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Standard Practice for Machine/Process Capability Study Procedure[1]

This standard is issued under the fixed designation F1503; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers provision of a proper method for determining process capability for new or existing machine processes. It is recommended that available statistical software be used for the calculation of the descriptive statistics required for decision making when using this practice. Where software is not available, Section 8 and Tables 1 and 2 are provided for manual calculations.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1469 Guide for Conducting a Repeatability and Reproducibility Study on Test Equipment for Nondestructive Testing

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bilateral specifications*—specifications that have both upper and lower values.

3.1.2 C_p—an index that indicates the variability of the process with respect to tolerance.

3.1.3 C_pk—an index of process variability and centering. This is a widely-used index which considers the process mean, range, and its relation to the specification nominal.

3.1.4 *inspection plan*—a set of instructions defining product characteristics, specifications, frequency of inspection, acceptance criteria, and methods of inspection for product at a specified operation.

3.1.5 *process parameters*—combination of people, equipment, materials, methods, and environment that produce output.

3.1.6 *unilateral specifications*—specifications that have only upper or lower values.

3.1.7 σ—an estimate of the standard deviation of a process characteristic.

4. Summary of Practice

4.1 A machine/process capability (MPC) study is conducted to provide a level of confidence in the ability of a machine/process to meet engineering specification requirements. This is accomplished through statistical process control techniques as defined in this practice.

4.2 For new equipment purchases, the purchaser's manufacturing engineering department, or equivalent discipline, shall have primary responsibility for ensuring that the requirements of this practice are met. The purchaser's quality assurance department shall be available to assist on an as-requested basis.

4.3 New machines/processes will not be accepted for use in production with C_p values less than 1.67. If a manufacturing process must be conditionally accepted, a process improvement/product control plan shall be developed.

4.3.1 The machine/process control plan shall identify specific process improvement activities, which will be implemented to make the process more capable as well as an interim inspection plan to ensure that nonconforming product is not shipped to a customer.

4.4 *Product Specifications:*

4.4.1 Prior to any MPC study, the product specifications (nominal dimension and tolerances) must be identified, and an appropriate method of variables type inspection selected.

4.4.2 This practice is limited to bilateral specifications whose distributions can be expected to approximate a normal curve. This practice should not be applied to unilateral specifications (flatness, concentricity, minimum tensile, maximum hardness, etc.).

4.5 *Gage Capability Analysis:*

4.5.1 All gaging systems used to evaluate product involved in the study must have documentation for a gage repeatability and reproducibility study in accordance with Guide F1469 before the machine/capability study is conducted.

4.5.1.1 Gaging systems which consume ≤10 % of the applicable product tolerance are considered acceptable.

4.5.1.2 Gaging systems which consume over 10 to 30 % of the applicable product tolerance are generally considered to be unacceptable. However, users of this guide may authorize their

[1] This practice is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.93 on Quality Assurance Provisions for Fasteners.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Machine/Process Average and Range

Calculate the average Range ($\bar{R}$) and the Process Average $\bar{X}$ For the study period, calculate:

$$\bar{R} = \frac{R_1 + R_2 + \ldots + R_k}{k}$$

$$\bar{X} = \frac{\bar{X}_1 + \bar{X}_2 + \ldots + \bar{X}_k}{k}$$

where:

k = the number of subgroups,
R_1 = the range and average of the first subgroup,
$\bar{X}_1$ = the range and average of the first subgroup,
R_2 = from the second subgroup, and
$\bar{X}_2$ = from the second subgroup, etc.

use depending on factors such as the criticality of the specification in question, the cost of alternative gaging systems, and so forth.

4.5.1.3 Gaging systems which consume more than 30 % of the product tolerance are unacceptable and must not be used.

4.5.2 All gaging systems must be certified as accurate using standards traceable to NIST, other recognized standards organizations, or the equivalent manufacturer's standard.

4.6 *Process Parameter Selection :*

4.6.1 For studies conducted at the equipment vendor's facility, all machine/process parameters (for example, infeed rates, coolant, dies, pressures, fixtures, etc.) must be established and documented prior to the MPC study so the requirements of 9.5 can be met.

4.6.1.1 Machine/process parameters may not be changed once an MPC study has begun.

4.6.1.2 All machine/process adjustments made during the MPC study must be documented and included with information required in Section 10.1 of this practice.

NOTE 1—Machine/process adjustments are defined as those adjustments made due to internal machine/process gaging (or other sources of feedback control), or by the operator as part of the normal operation of the machine/process.

4.6.2 The selection of machine/process parameters is the responsibility of the purchaser's manufacturing engineering or equivalent discipline, or, in some cases, the machine supplier depending on preestablished contractual agreements.

4.6.2.1 The machine/process parameters selected must be consistent with those intended to be used in production.

4.6.3 Machine/process parameters may be systematically varied after a study is completed and additional MPC studies performed for optimization purposes.

5. Significance and Use

5.1 This practice is designed to evaluate a machine or process isolated from its normal operating environment. In its normal operating environment, there would be many sources of variation that may not exist at a machine/process builder's facility; or put another way, this study is usually conducted under ideal conditions. Therefore, it should be recognized that the results of this practice are usually a "best case" analysis, and allowances need to be made for sources of variations that may exist at the purchaser's facility.

6. Material Selection

6.1 Material (for example, steel slugs, bar, wire, prefinished parts, etc.) used for MPC studies shall be selected at random. The variability of material used for MPC studies should be consistent with the variability of material the machine is likely to see in production. However, all selected samples shall conform to their applicable product engineering standards.

6.2 Presorting of material is not permissible for machine/process qualification purposes.

6.3 In some cases, machine/process capability results may be influenced by the specific product specifications selected for the study. The specific product selected for qualifying a new machine/process should be based on that which will yield the most conservative results. If the relationship between specific product specifications and machine/process capability is unknown, two or more distinct studies should be performed with different products to qualify and accept the new machine/process.

7. Procedure-Machine/Process Capability Study

7.1 Operate the machine/process for a sufficient period of time to ensure that the machine/process is stable and all initial setup adjustments are complete.

7.2 Control charting techniques should be utilized to determine the stability and capability of the machine/process.

7.2.1 When possible, a standard $\bar{X}$, R chart should be used with subgroup size n equals 2 through 5.

7.2.1.1 Sampling frequencies shall be established to ensure that all likely sources of variability occur.

7.2.1.2 A minimum of 25 subgroups are required to establish control.

7.2.2 When the quantity of sample measurements cannot be practically obtained, it is permissible to utilize a chart for individuals and moving ranges.

7.2.2.1 A minimum of 25 subgroups are required to establish control.

7.2.3 After the study is complete, calculate and plot the control limits, $\bar{X}$ and $\bar{R}$ (or $\bar{MR}$), for each specification identified in 4.4.1 (see Table 1). If during the study the machine/process was out of control, the MPC study is not valid. The root cause(s) of the out-of-control condition(s) must be identified and eliminated and the study repeated.

7.2.3.1 If the out-of-control condition is associated with no more than two subgroups on the range chart, one point on the $\bar{X}$ or individuals chart and the root cause of the out-of-control condition is identified and corrected, new control limits may be calculated by excluding the out-of-control points. A second study is not required.

7.2.3.2 In some instances, control chart analysis may reveal out-of-control conditions that are inherent to the machine/process. Trends due to tool wear or grinding wheel wear are typical examples. If the cause of the out-of-control condition is known, the out-of-control condition is both repeatable and predictable, and the condition cannot be eliminated, the MPC