Proactive Rolling Bias Test applied on Sample Stations

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The most basic concept of sampling theory is that "a sample is part of a lot", where the sample collected needs to be representative to the lot sampled. On sample stations, the lot to be sampled is represented by the material transported by the conveyor belt, while the sample is collected and further subsampled via cutters until the final sample collection point.

Current normal practices to evaluate the operation of sample stations that support processing, metallurgical balance, reconciliation, and final port shipments are typically based on visual inspections: Material build-up on cutters, sample spillage, reflux while sampling, pegging on sizing screens, worn cutter lips are all observations that indicate issues. Being subjective observations, these do not allow the quantification of the sample's representivity, and the risks for mining businesses due to a positive or negative bias being incorporated during sample collection stage.

Bias Tests are mentioned in several International Standards across commodities (ISO3082 for Iron, ISO 13909-8 for Coal and ISO12743 for Copper, Lead, Zinc and Nickel, for example) to compare the sample obtained against the material it is supposed to represent at the control point. The current methodology and strategy used in the industry requires the interruption of the regular production process multiple times in a row for extended periods of time, to manually extract the material from the conveyor belt (also including manual handling and safety considerations). For this reason, bias tests are not very popular in industry ("we lose a lot of money and time having to interrupt our process many times") - and are therefore usually performed only very reluctantly, or not at all, exposing mining companies to higher production and financial risks than necessary, hence it is simply assumed that the processes involved are not affected by bias.

This paper is presenting a proactive approach to perform a Bias Test, developed at Hay Point Port Coal, a Rolling Bias concept has been developed, switching the current reactive, time consuming and manual process task, to a more proactive and frequent methodology that allows for trending analysis of the sample station. Quarterly planned maintenance stops are used to perform the bias test, where a vacuum system developed and tested by ALS Laboratory and BHP Coal, performs the collection of the material from the conveyor belt drastically reducing the time required to perform the task manually, but more importantly reducing the exposure of people to safety and manual handling risks. This approach enables Hay Point Port to have quarterly performance data of the sample station, converting this process to a more objective, proactive, and sustainable approach where data, every quarter, has been monitored since 2019.

Introduction

Bias tests are performed to assess and quantify potential levels of bias present on sample stations, normally located on processing plants and ports. In this process, a belt is stopped and a representative reference sample is collected from the material on the belt (the lot). The belt is restarted, and next to the reference just collected, a normal sample going all through the sample station (primary cutter, secondary cutter, etc), is obtained by the sample plant. Both samples are analysed to determine if there is bias in the sample plant. A number of paired samples are required to achieve a statistically valid indication of bias. It is important to note that the method used to collect the representative reference sample must be in itself unbiased in order that this sample is suitable for use as a reference sample.

Bias tests are mentioned within ISO requirements in different commodities (ISO3082 for Iron**,** ISO 13909-8 for Coal and ISO12743 for Copper, Lead, Zinc and Nickel, for example), but current industry strategy is to perform it just once every several years, if at all after initial commissioning.

In this setting, when bias tests are performed, it is a reactive response as a part of an investigation into a significant deviation in observed results. A reactive approach to understanding bias in a sample plant is poor practice and increases the risk that key quality parameters will drift outside of required specifications. This will ultimately lead to higher production and financial risks.

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As a consequence of this reactive strategy and the interruptions in operations, bias tests unfortunately are not normally performed as a part of a routine schedule. To provide some control on the sampling operations, sample plants are typically monitored by visual inspections and the online monitoring of basic parameters. These subjective inspections often provide a "false sense of confidence" to operations that the sampling processes bias are working within specifications, even though they may have already failed in the quality quantification. In addition, where differences arise on reconciliation results, the quality of sample stations data (in the absent of bias test) can be considered as unknown, impacting directly the timeframe of investigation and making the impacts of the production deviations bigger.

A proactive rolling bias testing process can be continuously implemented to reduce the immediate impact on operations, this process allows for a small subset of samples, normally around 2-4, to be collected at each sampling time and be added to a data set up to the required number of samples to achieve statistical significance. Statistical significance varies with the material being tested, being primarily dependent on the homogeneity of the material.

Methodology – reactive vs proactive rolling bias tests

As per ISO requirements in different commodities, a stopped-belt sampling bias test is the accepted method to obtain a reference sample (from the lot) against which other sampling procedures may be compared (e.g. ISO3082). The frequency at which samples are collected in a rolling bias test is determined based of the requirements of the site and the perceived risk level. Rolling Bias testing would normally be completed on a quarterly or half yearly schedule. However, this process can be completed at a much higher frequency and more proactively if monitoring at such a level is deemed necessary. Conversely, extending a rolling bias sample program out beyond half yearly sampling intervals will significantly reduce the usefulness of this practice.

Changing the current industry reactive approach for a more proactive approach, samples are continuously collected to allow a robust statistical analysis, but importantly shifting the current investigation framework, normally performed at the start, by providing the opportunity to perform more trend analysis over period of times. In this way bias testing can be completed regularly and with minimal disruption to maintain assurance that the sample plants are objectively free from bias. It is important to note that before conducting any form of bias testing a thorough compliance audit of the sampling system is completed and any issues of concern are rectified. Otherwise, any significant error in the operation of the plant will almost certainly cause bias which will result in the bias testing being a waste of time and resources.

ALS's Mackay Coal Laboratory and BMA's Hay Point Coal Terminal have been collaborating for several years to develop the current rolling bias test process used at the terminal. This has resulted in a number of innovations that have been developed to ensure that the process is able to be completed with minimal disruption to the throughput of the terminal. The three major innovations are:

- The implementation of a rolling bias test program that minimises disruption to throughput at the terminal and where all the stakeholders in the supply chain are informed and aligned.

- A dedicated bias test mode was developed for the sample plants to automate the collection of the routine sample and ensure that the routine sample cut is all that comes through the plant until it is returned to normal operation. This also means the plant is operating in a "normal" way. Without this mode sample plants need to be operated in "manual" so that the primary cut can be triggered, and the system will process the sample, this leads to unusual operation in some plants as systems that sense and react are often disabled or ignored in manual operation.

- A vacuum system has been developed to replace normal manual methodology, allowing for rapid sample collection. This system allows for significant volumes of sample to be collected in a short period of time and minimises the health and safety risks associated with manual handling. Finally, the vacuum system eliminates the need for samplers to be on the belt itself.

Methodology – manual methodology versus vacuum system

<u>Current manual methodology</u>

Normally when collecting stop belt samples, the belt is stopped, and the system is isolated. Then a sample frame is driven into the material to the surface of the belt and the sample is shovelled and swept out of the frame. A sampling frame is utilised to ensure that only the material in the selected section of belt is collected and no additional material from the edges of the cut can fall into the sample being collected. This sample is then taken to the sample collection drums in buckets. Once this is completed the sample frame is removed and the system is de-isolated. This process requires significant quantities of labour and time, all the while exposing the people involved to significant manual handling risks. Also, depending on various factors at the site, this process can require a significant number of people to complete the sampling safely and efficiently.

Figure 1. Traditional Stopped belt sampling.

Vacuum system

One of the key processes used to reduce the impact to the operation during the sampling for bias testing is the use of the vacuum system, where the reference sample is collected by using a validated vacuum system replacing the current manual task which drastically minimises the stoppage time. The stoppage time will vary across sites largely due to variances in time it takes to isolate and deisolate the systems. At Hay Point Coal terminal, the stoppage time requires 10-20 mins per reference sample with the majority of that time consumed with isolation and deisolation processes. This also only requires a maximum of 2 people for sample collection. The reference sample (full grain size distribution) is rapidly vacuumed off the belt and deposited directly into the drum through an annulus on the top of the drum.

Part of the development process for the use of the vacuum system was to run a series of tests comparing the results of traditional sampling with the results achieved using the vacuum system. This test work provided confidence that the vacuum system itself was collecting representative samples. During this process there was also a series of comparison samples taken utilising a sampling frame and without a sampling frame, this series of tests established no significant variance between the two practices and the process was determined to be acceptable to move forward without the use of a sampling frame. By using the vacuum system and not having samplers on the belt there is minimal disturbance to the sides of the of the sample cut. For this approach to be used on different commodities/sites similar test work to determine the suitability of the vacuum system and sample collection without a sampling frame would be recommended to be completed.

Figure 2. Vacuum trial size distribution comparison plot.

Figure 3. Belt sampling using the vacuum system.

The basic process for sampling using the vacuum system is as follows:

- Upon arrival, and having completed all access requirements for site, the vacuum is moved down to the belt to be sampled and the area is reviewed for safe access and any potential issues. The sample plant is also reviewed for safe access and any issues.
- If a previous Job Safety and Environmental Analysis (JSEA) / Workplace Risk Assessment and Control (WRAC) exists this document is reviewed by the persons conducting the work and any changes required due to changed conditions/processes are documented and implemented. If there is not an existing document this process will be completed.
- The vacuum is moved into position for the sample collection or as close as can be achieved prior to isolation.
- After confirming with control, or other responsible party, the belt will be stopped, usually by means of the pull cord, to achieve an immediate stop. This is organised in such a way that the loading on the belt is appropriate when it is stopped.
- The sampling personnel then isolate the belt and complete any other isolations that may be required.
- The vacuum is then positioned into its operational position.
- The operator positions the hose and vacuum head at the point of the manual cut, and the vacuum is started collecting an area of 3 times the nominal top size, as per ISO requirements as a minimum The sample collected needs to comply with Theory of Sampling (TOS) requirements by including the full material in the conveyor belt (full grain size distribution) and not having preferential trends. This sample collected is considered under ISO as the reference, in other words, as representative to the lot to be sampled by the sample station.
- The operator then vacuums the sample, leaving the belt clean, and the sample is collected into a clean 205l drum located on the ground below the vacuum system.
- The vacuum equipment, and vacuum if required, are moved from the belt area and the belt is de-isolated and returned to operation.
- The sample plant is set up/prepared so that the sample from the matching Primary cut is the only sample collected at the sample collection point while the belt sample collection is taking place.
- If the sample plant is not set up with a Bias Test Mode, the cut position on the belt will be marked and the primary cutter will be manually triggered to try to achieve a cut as close as possible to the manual cut. If Bias test mode exists, the plant will be placed into this mode while the belt is stopped.
- The plant is then allowed to process the sample as normal and the final sample is collected from the nominated point (usually the final sample collection point but this can vary due to operational, access and safety requirements).
- Usually at least a second sample is collected. However, at the beginning of the program usually four samples are targeted to build the dataset rapidly. The second and subsequent samples are obtained by repeating the sampling processes as many times as required.
- The collected samples are returned to the laboratory for the analysis of the predetermined critical parameters and a basic review of the completed data set is undertaken to indicate if bias is likely to be present.
- Once there a sufficient number of data points are obtained a more robust statistical analysis of the results this is completed. This provides greater confidence in the determination of any bias.

Advantages for a proactive rolling bias test approach

There are several advantages to performing a rolling bias test as compared to a standard bias test. Downtime and interruptions to production are minimised due to the limited number of samples that are collected each time sample collection is scheduled. This practice also helps to ensure ongoing monitoring (trend analysis) of potential bias as samples are being regularly collected and analysis of results is completed as soon as possible after collection. This ensures that if bias begins to present itself in the data set it can be actioned before it becomes a significant deviation and presents commercial issues.

The more traditional approach of campaign sampling and only conducting bias testing when deemed absolutely necessary cannot identify issues until well after they have arisen and usually not until after the bias present has caused commercial issues.

For example, and as a context, Holmes (2021) quantified in US$23 M the potential value loss for just a 0.1% Fe bias in an iron ore mine exporting in a year 250 Mt…so any minor source of bias is having a big impact for businesses.

Sampling Date	Reference Sample Mass	Non-Reference Sample Mass	Reference Increment (Ri)	Non-reference increment (Ai)	Difference
	(kg)	(kg)	Ash (%)	Ash (%)	(Di = Ai - Ri) (%)
24/05/2019	147.28	2.309	11.15	11.20	0.05
24/05/2019	138.48	2.468	11.23	11.83	0.60
24/05/2019	149.06	2.437	10.57	10.52	-0.05
23/08/2019	162.22	3.678	10.15	10.37	0.22
23/08/2019	162.78	2.234	9.89	9.89	0.00
23/08/2019	146.32	2.868	9.72	9.30	-0.42
17/10/2019	133.50	3.304	8.58	8.59	0.01
17/10/2019	87.56	3.598	8.98	8.59	-0.39
17/10/2019	142.52	3.811	8.88	9.29	0.41
17/10/2019	155.84	4.012	8.78	8.48	-0.30
19/12/2019	134.02	2.642	10.02	9.93	-0.09
19/12/2019	138.46	2.160	10.92	10.73	-0.19
19/12/2019	140.25	2.280	10.82	10.92	0.10
6/03/2020	123.32	2.484	7.90	8.31	0.41
6/03/2020	169.74	1.318	9.03	9.02	-0.01
6/03/2020	176.40	2.395	8.61	8.72	0.11
21/05/2020	165.22	3.390	9.50	9.20	-0.30
21/05/2020	169.58	3.396	9.20	9.10	-0.10
21/05/2020	153.42	3.606	9.32	9.11	-0.21
19/08/2020	135.62	2.247	9.60	10.09	0.49
19/08/2020	157.90	2.138	9.20	8.99	-0.21
19/08/2020	112.20	3.590	10.99	10.60	-0.39
19/08/2020	145.94	2.404	9.49	9.59	0.10
27/10/2020	177.12	3.200	9.90	9.80	-0.10
11/03/2021	172.40	2.578	8.78	8.88	0.10
11/03/2021	181.04	3.154	8.60	8.74	0.14
9/09/2021	159.36	2.478	8.97	9.52	0.55
9/09/2021	173.50	2.894	9.26	9.34	0.08
10/12/2021	162.80	2.160	8.92	8.80	-0.12
10/12/2021	167.88	1.962	8.72	8.80	0.08
30	Rolling Mean		9.52	9.54	0.02
	Rolling Standard Deviation				0.27

Figure 4. Example results.

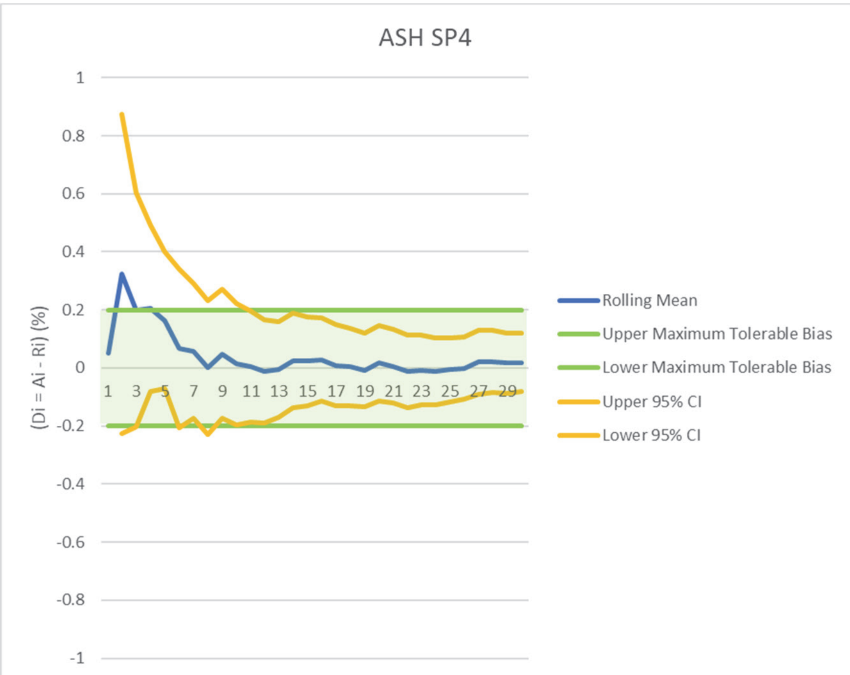

Figure 5. Example results plot.

Conclusion

Even though the requirement for Bias Tests are included in ISO Standards for several commodities, normally they are not performed due to the impact to production due to the downtime required to manually collect reference samples from conveyor belts that need to be stopped frequently.

Current industry approach for Bias Tests is reactive and subjective, because they are performed when issues have been already impacted production results, and because current subjective inspections cannot quantify the quality of the samples collected.

Rolling bias testing presented in this paper is a low cost, pragmatic and time effective process to manage bias in sample plants. Changing the strategy toward a more frequent sampling plan and by utilising the vacuum collection process serves to further drive down time taken for sample collection and costs involved with sampling. It balances the need to regularly monitor bias in the sample plant with the need to maintain throughput/production. The process is applicable to most bulk solids including coal, iron ore, mineral concentrates and can be completed with minimal disruption to site. Processes developed in collaboration between ALS and BHP are easily used, are readily transferable and, while there will be a certain limited amount of set up work required for each site, this process can be implemented rapidly and improved upon over time as site needs are better understood and local processes developed.

Overall rolling bias testing utilising the vacuum system:

- Significantly reduces manual handling and risks associated with mounting belts,
- Significantly reduces downtime,
- Can be planned and loaded into site maintenance systems,
- Provides proactive quality assurance/review of the sampling system, and
- Is suitable for most bulk solids.

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