ is the patented product separator which makes use of a closer spacing between the final disc and the rotor to centrifuge any coarse particles and media towards the shell. The rotor, which acts like a pump, then returns this material to the grinding zones. This mechanism allows ground product to flow through and exit the IsaMill™ whilst retaining the grinding media inside, all without the use of fine screens.

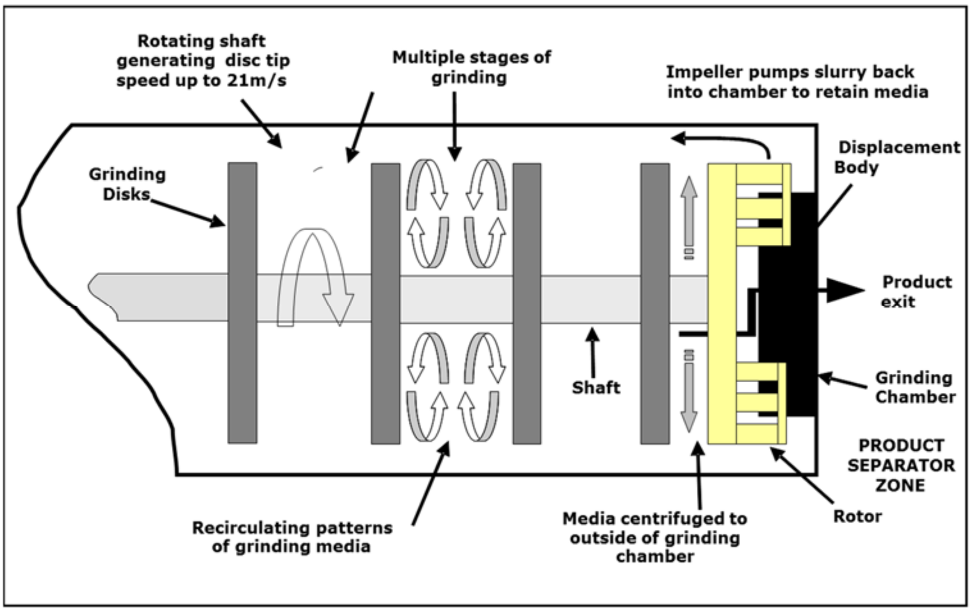

Figure 2 - Simplified IsaMill™ Grinding Mechanism

Laboratory Testwork

In 2010, a large IsaMill™ development testwork program was undertaken at the Netzsch Feinmahltechnik laboratory in Germany. The program utilised an M20 IsaMill™ (20 litre volume), with a clear shell, to investigate and understand the impact on IsaMill™ power draw and axial media distribution of different designs and configurations of the discs, shaft spacers and rotor in conjunction with different operating shaft speeds and media loadings. The use of conical shaft spacers was investigated as part of this work.

The clear shell M20 is the same as a standard M20 IsaMill™ used for pilot scale test work other than being fitted with a clear plastic shell to allow the inner workings of the IsaMill™ to be observed under different operating conditions. It was built specifically for investigative work and demonstration purposes. To allow observation of the inner workings and preserve the integrity of the clear shell, only water and glass beads are used in this mill.

Prior to any data recording, the M20 was operated for 20-30 minutes to allow the bearings to warm up, so as not to impact on the power draw readings. Two shaft configurations were tested to isolate the impact of changing from standard cylindrical to conical spacers. Firstly, standard grinding discs and standard cylindrical spacers were used to generate the baseline data. Following this, the standard cylindrical spacers were replaced with conical spacers – the disc spacing and disc position along the shaft remained the same. In each of the two cases, the M20 was filled with 13.6 litres of 2mm glass beads and operated at a steady 16.3 litres/min of water throughput while the shaft speed was varied in stages from 600 to 1400 rpm. Typical operating speed for the M20 is 1200-1400rpm. The media distribution inside the mill was visually observed and the overall mill power draw recorded for each case. Figure 3 shows the conical spacer arrangement inside the glass shell M20 IsaMill™, with the feed end on the left and the product separator on the right.

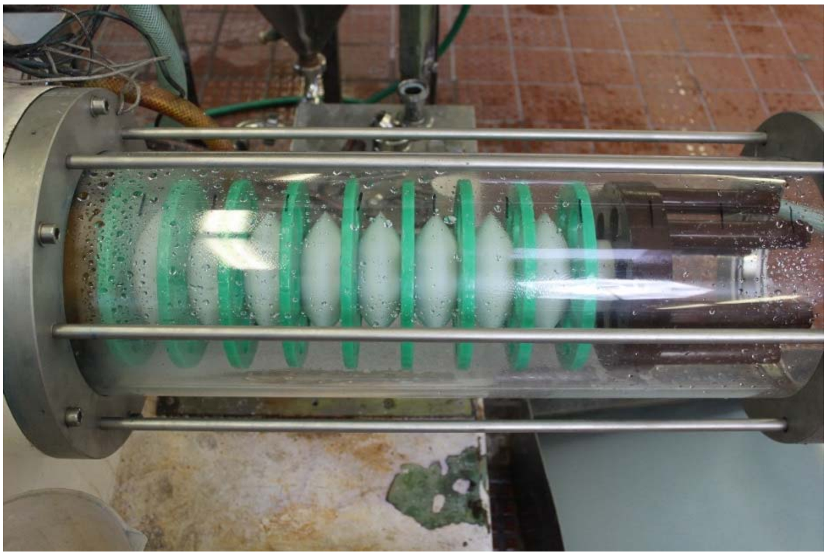

Figure 3 - M20 Clear-Shell IsaMill™, fitted with Conical Spacer Arrangement

As a note, the laboratory M20 IsaMill™ used was configured with a 9-disc arrangement and therefore a narrower shaft spacing compared to the standard 7-disc setup used for pilot scale metalliferous grinding. This could not be altered as all shaft parts were sized to fit the 9 disc arrangement. Other than that, the configuration was the same as that conventionally used with the 7-disc M20 arrangement.

Figure 4 illustrates the power draw as a function of the M20 IsaMill™ shaft speed and the shaft spacer type – which was the only parameter difference between the two curves. For a given shaft speed, there was a clear reduction in overall mill power draw when the conical spacers were used. A reduction of 20%-30% was evident at the typical M20 operating speeds of 1200-1400rpm. This was a direct result of using the conical spacers. As the shaft speed decreased, the difference between the two spacer designs decreased to zero at 800rpm and at 600rpm the conical spacer actually drew more power than the standard cylindrical spacer.

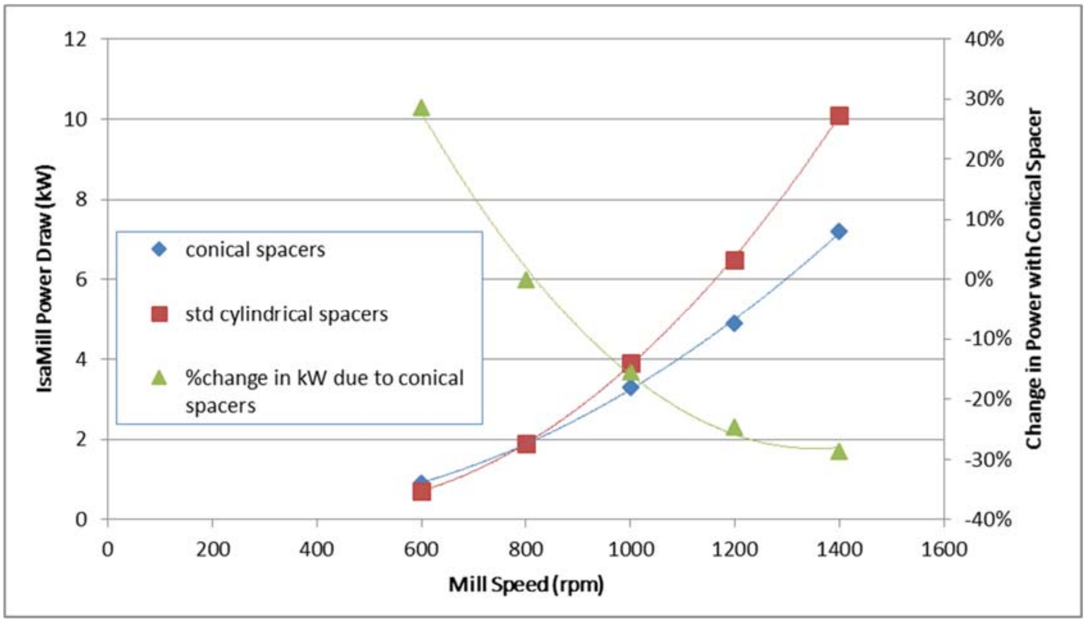

Figure 4 - Relationship between Shaft Speed and Power Draw for Cylindrical and Conical Spacers

The conical spacers allowed the same volume of media to be agitated at the same mill shaft speed, but at a lower drawn power, than when the standard cylindrical spacers were used. Given that the agitated media does the grinding, the impact of the reduced power draw on grinding efficiency – which could not be determined in the current testing program – was questioned. A separate pilot plant testwork program was designed and executed to answer this question.

Pilot Scale Testwork

An opportunity was identified during an onsite pilot campaign in January 2012, utilising an M20 IsaMill™, to conduct a grinding efficiency comparison between the standard cylindrical spacer and conical spacer configurations. This was a standard M20 pilot plant mill configured for metalliferous testing, with 7 discs rather than the 9 discs of the Netzsch laboratory M20. The spacing between each disc was therefore wider, which resulted in an increased included angle at the peak of the conical spacers. The spacers used in this testwork were specifically designed and built for the 7-disc arrangement and all tests conducted at the pilot plant utilised the 7-disc configuration.

Stage 1 of the pilot tests was designed to replicate the water and media testing carried out at Netzsch. Again, the only changed parameter between the two tests was replacement of the standard cylindrical shaft spacers with the conical spacers. The disc spacing and position along the shaft remained the same for both cases. At the selected pilot plant operating speed of 1390rpm and using 13 litres of 2.5mm ceramic grinding media at a water flowrate of 17.6 litres/min, there was a 15% reduction in the drawn power when the new conical spacer design was used. The overall power reduction attributed to the change in spacer design was less than that achieved at Netzsch but was still significant. Differences between the pilot tests and the Netzsch tests could likely be attributed to some of the key parameter differences including the number of discs, resultant changes in the conical spacer geometry, the shell material (rubber vs perspex), the media type (ceramic vs glass) and media volume. Figure 5 shows the cylindrical and conical spacer shaft configurations.

Figure 5 - M20 Pilot Plant IsaMill™ Shaft Configuration with Cylindrical (left) and Conical (right) Spacers

Stage 2 of the pilot tests involved conducting standard IsaMill™ signature plots using each configuration. The feed material was a coal and was managed such that the feed type and size distribution was as similar as possible between the two tests. Figure 6 illustrates the signature plot results for the two sets of spacer configurations.

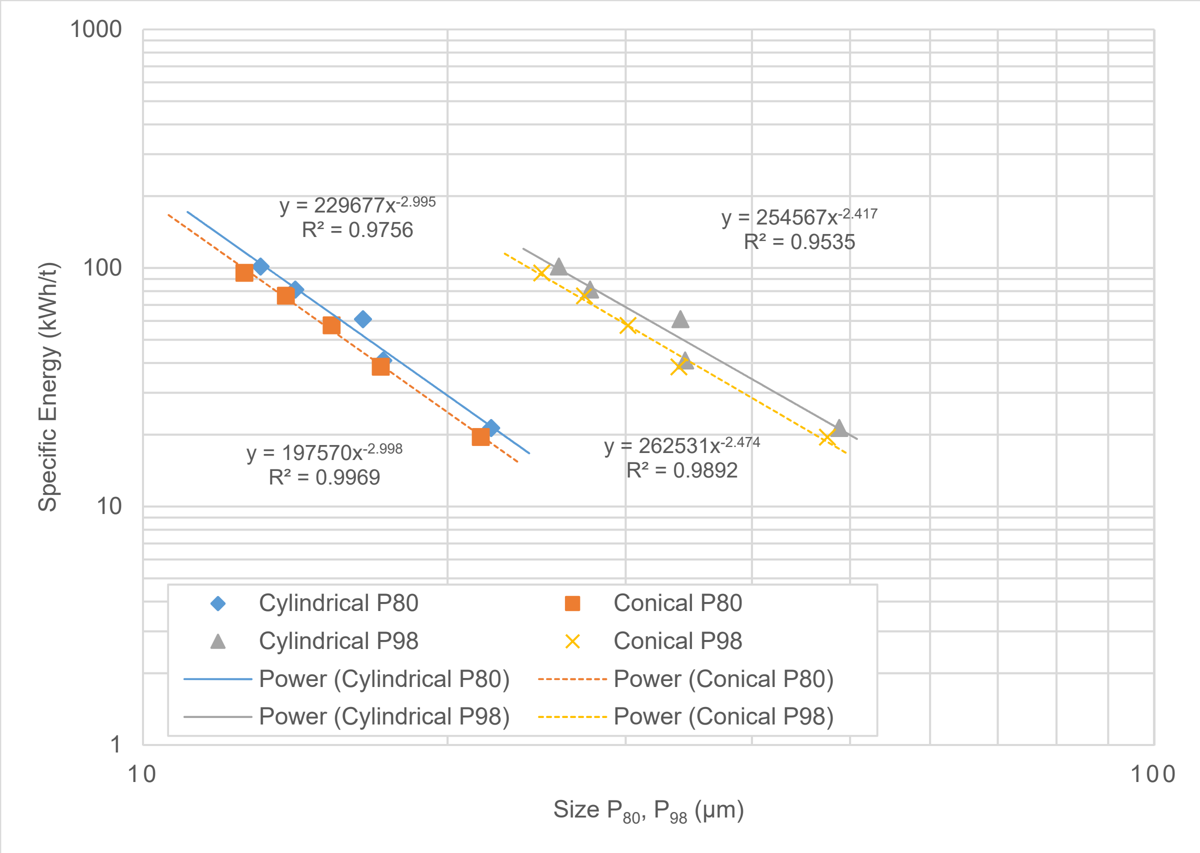

Figure 6 - Signature plot comparison between cylindrical and conical spacer configurations

There was a clear distinction between the two sets of curves. Average net power draw treating the slurry for the conical spacers of 7.5kW was 6% lower than the standard cylindrical spacers at 8.0kW. At the grind target P_{80} of 15 microns, the conical spacer configuration used 15% less specific energy than the standard cylindrical spacer configuration. This was the first evidence to support the contention that the conical spacers not only resulted in a reduced power draw for the same volume of agitated media, but that the resultant grinding action was more energy efficient.

Unfortunately due to the pilot plant requirements and schedule there was no further opportunity to complete any duplicate or further investigative work. However, it was considered that the result obtained in the single comparison, and the potential benefits it offered, warranted progression to full scale testing.

IsaMill™ M1000 Spacer Design

The initial production tests were carried out on an M1000 (500kW) IsaMill™. A series of design parameters for the M1000 spacer and for other full scale IsaMills™ were agreed upon based on the IsaMill™ M20 spacer design. In order to conduct the testwork as efficiently as possible, the test spacers were manufactured from polyurethane rather than the standard rubber lined method.

IsaMill™ M1000 Stage 1 Testwork

An initial, basic testwork program was designed to determine whether the observations from the pilot scale M20 IsaMill™ translated to the production scale M1000 IsaMill™. A site with a large surge tank ahead of the IsaMill™ circuit was identified to minimise variations in feed mineralogy, flow and size distribution between the tests as much as possible. The trial plan consisted of three stages with the aim of having the spacers as the only changed variable. The tests were conducted over a 4-day period in July 2013 and the results summarised in Table 1 below. All particle size analysis was done on a Malvern laser sizer.

Table 1 - M1000 Stage 1 testwork results

Survey	Test Comment	Spacer Type	Power (kW)	Feed (tph)	kWh/t	F_{80} (µm)	P_{80} (µm)
1	Std conditions	Cylindrical	430	7.5	54.7	129	21.1
2	Std conditions	Cylindrical	427	7.4	55.0	129	21.4
3	Std conditions	Conical	333	6.7	46.8	127	21.5
4	Lower tph	Conical	337	6.2	51.4	141	20.4
5	Std conditions	Cylindrical	428	7.9	52.1	138	21.3
6	Std conditions	Cylindrical	422	8.0	50.6	139	21.2

The first stage involved surveying the IsaMill™ circuit under the existing standard IsaMill™ configuration using the cylindrical spacers (survey 1, 2). Under standard operating conditions in survey 1, the IsaMill™ drew a gross power of 430kW for a specific energy of 54.7kWh/t, producing a product P_{80} of 21.1µm. In survey 2, the IsaMill™ drew a gross power of 427kW for a specific energy of 55kWh/t producing a product P_{80} of 21.4µm.

For the second stage (survey 3, 4), the IsaMill™ was reconfigured by swapping the standard cylindrical spacers with the conical spacers. As far as possible, the same volume of grinding media that was removed from the IsaMill™ after the completion of the first stage was returned to it. Figure 7 shows the conical spacers installed in the M1000 IsaMill™.

Figure 7 - M1000 IsaMill™ configured with conical spacers

After the initial startup of each stage and stabilisation, top up grinding media was added in the usual way to maintain the initial power draw for each stage. This ensured, as much as possible, that the grinding media volume in the mill remained constant throughout the testwork period.

In survey 3, the IsaMill™ drew a gross power draw of 333kW - a reduction of 22% compared to the standard cylindrical spacer configuration. The IsaMill™ operated at 46.8 kWh/t – a 15% reduction compared to the cylindrical spacer configuration – and produced a product P_{80} of 21.5µm, similar to that produced from the cylindrical spacer configuration survey 2 and slightly higher than survey 1. This first comparative result suggested that the introduction of the conical spacer design had the potential for a 15% reduction in the required specific energy to produce the same product size, similar to what was observed in the pilot scale work.

The aim of survey 4 was to increase the specific energy, using the conical spacers, towards that of survey 1 and 2. By reducing the tonnage through the mill, the specific energy was increased to

51.4kWh/t. The resultant product size decreased to a P_{80} of 20.4µm. Note that survey 4 onwards was subject to a slightly coarser feed size due to an upstream ore change, which coarsened the feed into the surge tank ahead of the IsaMill™. Although the specific energy was increased in survey 4, it was still less than that of survey 1 and 2. Despite this, and the coarser feed size of survey 4, a finer product size was produced from survey 4. This again suggested a grinding efficiency benefit from the conical spacers.

At the completion of survey 4, the IsaMill™ was returned to the original configuration using standard cylindrical spacers for the third stage of testwork. Again, as far as possible, the same volume of grinding media that was removed from the IsaMill™ at the completion of the second stage was returned to it. Two more surveys (surveys 5, 6) were completed to compare against the original standard configuration surveys and the conical spacer surveys.

In survey 5, the IsaMill™ gross power draw returned to 429kW, essentially the same power that was drawn under the same spacer configuration in the first two surveys. This confirmed that essentially the same volume of media was present in the IsaMill™ as had been present under the original conditions in stage 1. The IsaMill™ operated at 52.1kWh/t for a product size P_{80} of 21.3µm.

The specific energy in survey 5 with the cylindrical spacers had increased slightly from 51.4 to 52.1 kWh/t (in comparison to Survey 4, which had similar feed size distribution but with the conical spacers installed) but the product sizing had also increased from P_{80} of 20.4 to 21.3µm.

Survey 6 confirmed a similar result, consuming 50.6kWh/t to a P_{80} of 21.3µm. When compared to surveys 3 and 4, surveys 5 and 6 both suggested a grinding energy efficiency benefit for the conical spacers over the standard cylindrical spacers.

Overall, the results of the initial on site testwork were very encouraging and supported the findings from the pilot plant work. The M1000 data suggested that the same product size could be produced about 15% more efficiently by using the conical spacer configuration. Given the exponential increase in specific energy requirements when grinding to finer sizes, this was a significant finding. Based on this success, a further, more detailed technical program was proposed to better quantify and confirm the advantages of the conical spacers.

IsaMill™ M1000 Stage 2 Testwork – Standard Mill Operating Speed / Varied Throughput

The second stage of testwork was conducted at the same site in September 2013 and again involved trials of the two different spacer configurations. A standard IsaMill™ signature plot, shown in Figure 8, was generated for each configuration by varying the throughput, within the operational limitations of the site. As per the initial stage of M1000 site testwork, the IsaMill™ was operated with nominally the same media load in each case to isolate the impact of the change in spacer design.

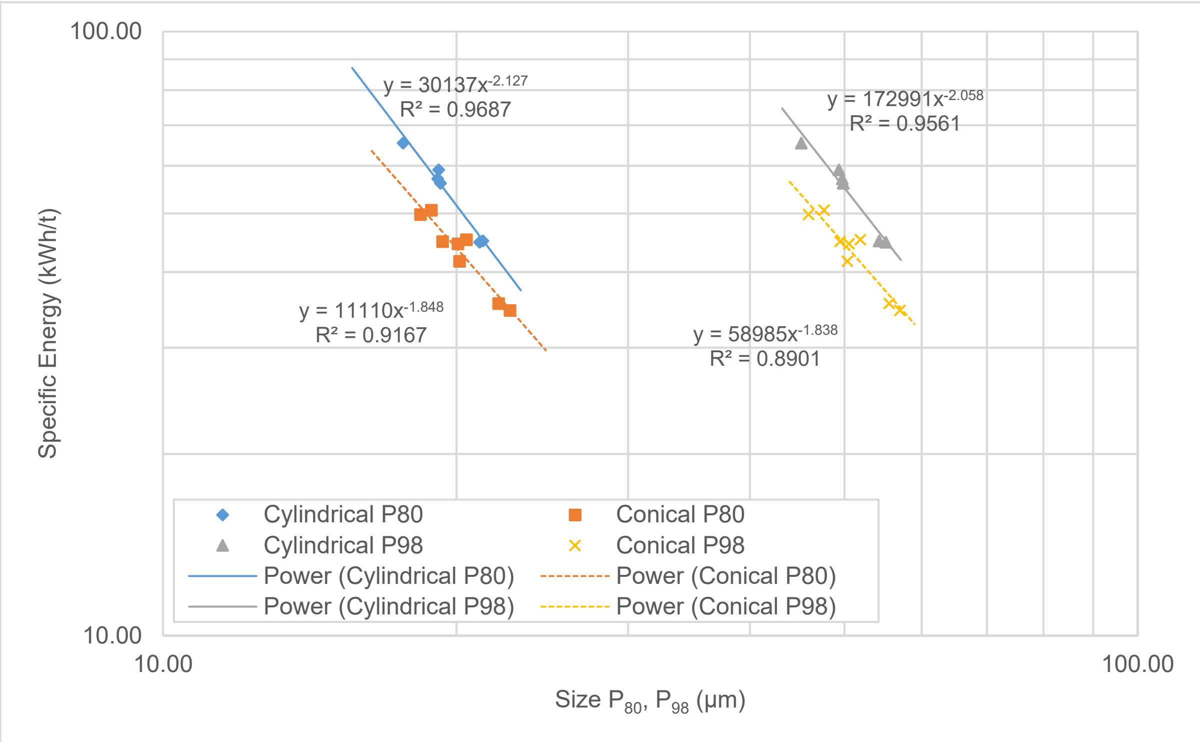

Figure 8 - M1000 IsaMill™ Signature Plot for Conical and Cylindrical Spacers - by varying Throughput

The signature plot equations from Figure 8 were used to construct Figure 9, which illustrates the reduction in specific energy requirement to a given target product P_{80} and P_{98} sizing. Table 2 summarises the data (within the range of product sizes produced during the testwork, i.e. 18µm < P_{80} < 22µm). The data indicated that for a P_{80} target of 22µm, the conical spacers require 36.8kWh/t. This was 12.7% more efficient than the cylindrical spacers which require 42.1kWh/t. The P_{98} predicted for the conical spacer configuration was 55.5µm at 36.8kWh/t, 17.4% more efficient than the cylindrical spacers, which would require 44.5kWh/t to produce the same P_{98}. Similarly, at a P_{80} target of 18µm, the conical spacers were predicted to consume 53.3kWh/t. This was 17.4% more efficient than the cylindrical spacers which would consume 64.5kWh/t. The P_{98} predicted for the conical spacer configuration was 45.3µm at 53.3kWh/t, 21.1% more efficient than the cylindrical spacers, which would require 67.4kWh/t to produce the same P_{98}.

An additional comparison to a target P_{80} of 15µm was made by using the signature plot equations (signature plots have been extensively proven to exhibit a linear relationship on a log-log plot (Larson M. , Anderson, Barns, & Villadolid, 2012)). Analysis of Figure 9 shows that the predicted efficiency improvement of the conical spacers increased further (21.5% in P_{80} terms and 24.1% in terms of the energy equivalent P_{98} of 37.8µm) as the desired grind size was reduced.

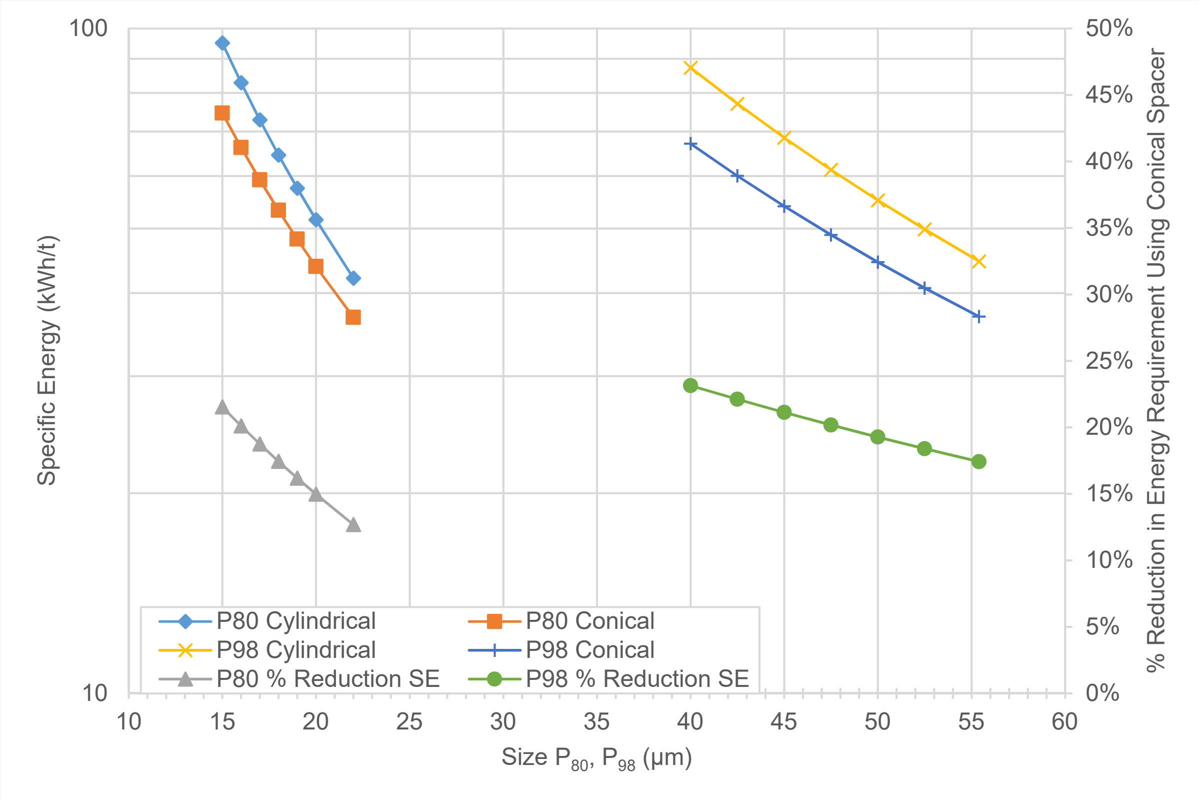

Figure 9 - Reduction in specific energy to target product P_{80} and P_{98} sizing (varied throughput)

Table 2 - Energy Efficiency Improvement Presented by Conical Spacers during Varied Throughput Trial

	P_{80} = 22µm	P_{80} = 18µm	P_{80} = 15µm	P_{98} = 55.5µm	P_{98} = 45.3µm	P_{98} = 37.8µm
Cylindrical (kWh/t)	42.1	64.5	95.1	44.5	67.4	98.3
Conical (kWh/t)	36.8	53.3	74.6	36.8	53.3	74.6
Efficiency Improvement	12.7%	17.4%	21.5%	17.4%	21.1%	24.1%

This data suggested that the impact of the conical spacers on grinding efficiency became more significant at finer grind targets and diminished at coarser targets. Although it was not proven whether the impact at coarser targets was neutral, or even negative.

It is well known that the shape of product size distributions from different grinding devices or circuits can vary such that the P_{80} values may be the same for two very differently shaped curves (Gao, Reemeyer, Obeng, & Holmes, 2007) and (Larson M. , Anderson, Morrison, & Young, 2011). Further, the downstream metallurgical performance can be influenced by the shape of the coarse end of the size distribution curve. In this case, the P_{98} of each product size distribution was also measured and compared to the corresponding P_{80} value as a method of quantifying changes in the shape of the coarse end of the size distribution – both between the two spacer designs and also as the specific energy input changed. The smaller the P_{98}/P_{80} ratio, the tighter the distribution and therefore a lower proportion of particles at coarser sizes for a given P_{80}.

Figure 10 illustrates the P_{98}/P_{80} ratios generated from the Figure 8 signature plot equations. It highlights the reduction in P_{80} and P_{98} values for a given specific energy as a result of using the conical spacers compared to the cylindrical spacers. For example, at a specific energy of 40kWh/t, the P_{80} was reduced by around 7% and the P_{98} by 9%. This corresponded to a reduction in the P_{98}/P_{80} ratio from 2.59 to 2.52 – indicating a slightly tighter size distribution produced by the conical spacers, at the same specific energy input. Figure 10 indicates that larger percentage reductions in P_{80} and P_{98} product sizings occurred at higher specific energies but the improvement in the P_{98}/P_{80} ratio between the spacer designs also diminished but was still in favour of the conical design.

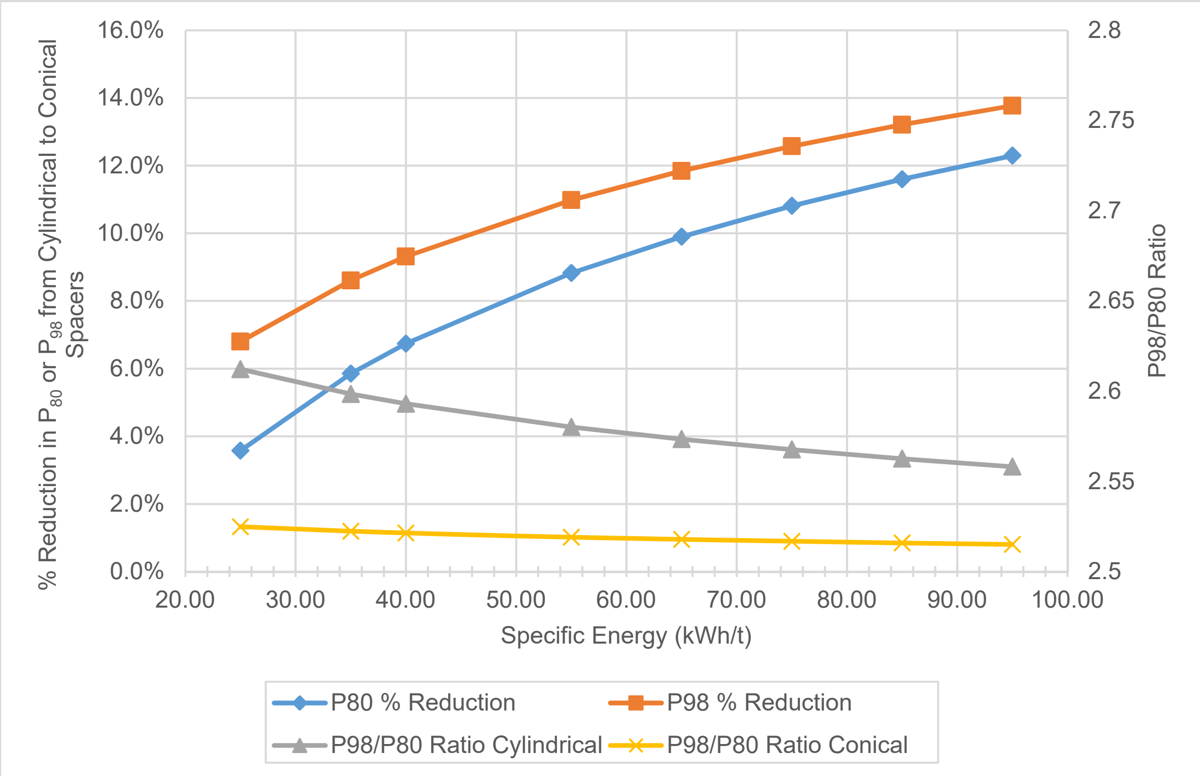

Figure 10 - Effect of Conical Spacers on P_{80}, P_{98} and P_{98}/P_{80} Ratio

In reality, any efficiency gains will likely be realised as reduced specific energy consumption to the target product size, rather than reduced product sizing at the same specific energy target. Table 3 summarises the impact on the P_{98}/P_{80} ratio at target sizes of 22, 18 and 15µm for the M1000 trials. Clearly, there was only a nil to small improvement to the P_{98}/P_{80} ratio once the same target P_{80} sizing was considered for both spacer designs; however, the important fact was to confirm that it had not increased. The P_{80}/P_{50} and P_{80}/P_{20} ratios are also included for completeness. The ratios were largely consistent between the two spacer types, indicating that the conical spacers did not adversely impact the shape of the size distribution curves (at equivalent P_{80} target sizing).

Table 3 - P_{98}/P_{80} ratio for cylindrical ■ and conical ⬢ spacers at same target P_{80} product sizing

	Specific Energy (kWh/t)			**P_{98}/P_{80}**		**P_{80}/P_{50}**		**P_{80}/P_{20}**	
Target P_{80}	■	⬢	**Saving**	■	⬢	■	⬢	■	⬢
15µm	95.1	74.6	21.5%	2.56	2.52	2.17	2.17	4.77	4.78
18µm	64.5	53.3	17.4%	2.57	2.52	2.22	2.20	5.16	5.13
22µm	42.1	36.8	12.7%	2.60	2.52	2.28	2.24	5.62	5.54

IsaMill™ M1000 Stage 2 Testwork – Varied Mill Speed

An additional set of tests to construct signature plots for both spacer designs was conducted where the mill speed was varied, rather than the mill throughput, to adjust the drawn mill power. Figure 11 illustrates the signature plots and indicates similar relationships to those developed when the mill throughput was varied.

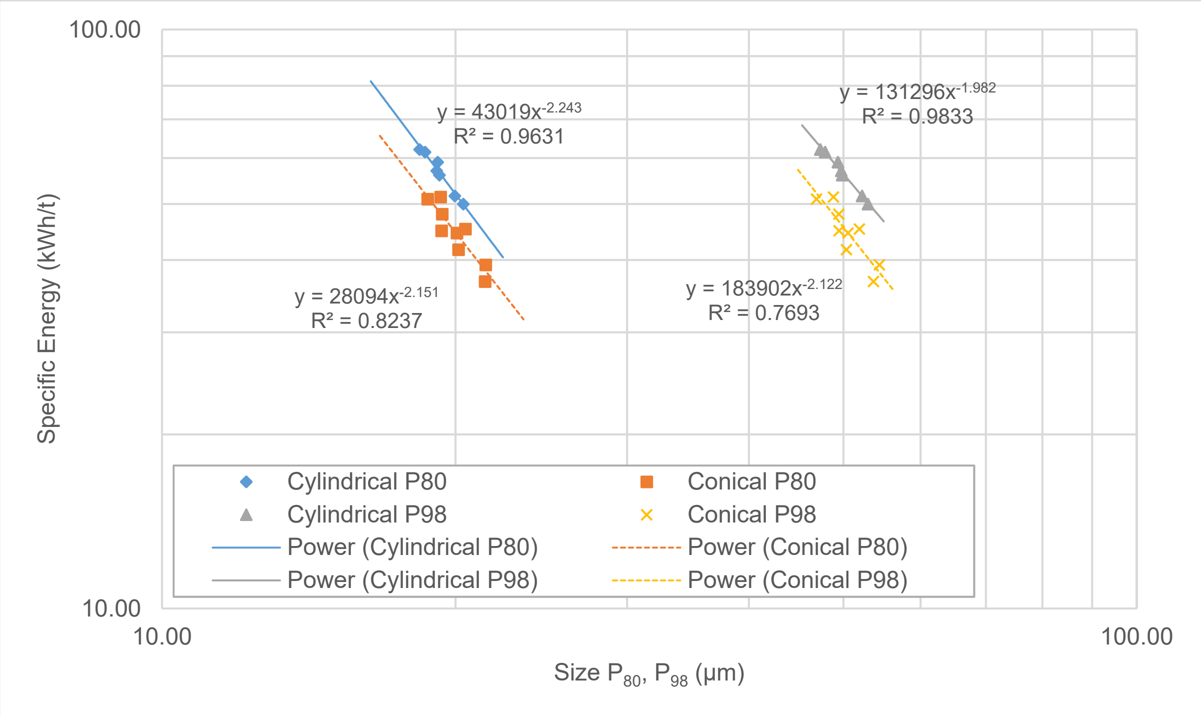

Figure 11 - M1000 IsaMill™ Signature Plot for Conical and Cylindrical Spacers – by varying Mill Speed

Figure 12 illustrates the reduction in specific energy requirement to a given target product P_{80} and P_{98}, based on the signature plot data equations from Figure 11, and shows similar to trends to those observed for Figure 9 where the IsaMill™ throughput was varied. Table 4 summarises some of the data. To achieve a P_{80} target of 22um, the conical spacers required 36.4kWh/t. This was 13.4% more efficient than the cylindrical spacers, which would consume 42kWh/t. The P_{98} predicted for the conical spacer configuration was 55.6µm at 36.4kWh/t, 20.3% more efficient than the cylindrical spacers, which would require 45.6kWh/t to produce the same P_{98}. Similarly, at a P_{80} target of 18um, the conical spacers would require 56kWh/t. This was 15% more efficient than the cylindrical spacers, which would require 65.9kWh/t. The P_{98} predicted for the conical spacer configuration was 45.4µm at 56kWh/t, 18% more efficient than the cylindrical spacers, which would require 68.2kWh/t to produce the same P_{98}.

An additional comparison to a target P_{80} of 15µm was made by using the signature plot equations above. Analysis of Figure 12 shows that the conical spacers required 82.9kWh/t for a P_{80} of 15µm, 16.4% more efficient than the cylindrical spacers, which required 99.1kWh/t.

These results are consistent with the magnitude of reductions observed by varying the mill throughput.

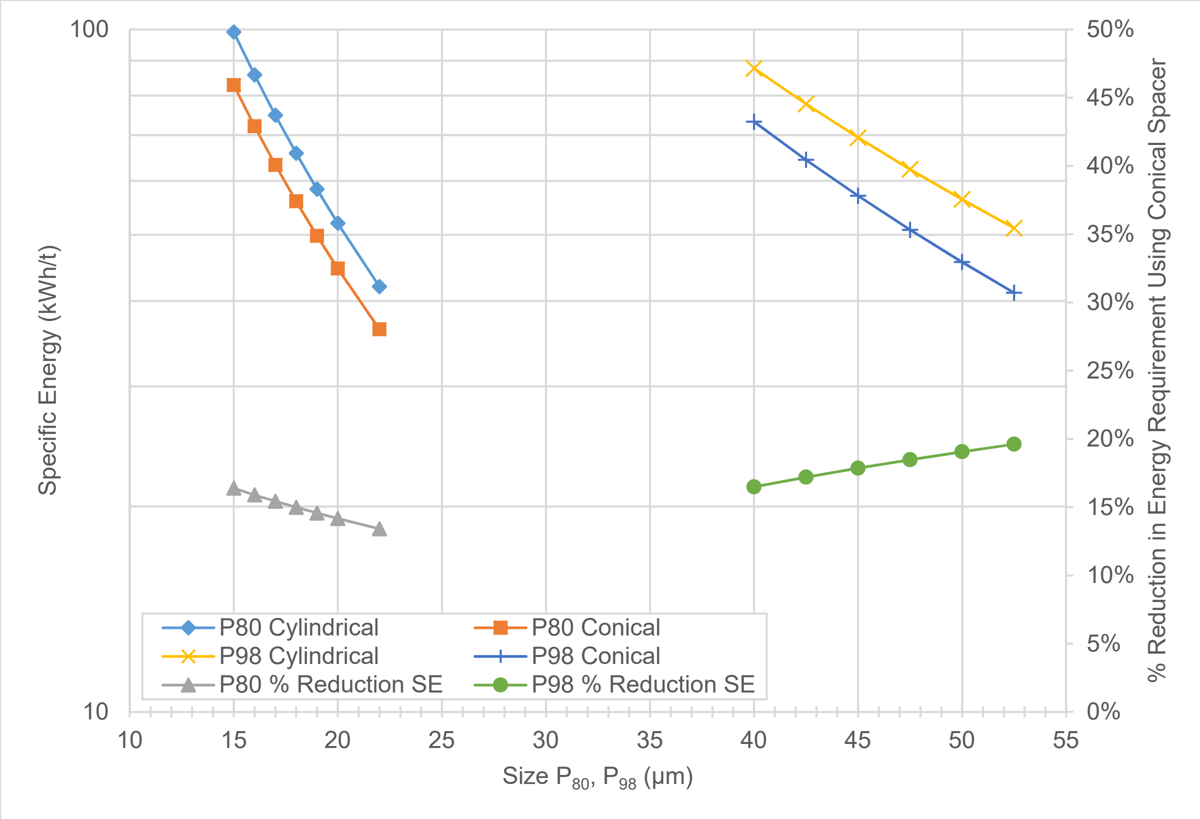

Figure 12 - Reduction in specific energy to target product P_{80} and P_{98} sizing (varied mill speed)

Table 4 - Energy Efficiency Improvement Presented by Conical Spacers during Varied Mill Speed Trial

	P_{80} = 22.0µm	P_{80} = 18.0µm	P_{80} = 15.0µm	P_{98} = 55.6µm	P_{98} = 45.4µm	P_{98} = 37.7µm
Cylindrical (kWh/t)	42.0	65.9	99.1	45.6	68.2	98.4
Conical (kWh/t)	36.4	56.0	82.9	36.4	56.0	82.9
Efficiency Improvement	13.4%	15.0%	16.4%	20.3%	18.0%	15.8%

Continuous Operation

Based on the results achieved during the testwork campaigns, the test site opted to install the spacers for continuous operation. A set of rubber-lined spacers was designed and manufactured for this purpose. The site was able to operate the IsaMill™ at reduced power draw and produce their required grind size, in line with the testwork results. The spacers were expected to become more of a wear item in the mill due to their contribution to the grinding process. Figure 13 shows the spacers after 375 hours operation.

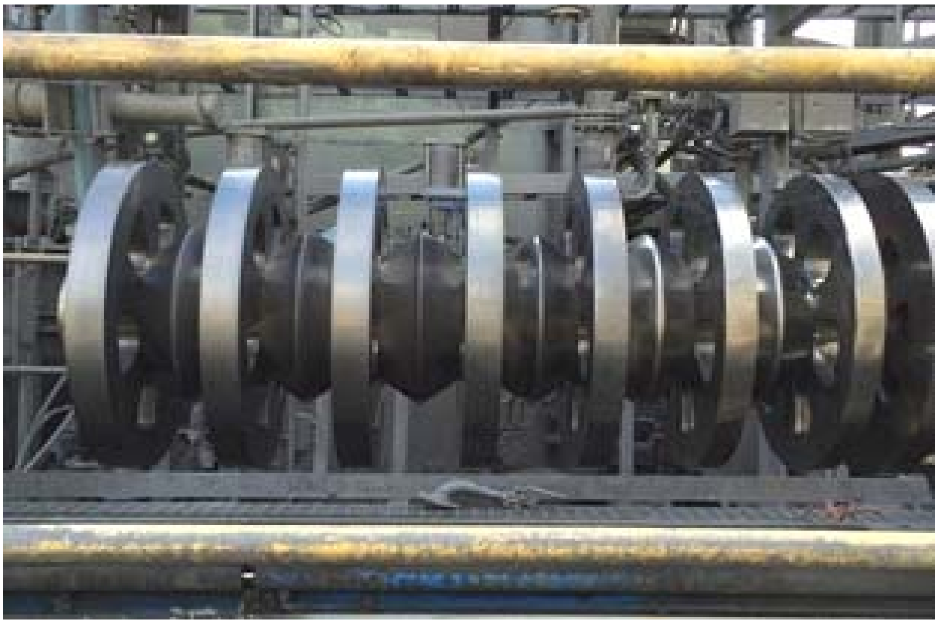

Figure 13 - M1000 IsaMill™ with Conical Spacers after 375 hours of Operation

Process Implications and Considerations

There are a number of potential benefits and considerations for IsaMills™ operating with the new conical spacers due to the improved grinding efficiency.

- Reduced specific energy consumption for the same product size target or a finer product at the same specific energy consumption.
- Small improvement in the top end of the size distribution (P_{98}/P_{80} ratio) and associated downstream benefits, particularly if the same specific energy input is maintained.
- Reduced operating temperature for the same product size target or improved product size at the current operating temperature.
- If the mill power draw can be increased (by further media addition), potential for increased mill throughput at the same product size target.
- Operation at lower power draw will result in reduced component wear rates in the IsaMill™, although the conical spacers are expected to become more of a wear item.

The conical spacers will occupy volumetric capacity within the mill and based on the work here will result in a lower drawn power. Depending on the typical media loading in the mill, it may not be possible to draw full power if no more media can physically fit into the mill.

If the percentage grinding efficiency improvement is the same as the percentage amount that the power draw decreases then the mill can continue operating at the reduced power without any effect on throughput. If the grinding efficiency improvement is greater than the percentage amount that the power draw decreases then the mill can operate with a reduced media load and the same throughput. If, however, the grinding efficiency improvement is less than the percentage amount that the power decreases, then an increased media volume will be required to allow the IsaMill™ to process material at the same throughput . This may be an issue if the spacers have taken up the remainder of the available operating media volume.

In the M1000 work discussed in this paper, the power decreased by approximately 22% for the given operating media volume. At an 18µm P_{80} target, the grinding efficiency improved by ~17%, meaning that if the IsaMill™ was at media capacity due to installing the conical spacers, the throughput would need to be reduced to maintain the same grind, as the media load could not be further increased.

Optimal Sites

Based on this work it appears that the sites which would benefit the most from installation of the new spacers are those with:

- Relatively fine grind targets
- Throughput constraints and a need to process more through the mill
- High specific energy applications running at close to the temperature limitations

Summary

The new conical spacer design was successfully tested from laboratory to pilot and then onto a full scale IsaMill™. At full scale, a reduction of approximately 13-17% in specific energy was observed over the range of throughput conditions tested (at standard operating mill speed) with an accompanying decrease of about 22% in drawn mill power. Based on the signature plots produced, the benefit was shown to increase to 21% at P_{80} of 15µm target. In fine grinding, where energy requirements increase exponentially as the target size decreases, this is a significant finding. The new design offers a number of potential benefits and options to existing and future IsaMill™ installations, the most significant of which is a substantial improvement in grinding efficiency.

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