Notes on the 4th Edition of the MSA Manual

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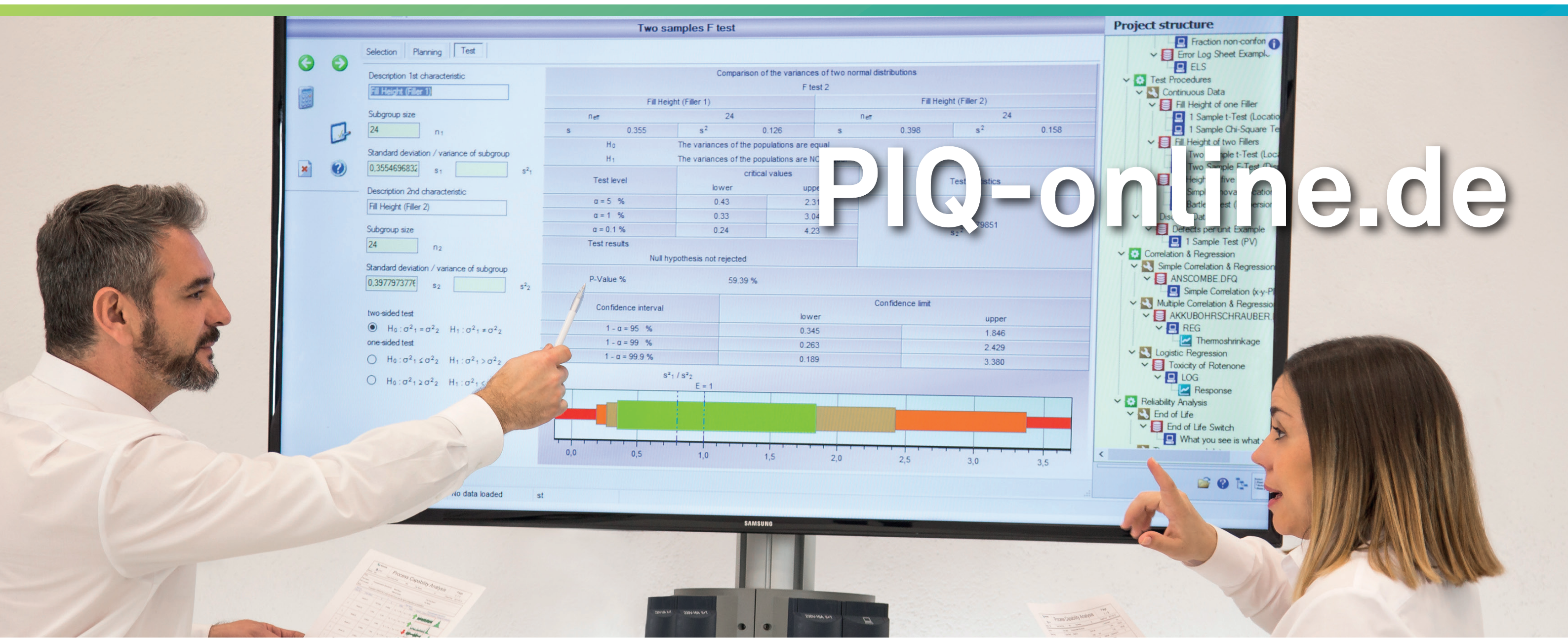

By comparing version 4 of the MSA manual [4] to the previous version [3] you will find more than 60 changes. Q-DAS provides you with a full list of all changes at http://www.q-das.de/en/competence-centerstatistics/norms-and-guidelines/. This article, however, tries to answer the following question: What is in it for us?

On the one hand, the updates are helpful textual changes and, on the other hand, some modifications in the evaluation methods. These modifications will force companies into adjusting their MSA studies to the 4th edition; otherwise they will not pass future audits. The answer to the question “What is in it for me” can be answered by a simple “NOTHING”. Capability analysis evaluating measurement systems do not only assess the current status but mainly help to improve the measurement process and keep it in statistical control under real operating conditions.

However, the 4th edition does not provide any information about improvements. In the author’s opinion, MSA 4 will not improve any measurement process. It will just cause considerable effort since companies will have to adapt their approach to the new version.

solara.MP solves the problem

Being a businessman and manager of the Q-DAS group, I would not be honest if I said that I was not glad about such changes. Users, especially our customers, will not be able to avoid the implementation of MSA 4 requirements in their company. The result is that they have to update the applied software. Now, I have some good news for our users: solara.MP (since version 10) includes an evaluation strategy based on MSA 4! Q-DAS customers using this version are well-prepared for the next audit since they can even transfer data from previous studies.

Meeting with MSA work group

Still I would like to make some critical comments about the new MSA version and discuss them. It was about 1 year before the release of the 3rd edition and thus about 10 years ago when I had the opportunity to attend a meeting of the AIAG's MSA work group in the US. At that time, Q-DAS and several big companies of the automotive and supplying industry had just completed the "Measurement System Capability Reference Manual" [9]. I had the privilege of presenting this manual to the committee and I particularly focused on the meaning of type-1 study (Cg and Cgk studies), since this study was also entrenched in the American automotive industry, e.g. in the "EMS" specification document by GM [7]. Another major point for discussion was the reference value. My recommendation was clear: Use the tolerance as a reference value (the more so as many company guidelines had already applied it as such). We had an extensive and honest discussion about these aspects and the members of the work group showed some understanding. However, as we all know now, these issues were not considered at all in the 3rd edition and not even in the 4th edition.

It is worth mentioning, however, that the comments on capability analyses provided in the 3rd edition are a quantum leap compared to the information given in the 2nd edition. I really perceived this change in a positive way. Especially the details about measurement uncertainty are very exhaustive and helpful, even though they include many passages requiring a lot of mathematical background knowledge in order to be able to understand the approach. This fact particularly applies to the section about attribute measurement processes.

Terminology

VIM (International Vocabulary of Metrology) [5] defines the term "measuring system". However, this definition does not comply with the one given in the MSA manual. Even though the manual also analyses the measurement system component, but the well-known %GRR value is based on influence components that are not part of the measurement system according to VIM. These components are mainly repeatability (variation of a measurement system while measuring a part under real operating conditions) and reproducibility. It thus makes sense to speak of a measurement process instead of a measurement system. However, this approach lacks some typical influence quantities such as uncertainty from repeatability on standards, uncertainty on test parts or uncertainty from temperature; the MSA manual hardly considers these influences at all.

Separate measurement system analysis

There are several reasons why considering only the components affecting the measurement system according to VIM is helpful. These components are, above all, the applied working standard, resolution, equipment variation of the measurement system, bias based on repeated measurements on a standard and, if available, linearity. On the one hand, this is an advantage for manufacturers of measuring instruments since all of them have to meet the same comparable acceptance requirements. And on the other hand, companies can easily assess the possible applications of a measurement system in practice due to the result of the analysis. Clustering forecasts whether the measurement system is qualified and suitable for certain measurement processes.

Resolution of the measurement system

The most important requirement in most company guidelines about measurement process capability analysis is that the resolution of the measurement system has to be less than 5% of the reference value. In case the resolution is insufficient, the measurement system classifies values and is thus not applicable. The MSA manual deals with this topic by using data categories introducing the ndc (number of distinct categories). Even though this statistic is actually suitable for this kind of evaluation, it is difficult to calculate, hard to understand and, by the way, the MSA manual only applies it in GRR studies.

Bias and linearity

In order to assess bias, you take repeated measurements on a reference standard based on a given actual value. This method is similar to the well-established type-1 study. Based on the measured values, you conduct a t-test and decide whether the calculated bias is acceptable. This evaluation lacks practical relevance since it requires experience in using the t-test and is rather inappropriate for practitioners. Moreover, the test is highly sensitive. In the author's opinion, practitioners will better comprehend type-1 study based on C_g and C_{gk} than the t-test. Additionally, type-1 study clearly distinguishes between equipment variation (C_g) and bias (C_{gk}). The 4th edition of the MSA manual demands a sufficiently small equipment variation EV (or variation of measured values); otherwise, the t-test leads to erroneous results. However, there is no specified limit indicating what "sufficiently small" means. Since the topic of data categories, i.e. sufficient resolution, is discussed later in the MSA, you might assume that this type of analysis does not consider resolution at first. As a result, the measurement system could classify the values and the equipment variation would be very small or amount to zero. This is the reason why you always have to evaluate the resolution before you perform such a test.

%GRR is the measure of things

All four editions of MSA [1, 2, 3 and 4] include the same case study to calculate %GRR. The applied data set is the same in all four editions. AIAG did not change the data in any of these editions. However, they did change the calculation formula for EV (equipment variation), AV (appraiser variation), ARM (average range method) and the method of ANOVA several times. The average range method applies K1, K2 and K3 factors based on the d_2-table given in the MSA manual. The 1st and 2nd edition considered a statistical uncertainty of 99% (referring to a k-factor of 5.15) in the calculation of K-factors whereas this uncertainty no longer applies to the 3rd edition. This fact, of course, changed the calculated results for EV, AV and GR&R. However, when you calculate these factors based on the method of ANOVA as given in the 3rd edition, the manual considers the statistical uncertainty of 99% as mentioned above; i.e. EV and AV include a factor of 5.15 (P = 99 %). Hence, the result of the average range method cannot be compared to the result of the method of ANOVA. The 4th edition even raised this factor from 5.15 to 6 (referring to 99.73 %).

In the author's opinion, this approach is very inconsistent. When you apply the same terms (EV and AV) to the average range method and the method of ANOVA, the results shall remain largely comparable independent of the calculation method you use. MSA 3 thus constitutes a serious breach, the more so as there is no obvious reason why you cannot leave out this factor in the method of ANOVA, too. For the sake of completeness, it is important to mention that the analysis of variance includes a variance component. This component is similar to EV/AV of the average range method. However, such specifications are rather confusing to most practitioners than helpful.

The 4th edition emphasizes that the evaluation method based on ANOVA is preferable. The author welcomes this approach. The reason for this recommendation is that the method of ANOVA considers interactions. The consequences, however, are far-reaching. From a global perspective, there will still be thousands of Excel from sheets available calculating GR&R based on the average range method. They have to be discarded overnight. It will become more difficult to create Excel tables; you will need professional software – a fact that is quite beneficial for Q-DAS.

Reference values affect the result

MSA 4 mentions four different reference values. In general, all reference values are referred to as TV (total variation) in formulas. There are different ways to calculate this reference value:

- You calculate process variation taken from the parts in the GRR study. This is the preferred approach of the MSA manual.
- You calculate the reference value by dividing process variation by six. Process variation always refers to the process producing the parts measured in the analysed measurement process.
- Another reference value is the tolerance divided by six.
- The most recently added reference value is the tolerance divided by Pp or Ppk (preliminary process variation) of the process applying the respective measuring instrument..

Part variation

In case there are several options available as given in the MSA manual, many companies will discuss the reference value to be applied and this discussion will never end. Results will only be reproducible when you always apply the same reference value in all your analyses. The recommended or preferred part variation is definitely reasonable as a reference value. However, this reference figure requires that the values of collected parts are evenly distributed across the entire tolerance range and that you also include parts whose values exceed the tolerance limits. This fact is often not feasible in practice. On the one hand, there are new processes including nothing but very few parts available in initial sampling and, on the other hand, it will be hard to collect parts near the specification limits of a running process where process capability is quite high ($C_p > 1.33$). You will thus have to produce such parts explicitly which lacks practical relevance and is expensive. For realistic sampling, the result must not depend on an influenced variation of parts.

Process variation and preliminary process variation

In order to use the current process variation as a reference figure, you have to know it. You can only know it when the process is already monitored by means of capable measurement systems. Nevertheless, it will even be hard to determine process variation after restarts. In case the process variation of a running process improves due to the approach of "never-ending improvement", you actually have to conduct a new GRR study. However, this fact also implies that you always have to record process variation. Even this will be considered an approach lacking practical relevance. The 4th edition seems to try to solve the problem of restarts in particular since it added preliminary process capability P_p or P_{pk} as a reference value. The reasons mentioned above, however, argue against this reference value.

Tolerance as a reasonable reference figure

What remains is the tolerance as total variation. But why is it reasonable? The tolerance is the reference value specified in and cemented into each and every agreement between customer and supplier. It is indicated in each technical drawing and test instruction based on process monitoring and thus on the required capability analysis of measurement systems. The tolerances agreed upon in an order hardly ever change. So the tolerance provides you with a stable and company-wide reference value that is easy to comprehend and uniformly applied. With regard to current company guidelines, such as General Motors [7], Mercedes Benz [9], guideline of the automotive industry [10] or Robert Bosch [12], you will realize quickly that all of them use "tolerance" as a reference value.

Probability of 99.73% instead of 99%

Raising the factor of ANOVA from 5.15 to 6 as mentioned before does not affect the overall result %GRR when you apply the part variation as a reference figure. In any other case, this change will affect the result considerably. Any other reference values do not depend on the part variation and thus you have to expect a different %GRR value. What is even worse is that this value will rise! As a matter of fact, measurement system assessed to be capable according to the 3rd edition might not be able to establish capability according to the formulas of the 4th edition. We thus recommend users of MSA 4 to focus on the company guidelines mentioned above.

Attribute measurement processes

The 3rd edition of MSA has already contained a detailed description of how to evaluate attribute measurement processes. There are not any changes in the 4th edition except for the probability; it was raised from P = 99% (factor 5.15) to P = 97.3% (factor 6). However, this change is comprehensible since it refers to the evaluation of variable measurement processes.

Whether the presented procedures will turn out to have practical relevance depends on each individual case. The author does not know any case where you select 50 parts in practice based on the signal detection approach and are able to measure these parts very accurately providing values rounded to 6 (!) decimal places. This is a purely hypothetical approach.

Summary

In the author's opinion, AIAG blew the chance to adapt the MSA reference manual to international standards. VDA volume 5 "Capability of Measurement Processes" [13] approached this topic in a much better way since it is based on the ISO standard 22514-7 "Capability of Measurement Processes" [8]. Time will tell which standard/guideline will establish itself in the long run.

Literature

[1] A.I.A.G. – Chrysler Corp., Ford Motor Co., General Motors Corp.
Measurement Systems Analysis, Reference Manual
Michigan, USA, November 1990

[2] A.I.A.G. – Chrysler Corp., Ford Motor Co., General Motors Corp.
Measurement Systems Analysis, Reference Manual
2nd edition, Michigan, USA, June 1998

[3] A.I.A.G. – Chrysler Corp., Ford Motor Co., General Motors Corp.
Measurement Systems Analysis, Reference Manual
3rd edition, Michigan, USA, 2002 (2nd reprint May 2003)

[4] A.I.A.G. – Chrysler Corp., Ford Motor Co., General Motors Corp.
Measurement Systems Analysis, Reference Manual
4th edition, Michigan, USA, June 2010

[5] DIN – Deutsches Institut für Normung
DIN ISO/IEC Guide 99:2007, International vocabulary of metrology (VIM)
Beuth Verlag, Berlin, 2010

[6] Dietrich, E. / Schulze, A.
Measurement Process Qualification: Gage Acceptance and Measurement Uncertainty According to Current Standards, 3rd completely revised edition
Carl Hanser Verlag, Munich, 2011

[7] General Motors Co. – GM Powertrain
SP-Q-EMS-Global 10.6 – Evaluation of Measurement Systems Specification
Detroit / Rüsselsheim, July 2004

[8] ISO – International Standard Organization ISO/CD 22514-7: Capability and Performance –Part 7: Capability of Measurement Processes Geneva, 2010

[9] Mercedes AG
Leitfaden LF 05 "Prüfprozesseignung" Stuttgart, 2003

[10] Q-DAS GmbH
Guideline of the Automotive Industry "Measurement System Capability"
Birkenau, 1999

[11] Q-DAS GmbH
VDA 5 vs. MSA 4
www.piq-online.de, Weinheim, November 2010

[12] Robert Bosch GmbH
"Quality Assurance in the Bosch Group" guideline, Booklet 10 "Capability of Measurement and Test Processes"
Stuttgart, draft 2010

[13] VDA – Verband der Automobilindustrie
VDA Volume 5: Capability of Measurement Processes
2nd edition, VDA, Berlin, November 2010

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