Capability of the Measuring Equipment

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Abstract: *The aim of the article is to practically illustrate the methodologies and verify the capability of measuring equipment in the production organization. The methodologies have been shown in measuring station in the production process of the lid torque converter. The first method that we used was the study bias measurement system by which we acquired capability indexes Cgm, Cgmk. The resultant values of the capability indexes C_{gm} = 2,154 and C_{gmk} = 1,378 meet the eligibility requirements according to the measuring device C_{gm} ≥1,34, C_{gmk} ≥1,33. The second used methodology was the method of repeatability and reproducibility R&R, where we calculated the result % R&R = 27,7 %. It shows us that the value of % R&R is in the range of 10 – 30 % of the variance (or tolerance). The measuring system is conditionally suitable depending on the importance of application, cost of repair and gauge. Some corrective measures are needed depending on the use of the measuring equipment. As a measuring device, we used measuring station from the Marposs manufacturer.*

Keywords*: measuring, measuring process, capability of measuring equipment, quality*.

INTRODUCTION

The quality of measured data is one of the main pillars of quality assurance. It is necessary to meet the customer‘s requirements and satisfaction. As quality should be constantly improved along with rising customer demands, a functional quality assurance system must is needed in production organization [3,4]. It is therefore desirable that quality management would be focused on the whole life cycle of the product that the organization produces [7,10]. If we want to verify the capability of the production process, we must first verify the capability of the measuring devices. It would be unnecessary to find an error in the process if we have an inappropriate measuring device [9]. Therefore, it is necessary to verify the measuring equipment itself, ensure that the meter is used by skilled and trained workers and in the verification of the capability, include all the ambient influences that influence the measuring process [1,5].

To implement this method, it is necessary to follow certain guidelines:

- the measuring device must be set according to manual before the start of the test,
- during the test, the measuring equipment must not be installed,
- the reference piece must be removed from the measuring instrument after each measurement and re-inserted before the next measurement,
- the measurement should be performed in the same position and in the same location,
- the reference is measured by one operator at least 10 times.

When specifying the acceptable deviation value, unless otherwise stated in the documentation, it is recommended to specify 1.5% of the tolerance of the measured characteristic. This value corresponds approximately to the value of one R & R standard deviation at % R & R = 10% determined against tolerance [8,15].

MATERIAL AND METHODS

Capability indices of the measuring equipment

The procedure for calculating meter capability indices the C_{gm} and C_{gmk} is as follows:

- calculate the average of all measured values:

$$\bar{X}_a = \frac{1}{N}\sum_{i=1}^{N} X_i \tag{1}$$

N – number of measurements
X_i = 1, 2, 3, ... N

– calculate the standard deviation:

$$s_w = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X}_a)^2} \quad (2)$$

– capability indices C_{gm} a C_{gmk} are calculated according to the following patterns:

$$C_{gm} = \frac{0{,}2\,.\,T}{6s_w} \quad (3)$$

$$C_{gmk} = \frac{(X_r + 0{,}1T) - \bar{X}_a}{3s_w} \quad (4)$$

$$C_{gmk} = \frac{\bar{X}_a - (X_r - 0{,}1T)}{3s_w} \quad (5)$$

The minimum requirement for an eligible measuring device is:

– $C_{gm} \geq 1{,}34$

– $C_{gmk} \geq 1{,}33$

R&R repeatability and reproducibility

It is a combined value of the measurement system. We call it R & R (Repeatability and Reproducibility). Its statement in % relative to the variability of the measured samples or process to the specification is denoted as % R&R. Total variability is the process variability that is designed to evaluate the capability of the measurement system.

Long-term eligibility studies

We select a sample of 10 pieces that represent the actual (assumed) scattering of the process. Parts are numbered. We select three operators (A, B, C). Operators must be selected from employees currently serving the MP / MS. We let the operators measure all 10 pieces (not successive) and write down the measured values in the appropriate table (the record can not be made by the operator himself). We will use this procedure the next day - test # 2. On the next day we repeat the procedure for the third time - test # 3. The condition is that at least two tests must be performed [3,4].

Further we follow these steps:

a) We calculate the arithmetic mean of all values of the observed characteristic of test 1 of operator A. We will also repeat the calculation for other A operator tests.

b) We calculate the average of operator A: $\bar{X}_A$ and enter the value in the form.

c) Repeat the procedures in a), b) for operators B, C.

d) Minimal value from $\bar{X}_A$, $\bar{X}_B$, $\bar{X}_C$ je $\bar{X}_{Min}$ and maximal is $\bar{X}_{max}$.

e) We calculate $\bar{X}_{DIF} = \bar{X}_{MAX} - \bar{X}_{MIN}$ and enter the value in form.

f) We calculate the arithmetic mean of all values that were measured on sample 1 in all tests for all operators and enter the value in the form. We will repeat this procedure for other samples.

g) We calculate the range $\bar{X}_P$ samples from 1 to 10. It's a difference of maximum and minimum value.

h) We calculate the R range of the measured values on the first sample by operator A in all 3 tests. This is calculated as the difference between the maximum and minimum values. The range is also calculated for other samples.

i) We calculate arithmetic mean $\overline{R_A}$ of ranges. The mean $\overline{R_B}$, $\overline{R_C}$ is also calculated for operators B and C.

j) We calculate arithmetic mean $\bar{R}$ from the mean of $\overline{R_A}$, $\overline{R_B}$, $\overline{R_C}$.

k) We calculate the upper regulatory limit $UCL_R = D_4.\bar{R}$, where D4 is the constant shown in the table and is dependent on the number of tests.

l) We calculate the repeatability / variability of the EV device and the reproducibility / variability of the AV operator. Furthermore, we calculate the combined R & R repeatability and reproducibility, sample variability and total TV variability. The value of total variability may be given: by the width of the tolerance field TV=USL-LSL or by the variability of the process for the observed characteristic $TV = 5{,}15.\sigma_{process}$ or by the samples variability $TV = \sqrt{R\&R^2 + PV^2}$

m) We calculate the values in % : % EV, % AV a % R&R. Their sum is not 100%.

The acceptability level of the measuring instrument or measuring system

It is given by the percentage of repeatability and reproducibility (R & R) in total process variance (TV) or production tolerance (T) -% R & R::

- less than 10% of total scatter (or tolerance) - MP / MS is acceptable,
- 10-30% of total scattering (or tolerance) - MP / MS is conditionally acceptable depending on its importance, its price, repair costs etc., the decision to use belongs to the quality assurance manager of the relevant department,
- more than 30% of total scatter (or tolerance) - MP / MS is considered unacceptable and maximum effort should be made to improve it [5,7].

The production organization is engaged in the production of automotive parts and is the world's leading technology leader in drive and chassis technology as well as passive and active safety technology. The company is represented with approximately 135,000 employees in about 230 plants in 40 countries. It is one of the world's largest subcontractors in the automotive industry.

RESULTS AND DISCUSSION

Determination of capability of the measuring device in the process of producing the lid

Product characteristics

Due to the requirement of the production organization, we have chosen the production process for the production of the hydrodynamic torque converter. The part is shown in fig.1. The production drawings of the component are shown in figure 3. The lid is made of 16MnCr5 DIN EN 10084. For the verification of the measuring equipment capability, we focused on the characteristics of the production organization: ø 59.7 with tolerance -0.05 mm for the systematic error we measured on the calibration standard and the diameter ø 39.93 mm with tolerances + 0.020, -0.033 mm for repeatability and reproducibility measured on the finished product from the process. The Merlin Marposs digital measuring station is used to measure the dimensions of the lid in the production process [2].

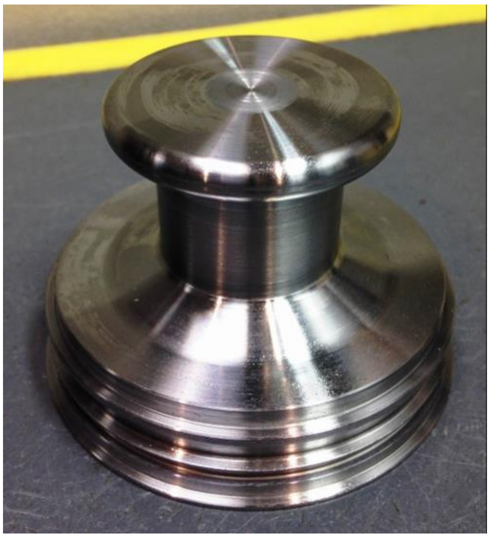


Fig. 1 Hydrodynamic torque converter

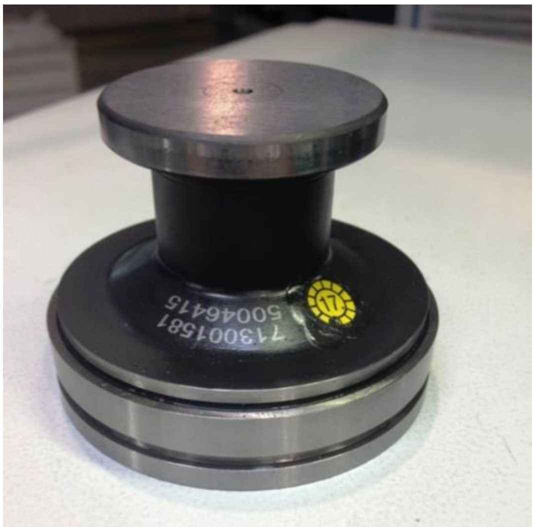


Fig. 2 Setting Standard

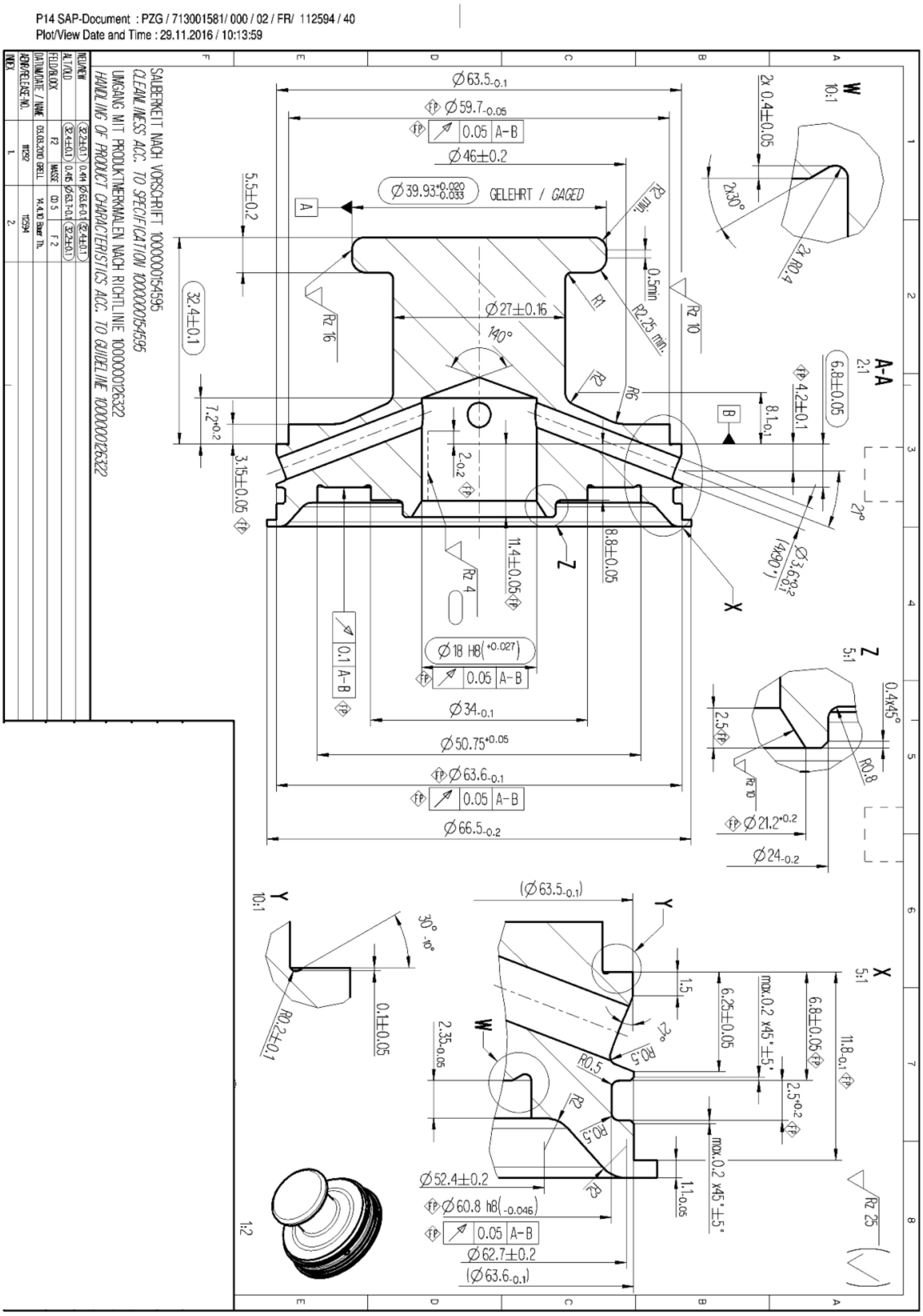


Fig. 3 The production drawings of the component

Characteristics of the measuring equipment

In the process of producing a torque hydrodynamic torque converter, a measuring station from the Marposs manufacturer is used, shown in Figure 4. The principle of measurement is by means of inductive sensors. The measuring sensors must be set to the calibration standard prior to any measurement. The sensor detects the reference value of the standard that it compares with the measurement value during the measurement. The measuring station consists of: a measuring, display and evaluation unit. The measuring station has two-way control, to ensure safety of work. The measuring station is also used for statistical process control. It allows you to discover the causes of variability based on sample selection from the process [2].

Name of measure station: Marposs Merlin
Evidence number: LVCF17120
Resolution: 0,001 mm

Fig. 4 Measuring station Marposs Merlin

Characteristics of the standard
Designation: calibration standard 50046415 (fig. 2)
Evidence number: 713001581

- diameter: ø 39.926 mm,
- diameter: ø 59.677 mm,
- run-out: 0.003,
- diameter: ø 60.782mm,
- distance : 32.398 mm,
- distance: 6.804 mm,
- run-out: 0.002

Date of calibration: 29.11.2016 with validity of 12 months.

Determination of the measuring equipments indices

Table 1 Evaluation of the capability of the measuring equipment

STUDY OF THE SYSTEMATIC ERROR OF THE MEASUREMENT SYSTEM

Department:	**Quality and Engineering technologies**
Measuring system:	**Marposs Merlin**
num. of the meas. system:	
Process:	**the lid of a hydrodynamic converter**
Parameter:	**the diameter**
value	**mm**

Document:	**BIAST 1, 00110 SK**
Date:	**22.2.2017**
Responsible:	**Ing. M. Prístavka, PhD.,**

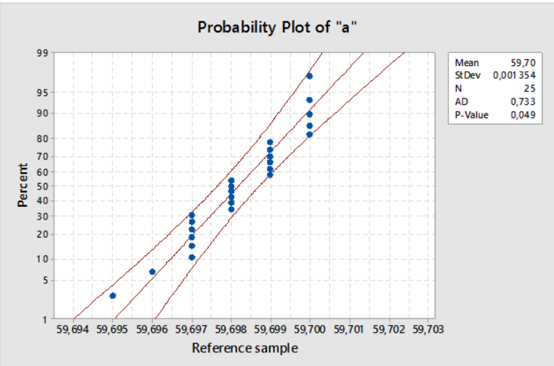
Description of the standard		
	Reference value	*59.7*
	The expanded uncertainty	*0.0014*

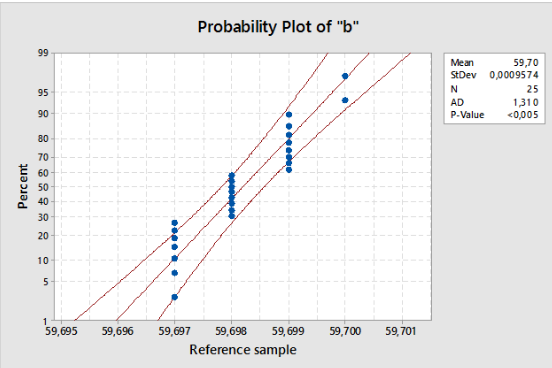
Repeated measurements of the reference sample, mm	a	b	c	d	e
1	59.699	59.699			
2	59.697	59.697			
3	59.7	59.7			
4	59.699	59.699			
5	59.698	59.698			
6	59.699	59.697			
7	59.697	59.699			
8	59.7	59.697			
9	59.696	59.699			
10	59.698	59.698			
11	59.699	59.698			
12	59.697	59.699			
13	59.7	59.697			
14	59.698	59.7			
15	59.698	59.698			
16	59.699	59.698			
17	59.697	59.699			
18	59.7	59.697			
19	59.697	59.697			
20	59.698	59.699			
21	59.699	59.698			
22	59.697	59.699			
23	59.7	59.698			
24	59.695	59.697			
25	59.698	59.698			

Deviation		
1.0% of the measured		
acceptable tolerance		0.597
number of measurements		30
Product (process)	LTL	*59.65*
	UTL	*59.7*
Tolerance (UTL-LTL)		0.05
The measurement of		
	number	50
The mean value of	average	59.6982
	LConfM	59.69787
	UConfM	59.69853
deviation for repeatability		0.0011606
% Repeatability		13.93%
expanded uncertainty of the value		
The uncertainty [%]		0.23%
Analysis of systematic error		
Systematic error	The value	-0,0018
	% Toler.	3.60%
	LConfB	-0,002129832
	UConfB	-0,001470168
	breadthB	0,000659665
uncertainty interval	LConfU	-0,003238329
	UConfU	-0,000361671
	breadthU	0,002876657

Test of statistical hypotheses	Alfa	p-value	Significant?
Center value measurements = Ref. Value	0.05	<1E-04	Yes
System error = 0, takes account of the uncertainty.	0.05	0.0141	Yes

Cg, Cgk	**p=95,45%**	**p=99,73%**
Cg	2.1541011	1.4360674
Cgk	1.3786247	0.9190831





The results of the analysis	**Evaluation by the staff**
Suits for an acceptable variance = 0.597 (1.0% of measured)	The measuring equipment is capable

R & R repeatability and reproducibility

In this work, we decided (at the initiative of the production organization) to analyze a long-term eligibility study for determination of repeatability and reproducibility. The measurements were performed by three workers. With this method, we measured 10 serial products directly from the process and focused on the characteristic: diameter: ø 39.93 mm with tolerances + 0.020, -0.033 mm.

Table 2 repeatability and reproducibility R&R

REPEATABILITY AND REPRODUCIBILITY OF THE MS
(ANOVA method with interaction)

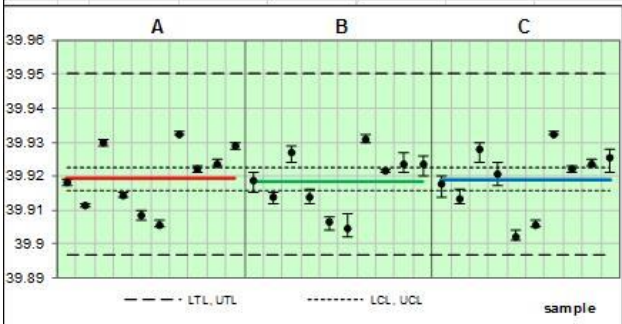
Department:	Quality and Engineering technologies			Document:	GRRA N 0112 SK
Measuring system:	Marposs Merlin			Date:	22.2.2017
number of the MS:					
Process:	the lid of a hydrodynamic converter		Responsible:	Ing. M. Prístavka, PhD.,	
Parameter:	average				
value	mm	Chart measurements:	S1		
		Note		The resolution of the	*0,001*
Operator (factor)	A			LTL	*39,897*
	B			UTL	*39,95*
	C			St. dev. of process	

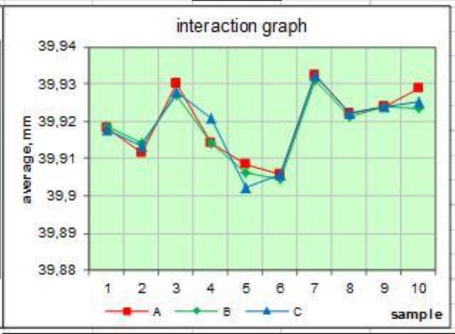
Sample		1	2	3	4	5	6	7	8	9	10	averages
A	1	39,919	39,912	39,931	39,915	39,91	39,907	39,933	39,923	39,925	39,93	39,9205
	2	39,919	39,911	39,93	39,914	39,908	39,905	39,932	39,922	39,923	39,928	39,9192
	3	39,917	39,911	39,929	39,914	39,907	39,905	39,932	39,921	39,923	39,928	39,9187
averages		39,91833	39,91133	39,93	39,91433	39,90833	39,90567	39,93233	39,922	39,92367	39,92867	39,91947
range		0,002	0,001	0,002	0,001	0,003	0,002	0,001	0,002	0,002	0,002	0,0018
B	1	39,921	39,915	39,929	39,916	39,908	39,902	39,931	39,922	39,927	39,92	39,9191
	2	39,92	39,915	39,928	39,912	39,904	39,909	39,93	39,921	39,921	39,924	39,9184
	3	39,915	39,912	39,924	39,914	39,907	39,902	39,932	39,921	39,923	39,926	39,9176
averages		39,91867	39,914	39,927	39,914	39,90633	39,90433	39,931	39,921333	39,92367	39,92333	39,91837
range		0,006	0,003	0,005	0,004	0,004	0,007	0,002	0,001	0,006	0,006	0,0044
C	1	39,92	39,916	39,93	39,921	39,904	39,907	39,933	39,923	39,925	39,928	39,9207
	2	39,914	39,912	39,929	39,917	39,901	39,905	39,932	39,922	39,923	39,921	39,9176
	3	39,919	39,912	39,924	39,924	39,902	39,905	39,932	39,921	39,923	39,927	39,9189
averages		39,91767	39,91333	39,92767	39,92067	39,90233	39,90567	39,93233	39,922	39,92367	39,92533	39,91907
range		0,006	0,004	0,006	0,007	0,003	0,002	0,001	0,002	0,002	0,007	0,004
averages		39,91822	39,91289	39,92822	39,91633	39,90567	39,90522	39,93189	39,921778	39,92367	39,92578	39,91897

	DF	SS	MS	F	p	Component	%proportion		
								UCLr:	0,008772
Sample	9	0,006653	0,000739	65,99813	<1E-04	8,09E-05	92,3%	Out of bounds margins:	0%
Operator	2	1,86E-05	9,3E-06	0,830266	0,4520	0	0,0%	UCLx:	39,92244
Interaction	18	0,000202	1,12E-05	2,495325	0,0043	2,24E-06	2,6%	LCLx:	39,91549
instrument	60	0,000269	4,49E-06			4,49E-06	5,1%	ver. of the outside limits:	77%
Together	89	0,007143	8,03E-05		R&R	6,73E-06	7,7%	Zero margins:	0%

NDC	PV	Process	Toler.
NDC	4		4
R/R	53		53
Stan. uncertainty of resolution			0,000289
The number of samples			10
The number of operators			3
The number of repetitions			3

	st. dev.	variability	Times: St. dev.		6
			%R&R		
TV	0,009361	0,0561639			
PV	0,008994	0,0539651	TV	Process	Toler.
AV	0	0	0,0%		0,0%
Interaction	0,001496	0,0089749	16,0%		16,9%
EV	0,002119	0,0127122	22,6%		24,0%
R&R	0,002594	0,0155611	**27,7%**		**29,4%**





The results of the analysis	Evaluation by the staff
Suits conditionally	

CONCLUSION

The submitted contribution was addressed in production organization for the production of predominantly automotive parts where quality is a very important factor in both life and safety. Methodologies for verification of measuring devices used in this organization serve as universal methods for assessing the capability of meters at the output control as well as directly in the production process. These methods significantly contribute to the continuous improvement of the quality of the manufactured components and increase the competitiveness of the organization in the market.

Given that using the first measurement method, the measure station is capable and using the R&R method is partially capable, corrective action needs to be taken

As a corrective measure, we propose to change the calibration interval of the measuring station's sensors from a 12-month interval to a six-month interval as the liner production increased in the organization, extending the work on the line from two work shifts to three work shifts. This results in more manufactured products and thus more measurements.

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