EVALUATION OF QUALITY OF THE VISUAL INSPECTION OF ALUMINUM COMPONENTS ASSEMBLY ACCORDING TO DIFFERENT METHODS

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Abstract

In the validation and evaluation of conformity between customer requirements and actually achieved quality of the products is always necessary to take into consideration two contradictory requirements. The first of them is the requirement for the most accurate and highest quality measurements or inspection. On the other hand, there is a requirement for the lowest possible financial, time and logistical requirements for the implementation of this measurement or inspection. The aim of this work is to evaluate the quality of the visual inspection of measurable quality characteristic. The quality of this measurement system will be evaluated using three methods used for evaluation of the acceptability of attributive measurement systems.

Keywords: Measurement system, visual inspection, acceptability, aluminum components

1. INTRODUCTION

The decision making based on facts is one of basic principles of the quality management. The application of this principle within the scope of planning, management and process improvement means that all decisions made on process interventions are based on data analysis of this process. Most often such data present measured values of quality characteristics of the product or of its parts. For this reason one of the prerequisites for success in the market is quality of the measurement system. This is the reason why the evaluation of measurement system quality is an integral part of the activities of quality planning and quality control in both the automotive and also in the metallurgical industry. At present the evaluation of the quality of used measurement system is mostly performed by using two approaches respectively methodologies. It is a Measurement System Analysis (MSA) methodology developed by the U.S. automotive industry and VDA 5 methodology developed by the German automotive industry. By using the methods included in both methodologies, it is possible to evaluate not only the quality of the measurement system for continuous variables, but also the quality of the measurement system for categorical variables (see **Fig. 1**) [1],[2].

1.1. Visual inspection

Both ways of evaluating of conformity between customer requirements and actually achieved quality of the products (measurement and control of attributive quality characteristics) have their advantages and disadvantages. The biggest advantages of measurement of continuous variables, respectively quality characteristics, is the possibility of obtaining very precise values of observed quality characteristic. Based on the thus obtained values it is possible to make the right decision about the fulfillment of customer requirements with high probability. The disadvantage can be its large financial, time or logistic requirements. An Alternative can be the control of attributive quality characteristics which can eliminate the mentioned disadvantages of measurements. On the other hand, in the case of visual inspection, when is the inspection result depends primarily on human abilities, can be the probability of wrong decision unacceptable. Before any change of the measurement or control method is therefore a necessary to assess the quality of the proposed measurement system by using appropriate assess methods. The main objective of this work is to assess the possibility of introducing visual inspections on the crimping process. This will be achieved by evaluating the quality of visual inspections by using three methods.

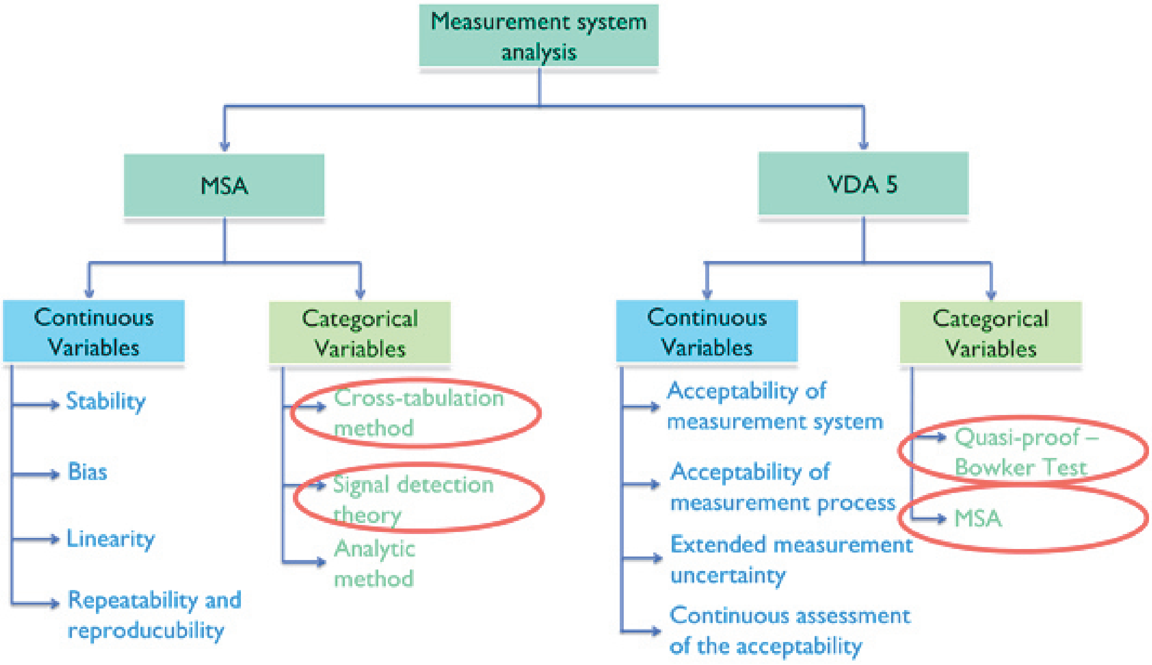

Fig. 1 Methods for evaluation the quality of the measurement system [1], [2]

2. PROCEDURE FOR EVALUATION OF THE OF ATTRIBUTIVE QUALITY CHARACTERISTICS

Quality Characteristic, which was chosen for the analysis is the position of the groove (see A on **Fig. 2**) on the body of part MGG 066/1 against the groove in the holder (see B on **Fig. 2**). For the inspection of selected quality characteristic (specifications ± 5.5°) is not using any comparative gauge. The reason for choosing this quality characteristic is the relatively easy manufacturability and preparing a set of products for the analysis. It is also necessary to take into account the fact that this quality characteristic is measurable. On the basis of this fact can be determined reference values, which are necessary for using the methods of attributive measurement systems study that will be described in the next part of this work.

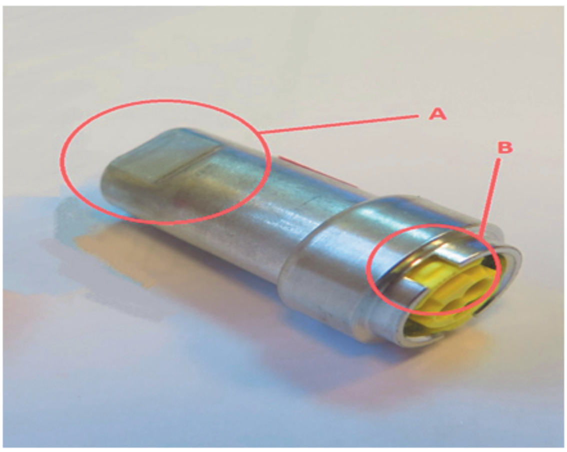

Fig. 2 Selected quality characteristic

In the absence of a sufficient number of parts that could be used for the analysis, was produced completely new set of parts according to the specified requirements, which are required by the MSA methodology. The parts were made so that the values of quality characteristic cover the entire production range, it means that there were parts from the rejection and acceptance zones and also parts from the "gray" zones (see **Fig. 3**).

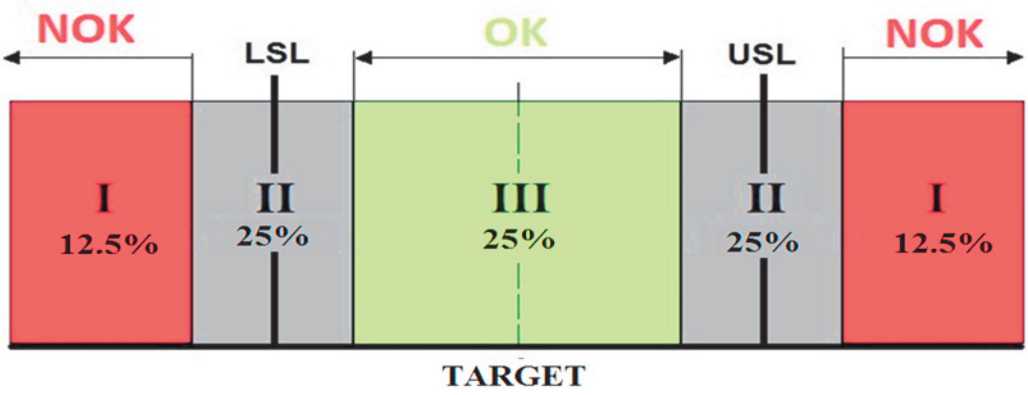

Fig. 3 Percentage distribution of parts in the zones [3]

2.1. Labeling of test samples and the reference values

Labeling allows us to clear identification of samples. This identification give not only the possibility to distinguish a particular part at random controlled mixing order of the samples, but also prevents the operator to be able to identify the particular sample with the previous control round. For this reason, the individual parts of the set were labeled with a code that replaces the sample number. Reference values were determined based on measurement results for samples that were obtained on the Vertex 110 gauge. The samples were successively submitted to the operators with random set of 10 pieces. In a previously prepared tables for recording the data were recorded the results of the control. Before the second and third round of control were the parts always randomly shuffled, so that operators will not be able to identify the inspection results for the individual parts, which have been already controlled [5].

2.2. Cross-tabulation method

The aim of the next step was to summarize obtained data from operators using cross tables. Cross tables must be constructed for each pair of operators (see **Table 1**).

Table 1 Cross tabulation study results for operator A and B

A * B Cross tabulation			B		Total
			NOK	OK	
A	NOK	Count	58	11	69
		Expected Count	31.7	37.3	69
	OK	Count	11	70	81
		Expected Count	37.3	43.7	81
Total		Count	69	81	150
		Expected Count	69	81	150

The calculated indicators of the degree of compliance between operators kappa κ (see **Table 2**), we can say that the level of agreement between all operators is good. Since the results differ only in the order of hundredths, it can be stated that operators make quite similar decisions.

Table 2 Level of agreement between operators

Kappa	A	B	C
A	-	0.70	0.67
B	0.70	-	0.73
C	0.67	0.73	-

Similarly to the case of agreement between operators is also necessary by constructing the cross-table and the subsequent calculation of the Kappa, to evaluate conformity between the evaluation of operators and the reference value. The values of kappa indicators for all three operators are in **Table 3**.

Table 3 Level of agreement between operators and reference values

	A	B	C
Kappa	0.72	0.72	0.77

Values of the Kappa indicator for comparison operators to the reference value showed that even in this case we can talk about good conformity between evaluation of operators and reference values.

Before we can determine the performance of visual inspection, it is necessary to calculate three basic characteristics (see **Table 4**), under which is this performance assesses. This is an effectiveness of measurement system (Marginal Acceptable ≥ 80 %), the risk of miss rate (Marginal Acceptable ≤ 5 %) and the risk of false alarm rate (Marginal Acceptable ≤ 10 %). Miss rate essentially represents the situation, when the operator marks the part to be in conformity, even when the reference value indicates nonconformity On the contrary false alarm rate essentially represents the situation, when the operator marks the part as nonconforming, even if the reference value indicates conformity [4].

Table 4 Effectiveness, miss rate and false alarm rate

Operator	Effectiveness	Miss Rate	False Alarm Rate
A	74 %	16.67 %	11.5 %
B	82 %	16.67 %	11.5 %
C	98 %	23.61 %	0.0 %

If we compare the obtained results with the criteria, we can say that the proposed method of visual inspection is not acceptable.

2.3. Signal detection theory

The principle of this method is based on determining an approximation of the width of the II (gray) area and from this the repeatability and reproducibility of the measurement system GRR. Subsequently is compared the percentage value of GRR with specified criteria. First, it is necessary to identify the end and start points of 'gray' areas. On the basis of these values can be then by the following formulas determined width of the "gray" areas.

$$d_{LSL} = d_{LSLy} - d_{LSLx} \qquad \mathrm{d_{LSL}} = -1.94 - (-6.222) = 4.282 \qquad (1)$$

$$d_{USL} = d_{USLy} - d_{USLx} \qquad \mathrm{d_{USL}} = 8.261 - 4.906 = 3.355 \qquad (2)$$

$$d = \frac{4.282 + 3.355}{2} = 3.819 \quad (3)$$

Evaluation of the acceptability of visual inspection is performed by calculating the percentage value of repeatability and reproducibility of the measurement system on the overall tolerance by the formula:

$$\%\ \mathrm{GRR} = \frac{d}{USL - LSL} \cdot 100 = \frac{3,8185}{5 - (-5)} \cdot 100 = 38.185 \quad (4)$$

Since the %GRR value is greater than 30 %, is the measurement system unacceptable.

2.4. Quasi-proof - Bowker test

This method evaluated on the basis of a statistical test (Bowker test) whether there are significant differences in the evaluation between different operators. This method does not allow assessing the conformity between operators and the reference value. Because the inspection is carried out by three operators, it must be constructed tables for all possible pairs of the operators. **Table 5** shows the distribution of the results between the operator A and B.

Table 5 Table for conformity between operator A and B

Frequency n_{ij}		Operator B		
		„+ + +“	Mixed results	„- - -“
Operator A	„+ + +“	16	1	0
	Mixed results	6	3	4
	„- - -“	0	0	10

The agreement between the operators should be determined based of the results on Bowker test for all pairs of operators (see **Table 6**).

Table 6 Result of Bowker tests

Interaction	T	K	Result
Operator A vs. Operator B	7.5714	7.81	H_0
Operator B vs. Operator C	8	7.81	H_1
Operator A vs. Operator C	12	7.81	H_1

Based on the results of the Bowker tests, we have two occasions to accept the alternative hypothesis H_1. So we reach the conclusion that between the evaluation of by operators B and C, as well as between operators A and C is a statistically significant difference, and we can therefore conclude that these operators have different results of visual inspection.

3. THE NEW INSPECTION METHOD

The cause of poor quality of visual inspections of selected quality characteristic is the fact, that the inspection is based purely on subjective opinion of the operator. In this case the only possibility how to improve the whole measurement system seems to be implementation of measures that would as much as possible of this subjective opinion of the operator prevented [6]. So, it is considering whether to stay with the existing method of inspection of a given quality characteristic or try to manufacture and the introduction of for example a test caliber with which could be possible very promptly evaluate the deviation of the monitored quality characteristic according to the specifications. The proposal of this caliber can be seen in **Fig. 4**.

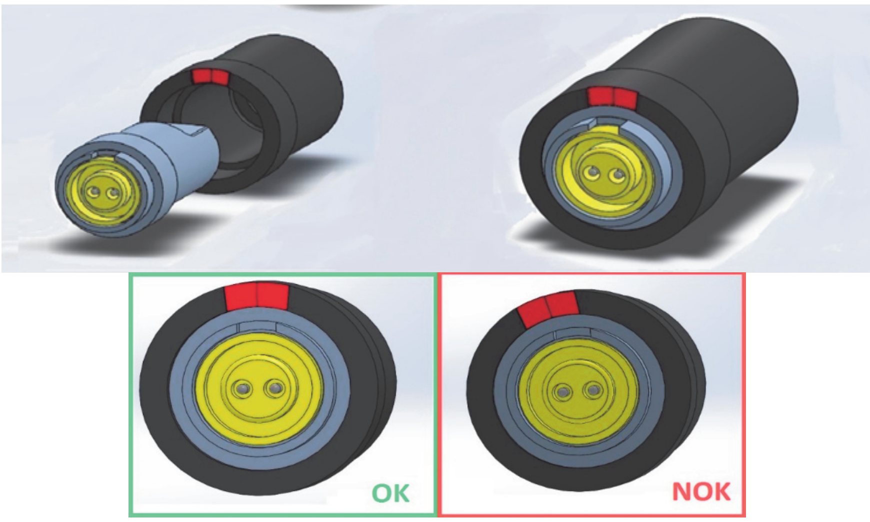

Fig. 4 The proposal of the new caliber

4. CONCLUSION

Based on the obtained results can be clearly stated, that the attributive measurement system used for visual inspection of monitored quality characteristic is unacceptable. The most important factor which negatively affecting the quality of the visual inspection is the fact, that this inspection is based purely on subjective opinion of the operator. The implementation of measures that can avoid of this subjective opinion is the only possibility how to improve this measurement system. Therefore worth considering whether it is better to use the current measurement method for monitored quality characteristic, or use the caliber, through which would be possible to simply evaluate the deviation between the monitored quality characteristic and specifications.

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