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UNIVERSAL FALLING STREAM SAMPLING SYSTEM FOR SOLID BULK COMMODITIES (UNI-SAMP)

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ABSTRACT

Designing sampling equipment for existing installations can cause many challenges. One of the most common problems is that there is hardly any space to 'squeeze in' a mechanical sampling system as an afterthought.

The solution is to design and develop equipment from a radically different approach and – at the same time – minimize the required modifications of the existing structures and equipment that were already commissioned; an example of such equipment would be a transfer point of a conveyor belt system and its steel supports. The Uni-Samp solution is a falling stream cutter that requires a minimum of space and allows a single cutter bucket to perform both primary and secondary sampling… whilst avoiding two of the most biasing sampling errors: delimitation error and extraction error. Uni-Samp will be ToS compliant!

Figure 1 shows the basic components of Uni-Samp.

(Fig. 1)

In Figure 1:

1. is an excavator-type sampling arm,
2. is the cutter bucket for primary and secondary increments,
3. is the hopper to discharge primary increments in,
4. are transport belts that return primary increments to the cutter,
5. are secondary increment collectors
6. houses the mechanical, hydraulics and electronic controls

Whereas conventional systems would require several movable pieces and a lot more vertical space and/or battery limits, the Uni-Samp design provides the ability to perform the successive tasks of primary and secondary sampling, lifting as well as turning with one key piece of moving equipment.

Hydraulic controls will ensure a smooth, constant and straight cut through the falling stream of solid particulate material; radial cutter lips are not needed.

The hydraulics of the Uni-Samp by itself is proven technology, this allows the company NIKAI to design, build and commission a Uni-Samp system in shortest possible amount of time. Mine and port maintenance personnel will likely be familiar with the Uni-Samp system, even before it is installed!

Bureau Veritas is the exclusive partner that will verify and validate compliance to mechanical, structural and electrical standards… and of course to applicable sampling standards such as ISO 12743 and the Theory of Sampling.

As the hydraulic arm can let the cutter move freely, it is a simple task to switch to a different cutter in a multi-product site and avoid cross-contamination, or an inappropriate cutter aperture.

Multiple modular hoppers (for primary increments) and return belts may be considered depending on available cleaning time between different products and the risk of cross-contamination. Other modular solutions such as an 'in-line' comminution, sieving, or cleaning station can be incorporated whilst still remaining close to the relatively small floor space of the span of the sampling arm.

INTRODUCTION

There are various reasons for implementing a mechanical sampling system that takes increments from a moving stream of solid bulk particles on a conveyor belt.

The most common reasons are to determine the qualitative properties in process control, or quantitative composition in which the estimations are used for commercial settlement purposes in a transaction between a seller and a buyer.

When sampling an ore or mineral, the term ‘representativeness’ is often heard. In a lot of cases ‘representativeness’ is used without specifying degrees of confidence and maximum allowed bias, let alone talking of variances in the lot and reproducibility. For simplification the term 'representative sample' is used in many sampling plans and sales contracts, but without specifying the desired precision and permitted quality variation.

One should always consider that a sample is a portion taken from a lot that must be representative of the lot with regard to the characteristics under investigation. The sample portion should be small enough to be manageable and affordable, yet large enough to be meaningful and accurately level out variances to avoid bias. These aspects can be in conflict. Being wrong could demonstrate itself as a too large sampling bias, impacting accuracy. Being wrong could be a range of results that is too large, too imprecise and not reproducible.

Thus a sample should be unbiased and result in a mean value that represents all particles of the lot. An inaccurate result renders a value that is far away from the true value.

A sample should be reproducible and result in the same value when the lot is sampled again at the same location by the same sampling plan. If there is a big difference between two sampling exercises this is called imprecision or bias and it is not reproducible.

A wrong sample is inaccurate, imprecise, or both. Whereas a representative and correct sample is unbiased, accurate and precise.

A good sampling system finds the proper balance between risk and cost. Again a ‘good’ sample must be small enough to handle yet large enough to be representative for the information that is required.

As Vogel (2017) explains, all ‘good’ sampling systems have three things in common:

1. the system can achieve proper ACCESS to the material;
2. the sampling implement allows equal probability of all particles being SELECTED;
3. the sampling plan will not disregard part of the stream or lose part of the sample in a subsequent step, everything is INCLUDED.

This paper on Uni-Samp focusses on points 1 and 3 i.e. ACCESS and INCLUDE and explains how Incorrect Sampling Errors (ISE) are avoided. However SELECT in terms of sample frequency and sample mass, which are the main components to reduce Correct Sampling Errors (CSE), is of utmost importance too. Therefore this will be considered when designing a bespoke Uni-Samp mechanical sampling system so that enough increments will be drawn and enough sample mass is achieved to minimize the Fundamental Sampling Error (FSE) to an acceptable level.

UNI-SAMP

Vogel (2017) highlighted the risk of being wrong in sampling and the possible high financial impact when the measured or tested values on a sample are not representative. The high unit value of bulk products and/or the high volumes in which bulk commodities are generally produced/shipped underline this risk. Minnitt’s paper (2007) on sampling cost and decision making should be regarded when correlating the risk of being wrong with cost of sampling and deciding what type of mechanical sampling system should be installed.

When it comes to the basic design of sampling systems, not much has changed for decades. Basically the two types of sampling implements are:

1) Falling stream cutters, and
2) Cross belt 'hammer' cutters.

From the ISE perspective a falling stream cutter is often preferred as it is in practice the least susceptible to Increment Delimitation Error (DE) and Increment Extraction Errors (EE). The disadvantage of traditional falling stream sampling systems is that they require careful consideration of location and space – especially headroom. Yet sampling is not always at the top of the agenda of the civil engineer who designs a terminal or port where solid bulk commodities are handled. Often the engineer is reminded of a sampling requirement at the very last stages, when he or she is well advanced in technical designs and actual building arrangements. At the very last moment sampling is literally squeezed in, as a result 'ACCESS' is compromised.

Alternatively cross belt ‘hammer’ cutters are installed as they require less headroom. In practice this type of cutters leaves a small gap between the cutter and the conveyor-belt to avoid damage to the belt and costly repairs and interruptions. To avoid Increment Extraction Error (EE) a brush is used to sweep the last remaining particles and INCLUDE as sample, however the abrasive nature of solid bulk commodities causes wear and tear of the brush and in practice this is the reason why EE is more of a risk with cross-belt cutters than with falling stream ones. Consequently, the resulting error will be larger for relatively coarse products where sifting increases segregation of particles. Also where physical properties such as particle size distribution are needed, a cross belt ‘hammer’ cutter may not be appropriate. As the name suggests a ‘hammer’ cutter delivers considerable force that can result in breakage and creation of fines. As such, change of the physical properties during sampling will result in a bias.

NIKAI’s challenge was to design and develop a mechanical sampling system that is as easy as a cross belt system to retrofit into an existing conveyor-belt system, yet one that has all the benefits in terms of correctness of a falling stream sampling system. We believe this is the universal falling stream sampling system for solid bulk commodities, abbreviated as ‘Uni-Samp’, which is described in this paper.

ONE MAIN MOVING PART

Falling stream sampling systems require a lot of headroom to accommodate the primary sample collection cutter, discharge sample chute and subsequent comminution / division steps incl. chutes transfer belts where applicable. The Uni-Samp system is designed with mutualisation of use and space in mind. In particular the main sampling unit – the mechanical arm that drives primary increment and subsequent steps – is used in more than one process. In order to have the required freedom of movement the arm will be able to have 5-axis rotation, or more depending on the situation, limitations of space and complexity of the path to the falling stream. The drive will be hydraulic. Of course the constant velocity condition is respected when the cutter traverses the falling stream. TOS pioneer Gy (1979) clearly favoured electric drives in his earlier publications, while achievement of constant velocity was a known issue with hydraulics, we are convinced that 40 years later constant cutter velocity will be achieved by Uni-Samp’s hydraulic drives in combination with continuous sensors and instant adjusting of the speed.

(Fig. 2)

Yet, it is expected that a bespoke Uni-Samp solution will be challenged on achievement of sampling accuracy, that the cutters will have the correct geometry at every stage of sampling, that the rebounding rule is respected and reflux does not occur. Therefore NIKAI will invite Bureau Veritas to scrutinize its Uni-Samp mechanical sampling systems in order to obtain objective third party verification and validation that compliance to mechanical, structural and electrical standards and applicable sampling standards such as ISO 12743 and above all TOS is achieved. For sake of good order we mention that NIKAI works at arm’s length with Bureau Veritas when it comes to ‘sampling correctness’ in designing, developing and installing of Uni-Samp solutions.

ACHIEVEMENT OF SAMPLING ACCURACY

Gy (1979) has detailed the possible sources of selection and preparation bias and highlights the prerequisites of achieving sampling accuracy: there cannot be increment delimitation error, increment extraction error, or preparation error.

The main sources of increment delimitation error are incorrect geometry of the cutter and a non-constant velocity of the cutter when crossing the falling stream. Uni-Samp cutters will either have a rectangular cutter opening with parallel cutting edges that traverse the stream in a perpendicular, straight path; or the cutter will have radial cutter edges that converge towards the rotation axis in case of a circular path application. Contrary to what the name Uni-Samp may indicate, the need to design a bespoke cutter to the situation at hand is clear. This includes the material properties such as flow propensities – that defines shape and cutter-lining and nominal top size of particles – that will determine increment mass. Constant cutter velocity is of paramount importance and is achieved by using drives that have capacity with ample excess power and robust integrated encoders that make the main moving part a ‘smart hydraulic system’ where data of path, positioning, angle and velocity can be traceably stored and retrieved when required. The geometry of the cutter shall be such that the cutting time at each point in the stream does not deviate by more than 5%. This tolerance is used as well for cutter velocity between increments, which should avoid introduction of weighting error (WE). The cutter speed shall not exceed 0.6 m/s unless it is experimentally shown that no significant bias is introduced. These aspects ensure that the cutter has proper access and all particles have the same chance of being selected and included in the sample.

Once the increment has been delimited correctly and the cutter traverses the falling stream to take an increment, it should then take a complete cross section of the stream – including leading and trailing edges – and collect all the particles This should occur without an impediment to the flow of material into the cutter; even at maximum flow rate capacity of the conveyor belt. Equally importantly the cutter should properly contain all the solid bulk particulate material and nothing shall fall out or 'escape' (reflux). To discharge, the cutter will either tip or rotate into a surge hopper when subsequent sampling is needed, or into a storage container awaiting collection and sample processing. After discharge there shall be no significant remnants left behind in the cutter; meaning it will be self-clearing so that each increment or divided increment will be discharged completely. If necessary a small hydraulic 'shake' can liberate the last remaining particles. All delimited and selected particles will remain in the sample; and as such the INCLUDE conditions are ensured! As there is just one main moving part Uni-Samp will typically not have chutes which can be a major source of bias in a mechanical sampling system: sample remnants can remain, dust can collect and moisture has more time to evaporate. It is time to elaborate on more advantages of the multiple use and having one main moving part.

FUNCTIONS OF THE ONE MOVING PART

The thought behind the one main moving part of the Uni-Samp system is one of 'saving'. This includes saving space as highlighted already, but also on saving operational costs that more traditional mechanical sampling systems have: such as the costs of cleaning and maintenance. All too often cutters are found in spaces that are hard to reach. As such they are difficult to inspect and clean after switching between grades or different products. It is hard to perform maintenance on traditional, enclosed cutters and to replace their worn cutter lips. With 5-axis movement the cleaning of the cutter becomes an easy task and can even be automated by adding a modular cleaning station, for example by rinsing the cutter out of stream and without the risk that dust will fall into the sample chute and introduce extraction error. Inspectors or maintenance crews can essentially let the cutter come to them for their duties, making the tasks more efficient and lean.

Back to multiple use: Once the primary increment was drawn and when secondary sampling is required, the cutter bucket will either tip or tilt to discharge the material in a surge hopper (Fig. 3) this enables immediate 'feed back' of the material where the same cutter bucket will be ready meanwhile to take secondary increments of the falling stream. As the 5-axis arm is versatile it is also possible to have two apertures at both opposite ends of the cutter: one primary, large volume cutter bucket and at the other end a smaller volume cutter bucket that is tailored to the 'secondary' stream, the required number of secondary increments, the particle size and the subsequent stage of the workflow. Interval between increments at any stage can be fixed on time or mass basis, or even stratified; this all depends on the user of the information of the resulting samples. The information-user is the only one that can find the balance between the combined cost of sampling and testing on the one hand, and the cost of being wrong on the other hand.

Fig. 4.

After increment extraction the cutter bucket can either transport the collected material to a storage container as mentioned before. However as with all mechanical sampling systems there may be a need for in-line comminution and integration of e.g. a jaw-crusher, followed by moisture, ash or other types of on-line analysers. The difference between the Uni-Samp concept and other solutions is that the 5-axis arm and cutter take care of the sample transport between all the modular stations. Moreover all movements take place in the same elevation plane and all the activities take place directly around the main moving part.

In addition to the encoders that are integrated in the arm to track and record path, velocity and position integrated load-cells can enable weighing of the mass of an increment. This facilitates continuous monitoring of sample and extraction ratios and gives the operators an almost instant warning; for instance when an oversized lump gets stuck between the cutter edges.

FAMILIAR TECHNOLOGY & SAFETY ASPECTS

Obviously with one main moving part the dependency on this part is obviously high: in case of malfunction the whole sampling process will stop! This is however arguably also the case with other sampling solutions that may shut down in their entirety whenever a malfunction occurs. As there is one main moving arm the stock levels of spare parts will be fairly limited and cost friendly. Especially as in a port, terminal or mine environment the hydraulic technology of Uni-Samp will be familiar and the maintenance and repair workshops will not have much difficulties with it. As such the system can be restarted in shortest possible period of time. The regular maintenance costs for projected launch client – a dual belt, 6 500 tonnes each per hour iron ore port – are estimated at EURO 10 000 annually.

With respect to safety, there will be clear manuals with safety and lock-out procedures. Moreover Uni-Samp will be equipped with sensors and physical barriers that prevent movement of parts when maintenance activities take place. During normal operation the same sensors and barriers will shut down all systems when unauthorized access of personnel into the direct vicinity of moving parts is detected. As such all international, national and site specific health and safety regulations will be considered. Mechanical safety and damage prevention to primary belts and other surrounding structures is ensured by the use of block valves that prevent sudden and dramatic movements in case of an abrupt electrical or hydraulic failure.

MULTI COMMODITY APPLICATION

A problem that is often encountered in multi-commodity ports is the risk of cross-contamination. Another problem is that the nominal top size of the various commodities can be very different from each other. In such cases there are often separate sampling streams installed on the same conveyor belt; e.g. one for lumpy material and one for fines. Such installations take up considerable battery limits, head space and capital. With the Uni-Samp system the cutter bucket can be swapped out quickly by using industry standard couplers and connectors. Thus only the cutter has to be swapped, everything else remains the same. Still, if desired by the user, to further avoid slightest risks of cross-contamination, only the surge hopper and feed-back belt require redundancy whilst remaining in the same elevation pane and battery limits.

CONCLUSION

As an alternative to traditional falling stream cutters – which often take up a lot of head space and battery limits and are difficult to fit into existing conveyor systems – the universal falling stream sampling system for solid bulk commodities ‘Uni-Samp’ makes use of a single moving arm for taking increments and transport of the sampled material to subsequent stages in the work-flow. The arm will be hydraulically driven as the technology is able to counter the headwind arguments of yesteryear. Sensors and encoders will provide continuous and traceable data to underpin compliance to theory of sampling and avoidance of increment delimitation, increment extraction and weighting errors. Current technology allows hydraulically driven cutters to provide 'equal access to all particles' and proper design and focus on avoidance of increment extraction error will ensure that, once delimited, all particles remain included and have the same probability of ending up in the final tested sample.

Multi-use of the main arm helps to keep the capex requirements low when compared to other traditional falling stream sampling towers which often require significant head space. Operational costs are managed by the multi utilization and familiarity of maintenance departments with main hydraulic systems. It is time to review traditional falling steam sampling systems and move sampling into this day and age of Industry 4.0.

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Figures

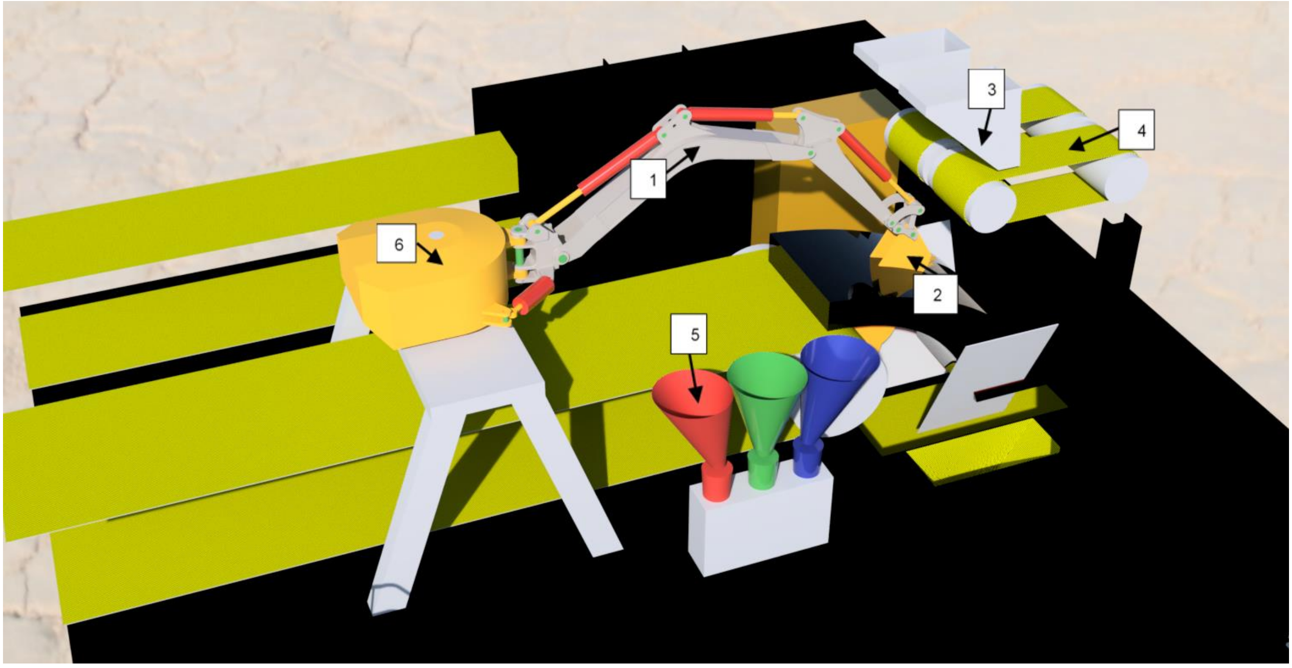

Fig. 1 – Example of a Uni-Samp for conveyor-belt that is used for multiple products and separate secondary sampling is required to avoid contamination.

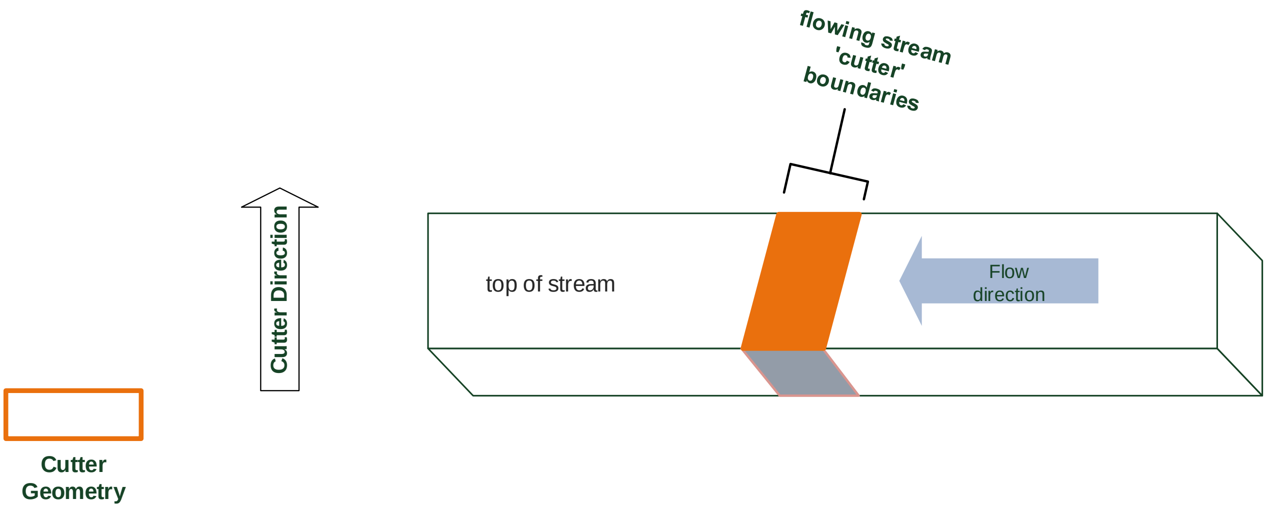

Fig. 2 – Example of rectangular cutter with parallel edges, straight & perpendicular path and constant velocity resulting in correct Increment Delimitation.

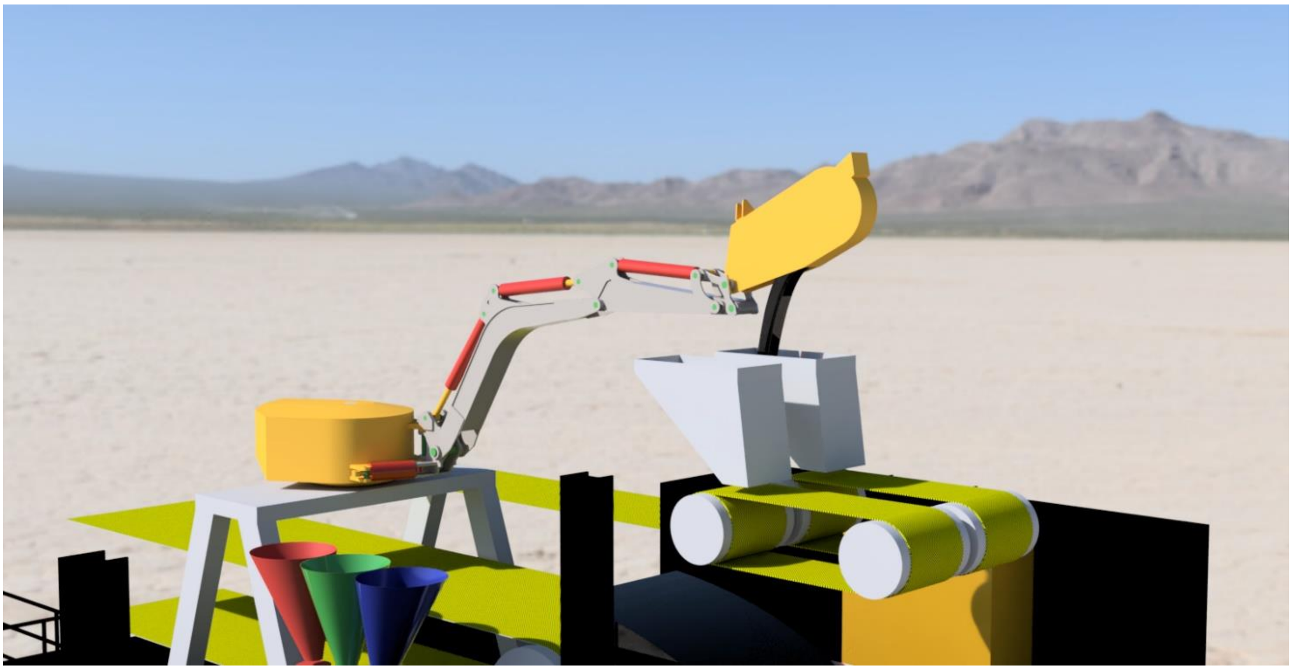

Fig. 3 – Uni-Samp feeding hopper for ‘feedback’ falling stream secondary sampling with same cutter.

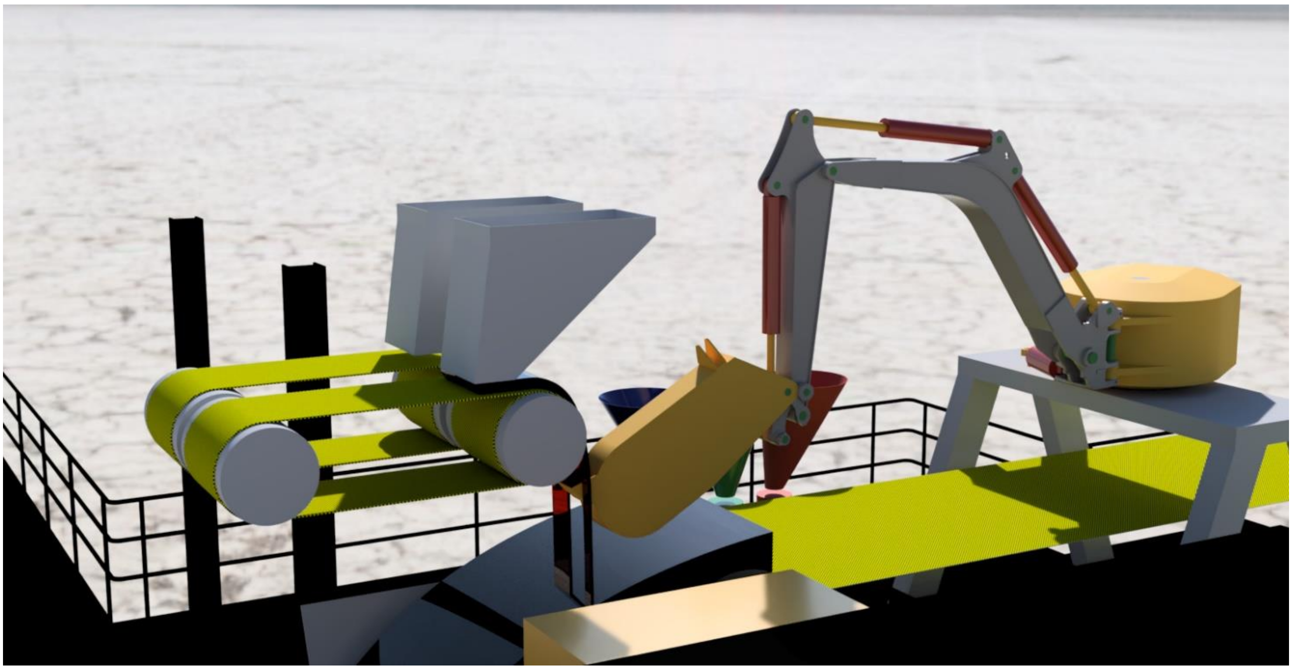

Fig. 4 – Secondary sampling using the ‘opposite end’ secondary cutter aperture.