MSA PLANNING - A PROPOSITION OF A METHOD

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Abstract: (250 Words)
Measurement System Analysis (MSA) is a mandatory element of quality management systems in automotive industry. Suppliers has to comply both with ISO/TS 16949 and meet customer requirements specified in APQP (Advanced Product Quality Planning), PPAP (Production Part Approval Process) and MSA manuals.
Manufacturing companies (not only in automotive industry) perform MSA studies for all measuring instruments specified in Control Plans. There are variety of methods available, with gauge R&R as the most popular, to conduct assessment of capability of a measuring system. However, although the assessment has to be performed periodically, none of the above mentioned standards and manuals suggest any method for MSA planning. The paper describes a few propositions on how the problem can be resolved basing on a risk associated with each measurement system.
The first proposed method is based on simple risk analysis, which can be easily run together with developing a Control Plan. It uses process capability index (required or achieved) and characteristics impact on product/process function for making a decision on MSA frequency and scope.
The second method assumes that a process FMEA (Failure Mode and Effects Analysis) is developed. The method uses performed FMEA to establish priorities for MSA. Basing on the priorities, frequency and scope of MSA can be planned.

Keywords: MSA, GR&R, APQP, FMEA

1. INTRODUCTION

MSA (Measurement System Analysis) methods are widely used in various industries in order to identify and assess extra variation (noise) generated in manufacturing process control and product inspection by a selected measurement system, This variation, i.e. measurement errors, if not controlled, may result in false decisions regarding to product or process quality. Standard calibration procedures do not address the issue of measurement system variation. Therefore, to reduce risk of false decisions based on process and product measurements, many manufacturing companies use MSA not only at a measurement system validation phase (before manufacturing process for a new project is approved and started) but also after launching a production process.

The MSA standard procedures originate from automotive industry OEMs. The standard procedures are defined as mandatory quality system requirements for suppliers, who are referred to the so-called supplier manuals, with MSA-4 [1] from U.S. automotive industry being the most commonly used MSA good-practice standard all over the world, apparently not only in automotive industry.

World-wide known and used quality management system specification for automotive industry ISO/TS 16949 [2] requires that "Statistical studies shall be conducted to analyze the variation present in the results of each type of measuring and test equipment system. This requirement shall apply to measurement systems referenced in the control plan. The analytical methods and acceptance criteria used shall conform to those in customer reference manuals on measurement system analysis". The above mentioned MSA-4 manual is most often the one agreed between customer and supplier as a MSA reference (it is also a common practice to develop company specific MSA procedures, basing on MSA-4 [1] manual).

ISO/TS 16949 requires that all measurement systems included in control plan have MSA performed with acceptable results. The most common guidelines on how to develop and manage control plans is - also coming from U.S. automotive industry - APQP (Advanced Product Quality Planning) [3], which addresses MSA stating that "The specified monitoring and measuring devices and methods should be used to check the control plan identified characteristics to engineering specification and be subjected to measurement system evaluation during or prior to the significant production run. Where special gages, fixtures, test equipment or devices are required per the control plan, verify gage repeatability and reproducibility (GR&R)…"

The third important manual developed by U.S. automotive industry, addressing MSA, is PPAP (Production Part Approval Process) [4], which define documents required from a supplier to demonstrate successful project implementation. Submitted documents should also comprise MSA records. PPAP [4] states that "The organization shall have applicable Measurement System Analysis studies, e.g., gage R&R, bias, linearity, stability, for all new or modified gages, measurement, and test equipment.".

Originated from automotive industry, the above guidelines spread across various manufacturing industries, being adopted as a good practice standard in MSA. Applications can be found in machine building, electronics, aircraft, domestic appliances manufacturing, etc.

2. PROBLEM STATEMENT

2.1 Resources for MSA

Vast majority of manufacturing companies performing MSA studies report deficiencies of human resources necessary to address all measuring systems referenced in control plans. Resources are necessary not only to properly select and perform MSA study, but also to plan, conduct and validate (through another MSA study) corrective actions in case of unsatisfactory results. The paper does not directly address a problem of resources necessary for MSA. However, application of the proposed method of MSA planning can contribute to more efficient usage of available resources for conducting MSA.

2.2 MSA Planning

MSA manual [1] requires that measurement capability of measurement systems should be evaluated taking into consideration both a short and a long term behavior of the measuring system. This requirement incurs a necessity of planning MSA studies, not only at manufacturing process validation phase, but also during serial production phase to control stability and periodically re-validate measuring systems referenced in control plan (which also may be subject to changes).

There is no standard method developed for this purpose. Author of the paper reviewed about 50 manufacturing companies (in Poland) with respect to MSA planning, coming into conclusion that very few of them (approx. 5%) used other than "once a year" approach. Those few tried to perform MSA studies more often for critical characteristics, but did not pay any attention to MSA method selected, using only standard GR&R analysis, ignoring other methods, e.g. control charts.

There is a growing need to develop a method of MSA planning, easy and little time consuming, applicable in industrial conditions, using available data regarding product and process addressed. The purpose of the method would be to give guidelines on MSA planning in term of methods selected and frequency of studies, so that deficient resources devoted to perform MSA are more efficiently consumed in terms of reducing risks connected with incapable or unstable measurement systems.

3. SOLUTIONS PROPOSED

The basis for the proposed MSA planning method are the following assumptions:

1. actual or required process capability/performance indices are known for characteristics being measured, i.e. short term capability Cp, Cpk and long term process performance Pp, Ppk after launching a production,
2. personnel responsible for planning MSA is aware of product functions and their connections with measured characteristics,
3. up-to-date PFMEA (process FMEA) is available,
4. the main criterion for deciding on MSA frequency and method is a risk connected with a measured characteristics in terms of non-conformance potential effects and its probability,
5. all gauges undergo effective calibration program.

The method is proposed in two basic variants:

- Variant A. Simplified risk matrix (SRM).
- Variant B. PFMEA based MSA planning.

4. MSA PLANNING BASED ON SRM

Each measured characteristics affects product quality. Basing on failure effects severity ranking recommended in FMEA in automotive industry [5] one can group quality characteristics into 3 or 4 subgroups. The most important are special characteristics, as defined by ISO/TS 16949 [2]. They typically include all safety related characteristics (or relating to legal requirements) and those affecting product functionality (with possible distinction between main and secondary functions). Less (but still important, rarely referred to as special) are characteristics associated with product appearance (e.g. uniform color) or behavior (e.g. silent operation) influencing customer pleasure, not affecting any functions.

Each characteristics present different levels of non-conformance risk in terms of probability. Looking at requirements for capability indices, based on safety area between process variation (usually estimated as six standard deviation spread for normal distribution) and characteristics specification limits, expressed in process standard deviations, one can group quality characteristics into 3 subgroups determined by standard Cpk (or Ppk) limits 1,33 and 1,67.

Those two criteria, when connected, form a simplified risk matrix – Table 1. (no function gradation), Table 2. (with distinction between main and secondary functions).

Table 1: SRM for grouping quality characteristics by risk.

Cpk / Ppk / Impact	≥ 1,67	< 1,67	< 1,33
Safety / legal requirements			Extreme risk
Functions (main / secondary)		Moderate risk	
Appearance/ behavior	Negligible risk		

Table 2: SRM for grouping quality characteristics by risk.

Cpk / Ppk / Impact	≥ 1,67	< 1,67	< 1,33
Safety / legal requirements			Extreme risk
Main functions		High risk	
Secondary functions		Moderate risk	
Appearance/ behavior	Negligible risk		

Each measured characteristics belongs to a relevant cell in the matrix. Depending on risk perception (or risk elimination strategy in a project or in an organization), each cell can be given a relevant, descriptive risk assessment (e.g. low risk, high risk, etc.). Then one can define reasonable requirements regarding MSA for each cell. Thus, each characteristics can be associated with specific MSA requirements.

Table 3: Requirements for MSA planning – example.

Cpk/Ppk / Impact	≥ 1,67	< 1,67	< 1,33
Safety / legal	Often, rigorously		Very often, very rigorously
Functions	Moderate frequency, rigorously		Often, rigorously
Appearance/ behavior	None	Rarely, simplified	Often, simplified

The MSA requirements for each cell can be set by selecting the MSA method of measurement system capability assessment and/or stability control, approved limits for MSA indices (e.g. %GR&R) and frequency of MSA activities. To make the method easy for industrial

applications it is suggested to use a (heuristic) rule of thumb - the higher is the risk, the more rigorous MSA requirements should be (similar to FMEA approach).

Table 3. shows an example of SRM filled with specific MSA requirements for MSA planning (for the purpose of clarity, content of the cells has been detailed in Table 4).

Table 4: Requirements for MSA planning – specification.

MSA planning requirements	Specification	
	Stability - Control Chart	Capability
Very often, very rigorously	Xbar-R; n=5, sampling every 4 hours (3 times / shift)	Linearity study (n=5); GR&R- ARM method: 10 parts x 3 trials / operator, GR&R ≤ 10%; monthly
Often, rigorously	Xbar-R; n=3, sampling daily;	Bias study; GR&R-ARM method: 10 parts x 3 trials per op., %GR&R ≤ 10%; every 3 months
Moderate frequency, rigorously	X-mR; sampling weekly;	Bias study; GR&R-ARM method: 5 parts x 3 trials / operator, %GR&R ≤ 10%; every 6 months
Often, simplified	X-mR; sampling daily;	GR &R- RM or ARM method: 5 parts x 3 trials per op., %GR&R ≤ 20%; every 3 months
Rarely, simplified	None	GR&R- RM or ARM method: 5 parts x 2 trials per op., %GR&R ≤ 20%; every 12 months
None	Capability and short term stability assessed only at the PPAP phase.	

While risk description in SRM (Table 3) has to fit company risk perception or risk management strategy, MSA specification has to be adjusted to available resources capable of setting up and running control charts and conducting measurement system capability studies (Table 4). Attempts of such adjustments performed by author showed deficiencies of resources for MSA in companies trying to optimize MSA planning. There are two alternatives in such a case:

1. acquire necessary resources (proactive approach, recommended),
2. adjust MSA planning specification to available resources, reducing frequencies and, if necessary, methods, in a proportional manner to retain dependence between MSA plan and risk identified in SRM - Tables 1,2,3 (reactive approach).

The latter can be achieved e.g. by iterative process of reducing the plan and summing up number of MSA studies and number of control charts samples to collect during a predefined period of time (e.g. one year) and comparing it with company actual capabilities (depending on resources devoted for MSA), until both match each other.

5. MSA PLANNING BASED ON PFMEA

Assuming that a company has PFMEA in place, one finds in PFMEA all measurement systems referenced in control plans (according to [2] control plan should be based on PFMEA). Moreover, each measurement system referenced in PFMEA as failure or cause detection, is precisely associated with corresponding process step and controlled characteristics. Therefore, replacing SRM in the first proposed solution by risk matrix built on Severity and Occurrence indices, it is possible to plan MSA taking additional advantage of developed PFMEA. Moreover, one can consider updates of MSA plan as PFMEA is periodically reviewed and updated, reflecting process improvement. Thus, MSA plan changes can follow process improvements.

Obviously, there is no need to make MSA specification different for each of 100 cells of the above mentioned risk matrix (Severity x Occurrence). Instead, rather few (but precisely bordered) risk areas can be defined, as it is recommended in process optimization based of PFMEA [6]. An Example is shown in Fig. 1.

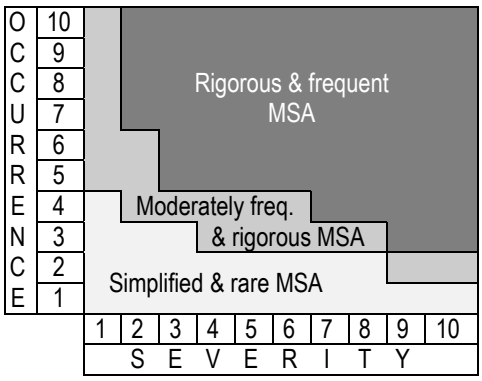

Fig. 1: MSA planning guidelines based on PFMEA risk areas recommended for process improvement [6].

Another possible way of taking advantage of PFMEA for MSA planning is by process risk ranking. Sorting failures with their causes by Severity (Sev), Occurrence (Occ) and Detection (Det) one automatically obtains a ranking of process detection controls, i.e. the ranking of measurements systems addressing characteristics with the highest effect risk for external and internal customers (Sev), with the highest probability of a cause (Occ), sorted at the and by risk of not detecting a non-conformance (Det). Such a risk analysis approach has been recently recommended [6, 7, 8] as opposed to criticized traditional RPN (Risk Priority Number) strategy, in which risk had been measured as multiplication of all risk indices, giving misleading recommendations for process improvement. Similar effect is obtained if RPN is replaced by SOD index, which is a product of combining Sev, Occ and Det digits [5]. Example of sorting effect is shown in Table 5.

Please note, that the same inspection method (see Table 5 – methods X and E) can be mentioned in PFMEA more than once (typically: final inspection).

Each detection method referred in PFMEA is connected with relevant measurement system (specified in more detail in Control Plan), Thus, according to the process risk ranking, measurement system ranking can be developed. being a basis for MSA planning. The higher is a measurement system position in the ranking, the stricter MSA requirements should apply, both in terms of rigor and frequency. Evidently, defining separate MSA requirements for each ranking position is not reasonable. Instead, rational

grouping would be suggested. An example is shown in Table 6., where three groups were defined, somewhat resembling a concept of ABC method.

Table 5: Risk ranking as a result of PFMEA.

Operation	Failure Mode	Failure Effects	Severity	Failure Cause	Occurrence	Detection - Cause	Detection - Failure	Detection	SOD
Developed PFMEA for operations O1, O2, O3									
O1	A	B	7	C	4	D	E	5	745
O1	A	B	7	F	2	G	E	4	724
O2	H	I	4	J	7	K	X	9	479
O2	M	N	9	P	3	Q	X	6	936
O2	M	N	9	Q	5	R	X	3	953
O3	T	U	9	V	4	W	X	2	942
PFMEA after SOD sorting									
O2	M	N	9	Q	5	R	X	3	953
O3	T	U	9	V	4	W	X	2	942
O2	M	N	9	P	3	Q	X	6	936
O1	A	B	7	C	4	D	E	5	745
O1	A	B	7	F	2	G	E	4	724
O2	H	I	4	J	7	K	X	9	479

Table 6: Risk ranking as a result of PFMEA.

No.	Measurement Systems	MSA requirements
1	R (O2), X (O2, O3)	Very high (SCC* daily, GR&R monthly)
2	W (O3)	
3	Q (O2)	High (SCC weekly, GR&R quarterly
4	D, E (O1)	
5	G (O1)	Moderate (GR&R yearly)
6	K (O2)	

* abbreviation SCC here denotes: Stability Control Chart

As a guideline, ABC analysis, referred to as a variation of Pareto analysis [8] could be used to divide the risk ranking into subgroups A, B, C (typically - A: 20% of the ranking – highest risks, B: 30% of the ranking – medium risks, C: 50% of the ranking – low risks, the subgroups addressing 80%, 15% and 5% of the risk potential effects respectively). Of course, typical subgroups share (20%, 30%, 50%) and contribution (80%, 15%, 5%) can be adjusted to a company specific risk management approach, products, legal and customer requirements, etc. Other values, recommended in quality control, for example include: A:15%/65% (share/effects), B:20%/20%, C:65%/15% [9]; A:20%/70%-80%, B:30%/15%-20%, C:50%/5%-10% [10].

The above described method faces the same problem of resources, as described in chapter 4. The solutions can also be similar to those mentioned: estimate and acquire necessary resources for MSA plan or adjust MSA plan to match available resources. Both approaches require relevant models, which are not addressed by this paper.

6. CONCLUSSIONS

The paper intends to start discussion about MSA planning as a vexed problem in manufacturing companies with management systems according to ISO/TS 16949 [2]. The following problems related to MSA planning would need to be further included in proposed methods in further developments:

1. A few identical or similar gauges are assigned to the same measurement task (characteristics).
2. There are significant differences between gauges, affect-ting a probability of measurement system falling into of out of control state: a gauge robustness and frequency of measurements (e.g. 100% inspection vs sampling).
3. Differences in time of measurement cycle affects time of MSA test, which could affect MSA planning in terms of a test specification (see – Table 4.) and resources.
4. Apart from measurement systems for variable data, there can also be measurement systems for attribute data in place (e.g. go-nogo gauges, visual inspection) with other MSA methods (Cross Tab – Cohen Kappa, Signal Detection, Analytic [1]) to include in MSA plan.

Despite the above considerations, the proposed methods – heuristic and simple, matching widely used quality tools in industry, with no special qualifications necessary from quality engineers and requiring no extra experimental data – would radically increase benefits from MSA by rational planning.

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