Serious About Samples

Understanding different approaches for process monitoring and when to use them | **by Manuel E. Peña-Rodríguez**

Sampling is one of the most-used methods in quality systems to control the output of any given process. Specifically, sampling allows organizations to distinguish between good product and defective product. In this way, defective product is rejected, while good product continues through the production stream.

One of the most-discussed topics in sampling is sample size. There are many methods used to determine the size of the sample. There is, however, another important aspect of sample selection: representativeness of the samples.

To be representative, a sample must have the same chance of being collected as the other samples do. Suppose that a sample size is calculated as 32, for example. Obtaining a representative sample would mean collecting four samples every hour during an eight-hour shift.

A non-representative sample would be obtained if you collected the first 32 samples of the shift or the last 32 samples of the shift. Using the first approach (four samples every hour), it would be easier to detect defects if they occur randomly throughout the shift. Sampling only at the beginning or end of the shift, however, makes it difficult to detect defects if they happen randomly throughout the shift.

An example would be sampling labels in a continuous

Just the Facts

Determining the sample of product is an important consideration for most organizations when they are trying to distinguish between good and defective product.

There are different sampling approaches for the inspection stages: incoming, in-process and final inspections.

By implementing these approaches, organizations can improve their inspection activities and provide better product to customers.

roll of paper. If an organization just takes a sample either at the beginning of the roll or at the end of the roll (or both), how would it be possible to detect defects somewhere in the middle of the roll? Even adding a sample in the middle of the roll might not be enough.

What will happen if, at three-quarters of the roll, there is a power failure that causes the printer to lose the programming? If you wait until the next sample at the end of the roll, it would be too late. For that reason, another sample should be collected after any planned (or unplanned) interruption of the process.

Sampling vs. SPC

Sampling is an easy and cost-effective way to monitor a process. The main disadvantage of sampling is that it does not provide much information about the quality level of the process. It only provides binary information: good product or defective product.

It does not tell you how good the product is or how bad the defective product is. Based on the traditional concept of variation explained in Genichi Taguchi's loss function (see Figure 1), most organizations measure their product quality against specification limits. If the process is within the upper and lower specification limits, the process is assumed to be good and nothing else is done (left side of Figure 1).

But Taguchi explained that this is not a good approach. Losses start to develop as soon as you deviate from the target value (right side of Figure 1). Taguchi calculated the losses using the formula:

$$L = k(y - T)^2$$

in which L is the monetary loss, k is a cost factor, y is the actual value and T is the target value.

Based on Taguchi's loss function, if you want to reduce the losses, you must focus on variation—specifically, on reducing process variation.

From the formula, it means that the output value (y) must be as close as possible to the target value (T). As noted earlier, sampling does not tell you about the variation of the process. It only allows you to determine whether the product is accepted (good product) or rejected (defective product).

So, if you want to learn about process variation, you should not rely only on acceptance sampling. You must have a more dynamic approach. A good method is statistical process control (SPC) using the control chart.

A well-known assumption is that all processes are subject to some kind of variation. The two main types of variation are common-cause variation and special-cause variation:

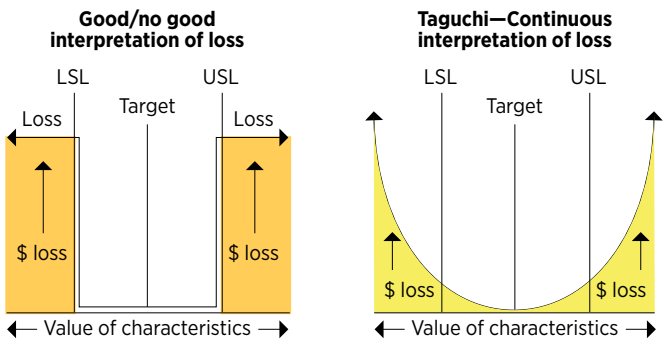
- **Common-cause variation** is present in every process because no process is perfect. It is inherent in every process.
- **Special-cause variation** is not present in every process and is caused by assignable events—that is, by certain things that have a significant impact on the process.

In a control chart, the control limits define where the common causes of variation are expected to lie. In other words, as long as the process is in statistical control, all the points will lie within the control limits defined by the interval of ±3s from the mean, without any nonrandom pattern. When you see a point outside of those control limits (or points showing a nonrandom pattern), that indicates some sort of assignable or special cause that must be studied and corrected.

A control chart not only allows you to see how the process centering and variation behave on a time-based scale, but it also allows you to see the result of some process improvements. Figure 2 shows an example of a control chart in which process improvements have been implemented. Note that because the control limits are calculated based on the process variation, when variation decreases, the control limits must be recalculated to reflect the new, lower variation.

FIGURE 1

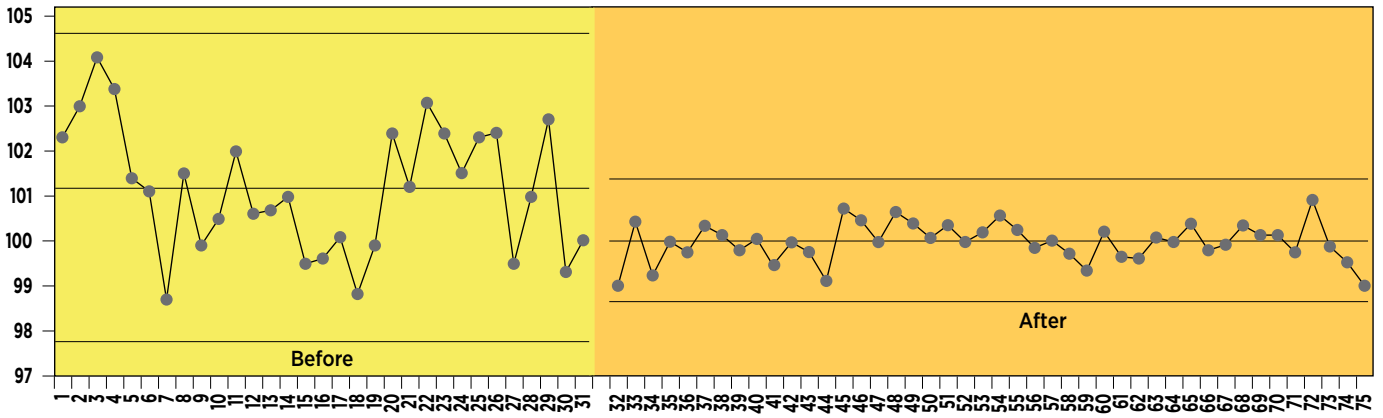
Concepts of process variation as compared to customer specifications



LSL *= lower specification limit*
USL *= upper specificaion limit*

FIGURE 2

Control chart—before and after improvements



Recommended approaches at various stages

Now that you know some of the advantages and disadvantages of sampling and SPC control charts, let's explore when it is convenient to use sampling and when it is convenient to use control charts to monitor the quality of the process. Let's divide the inspection location into three areas: incoming, in-process and final.

Incoming inspection: At this part of the process, the organization is receiving raw materials, packaging materials, purchased components and so on. It is important to measure the quality of the materials at this stage to avoid accepting defective product that will cause problems downstream.

But what is the best approach at this stage of the process? As noted earlier, acceptance sampling is an easy and cost-effective way to assess the quality of the incoming product. Acceptance sampling plans—such as the ANSI/ASQ Z1.4 (for attribute data) and ANSI/ASQ Z1.9 (for variable data)—are common approaches at this stage.

The main disadvantage of these acceptance sampling plans is that, depending on the acceptance quality limit (AQL) values selected, you could have a plan that will accept the entire lot even with one or more defective parts. But this is not a major constraint at this stage. Why?

Because the processes must have enough controls to detect all those defective parts that were not detected during the incoming inspection process and reject them during the subsequent process steps. These acceptance sampling plans are designed to provide a high probability of acceptance if the percentage defective is at or below the established AQL. In other words, these plans provide a safeguard to the supplier of the incoming material because you would be still accepting the lot even with a small number of defects.

In-process inspection: There are many approaches that organizations use to inspect product while the process is going on. For example, many organizations

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use acceptance sampling plans, such as the ANSI/ASQ Z1.4. Other organizations develop some sort of sampling and establish alert limits and action limits to determine the course of action after the sample is collected.

The main problem with these approaches is that the decision is still pass/fail (continue the process or stop the process and make some adjustments). Typically, the reaction is too late. Another disadvantage of this type of approach is that it does not have memory—that is, each day's decision is taken, but it is registered only on that day's documentation. In this case, because the data are not recorded in a time-based scale, there is no way to see any possible trend. A solution to this dilemma is to record the data and plot it in a control chart.

For example, an organization might be sampling parts at a specific station using the alert limit/action limit approach. At the end of the day, if nothing out of the action limit happens, the organization just archives the form containing the number of defects for that day. If there is an out-of-the-action-limit event, the organization adjusts the process, records the amount of defects and also archives the form. However, nothing else happens.

The recommendation to this organization is to plot the number of defects each day (or each shift, preferably) in a c-control chart, which is a control chart for number of defects. After enough data (at least a month) have been collected, the organization should calculate the control limits. From that point, it can use the control chart to evaluate the process and determine when an assignable cause has been identified.

The control chart is a monitoring tool that can feed other statistical tools to improve processes. If control charts show that shift-to-shift variation is too high, for example, other tools can be used to determine the source of such variability, such as the F-test, Levene test or design of experiments. After the improvements are implemented, control charts can be used to track the improvement, as shown in Figure 2 (p. 21).

Final inspection: If all previous inspections (incoming and in-process) are well-executed, there should not be too many defects left from the process after it's completed. Figure 3 shows how defects should be funneled throughout the different inspection points. Still, a final inspection is necessary as a warranty that no defective product is released to the customer.

A common approach used by organizations at this stage is to implement the same acceptance sampling plans they used at incoming inspection: ANSI/ASQ Z1.4 or ANSI/ASQ Z1.9. However, as mentioned earlier, there is a big disadvantage to using this kind of approach: accepting a lot with one or more defects.

To avoid this situation, many organizations start tweaking the inspection plans to obtain a plan with acceptance of zero defective product and rejection of one or more defective products. Most of the time, they achieve that plan by selecting a lower AQL. Not only is this an incorrect application of

FIGURE 3

Approaches to monitor the process

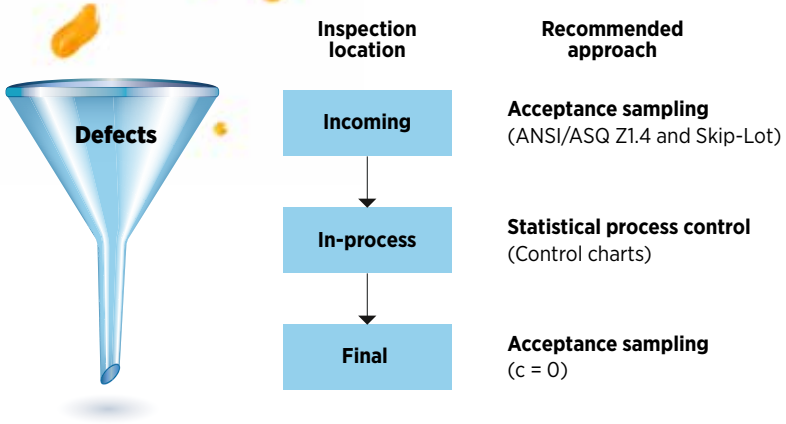

TABLE 1

Example of a sampling plan using ANSI/ASQ Z1.4 and c = 0

Lot size	12,000	12,000
Inspection level	II	N/A
AQL	0.65	0.65
Sample size	315	77
Accept (Ac)	5*	0
Reject (Re)	6*	1

** If an Ac = 0 and Re = 1 want to be obtained, an AQL of 0.040 would be required.*

the sampling plan, but the sampling sizes obtained by these plans also are unnecessarily high.

An alternative is to use the zero-acceptance (c = 0) sampling plan developed by Nicholas L. Squeglia. This plan is an adaptation of the acceptance sampling plans covered earlier (specifically, for the ANSI/ASQ Z1.4). In the zero-acceptance sampling plan, however, the probability of accepting a lot with a certain percentage of defective product or higher is very low. In this case, there is a safeguard to the customers that no defective product will be released.

This safeguard to the customer is not the only reason to use this type of plan at final inspection. Most of the time, the sample sizes calculated from the zero-acceptance sampling plans are much lower than those for the ANSI/ASQ Z1.4 and at the same AQL values. In other words, the sample sizes will be much lower, while keeping the same protection to the customer.

Table 1 shows an example of a sampling plan for a lot size of 12,000 parts and an AQL of 0.65. Using the ANSI/ASQ Z1.4, a total of 315 samples would have to be collected, whereas by using the c = 0 sampling plan, only 77 samples would have to be collected (a 76% reduction).

Not only is there a significant reduction in the sample size, but for the ANSI/ASQ Z1.4 plan, the lot could be accepted with five defective parts and rejected with six rejected parts. If zero defective parts is the only accepted level, the AQL must be reduced to 0.040. As noted earlier, reducing the AQL is not the right approach.

It is important to note another aspect of the c = 0 sampling plan: When one or more defective products are obtained using this plan, the lot is withheld. The phrase "withhold the lot" is significant because it does not necessarily mean rejection.

Under these plans, the inspector does not necessarily reject the lot if one or more defective products is found. The inspector only accepts the lot if zero defective product is found in the sample. Withholding the lot forces a review and disposition by engineering or management personnel to determine the extent and seriousness of the defective product.

Improving inspection activities

Sampling is an important consideration in most organizations, especially when the sampling is destructive in nature. Organizations spend huge amounts of resources (personnel and economic) during inspection activities. Often, even with many samples, defective product is released to the customer.

Sampling is an important consideration in most organizations, especially when the sampling is destructive in nature.

This is, in part, because the correct sampling approaches weren't implemented. By implementing the correct incoming, in-process and final inspection approaches, organizations can improve their inspection activities and provide a better product to their customers. QP

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