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Standard Practice for Rubber—Calculation of Producer's Process Performance Indexes[1]

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1. Scope

1.1 This practice provides a calculation procedure and a format for reporting the process performance of a manufacturing operation for a rubber or rubber product.

1.2 This practice is specifically designed to be used for technically significant properties of the final product.

2. Referenced Documents

2.1 *Quality Assurance for the Chemical and Process Industries*, American Society for Quality Control, Chemical and Process Industries Division, Chemical Interest Committee, 1987.[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *common cause variation*—that residual variation inherent in any process that (1) is operating in a state of statistical control, and (2) is operating at some recognized or ascertained level of technological competence.

3.1.2 *lower specification limit (LSL)*—the producer's minimum permissible value of any relevant measured product property.

3.1.3 *Pp′ producer's process performance index*— the ratio of the difference (USL − LSL) to the total process variation; the index does not consider where the process is centered. (See 7.4.)

3.1.4 *Ppk′ producer's process performance index*— the minimum of two ratios: (1) the ratio of the difference (USL − process mean) to one-half of the total process variation, or (2) the ratio of the difference (process mean − LSL) to one-half of the total process variation; the magnitude of the minimum index value, used with the Pp′ index, indicates how well the process mean is centered. (See 7.5.)

3.1.5 *special cause variation*—that variation attributable to certain specific or assignable sources that have been (or may be) discovered through an investigation of the process.

3.1.6 *target value*—the aiming point of the process; this is often (USL + LSL)/2.

3.1.7 *total process variation*—a range, along the measured property scale, defined as six times the standard deviation (determined under specified process conditions); the variation may contain either common or combined common and special cause sources.

3.1.8 *upper specification limit (USL)*—the producer's maximum permissible value of any relevant measured product property.

4. Summary of Practice

4.1 During the production of any product, certain physical or chemical properties, or both, are normally measured to control the properties of the final product. When enough data have been accumulated to form a sufficient database, it is possible to determine the centering (mean) and variation (range or standard deviation) of the process property distribution. These results may be informally compared to the desired target and specification limits to determine if the process is producing an acceptable product.

4.2 On a more formal basis, the two process performance parameters, the 'process mean' and the 'standard deviation,' are used to calculate two Producer's Process Performance Indexes designated as Pp′ and Ppk′. These indexes allow a standardized comparison of an actual process performance to the general specifications, the comparison of different processes for producing the same product, or comparison of the same process at different times.

5. Significance and Use

5.1 This practice is used to evaluate the conformance of a production process to specifications when (1) special causes of variation may be present and (2) the process may not be in a state of statistical control. This evaluation may also be used to compare different manufacturing operations for conformance to specifications.

6. Background and Precautions

6.1 A process is said to be in a state of statistical control when there are only common causes of variation present (no assignable causes). A state of statistical control is a requirement to perform a process capability calculation which can be used for prediction. A state of statistical control is not required to perform the process performance calculations covered by this practice.

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[1] This practice is under the jurisdiction of ASTM Committee D-11 on Rubber and is the direct responsibility of Subcommittee D11.16 on Application of Statistical Methods.

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[2] Available from American Society for Quality Control, 310 W. Wisconsin Ave., Milwaukee, WI 53203.

6.2 Although the defining calculation equations for the producer's process performance indexes (Pp′ and Ppk′) given in 7.4 and 7.5 bear a resemblance to the defining equations for the process capability indexes (Cp and Cpk), a legitimate calculation of Cp and Cpk can be made only when a process is in a state of statistical control. The symbols Pp′ and Ppk′ have been selected to represent the producer's process performance indexes to distinguish them from other capability and process performance indexes.

6.3 The Pp′ and Ppk′ indexes are historical in nature. They indicate whether or not the process variation could have met the specifications over the time period covered by the data. Since a state of statistical control is not required to do these calculations, the indexes can not be used to predict future performance.

6.4 For the best understanding of the information presented, associated control charts, histograms, performance, and capability indexes should be reviewed.

6.5 The formula for calculating the standard deviation (7.3) will be used for test results which have a normal (Gaussian) or non-normal distribution. Although possible presence of special cause variation could also cause the results to be non-normally distributed, the calculation of Pp′ and Ppk′ indexes from such non-normally distributed test results is useful for the purposes of this standard (5.1).

6.6 The selection of the time period covered by the data set is critical if the process is known, or suspected, to have time–dependent cycles or trends. The data should include a period long enough to encompass these cycles or trends. If the data period does not include these cycles or trends, the reported results will understate the true process variability.

6.6.1 The time period covered in the report should be established by mutual agreement between the producer and consumer subject to the precaution given in 6.6. Typically, this period would be for three months, but not less than 30 data points.

6.7 Individual test results as defined in the appropriate test method shall be used for these calculations. Sample averages tend to have a normal distribution even when they are taken from non-normal populations. The use of averages in the calculations will hide the true individual data distribution. The standard deviation of the individual values will be greater than the standard deviation of the sample averages. They are related by the square root of the number of values averaged:

$$S_i = S_A \sqrt{n} \tag{1}$$

where:
S_i = standard deviation of individual values
S_A = standard deviation of averaged values
n = number of individual values averaged.

6.8 For asymmetric two-sided specifications, each portion of the specification range from the target to the limit must be calculated separately as if it were for a one-sided specification.

6.9 For one-sided specifications, only the Ppk′ index is applicable; however, if there is no target value because the goal is to be as low as possible (for example, impurities) or as high as possible (for example, strength), interpretation of the Ppk′ index should not be used to permit intentional contamination or degradation of the product. See 2.1.

6.10 The Ppk′ index is inherently less than or equal to the Pp′ index. Maximum performance is achieved when the process is perfectly centered on the target and the Ppk′ is equal to the Pp′. A Pp′ or a Ppk′ index that steadily increases over time demonstrates an improvement in the control of, or elimination of, special causes of variation in the process.

6.11 A Pp′ or Ppk′ index of less than 1.0 indicates that the process did not meet the specifications during the period covered by the data. When these indexes are less than 1.0, the process or the specification limits, or both, need to be studied.

6.12 Nothing in the calculation of these indexes requires or indicates that the process is in a state of statistical control or is predictable. This practice is not meant to replace statistical process control (SPC) charts or any other statistical tool aimed at controlling or improving the process.

7. Calculation

7.1 Data used in the statistical calculation shall cover all products produced while operating to a single aiming point (or target) that went into a finished product area for shipment to a customer. Thus, transition product made while switching from one product or subproduct to another product or subproduct may be excluded. Any off-specification or out-of-control product made while producing to a common aiming point must be included.

7.2 The process mean, $\bar{x}$, is calculated as follows:

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{2}$$

where:
n = number of test results
x_i = individual test result

7.3 The calculation of the process standard deviation should be based on at least 30 test results (see 6.6). The sample standard deviation, s, is calculated as follows:

$$s = \sqrt{\left(\frac{1}{n-1}\right) \sum_{i=1}^{n} (x_i - \bar{x})^2} \tag{3}$$

where:
s = sample standard deviation
n = number of test results
x_i = individual test result
$\bar{x}$ = process mean

7.4 The total process variation is six times the process standard deviation; that is, 6s. The producer's process performance index, Pp′, is calculated as follows:

$$Pp' = \frac{USL - LSL}{6s} \tag{4}$$

where:
USL = producer's upper specification limit
LSL = producer's lower specification limit

7.5 The Ppk′ index, when used with the Pp′ index, reveals how well the production process was centered in the specification range. The minimum value of either (5) or (6) is used for two-sided specifications. With one-sided specifications, either (5) or (6) is used, as appropriate.

$$P\text{pk}' = (USL - \bar{x})/3\,s \quad (5)$$

or

$$\text{Ppk}' = (\bar{x} - LSL)/3s \quad (6)$$

where:

$\bar{x}$ = mean value of process property for the period as specified in 6.6.

7.6 If the process center is outside the specification limits, negative values of Ppk′ will result.

7.7 A histogram prepared from the individual results will increase understanding of the nature of the data distribution. increase understanding of the nature of the data distribution.

8. Report

8.1 The report shall include the following as a minimum:

8.1.1 A description of the product and the property being reported.

8.1.2 Time period of production chosen for analysis.

8.1.3 Pp′ (for two-sided specifications only) and Ppk′ indexes.

8.1.4 Producer's USL, LSL, and target value.

8.1.5 Mean, standard deviation and number of test results.

8.2 If a histogram was prepared, it may be included in the report.

9. Keywords

9.1 performance index; Pp′; Ppk′; producer's process performance