Which Information Do Capability Indices Provide?

Dipl.Ing. Stephan Conrad, TEQ® Training & Consulting GmbH

Principle of Maximum Information

While developing the ISO 22514 series of standards, it is about time to think about the meaning and purpose of a capability index once again.

You often face capability indices for the first time when evaluating the number of defective parts. You can find countless tables in technical literature specifying fractions nonconforming expected for each specific capability index. This mainly superseded calculation method based on fractions nonconforming is still contained in ISO/TR 22514-4; however, only with reasonable restrictions. Almost 15 years ago, this method was even a standard in some parts of the automotive industry.

But why using quite an abstract capability index instead of "ppm", many people asked themselves soon though. In case of capability indices exceeding 1,67 considerably, estimating fractions nonconforming is rather comparable to gazing into a crystal ball. The benefit was highly doubtful indeed. This capability index only provides information about the process output but does not indicate anything about the properties of the process or the process behavior. Moreover, completely different process qualities and process structures might lead to absolutely identical results (see figure 1). Consequently, even this capability index did not help to discover the factors to be optimized in order to reach full potential.

Example

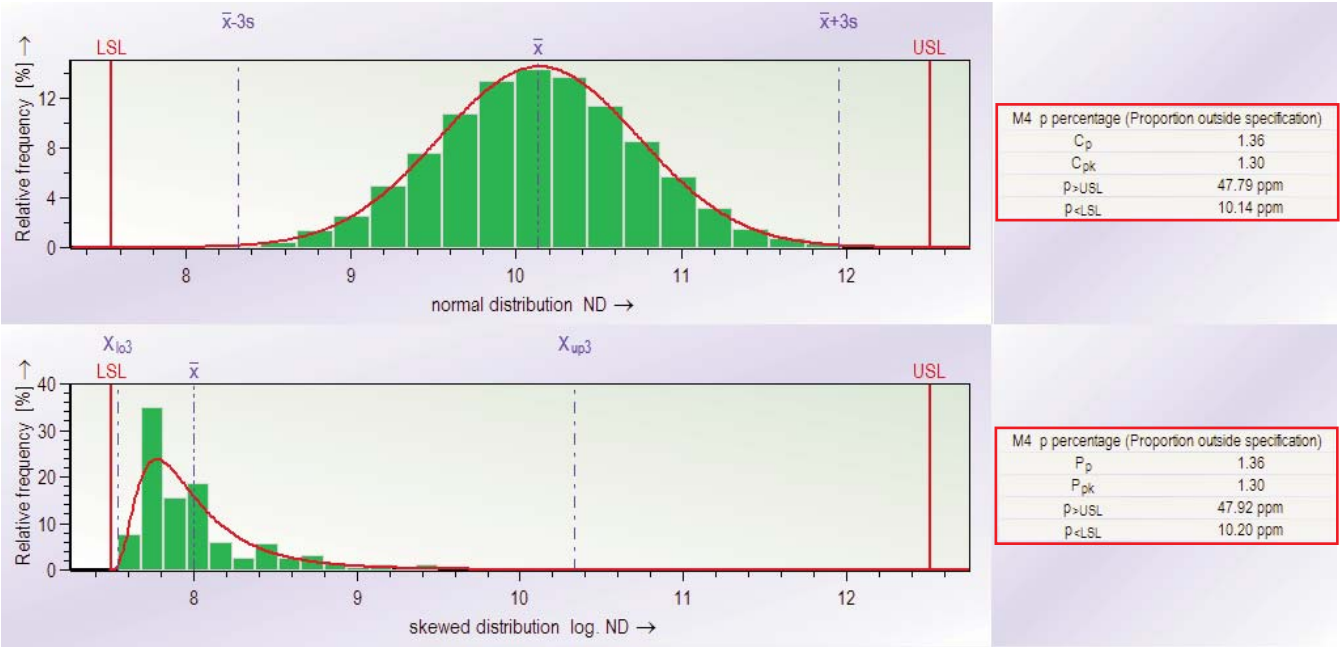

Figure 1: The C_{pk} of both processes amounts to 1,30 and was calculated from the fractions nonconforming. This capability index is thus not able to describe the differences between processes.

Other calculation methods calculate the capability index from distribution parameters and provide considerably more information.

All the methods ISO 21747 already summarized as "general geometric method" in 2006/2007 offer clear information about the process variation and process location relative to the specified characteristics tolerance. The gathered information is based on C_p and C_{pk}. Today, ISO 22514-2 is mainly about these methods including the classical "6•σ" method and the percentile or quantile method. Provided that the determined distribution model is correct, you may also derive any potential for improvement from these capability indices immediately. In case of two-sided characteristics, C_p describes the variation behavior and indicates the maximum capability for an optimal location whereas C_{pk} describes the quality that was actually achieved for the current process location. In case C_p is insufficient, you have to aim at optimizing the process. If C_p is sufficient but C_{pk} is not, you need nothing but a correction of location in most cases. The amount of information gathered by using this calculation method is considerably higher than the amount of information obtained with the method of excess fractions (see figure 2).

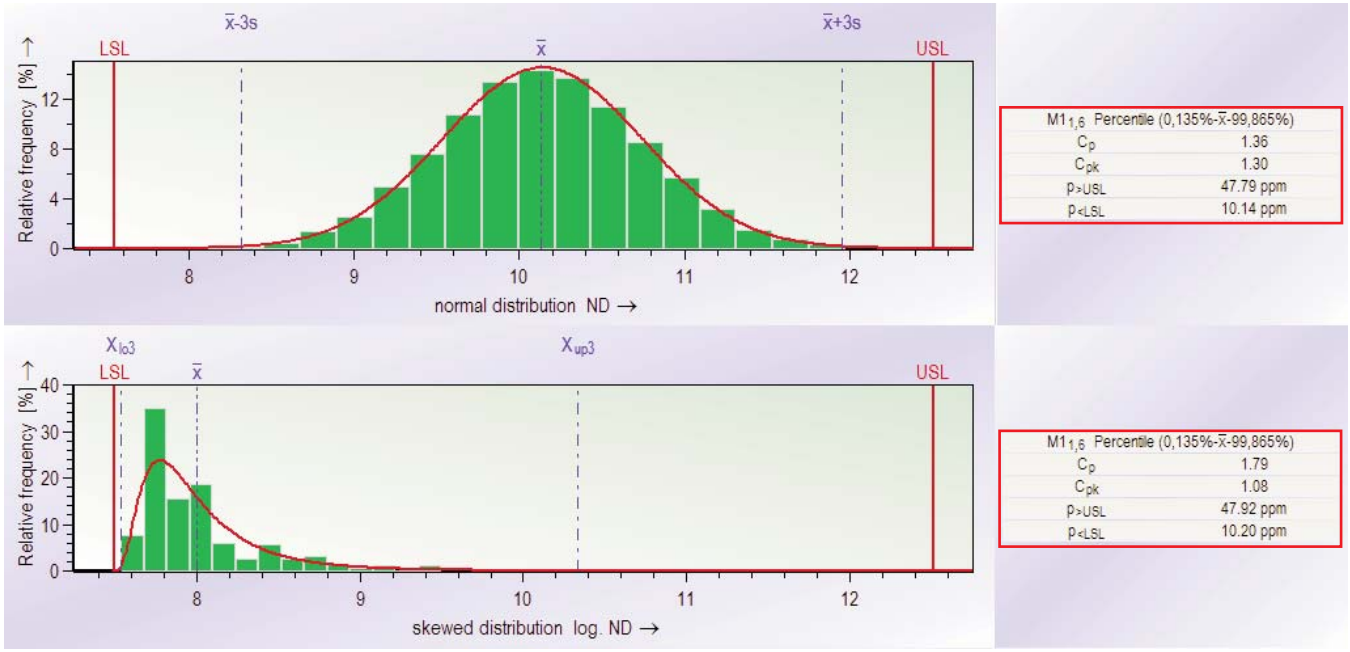

Figure 2: The capability indices calculated according to the percentile method better describe the real process behavior and provide additional information about possible process optimization.

However, there are phenomena that even the "general geometric method" is not able to describe sufficiently. We need new technology in order to record the higher amount of information, e.g. for hole patterns or balancing machines. The evaluation of a position according to DIN only considers the radius or the circle diameter the center of the borehole lies on. You may easily calculate capability indices in this situation by using the "general geometric method", however, there is a catch. The following two hole patterns have the same calculated capability indices C_p/C_{pk} even though they demonstrate totally different qualities (see figure 3).

Example

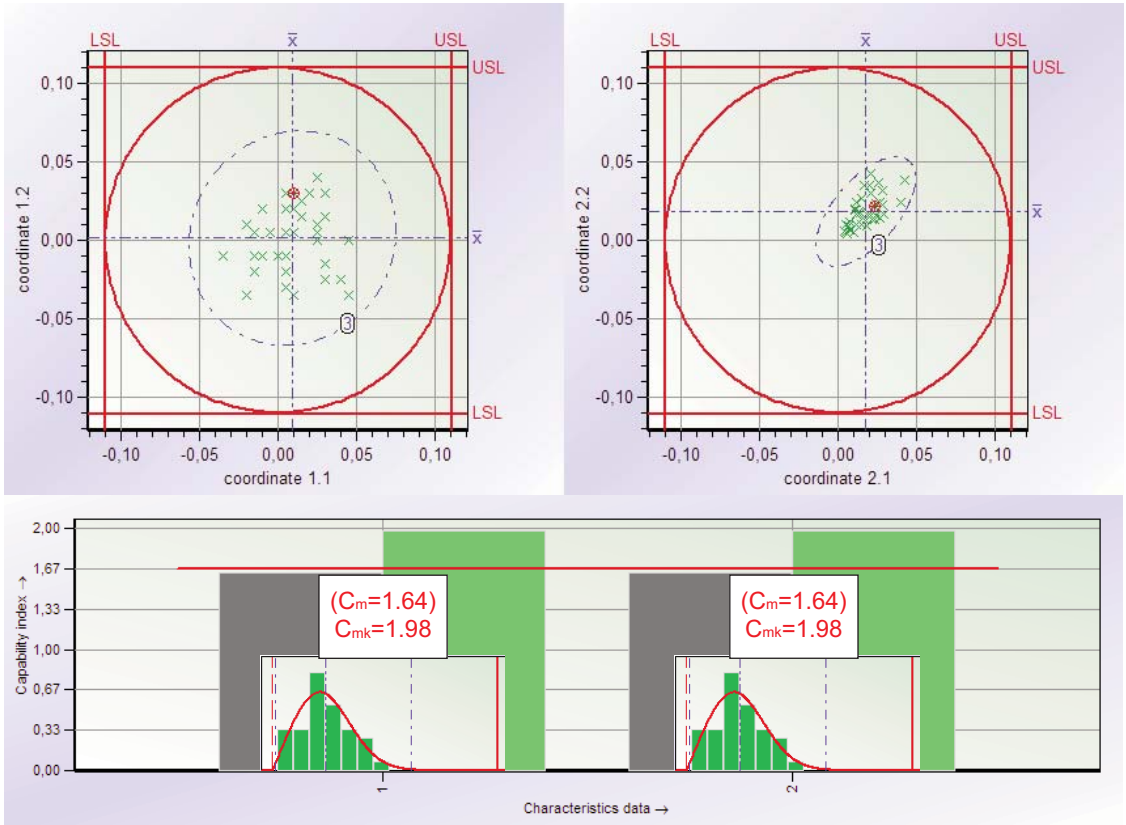

Figure 3: Both hole patterns have the same (one-dimensional) capability indices C_p/C_{pk} since the deviation from the radius is the same

Example

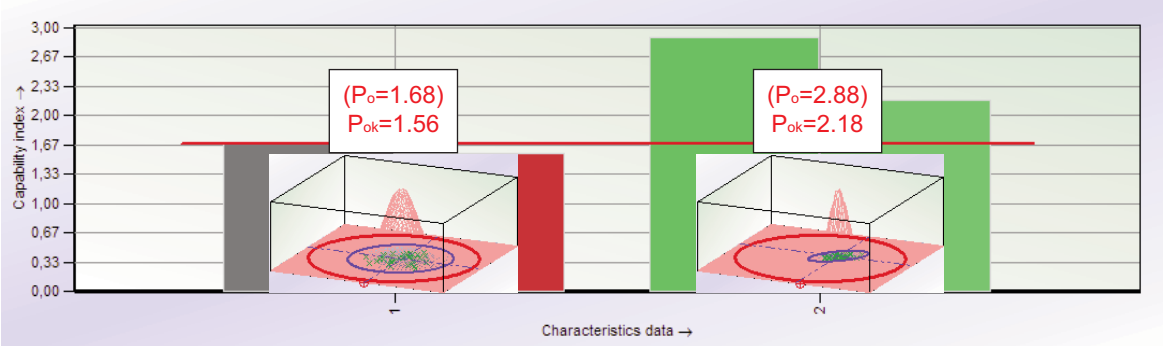

Figure 4: The two-dimensional capability indices Po/Pok are able to describe the different process qualities

In the first case the average is quite in the center but the variation is too high. The second case shows a process that is not in the center but includes considerably less variation. Since we only observe radiuses without any specified angles, we are not able to use these additional pieces of information.

ISO 22514-6 offers the solution to the problem. Based on the two-dimensional normal distribution you calculate the capability indices P_o/P_{ok} since they can describe different qualities analogously to C_p/C_{pk} (see figure 4). Of course, you may estimate fractions nonconforming and calculate capability indices even based on these hole patterns and the two-dimensional normal distribution – but you will lose all the gathered information about location and variation.

Which conclusions can you draw now? You should always calculate capability indices in a way that you gather the most possible amount of information, i.e.:

- only estimate capability indices from fractions nonconforming if there is nothing but information on the proportions of defects available. Consequently, you only use the calculation method based on fractions

nonconforming in the evaluation of discrete characteristics. You should do without these methods as soon as measured values are available to you.

- calculate capability indices based on the "general geometric method" in case of any one-dimensional characteristics. One-dimensional characteristics are characteristics that only need a single measured value in order to be displayed comprehensively, e.g. length, weight, hardness, etc.
- always calculate two-dimensional capability indices in case there are two pieces of information required in order to describe the characteristic comprehensively, e.g. x/y-coordinate, radius and angle, mass moment and angle (imbalance).

And now the whole issue gets even more complicated. Two-dimensional and multidimensional characteristics are also characteristics that are linked e.g. by the maximum material principle. There are also various measures of shape and measures of location describing spatial phenomena (e.g. cylindrical shape). In case there is an interaction between more than two characteristics - e.g. in welding or injection molding where you try to assure the product quality by controlling the process characteristics – you may even calculate multidimensional (multivariate or multicriterial) capabilities. These capabilities exceed our three dimensions of space; thus they are beyond our spatial sense. The mathematics behind it now becomes quite complex. Fortunately, ISO 22514-6 provides a solution based on "assessment functions". However, select them with caution in order not to reduce a multidimensional problem to a simple calculation method based on fractions nonconforming due to an oversimplified assessment function.

Even in the simple daily application you may reflect about the principle of "maximum information". In case of discretized characteristics, measured values are "simplified" and reduced to error proportions. Some information about these characteristics gets lost. This fact also applies to automated test systems actually measuring parts but only counting defective parts. Another example is a one-sided limit having a second "natural" boundary. In most of these cases, only the capability index C_{pk} is calculated even though C_p could also be calculated and would offer some more information. PIQ 2/2012 [5] described this issue in detail. However, many companies do not calculate this capability index for very pragmatic reasons – and thus they do without the additional knowledge of their processes.

The target of the new ISO 22514 series of standards is the acquisition of information. It is about reaching an understanding of processes, identifying optimization potentials and gaining confidence in your own processes and the processes of suppliers. In the end it is a question of gathering and maximizing information. In order to succeed in doing so, always select the optimal calculation methods depending on the respective situation.

Literature

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Einseitige und natürliche Toleranzen in der Prozessfähigkeit

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