# Use of MSA (Measurement statistical analysis) for evaluation of measuring systems for quality control of an automatic production line

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***Abstract*—The MSA (Measurement statistical analysis) method was used to evaluate the measuring systems for quality assessment in the production of connectors (electromechanics) for the automotive industry on an automatic production line. Based on the collected data, an analysis of the capabilities of the measuring system was performed using QSTATLAB. A conclusion was made on the basis of the obtained results with conclusions regarding the admissibility of the process and its improvement.**

***Keywords— quality, measurement, control, repeatability and reproducibility***

## I. INTRODUCTION

In fast automatic production processes, secure measuring and control modules are used, which must be properly set up and verified. A modern method for evaluation and verification of such modules is MSA [1], which examines the impact of equipment, method, materials, operator and environment [2] and ensures their proper use. Many software products [3, 4] are used for the application of MSA, in which there is a built-in module for MSA assessment. The evaluation parameter is R&R, which is a measure of the repeatability and reproducibility of the measuring system. Based on statistics and correlations, the limits of R&D [5] are determined, at which measuring systems can be used or need to be improved.

The procedure for conducting an MSA includes the following steps:

1) Sampling of controlled objects (volume n => 10);

2) Measurement of individual objects by several controllers several times;

3) Processing of the obtained results and determination of the components of the full variation;

4) Comparison of the result with the admissible values and assessment of the measuring system.

The main components of the complete variation of the measuring system are:

- Deviation;
- Repeatability;
- Reproducibility;
- Stability;
- Linearity.

Deviations of these components are caused by various problems - wear standard or error in the standard, worn components of the device, poorly designed device or incorrect application, wrong measuring method or calculation, incorrect calibration of the tool, environmental impact, the tool is used inappropriately or incorrectly by other operators. The obtained data are then suitable for application and development of new processes that need to be tested.

## II. EXPERIMENTS

The test product is shown on fig. 1.

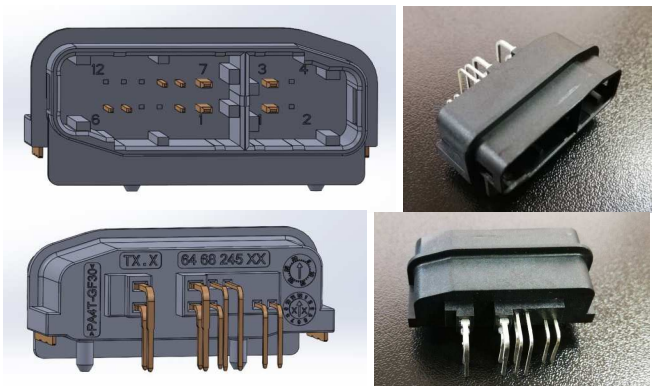


Fig.1. g8680x connector

Automatic production is done in several steps:

- Injection molded plastic body;
- Automatic assembly of metal terminals (CuSn6) in the plastic body;
- Automatic 100% product control for functionality-critical features;
- Automatic packaging in roll packaging (strap with separate slots for each product).

In fig. 2. the automatic production line for conectors assembly with the control stations is shown.

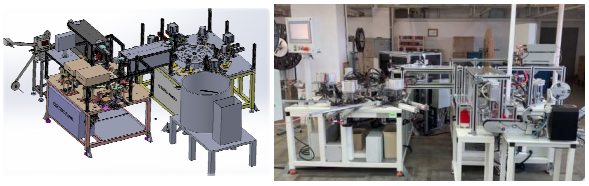

Fig. 2. The studied automatic production line

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The critical controlled parameters of the g8680x connector product are rendered on fig. 3.

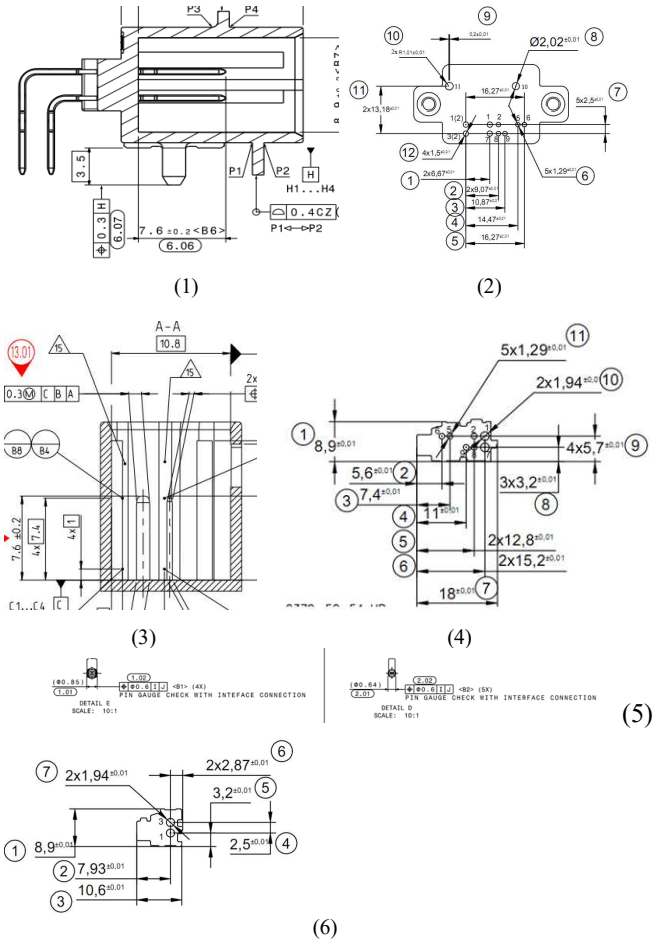


Fig. 3. Critical dimensions

The control stations are:

- 24 V – control for missing terminal, short or long terminal on the interface side and distorted terminal interface or PCB side – fig.3.(1),(3), (5), (6);
- pattern board - distorted terminal on the PCB side - fig.3.(2), (5);
- pattern interface - distorted output on the interface side – fig.3.(3), (4);
- 1000V – control for short circuit from inclusions and contaminants using a tester AC/DC Withstand Voltage / IR / GB.

Next is a packaging station, which is also a stamp for a suitable product. Non-compliant products are automatically separated in a special red box.

The control stations work on the principle of using patterns and electrical measurements for the presence or absence of contact and circuit.

## III. Results

The results and analysis were made for each type of control using the MSA method by collecting and processing data for analysis of the measuring system. For this purpose, reference samples were used, which were pre-measured to the appropriate dimensions with a precision measuring instrument model CNC Quick Scope QS-250 - Mitutoyo. The results were obtained using the software product QSTATLAB, which has a built-in MSA method.

### *A. HEIGHT OF THE TERMINALS OF THE INTERFACE*

*a)* The height of the contact terminals is checked by measuring a size of 7.6 ± 0.2 mm, which is shown in fig. 3 (1). The size tolerances are determined according to ISO 2768-m. This defect will result in improper connector assembly during the next manufacturing operation. The required reference standard samples of this station are OK and NOK with different values close to the limit 7.4mm / 7.8mm. Tables 1, 2 and 3 show the measurement of reference samples, with the help of which an R&R analysis is made by qualitative characteristics - check for the presence of short or long leads.

TABLE I.

| OK sample | | | |
|---|---|---|---|
| Pin1 Int 2 | 7.785 | | 0.185 |
| Pin3 Int 2 | 7.528 | | -0.072 |
| Pin1 Int 1 | 7.616 | | 0.016 |
| Pin2 Int 1 | 7.547 | | -0.053 |
| Pin5 Int 1 | 7.54 | | -0.06 |
| Pin6 Int 1 | 7.547 | | -0.053 |
| Pin7 Int 1 | 7.514 | | -0.086 |
| Pin8 Int 1 | 7.487 | | -0.113 |
| Pin9 Int 1 | 7.509 | | -0.091 |

TABLE 2.

| NOK sample – short leads | | | |
|---|---|---|---|
| Pin1 Int 2 | 7.601 | | 0.001 |
| Pin3 Int 2 | 7.542 | | -0.058 |
| Pin1 Int 1 | 7.506 | | -0.094 |
| Pin2 Int 1 | 7.479 | | -0.121 |
| Pin5 Int 1 | 7.37 | | -0.23 |
| Pin6 Int 1 | 7.427 | | -0.173 |
| Pin7 Int 1 | 7.575 | | -0.025 |
| Pin8 Int 1 | 7.425 | | -0.175 |
| Pin9 Int 1 | 7.435 | | -0.165 |

TABLE 3.

| NOK sample – long leads | | | |
|---|---|---|---|
| Pin1 Int 2 | 7.773 | | 0.173 |
| Pin3 Int 2 | 7.536 | | -0.064 |
| Pin1 Int 1 | 7.613 | | 0.013 |
| Pin2 Int 1 | 7.849 | | 0.249 |
| Pin5 Int 1 | 7.849 | | 0.249 |
| Pin6 Int 1 | 7.853 | | 0.253 |
| Pin7 Int 1 | 7.673 | | 0.073 |
| Pin8 Int 1 | 7.473 | | -0.127 |
| Pin9 Int 1 | 7.489 | | -0.111 |

The R&R analysis was performed by checking with 20 samples - suitable and unsuitable for the respective indicator. The "Sign" column records the result to be given by the relevant sample during the inspection. The samples are placed at the station five times and a result is reported. The data are a total of 100. The result is shown in Table 4.

TABLE 4.

**Attribute Gage R & R/Gage R & R по атрибути**

Report / Доклад

| | |
|---|---|
| Date/Дата | 22.11.2020 |
| Name/Име | Юлиана Асенова |
| Product/Продукт | 202-646824-00-299 |
| Process/Процес | Control for height of pins from interface side/Проверка височината на изводите от интерфейс страната |

Attribute Legend/ Легенда
1. pass/съотв. - Yes/Да
2. fail/несъотв. - No/Не

| Known Population | | | | | | | Y/N |
|---|---|---|---|---|---|---|---|
| Sample# Мостра No | Attribute Признак | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Agree Становище |
| 1 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 3 | No | No | No | No | No | No | Yes |
| 4 | No | No | No | No | No | No | Yes |
| 5 | No | No | No | No | No | No | Yes |
| 6 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 7 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 8 | No | No | No | No | No | No | Yes |
| 9 | No | No | No | No | No | No | Yes |
| 10 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 11 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 12 | No | No | No | No | No | No | Yes |
| 13 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 14 | No | No | No | No | No | No | Yes |
| 15 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 16 | No | No | No | No | No | No | Yes |
| 17 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 18 | No | No | No | No | No | No | Yes |
| 19 | No | No | No | No | No | No | Yes |
| 20 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Note/Забележка: **Attribute Gage R&R Control for height of pins from interface side with EOL 0200188 - working station № 4 according to drawing 6468245-01/17.09.2019.**
Gage R&R за атрибути е направен за проверка височината на изводите от интерфейс страната с линия 0200188- Станция № 4 по работен чертеж 6468245-01/17.09.2019.

Conclusion/Заключение: **The results are acceptable and EOL can be used in production.** / Въз основа на показаните резултати линията се приема за използване в производството.

*B. CURVED OUTPUT ON THE SIDE INTERFACE*

The curved terminal of the interface side is checked by measuring the size 0 + 0.3 / -0mm, which is shown in fig. 3. (3), (4). Tables 5 and 6 show the measurement of reference samples, with the help of which R&R analysis is performed by qualitative features - check for the presence of curved terminals on the interface site.

TABLE 5.

| cv.5/Part 1 | | |
|---|---|---|
| Otklonenie po X #13.01 (±0,15) | Otklonenie po Y #17.02 (±0,2) | Number pins |
| -0.132 | 0.031 | Pin 1 Interface 2 |
| -0.022 | -0.005 | Pin 3 Interface 2 |
| Otklonenie po X #8.07 (±0,15) | Otklonenie po Y #10.01 (±0,2) | Number pins |
| 0.143 | 0.063 | Pin 1 Interface 1 |
| 0.001 | 0.002 | Pin 7 Interface 1 |
| Otklonenie po X #8.01 (±0,275) | Otklonenie po Y #11.05 (±0,275) | Number pins |
| 0.071 | 0.280 | Pin 2 Interface 1 |
| -0.116 | -0.070 | Pin 5 Interface 1 |
| -0.063 | 0.054 | Pin 6 Interface 1 |
| -0.093 | -0.012 | Pin 8 Interface 1 |
| -0.146 | -0.024 | Pin 9 Interface 1 |

TABLE 6.

| cv.1/Part 1 | | |
|---|---|---|
| Otklonenie po X #13.01 (±0,15) | Otklonenie po Y #17.02 (±0,2) | Number pins |
| -0.087 | 0.002 | Pin 1 Interface 2 |
| -0.034 | 0.042 | Pin 3 Interface 2 |
| Otklonenie po X #8.07 (±0,15) | Otklonenie po Y #10.01 (±0,2) | Number pins |
| -0.167 | -0.065 | Pin 1 Interface 1 |
| 0.057 | 0.119 | Pin 7 Interface 1 |
| Otklonenie po X #8.01 (±0,275) | Otklonenie po Y #11.05 (±0,275) | Number pins |
| -0.003 | -0.233 | Pin 2 Interface 1 |
| -0.145 | -0.251 | Pin 5 Interface 1 |
| -0.003 | -0.331 | Pin 6 Interface 1 |
| -0.069 | 0.265 | Pin 8 Interface 1 |
| -0.215 | 0.214 | Pin 9 Interface 1 |

In fig. 4. NOK and OK samples are shown.

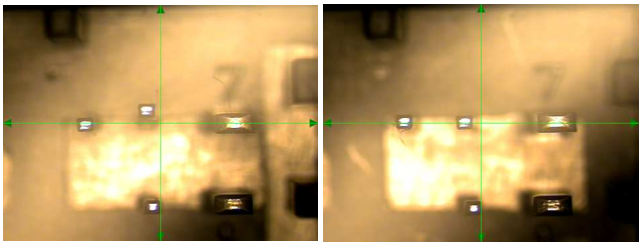

Fig. 4. NOK and OK samples

The test was performed with 20 samples and the result is shown in a table 7.

TABLE 7.

**Attribute Gage R & R/Gage R & R по атрибути**

Report / Доклад

| | |
|---|---|
| Date/Дата | 22.11.2020 |
| Name/Име | Юлиана Асенова |
| Product/Продукт | 202-646824-00-299 |
| Process/Процес | Check pins position from interface side / Проверка позицията на изводите от интерфейс страна |

Attribute Legend/ Легенда
1. pass/съотв. - Yes/Да
2. fail/несъотв. - No/Не

| Known Population | | | | | | | Y/N |
|---|---|---|---|---|---|---|---|
| Sample# Мостра No | Attribute Признак | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Agree Становище |
| 1 | No | No | No | No | No | No | Yes |
| 2 | No | No | No | No | No | No | Yes |
| 3 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 4 | No | No | No | No | No | No | Yes |
| 5 | No | No | No | No | No | No | Yes |
| 6 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 7 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 8 | No | No | No | No | No | No | Yes |
| 9 | No | No | No | No | No | No | Yes |
| 10 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 11 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 12 | No | No | No | No | No | No | Yes |
| 13 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 14 | No | No | No | No | No | No | Yes |
| 15 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 16 | No | No | No | No | No | No | Yes |
| 17 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 18 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 19 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 20 | No | No | No | No | No | No | Yes |

Note/Забележка: **Attribute Gage R&R Control pins position from interface side with EOL 0200188 - working station № 6 according to drawings № C-208-18095-1/06.04.2018,C-208-18096-1/06.04.2018.**
Gage R&R за атрибути е направен за проверка позицията на изводите от интерфейс страна/позицията на изводите от страна на платката с линия 0200188- Станция № 6 по работни чертежи № C-208-18095-1/06.04.2018,C-208-18096-1/06.04.2018.

Conclusion/Заключение: **The results are acceptable and EOL can be used in production.** / Въз основа на показаните резултати линията се приема за използване в производството.

*C. CURVED OUTPUT ON THE PCB SIDE*

A curved terminal on the PCB side is checked by measuring a size of 0 + 0.6 / -0mm, which is shown in fig. 3.(2), (5).

Tables 7 and 8 show the measurement of reference samples, with the help of which an R&R analysis is made by qualitative features - check for the presence of curved terminals of the site for the printed circuit board.

TABLE 8

| cv.2/Part 2 | | | | |
|---|---|---|---|---|
| Position x 2 0,6 r-r 1.02 | Pins Position PCB | Otklonenie po X | Otklonenie po Y | Number pins |
| 0.506 | 0.253 | -0.080 | -0.240 | Pin 1 Interface 2 |
| 0.000 | 0.000 | | | Pin 3 Interface 2 |
| 0.625 | 0.313 | -0.141 | -0.279 | Pin 1 Interface 1 |
| 0.000 | 0.000 | | | Pin 7 Interface 1 |
| Position x 2 0,6 r-r 2.02 | Pins Position PCB | Otklonenie po X | Otklonenie po Y | Number pins |
| 0.397 | 0.199 | 0.185 | 0.072 | Pin 2 Interface 1 |
| 0.439 | 0.219 | -0.173 | 0.135 | Pin 5 Interface 1 |
| 0.240 | 0.120 | -0.003 | -0.120 | Pin 6 Interface 1 |
| 0.347 | 0.173 | -0.059 | 0.163 | Pin 8 Interface 1 |
| 0.425 | 0.213 | -0.182 | 0.110 | Pin 9 Interface 1 |

TABLE 9

| cv.8/Part 1 | | | | |
|---|---|---|---|---|
| Position x 2 0,6 r-r 1.02 | Pins Position PCB | Otklonenie po X | Otklonenie po Y | Number pins |
| 0.513 | 0.257 | 0.167 | -0.195 | Pin 1 Interface 2 |
| 0.197 | 0.098 | 0.021 | -0.096 | Pin 3 Interface 2 |
| 0.284 | 0.142 | 0.037 | -0.137 | Pin 1 Interface 1 |
| 0.327 | 0.163 | 0.011 | -0.163 | Pin 7 Interface 1 |
| Position x 2 0,6 r-r 2.02 | Pins Position PCB | Otklonenie po X | Otklonenie po Y | Number pins |
| 0.088 | 0.044 | -0.024 | -0.037 | Pin 2 Interface 1 |
| 0.273 | 0.136 | -0.117 | 0.070 | Pin 5 Interface 1 |
| 0.596 | 0.298 | -0.285 | 0.087 | Pin 6 Interface 1 |
| 0.282 | 0.141 | -0.126 | -0.063 | Pin 8 Interface 1 |
| 0.562 | 0.281 | -0.244 | -0.139 | Pin 9 Interface 1 |

The test was performed with 20 samples and the result is shown in a table 10.

TABLE 10.

**Attribute Gage R & R/Gage R & R по атрибути**

Report / Доклад

Date/Дата: 22.11.2020
Attribute Legend/ легенда — Name/Име: Юлиана Асенова
1. pass/съот. - Yes/Да — Product/Продукт: 202-646824-00-299
2. fail/несъот. - No/Не — Process/Процес: Check pins position from PCB side / Проверка позицията на изводите от страна на платката

| Known Population | | | | | | | Y/N |
|---|---|---|---|---|---|---|---|
| Sample# Мостра No | Attribute Признак | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Agree Становище |
| 1 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 3 | No | No | No | No | No | No | Yes |
| 4 | No | No | No | No | No | No | Yes |
| 5 | No | No | No | No | No | No | Yes |
| 6 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 7 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 8 | No | No | No | No | No | No | Yes |
| 9 | No | No | No | No | No | No | Yes |
| 10 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 11 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 12 | No | No | No | No | No | No | Yes |
| 13 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 14 | No | No | No | No | No | No | Yes |
| 15 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 16 | No | No | No | No | No | No | Yes |
| 17 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 18 | No | No | No | No | No | No | Yes |
| 19 | No | No | No | No | No | No | Yes |
| 20 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Note/Забележка: **Attribute Gage R&R Control pins position from PCB side with EOL 0200188 - working station № 5 according to drawings 6468245-01/17.09.2019.**
Gage R&R за атрибути е направен за проверка позицията на изводите от страна на платката с линия 0200188- Станция № 5 по работни чертежи 6468245-01/17.09.2019.

Conclusion/Заключение: **The results are acceptable and EOL can be used in production.** / Въз основа на показаните резултати линията се приема за използване в производството.

### *D. 1000 V LEAK TEST*

The inspection was performed with 20 samples, which are shown on fig. 5.

Fig. 5. Leak check samples at 1000 V

Table 11. shows R&R analysis by qualitative characteristics - high voltage test - 1000V.

TABLE 11.

**Attribute Gage R & R/Gage R & R по атрибути**

Report / Доклад

Date/Дата: 23.11.2020
Attribute Legend/ легенда — Name/Име: Юлиана Асенова
1. pass/съот. - Yes/Да — Product/Продукт: 202-646824-00-299
2. fail/несъот. - No/Не — Process/Процес: Short circuit cintrol via high voltage/ Тест високо напрежение (1000V)

| Known Population | | | | | | | Y/N |
|---|---|---|---|---|---|---|---|
| Sample# Мостра No | Attribute Признак | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Agree Становище |
| 1 | No | No | No | No | No | No | Yes |
| 2 | No | No | No | No | No | No | Yes |
| 3 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 4 | No | No | No | No | No | No | Yes |
| 5 | No | No | No | No | No | No | Yes |
| 6 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 7 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 8 | No | No | No | No | No | No | Yes |
| 9 | No | No | No | No | No | No | Yes |
| 10 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 11 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 12 | No | No | No | No | No | No | Yes |
| 13 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 14 | No | No | No | No | No | No | Yes |
| 15 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 16 | No | No | No | No | No | No | Yes |
| 17 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 18 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 19 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 20 | No | No | No | No | No | No | Yes |

Note/Забележка: **Attribute Gage R&R Short circuit cintrol via high voltage with EOL 0200188 - working station № 7 according to Control Plan Number ПОК-001-МНТ-228.**
Gage R&R за атрибути е направен за тест високо напрежение с линия 0200188- Станция № 7 , съгласно работна инструкция номер ПОК-001-МНТ-228.

Conclusion/Заключение: **The results are acceptable and EOL can be used in production.** / Въз основа на показаните резултати линията се приема за използване в производството.

## IV. CONCLUSION

After many measurements and analysis of the obtained results, we can assume that the described method is a necessary tool for validation, as well as a method for localization and proof of incorrect control.

In the course of the research work, many improvements were made on the basis of the statistical information obtained and analyzed from the experiments. By correlation, the control parameters were set with optimal limits, which allowed real-time control of the product and a significant reduction in re-testing.

By preparing FMEA (risk analysis) can be organized predictive maintenance of samples, which will significantly reduce the risk of using worn-out samples and will improve their functionality, will increase their reliability.

The tested procedure and equipment can also be used for measurements of samples from experimental production and processes.

## ACKNOWLEDGMENT

The authors is grateful to MIKROAK Ltd for the resources they have provided in conducting the experimental work.

The authors would like to thank the Research and Development Sector at the Technical University of Sofia for the financial support.

## REFERENCES

[1] MSA, Fourth edition, 2010.

[2] Measurement System Variability Cause and Effect Diagram, MSA, Fourth edition,pp.17.

[3] Minitab 17, 2016.

[4] QSTATLAB 6, 2012.

[5] MIKROAK MSA instruction, 2020.