SAMPLING COLUMN

Process sampling: the importance of correct increment extraction

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After the previous column's introduction to the *why*, the *how* and the *technicalities* involved in process sampling and variographic analysis, it is time for a bonanza of applications and case histories covering as broad a practical scope as possible. In this column, we introduce the critical *prerequisites* for the *variographic experiment*, by focusing on the importance of TOS-correct increment extraction for proper variographics. This issue cannot be overemphasised.

Moving, or static, 1-dimensional lots: increment cutting must be TOS-correct

Figures 1 and 2 illustrate how focus is on the extension dimension in process sampling (aka one-dimensional sampling), as long as each increment complies with TOS' stringent demand for a *complete slice* of the two width–height dimensions. By securing increments of this geometric configuration, there is only the extension dimension heterogeneity left, i.e. the longitudinal in-between increment spatial heterogeneity (DH = distributional heterogeneity). All variographic characterisation is aimed at describing, and managing $DH_{process}$.

If this demand is not observed, see Figures 3 and 4, it is clear how there will be a fundamental compositional imbalance (see incorrect sampling errors in earlier sampling columns) from one increment to another, which therefore should not be used for the purpose of characterising the 1-dimensional DH.

Correct planar–parallel or curvy–planar cross-sections of a moving stream is the **only** correct delineation of process sampling increments, Figure 5 (cases "A" and "C") and Figure 6 top panel, eliminating a potential incorrect delineation error [one of the three potential incorrect sampling errors (ISE)].

Incorrect increment delineation, and extraction, will give rise to an inflated nugget effect in variographic process sampling characterisation (see below and the previous sampling column). Non-compliance with these basics will give rise to incorrect sampling errors (IDE; IEE: Incorrect Delineation Error; Incorrect Extraction Error) which are **unnecessary** and which **can** in fact be eliminated from the sampling process.

Manual increment extraction is nearly always a bad idea, and can never be

Figure 1. Dynamic (moving) 1-dimensional lots, from left to right: a conveyor belt transporting coal to a power plant, a pipeline, a series of produced goods). Photo credit: Hans Møller, with permission, and KHE.

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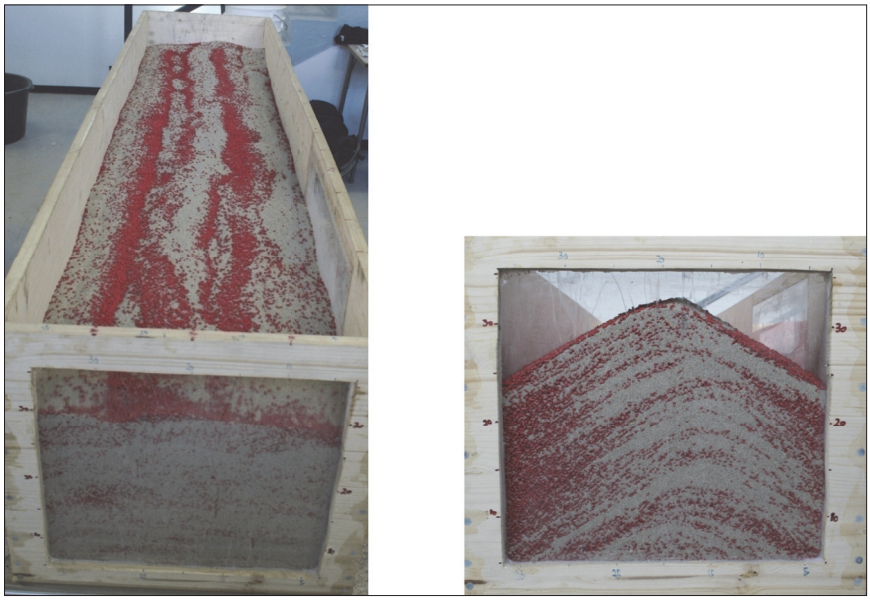

Figure 2. Stationary 1-dimensional lots produced in a laboratory scale-study of internal distributional heterogeneity (DH) as a function of the specific laying up process. Photo credit: KHEC teaching collection.

TOS-correct in practice, see horrific examples in Figure 7. Whenever all Incorrect Sampling Errors (IDE, IEE, IPE, IWE) have not been eliminated, the sampling process will invariably be fraught with a fatal, inconstant sampling bias, which can be never be corrected for, see, for example, References 1 and 2.

There is actually no excuse for not getting the fundamental increment sampling right—and from the first time. Figure 8 shows three examples that are all completely TOS-correct, which is the first condition for sampling representativity.

Only representative increment sampling processes are of interest in science, technology and industry. All examples shown in Figure 8 allow proper variographic process characterisation. Any violation of these simple requirements affects a given sampling process and will lead to an inflated nugget effect, see further below.

Observe above how 1-dimensional lots of both types, static and dynamic (moving), must live up to the same demands concerning the fundamental increment cutting requirements.

"Sooner or later" …

Sooner or later, however, we are ready to perform proper process sampling—enter *variographics*. The variogram was introduced in the previous column in some detail, so most of what is lacking is simply a basic understanding of what the variogram portrays with respect to the process, and how this comes about. A very small matter of a mathematical equation is all it takes: the professional sampler has to understand the meanings and implication of the variographic master equation, ..., all will be revealed in the next column.

Figure 3. Examples of irregular, unacceptable, partial cross-section slices compared to a correct full slice of the moving stream; the first two do not comply with the definition of correct increments. Observe also the marked asymmetrical load on the conveyor belt, which would wreak havoc with either of the partial cross-sections. The insert shows when this adverse issue is taken to its extreme, with no observance of the need of securing a balanced cross-section of the moving stream. Indeed, here the objective here seems to be "get a full bucket with the least hassle", which does not make for representativity—it is grab sampling plain and simple. Photo credit: KHEC teaching collection.

Figure 4. Evidence of a very irregular "sampling" in effect only *grab sampling* from one side of a conveyor belt, cf. Figure 3. Also shown is a trace of what *would have been* a correct cross-stream increment. Photo credit: KHEC teaching collection.

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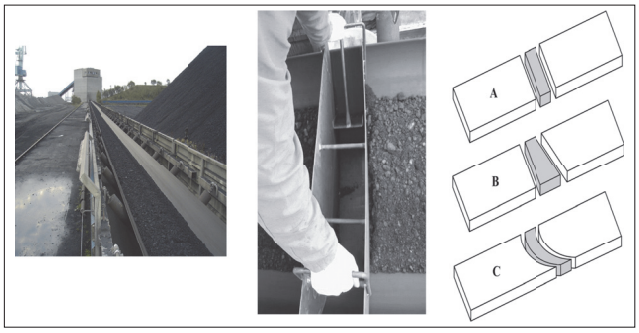

Figure 5. Illustration of the "stopped belt" situation in which it is possible to extract a perfect, TOS-correct cross-belt slice (central panel). The geometric delineation may be as in "A" or "C", but never "B", which depicts an unbalanced cross-cut. Example taken from a calibration test of an on-line sampler a coal power plant (not shown), to be validated against the representative samples extracted as illustrated. Photo credit: Hans Møller; with permission.

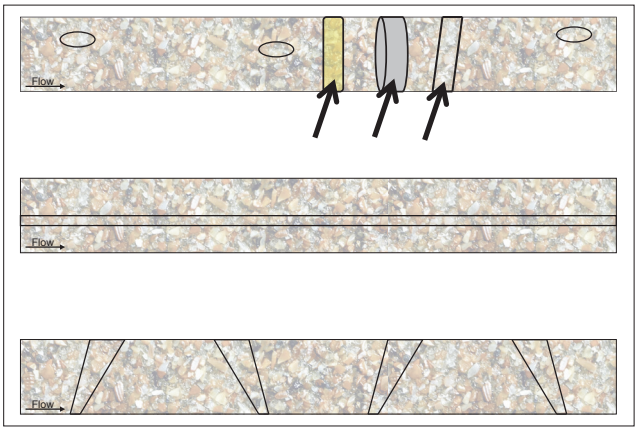

Figure 6. The "complete stream slice" dictum: only a *complete* cross-section of the moving stream of matter will satisfy TOS' principles re. correct increment extraction. This illustration can be thought of both as looking down on the top surface of a conveyor belt, or as a longitudinal cross-section of a pipeline. Observe that the "oblique" trace (rightmost slice) which is the practical realisation of all cross-cutter samplers when working "on-line". Illustration credit: KHEC teaching collection.

Figure 7. Horrific examples of extremely unbalanced, IDE/IEE-ridden attempts of manual increment process sampling—always doomed to fail. Manual process sampling is pretty much always a fatal give in to practical complacency. Photo credit: KHEC teaching collection.

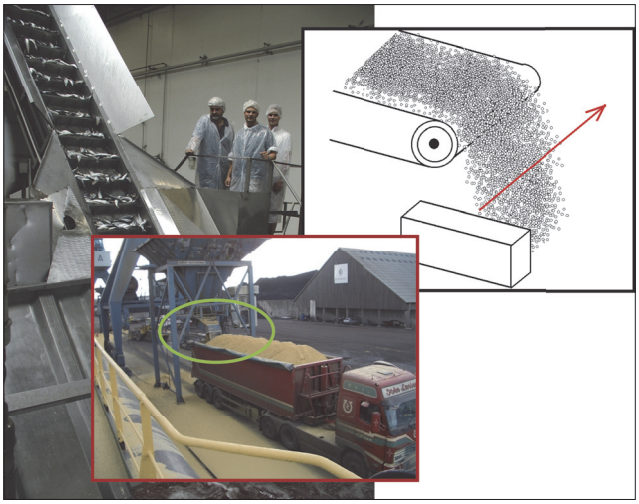

Figure 8. Examples of TOS-correct increment delineation/extraction. Left: a "fish stair case" transporter is functioning as a correct increment "cross stream" cutter (even if the unit particles in this case are *unusually* large). Centre: the bottom outlet opening of a grain off-loading hopper also functions so as to delineate increments without IDE/IEE. Right: a role model "cross-stream" cutter at work at the terminal end of a conveyor belt. All increment sampling process shown here are representative. Credit: KHEC teaching collection.

For readers who have been inspired to know more about variographics, and who can't wait, there is salvation in the two standard references[1,2] as well as the new professional introduction published recently by Minnitt & Esbensen.[3] This latter also takes you through the matheatical intricacies; well suited as a follow-up to the present columns.

This column has presented the critical issue of correct increment delineation and extraction in great detail (eliminating the otherwise fatal Incorrect Sampling Errors contributing to a sampling bias)—for a good reason. Full attention to these issues is absolutely necessary before embarking on the powerful variographic process characterisation. The next two columns are filled with practical case histories in which both benefits and throwbacks will be revealed.

References

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2. K.H. Esbensen and C. Wagner, "Theory of Sampling (TOS) versus Measurement Uncertainty (MU)—a call for integration", *Trends Anal. Chem. (TrAC)* **57,** 93–106 (2014). https://doi.org/10.1016/j.trac.2014.02.007
3. R. Minnitt and K. Esbensen, "Pierre Gy's development of the Theory of Sampling: a retrospective summary with a didactic tutorial on quantitative sampling of one-dimensional lots", *TOS forum* **7,** 7–19 (2017). https://doi.org/10.1255/tosf.96