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MEASUREMENT TO DEVIATION OF ROUNDNESS ON CMM AND ITS STATISTICAL ASSESSMENT

MĚŘENÍ ODCHYLEK KRUHOVITOSTI NA CMM STROJÍCH A JEJICH STATISTICKÉ HODNOCENÍ

Abstract

The paper deals with various measuring methods for measuring of roundness deviation on CMM (Coordinate Measuring Machines). We compared two methods, between measurement systems analysis and uncertainty of measurement with using statistical methods for assessment of our measurements.

Abstrakt

Příspěvek se zabývá různými měřícími metodami měření odchylek kruhovitosti na CMM strojích (třísouřadnicové měřící stroje). Jako výchozí metody jsme zvolili porovnávání mezi analýzou systému měření a nejistotou měření s následným využitím statistických metod pro hodnocení naměřených hodnot.

1 INTRODUCTION

Currently we know two ways for a valuation of measuring. Uncertainty of measurement is the first way and measurement systems analysis is the second way. The crucial difference between the two ways is how the uncertainty of measurements relates to the result of measurements and measurement analysis focused directly on the measurement system [1]. Uncertainty of measurement is the parameter added to the result of measurement, which is characterized by the dispersion of values and how they can be validly added to the measurement of value STN 01 0115, 3.9 [2]. One of the parameters can be, for example, superior standard deviation (or it’s multiple). Practical meaning: Uncertainty measuring introduces intervals about valuation measuring of parameters in which one finds actual (conventionally right) value measuring parameters with definite probability. A laboratory of metrology needs valuation uncertainties of measuring for following qualities of measuring repair using these qualities. Also, valuation uncertainties of measuring are directly insistent to ISO standard 17025 [3]. For evaluation measuring of roundness, we use standard uncertainty of measuring Type A, which is the standard deviation average of values. System of measurements are these machines, values, etalons, preparations, method, personnel, environs and presumptions used toward quantification units measuring and their correlation [4]. More simply told,

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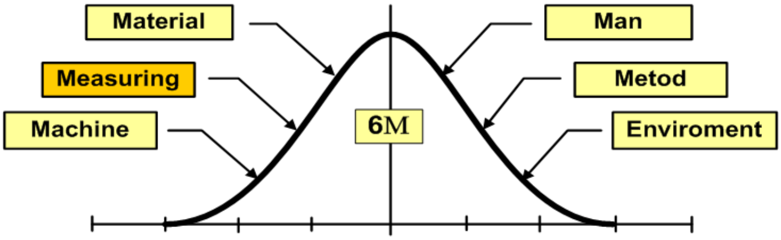


Fig. 1 Influence of 6M on variability of the process production

Tab.1 Difference between measurement systems analysis y and uncertainty of measurement

Measurement systems analysis	Uncertainty of measurement
Source for methodologist: DC, Ford, GM: Measurement systems analysis, ČSJ Prague. 3. spends [5]. **Ascent from analyses :** output is general valuation of measurement system, resolution, if system is competent for query of used or no. **Data character:** Defects as measured can be systematic and accidental, Bias, linearity, stability bind to systematic mistake as measured - to manipulate average value partitions measure out values, repeatability,reproducibility, homogeneity is an adventitious mistake as measured by influence dispersion distribution measured values. **Region usage:** In automobile industry – mainly "USA" car company (before car company used QS9000) – Ford, General Motors etc.	**Source for methodologist:** VDA 5: Competence checks process, ČSJ Prague [6]. **Ascent from analyses :** ascent is interval on specific confidence levels, which one assigned results as measured by and augmented of measured value at this interval, All values were measured under the conditions by those who performed the measurement. **Data character:** From principle uncertainty we always talk about dispersion of measured values or about change of dispersion. In the entire steps one is headed to appraisal dispersion, then to design accidental measurement errors. Notwithstanding that one evaluates operator influence, settings etc., we always deals with change of dispersion. **Region usage:** In automotive industry – mainly the "German"car company (even before the car company certified according to VDA) – Volkswagen etc., but was also in other fields.

a system of measuring that marks the complete process whose aim is to obtain measuring of value and includes all that cohere with measurement. Responsibilities measurement systems analysis is decided if the system of measurement is for the given purpose acceptable, vel non. Results analysis is the determination standard of uncertainties (in which measure ones system of measurement sharing a resultant dispersion) and suitability given system measuring for a spotted parameter. When practical, finding a savoir that detects, if possible, concrete predetermined system measuring (values, methods, service, etc.) reaches **QoS** of the process, measuring can then verify that product requirements were completed.

Ground characteristic measurement systems analysis is bias, repeatability, reproducibility, linearity and stability. The basic idea of this characteristic is to search for an individual factor (operator, gauge, time, measurement method) on measuring values. The aim is to determine the value measuring and uncertainties, which then guarantee probability of results. It is a fact that measuring, systematic, and accidental situations influence us and may hamper determination right values measuring parameters. System of measurement is variable, which we must know and quantify.

What is the difference of a standing variability system measuring from a variability of the process production? Variability of the process production includes sources summarized in 6M (fig. 1). As far as the system measuring variable, they must exist on other sources receiving excessively high pretensions to stability. One part of the 6M is a system of measurement analysis concentrating on these contributions.

2 EXPERIMENTAL EXAMINATION

Our experiments directed at measuring deviations of roundness on the outside surface of ball bearing type 62 206-2RS operations A and B is illustrated (fig.2). Measuring by scan method was realized using coordinate measuring machine Zeiss Prismo 5 with scan head VAST (fig.3), machine parameters: U1 = (2,2 + L/350) mm, L (mm) and resulting evaluation program UMESS – Graphic. Analysis measuring was applied using the **R&R method.**

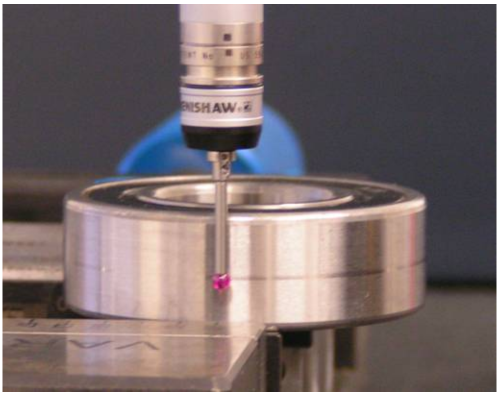


Fig. 2 Measurement of roundness on ball bearing scanning head VAST

Fig. 3 CMM Zeiss Prismo 5 with diameter D = 62mm - type 62 206-2RS

Progress **R&R methods**:

1) **Preparation of tests:**
   - measuring accuracy equipment in state of calibration,
   - 2 until 3 operations staff,
   - 10 different part with values at all range of tolerance,
   - 2 until 3 measuring, everyone's segment by every operator,
   - determine date and place, where measurement has realize,
   - determine number of measurement (measuring accuracy technique regulation).
2) **Requirement on carrying out of exam:**
   - in the same place of sample,
   - in a different time example: morning, in the half changes, at the end changes,
   - results inscribe in form.

3) **Process for carrying out of exam:**

- ❑ to prepare gauge on exam,
- ❑ adjust gauge on the reference etalon,
- ❑ mark place of measurement on sample,
- ❑ prepare necessary form,
- ❑ carry out 1x measuring everyone's sample by every operator (10 measured),
- ❑ after designation off-set carry out measuring like the previous case,
- ❑ after another date off-set carry out again equal number measure out poop inscribe in form.

4) **Evaluation examination [7].**

R&R method

Repeatability and reproducibility is illustrated on fig.4 and it is percentage expression of variability causing measurement system in face of generally process variability or tolerance zones width. This method can distinguish variability of causing operated and measuring equipment.

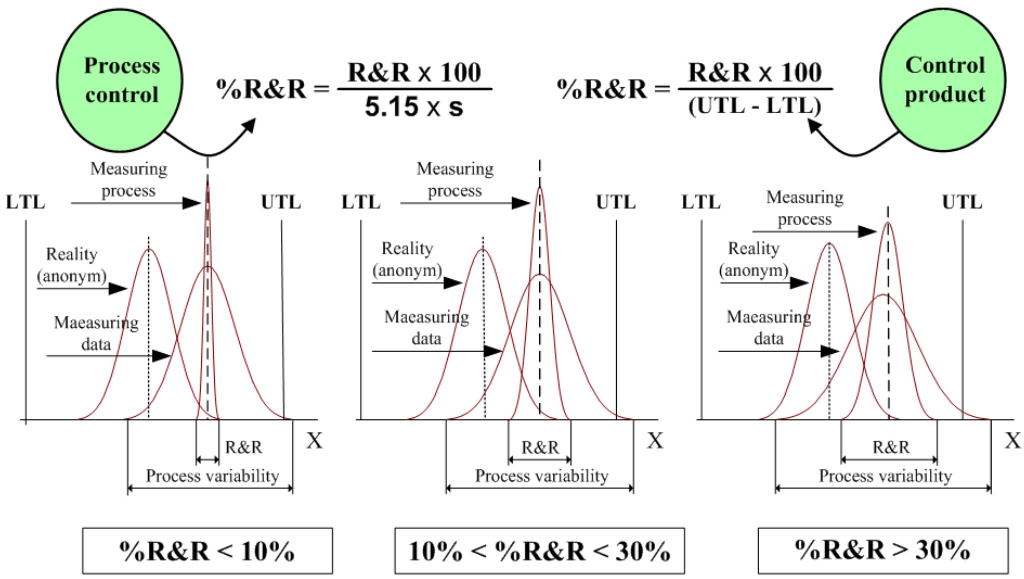
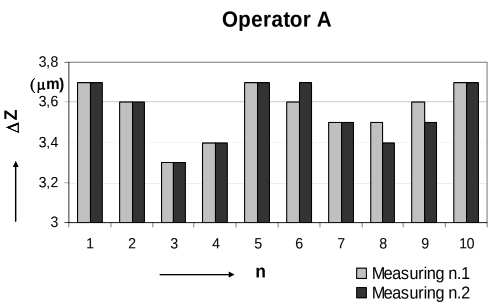


Fig. 4 Repeatability and reproducibility (LTL–lower tolerance line, UTL–upper tolerance line)

Results measured roundness on mentioned ball bearing placed on the stage (tab.2). In another step, we practiced measurement systems analysis (tab.3) by means of **R&R methods**. After calculating the extension uncertainty of measuring Type A in (tab.4). **R&R method** (repeatability and reproducibility) belongs among combination characteristic.

Tab.2 Measuring of roundness on outside surface of ball bearings type 62 206-2RS

Operator A	**Number of piece and results of measurement of roundness (μm)**											
Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average value (μm)**	**Average of test averages (μm)**
1	3,7	3,6	3,3	3,4	3,7	3,6	3,5	3,5	3,6	3,7	3,56	3,555
2	3,7	3,6	3,3	3,4	3,7	3,7	3,5	3,4	3,5	3,7	3,55	
Range RAi	0	0	0	0	0	0,1	0	0,1	0,1	0	$\overline{R}_A = \sum_{i=1}^{10}(R_{Ai})$ =0,03μm	
Operator B	**Number of piece and results measurement of roundness (μm)**											
Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Average value (μm)**	**Average of test averages (μm)**
1	3,7	3,6	3,3	3,3	3,7	3,7	3,5	3,4	3,6	3,8	3,56	3,56
2	3,7	3,6	3,3	3,4	3,7	3,7	3,5	3,4	3,5	3,8	3,56	
Range RBi	0	0	0	0,1	0	0	0	0	0,1	0	$\overline{R}_B = \sum_{i=1}^{10}(R_{Bi})$ =0,02μm	
Average $\overline{X}$ for A,B (μm)	3,7	3,6	3,3	3,37	3,7	3,67	3,5	3,42	3,55	3,75	**RP** =0,45 μm	



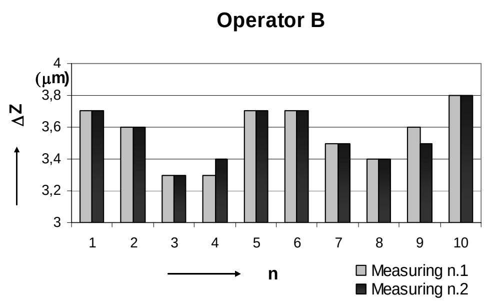


Fig.5 Graphic comparison deviations of roundness for outside surface of ball bearings for operators A and B

Tab.3 Measurement systems analysis

STUDY REPEATABILITY AND REPRODUCIBILITY OF MEASUREMENT SYSTEM			
Machine	CMM - Zeiss Prismo 5	**Date**	15.2.2007
Selection of samples	**Sample with one run**		

TV calculation:

(•) **R&R a PV** ( ) **specification** ( ) **σ process**

Number of operators	2	**Operator A** Lenka Očenášová	**Operator B** Ivan Litvaj
Number of samples (n)	10		
Number of tests (r)	2		

n	2	3	4	5	6	7	8	9	10	$X_{DIF} = \bar{X}_{MAX} - \bar{X}_{MIN}$
K_3	3,65	2,70	2,30	2,08	1,93	1,82	1,74	1,67	1,62	$X_{DIF} = -0{,}005\,\mu m$

r	**D_4**	**K_1**	**Number operators**	**K_2**	$\bar{R} = \frac{\bar{R}_A - \bar{R}_B}{\text{Number operators}}$	$UCL_R = \bar{R} \text{ x } D_4$
2	3,27	4,56	**2**	3,65		
3	2,58	3,05	**3**	2,70	$\bar{R} = 0{,}025\,\mu m$	$UCL_R = 0{,}8175\,\mu m$

For some range apply R > UCLR , value responsible operator have to be ruled out from calculation.

Analysis	**Part variation (PV)**	**Total variation (TV)**
	$PV = R_P \times K_3$	$TV = \sqrt{R\&R^2 + PV^2}$ alebo $TV = 5{,}15 \times \sigma$ proces, or $TV = UTL - LTL$
	$PV = 0{,}729\,\mu m$	$TV = 0{,}73785974\,\mu m$

AV = 0 in case, that value is under square root in formula is negative for AV calculation.

Analysis	**Repeatability (EV)**	**Reproducibility (AV)**	**Repeatability and reproducibility (R&R)**
	$EV = \bar{R} \text{ x } D_4$	$AV = \sqrt{(X_{DIF} \times K_2)^2 - \frac{EV^2}{n \times r}}$	$R\&R = \sqrt{EV^2 + AV^2}$
	$EV = 0{,}114\,\mu m$	$AV = 0\,\mu m$	$R\&R = 0{,}114\,\mu m$
Percentage of total variation	$\%EV = 100 \times \frac{EV}{TV}$	$\%AV = 100 \times \frac{AV}{TV}$	$\%R\&R = 100 \times \frac{R\&R}{TV}$
	$\%EV = 15{,}45\%$	$\%AV = 0{,}0\%$	$\%R\&R = 15{,}45\%$
	Satisfy: % R&R ≤ 10%	**Satisfy inchoatively: 10% < % R&R ≤ 30%**	**Not satisfy: % R&R > 30%**

Tab.4 Uncertainty of measurement for type A

Calculation of standard deviation from arithmetic means for standard uncertainty									
$u_A = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n.(n-1)}}$			**Operator A**			**Operator B**			
			$u_A = 0{,}14\,\mu m$			$u_A = 0{,}17\,\mu m$			
Stimulate factor of correction $\mathbf{k_f}$									
n	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
$\mathbf{k_f}$	7	2,3	1,7	1,4	1,3	1,3	1,2	1,2	1
(for n = 10 , is k_f = 1)									
Calculation uncertainty of enlarge U (µm)									
$U = k_f .u$			**Operator A**			**Operator B**			
			$U = 0{,}14\,\mu m$			$U = 0{,}17\,\mu m$			

3 CONCLUSION

Measurement systems analysis is a qualitatively arbitration measurement of a system. As a result, the analysis determines the accuracy (in what is measure system measurement participate on resultant dispersion) and suitability applications given the measurement system for a spotted parameter. Competence of the process measuring designates a general variability that calls out accidental parameters affecting measuring. Officiating competence measurement systems is convenient primarily at the organization of production.

Whenever practical, finding a savoir that detects concrete predetermined measurements regarding qualities of the process measuring verifies that product requirements were completed. However, results measuring uncertainty require quantitative examination. It can be said there is different access to the solution of a problem (measurement systems analysis, uncertainty of measurement). Quantitative exams are inclusive as a determination numerically measuring values of parameters. The metrology of laboratory estimates uncertainties measuring and developing qualities. Also, estimation uncertainties is a direct requisite of norm STN EN ISO 17 025. Principle uncertainties lead to discussions about dispersion measured values or about change of dispersion.

All of the steps lead up to an estimation of dispersion and determination of an accidental error of measurement through operator influence, environment, etc. Dealing with the change of dispersion is a constant. Differences between measurement systems analysis and uncertainty of measurements are mentioned (tab.1).

Evaluation of experiments: In the first evaluation experiment, the **R&R method** of measurement was used followed by experiments with concentrate to determine the extension uncertainty Type A. The calculation standard deviations arithmetical average of standard uncertainties was used. Measuring roundness on the outside of surface quoits ring ball bearing was performed by two operations staff (Operator A and Operator B) at which time both operators measured 10 parts. The standard deviation arithmetical average of standard uncertainties for Operator A was 0,14 mm, with the standard deviation arithmetical average of standard uncertainties for Operator B was 0,17 mm. The extension uncertainty for Operator A was 0,14 mm with the extension uncertainty for Operator B was 0,17 mm.

The results were analyzed by means of the **R & R method** using a general percent variability. Typically, the general percent variability is **10% < R&R < 30%**. This particular experiment used a general percent variability of 15,45% so that the heretofore mentioned system of measurement of roundness on the outside of the surface ball bearing is satisfactory.

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