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Statistical methods in process management — Capability and performance —

Part 3: Machine performance studies for measured data on discrete parts

Méthodes statistiques dans la gestion de processus — Aptitude et performance —

Partie 3: Études de performance de machines pour des données mesurées sur des parties discrètes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22514-3 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 4, *Applications of statistical methods in process management*.

ISO 22514 consists of the following parts, under the general title *Statistical methods in process management — Capability and performance*:

— *Part 1: General principles and concepts*

— *Part 3: Machine performance studies for measured data on discrete parts*

— *Part 4: Process capability estimates and performance measures* [Technical Report]

In the future, it is planned to revise ISO 21747:2006 (*Statistical methods — Process performance and capability statistics for measured quality characteristics*) as Part 2.

NOTE ISO 22514-3 was initially prepared as ISO/DIS 13700. It was renumbered before publication to include it in the ISO 22514 series.

Introduction

This part of ISO 22514 has been prepared to provide guidance in circumstances where a study is necessary to determine if the output from a machine, for example, is acceptable according to some criteria. Such circumstances are common in engineering when the purpose for the study is part of an acceptance trial. These studies may also be used when diagnosis is required concerning a machine's current level of performance or as part of a problem solving effort. The method is very versatile and has been applied to many situations.

Machine performance studies of this type provide information about the behaviour of a machine under very restricted conditions such as limiting, as far as possible, external sources of variation that are commonplace within a process, e.g. multi-factor and multi-level situations. The data gathered in a study might come from items made consecutively, although this may be altered according to the study requirements. The data are assumed to have been, generally, gathered manually.

The study procedure and reporting will be of interest to engineers, supervisors and management wishing to establish whether a machine should be purchased or put in for maintenance, to assist in problem solving or to understand the level of variation due to the machine itself.

Statistical methods in process management — Capability and performance —

Part 3: Machine performance studies for measured data on discrete parts

1 Scope

This part of ISO 22514 prescribes the steps to be taken in conducting short-term performance studies that are typically performed on machines where parts produced consecutively under repeatability conditions are considered. The number of observations to be analysed will vary according to the patterns the data produce, or if the runs (the rate at which items are produced) on the machine are low in quantity. The methods are not recommended where the sample size produced is less than 30 observations. Methods to be used for handling the data and carrying out the calculations are described. In addition, machine performance indices and the actions required at the conclusion of a machine performance study are described.

The document is not applicable when tool wear patterns are expected to be present during the duration of the study, nor if autocorrelation between observations is present. The situation where a machine has captured the data, sometimes thousands of data points collected in a minute, is not considered suitable for the application of this part of ISO 22514.

2 Symbols and abbreviations

P_{m} machine performance index

P_{mk} minimum machine performance index

$P_{\text{mk}L}$ lower machine performance index

$P_{\text{mk}U}$ upper machine performance index

f frequency

Σf cumulative frequency

i subscript used to identify values of a variable

L lower specification limit

N total sample size

$X_{\alpha\%}$ $\alpha\%$ distribution fractile

X_i ith value in a sample

σ standard deviation, population

S standard deviation, sample statistic, $S = \sqrt{\dfrac{\sum_{i=1}^{N}\left(X_i - \bar{X}\right)^2}{N-1}}$

U upper specification limit

z_α fractile of the standardized normal distribution from $-\infty$ to α

μ population mean value in relation to the machine location

$\bar{X}$ arithmetic mean value, sample, $\bar{X} = \dfrac{\sum_{i=1}^{N} X_i}{N}$

GRR gauge repeatability and reproducibility

χ_α^2 fractile of the Chi-square distribution

3 Pre-conditions for application

3.1 General

The pre-conditions given below are the minimum and may be exceeded when needed. In this type of study, it is important to maintain constant all factors, other than the machine, which will influence the results, if the study is to properly represent the machine itself, e.g. the same operator, same batch of material, etc.

3.2 Number of parts to be used in the study

The number specified will usually be 100. However, if the pattern of variation is expected to form a non-normal distribution, the number of parts should be at least 100. The methods given within this part of ISO 22514 may also be used when conducting audits of a process, in which case the number of measurements taken might be less than the above number, e.g. 50.

NOTE 1 This is to ensure that a reasonably narrow confidence interval can be calculated for the machine performance indices when a normal distribution has been used. The interval will be approximately ± 12 % of the estimated index with a confidence of 90 % for samples of 100.

Some machines have very slow cycle times and a "run" cannot produce 100 parts. In such circumstances, it will be necessary to proceed with available data. The minimum number that this part of ISO 22514 recommends with the methods described herein is 30.

NOTE 2 Special techniques beyond the scope of this part of ISO 22514 exist for circumstances when there are fewer samples.

By contrast, a machine that produces parts at a very high rate, e.g. a rivet-making machine, the sampling strategy may require alteration since 100 parts will be produced in a few seconds. In circumstances such as these, several studies may be required each allowing a different sampling approach to examine the machine's behaviour.

3.3 Materials to be used

Ensure all input materials to be used in the study have been checked, conform to specifications and belong to the same batches. It is not advised that a study be conducted with materials that are outside specification since this could lead to unrepresentative results.

Care should be exercised not to introduce any other sources of variation other than those to be studied. A typical example is where a machine run has to change to another batch of a particular material within a single process batch, and batch material variation is not included in the study. In this instance, only data taken while the first batch of that particular material was in use should be used in the analysis.

3.4 Measurement system

Ensure the measurement system to be used during the study has adequate properties, is calibrated and the measurement system variation has been quantified and minimized. Special studies on the measurement system should be undertaken to establish the amount of variation present due to measuring. The measurement system should ideally have a combined gauge repeatability and reproducibility (GRR) of less than 10 % of the process spread of the characteristic that the machine study is to investigate as determined through a properly conducted measurement system analysis. This analysis should address issues of bias, stability, linearity and discrimination, as well as GRR.

It may be appropriate to express the GRR as a percentage of a given specification tolerance. If the measurement system has between 10 % and 30 % GRR, it may still be regarded as acceptable dependant upon application. If it exceeds 30 %, the measurement system should be regarded as inappropriate. In addition, the measurement system should have a measurement uncertainty appreciably less than the tolerance or of the expected total variation of the characteristic, if known, as indicated above. Should a study be performed using a measurement system with a performance worse than these requirements, some erroneous conclusions to the study might be reached.

3.5 Running the study

Ensure an uninterrupted run takes place, under normal operating conditions. This will include any warm-up time for the machine necessary to bring it up to its usual operating condition and with the machine set at nominal for the characteristic to be studied. If the machine is stopped during the study for whatever reason, either re-run the study again or analyse the data collected, as long as sufficient data has been collected and as long as the repeatability conditions have not been violated. Under no circumstance should less than 30 results be used.

3.6 Special circumstances

In a multiple fixture set-up, multiple-cavity or multi-stream situation, each station, fixture, cavity or stream should be treated as a separate machine for machine performance purposes since those streams may violate the repeatability conditions.

In the case of a multiple-cavity tool, some extra studies may be performed to examine the between-cavity and within-cavity variation. Consecutive observations from all cavities may be used in the study so as to examine the total machine performance. Other statistical techniques may be employed, e.g. analysis of variance (ANOVA), to assist with the analysis of such circumstances.

4 Data collection

4.1 Traceability of data

It is important for all data to be traceable so that unexpected values can be investigated. The collection sequence should be preserved so that a time series can be plotted of the data that might indicate unexpected variations. Such occurrences should be explained and a decision taken about the admissibility of such data. A “log-book” would be suitable for recording all machine settings including any prior work on the machine, e.g. maintenance, and for recording all events during the study, such as adjustments.

4.2 Retention of specimens

Unless the tests performed are destructive in their nature, all specimens should be retained so that all necessary examinations can be made. They should only be disposed of once the study is complete and all conclusions determined.

4.3 Data recording

Data should be clearly recorded either electronically or on the appropriate analysis sheet in numerical form to the appropriate number of significant digits. This should be determined prior to the measuring process and will be dependent on the resolution of the measuring instrument.

5 Analysis

5.1 General

The analysis of the data generated in the study may be done manually, an example of which is given within this clause, or by means of computer programs an example of which is in given in Annex B.

5.2 Run chart

5.2.1 Purpose

When conducting a machine study, it is important to understand whether the data collected form a single and stable pattern or not. There will be occasions when the conditions within the machine under study will lead to a drift in its settings that will influence the pattern of data produced. There might be occasions when an unauthorized adjustment has been made to the machine or data have been mixed in some way. Such an event should stop the study and a new study should be begun. A run chart will be helpful to identify such circumstances. The pattern on the run chart in Figure 1 might have been caused by such an adjustment or something might have gone wrong with the machine itself or it is being used wrongly.

If a change such as that indicated in Figure 1 occurs, it will be necessary to take special measures according to the circumstances. These might range between repeating the whole study to analysing the data in its separate parts or eliminating certain results.

A manual graphical approach or a suitable software tool may be used to construct the run chart.

ISO 7873 contains guidance about the application of control charts and their associated statistical tests that should be applied to plots such as that shown in Figure 1 to assist with the interpretation of the plots.

5.2.2 Review the plot

Inspect the plot for evidence of instability. This may be apparent as in Figure 1 where there has been a step change in the data. Other patterns might appear such as a drift. It is possible to use control limits and control chart rules to assess, easily, for any other assignable causes in the data. The data might be put into an individuals and moving range chart to check for potential outliers in the data. (See ISO 8258 for further information about such limits and rules.)

There exist a number of software products that can replace the above manual methods. These have become popular because they produce the graphs mentioned above quickly and easily.

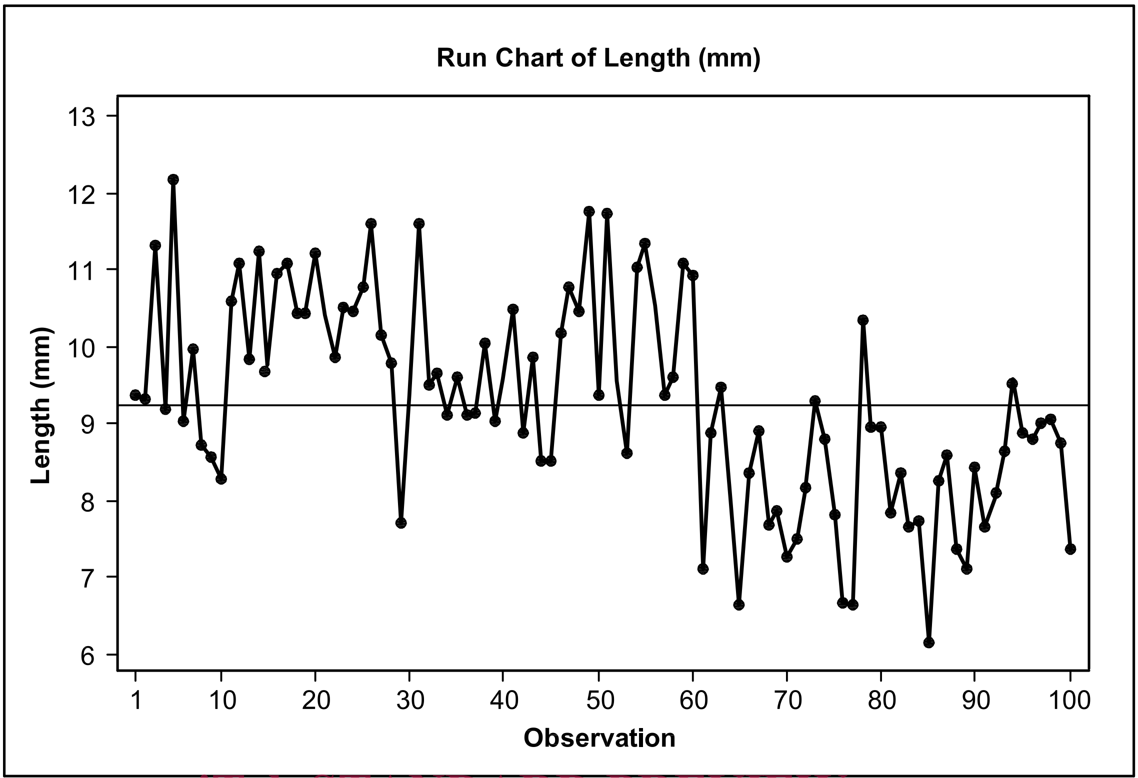

Figure 1 — Example of a run chart [1)]

5.3 Analyze the pattern of the data

5.3.1 Manual approach

A simple manner to begin analyzing the pattern the data form is to construct a tally chart.

The data are arranged into “classes”. The convention of counting the data into groups of five is often used and an example of this can be seen in Figure 2. In this example, the data have been recorded to the nearest 5 mm that is appropriate for the process from which the data are coming from.

1) This run chart was generated using a software programme called MINITAB™. MINITAB™ is the trade name of a product supplied by Minitab Inc. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

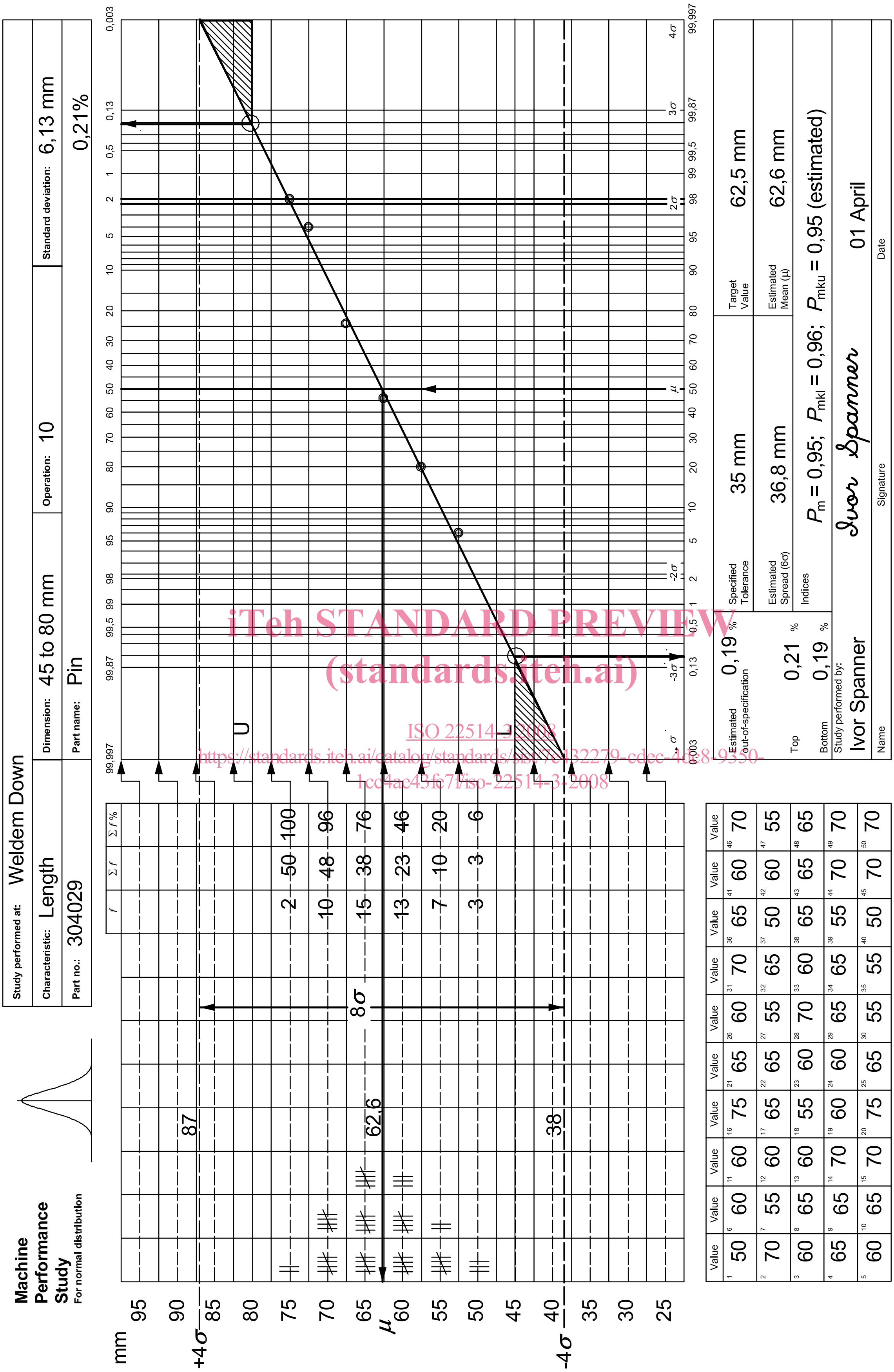

Figure 2 — Example of a worksheet for normally distributed data