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Contribution to the evaluate the suitability of the measuring equipment

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Abstrat This paper deals with the issue of verifying the suitability of measuring equipment, as meters used in production must meet the required degree of accuracy. However, there are several approaches to measuring and evaluating measuring systems. This paper focuses on measuring the suitability of meters according to the methodology of Ford and Bosh. The aim of the experiment was to compare the limits of tolerance fields for two types of measuring systems. A fixed and rotating measuring head, which can be used with the Zeiss Prismo Navigator, was used as the measuring system.

Key words capability, measurement, tolerance, measuring system

1. INTRODUCTION

Today, it is a matter of course that the measuring equipment used in production meets the required degree of accuracy. Companies and organizations dealing with the field of quality have developed several standards and guidelines that define requirements for the properties of measuring instruments and equipment, which are designed to ensure the high quality of manufactured products. These are, for example, the ISO 9000 series standards, VDA, and others. Manufacturers obtain a certificate of quality compliance, which is required for placing products on the market, etc.

2. THE CURRENT APPROACH TO QUALITY IN THE FIELD OF MEASUREMENT

When we focus on the evaluation of the measurement systems and specific instructions for evaluating measuring systems in practice, there area lot of standards just for evaluating the measuring system (MSA, etc.), but there is no information in the standards about evaluating the measuring equipment. Therefore, the largest car producers have developed their own directives. These directives are then used as supplements to the standards for evaluating the measuring systems within their companies or their suppliers.
There are two basic approaches to the field of measurement and evaluation of measuring systems. These are the MSA Manual and the VDA 5 standard. The MSA Manual summarizes the methods, the main proponents of which are the American automotive companies Chrysler Group LLC, Ford Motor Company, and General Motors Corporation, under the auspices of the Automotive Industry Action Group (AIAG). In the case of VDA 5, the main proponents of these methods are the German BMW Group DaimlerAG, GKN Driveline, KFMtec, MQSConsulting, MAN Nutzfahrzeuge, Robert Bosch GmbH a Volkswagen AG. [1]

In this article is describe not on the evaluation measuring system (MSA, VDA 5,...), but in this article, we focused on measuring the capability of measuring equipment according to the methodology of company Ford and company Bosh.[2][3]

Both these methods are based on the assumption that the suitability test is performed on a real product. In these methods, the real product fulfils the role of a standard. The real value of the standard (the real product) must be determined using measuring equipment that has the accuracy of two orders of magnitude higher than that used when manufacturing real product.[4]

The method then consists of repeatedly measuring the value of the standard. The detected variance is compared with a part of the tolerance field, usually 15% or 20% of the tolerance field.

The procedure of using the method to evaluate the suitability of the measuring equipment is simple. It is performed by repeated measurements of a standard (real part) for which we know the nominal values. Measuring is performed by only one operator on the same measuring equipment which is being evaluated and one measured part. The measured values are then compared with a part of the tolerance field, usually with a proportion of 15% to 20% of the tolerance field.

The basic indicators of measuring equipment capability are the parameters Cg and Cgk. These indicate the value of repeatability (Cg) and reproducibility (Cgk) of the inspected measuring equipment. The method of calculating these parameters varies according to the methodology used (by company Ford, or by company Bosh)[2].

2.1 Bosh

Parameters that are used by the company Bosch are calculated as 20% of the width of the specification field. The required value of Cg and Cgk is compared with a value of 1.33 and more. The formulas for calculating the Cg index are as follows:

$$c_g = \frac{0{,}2s_p}{s_g} \quad \text{or} \quad c_g = \frac{0{,}2T}{6s_g}$$

where the calculation is related to the width of the specification field T. In both cases, sp is the standard deviation of the process and sg is the standard deviation of the measured values.

The second eligibility indicator is Cgk. Cgk indicators can also be determined in various ways. A method related to process variance or specification field width is used. The relation to process variance is:

$$c_{gk} = min\left\{\frac{(x_r + 0{,}1T) - \bar{x}}{3s_g} \middle| \frac{\bar{x} - (x_r - 0{,}1T)}{3s_g}\right\}$$

When using the method for calculation according to the variance of the process, the relations are similar. Instead of the variable T, the selection standard deviation of the process 6sp is used. The relation to the specification field width is:

$$c_{gk} = min\left\{\frac{(x_r + 0{,}1 \times 6s_p) - \bar{x}}{3s_g} \middle| \frac{\bar{x} - (x_r - 0{,}1 \times 6s_p)}{3s_g}\right\}$$

2.2 Ford

The variant according to Ford takes into account a bandwidth of 15%. In this method of calculation, measuring devices are recognized as eligible if the values of Cg and Cgk are greater than 1. The relationships for the calculation of the indicator Cg are as follows:

$$c_g = \frac{0{,}15s_p}{s_g} \quad \text{or} \quad c_g = \frac{0{,}15T}{6s_g}$$

where the calculation is related to the width of the specification field T. In both cases, sp is the standard deviation of the process and sg is the standard deviation of the measured values.

To determine the indicator Cgk, the relation related to the variance of the process is used:

$$c_{gk} = min\left\{\frac{(x_r + 0{,}075T) - \bar{x}}{3s_g} \middle| \frac{\bar{x} - (x_r - 0{,}075T)}{3s_g}\right\}$$

The relationship related to the width of the specification field occurs after adjustment similarly to the Bosch variant:

$$c_{gk} = min\left\{\frac{(x_r + 0{,}075 \times 6s_p) - \bar{x}}{3s_g} \middle| \frac{\bar{x} - (x_r - 0{,}075 \times 6s_p)}{3s_g}\right\}$$

3. DESCRIPTION OF MEASURING EQUIPMENT

The aim of the experiment was to compare the limits of the tolerance fields of two types of measuring systems. A fixed and rotating measuring head, which can be used with the Zeiss Prismo Navigator, was used as the measuring system.

3.1 Zeiss Prismo Navigator

PRISMO enables maximum accuracy for high-speed scanning. It automatically sets the maximum measurement speed when scanning - with guaranteed accuracy. All functionally important machine components are perfectly matched to one another. This is achieved by using functionally relevant components produced in-house. Because it is equipped with a multiapplication sensor system from ZEISS as standard, it allows contact and contactless measurements on one machine. It is possible to use two different measuring heads for measuring. One is a fixed head and one is a rotating head. [5]

3.2 Fixed head VAST Gold

The fixed measuring head is a sensor for active scanning with high dynamics thanks to optimized moving weights and high rigidity due to improved articulation. It is extremely robust thanks to integrated collision protection. Dynamic damping allows use in continuous operation. The sensing force can be adapted to the geometry of the sensor and the material of the part and is still constant - it can be programmed in the range of 50 to 1000 millinewtons. [6]

Fig. 1:Zeiss Prismo Navigator, Fixed and Rotating head [5][6][7]

3.3 Rotating head VAST XXT

The VAST XXT swivel head is ideal for measuring tasks where it is necessary to use a combination of swivel head flexibility with scanning capability. The compact and lightweight design of scanning sensors on the swivel head requires various sensor modules. VAST XXT covers with three modules the range of typical sensor lengths for this sensor design. Side sensors up to 65 millimetres in length can be attached to this sensor. [7]

4. DESCRIPTION OF MEASURING

Fig. 2: The calibration ring

The process of measuring was the same for both heads. The stylus for measuring was a ruby ball with a diameter of 2 mm and contact measuring was used. Measurements were performed in 50 cycles by one worker, under constant environmental conditions.

The calibration ring was measured by contact scanning at a speed of 8 mm/s with the step between points 0.1 mm (approx. 400 points). The diameter of the calibration ring was evaluated. The nominal size of the calibration ring is 39.9979mm.

The following tables (tab.1 and tab.2) show the measured values when using a fixed and rotating head.

Tab. 1: Measured values – fixed head VAST GOLD

Nr.	Actual ø	Nr.	Actual ø	Nr.	Actual ø	Nr.	Actual ø	Nr.	Actual ø
1	39.99692	**11**	39.997	**21**	39.99692	**31**	39.99689	**41**	39.99698
2	39.99692	**12**	39.9969	**22**	39.99689	**32**	39.99689	**42**	39.99697
3	39.99692	**13**	39.99691	**23**	39.99699	**33**	39.99698	**43**	39.99688
4	39.99689	**14**	39.99699	**24**	39.99698	**34**	39.99698	**44**	39.99697
5	39.99698	**15**	39.99691	**25**	39.99699	**35**	39.9969	**45**	39.99698
6	39.9969	**16**	39.99699	**26**	39.99699	**36**	39.99697	**46**	39.99698
7	39.9969	**17**	39.99699	**27**	39.99689	**37**	39.99698	**47**	39.99688
8	39.9969	**18**	39.99691	**28**	39.99699	**38**	39.99698	**48**	39.99688
9	39.99699	**19**	39.99691	**29**	39.9969	**39**	39.9969	**49**	39.99697
10	39.99699	**20**	39.99699	**30**	39.99699	**40**	39.99688	**50**	39.99686

Tab. 2: Measured values– rotating head VAST XXT

Nr.	Actual ø	Nr.	Actual ø	Nr.	Actual ø	Nr.	Actual ø	Nr.	Actual ø
1	39.9976908	**11**	39.9977118	**21**	39.997651	**31**	39.9976577	**41**	39.9976184
2	39.9976951	**12**	39.9976754	**22**	39.9976436	**32**	39.9976168	**42**	39.997635
3	39.9977162	**13**	39.9976725	**23**	39.9976282	**33**	39.9976595	**43**	39.9976351
4	39.9977058	**14**	39.9976711	**24**	39.9976556	**34**	39.9976433	**44**	39.9976327
5	39.997694	**15**	39.9976637	**25**	39.9976561	**35**	39.997622	**45**	39.9976081
6	39.9976853	**16**	39.9976536	**26**	39.9976574	**36**	39.9976607	**46**	39.9975981
7	39.9976753	**17**	39.9976463	**27**	39.9976387	**37**	39.9976637	**47**	39.9975981
8	39.9976761	**18**	39.9976969	**28**	39.9976239	**38**	39.9976436	**48**	39.9976157
9	39.9976826	**19**	39.9976324	**29**	39.9976311	**39**	39.997614	**49**	39.9975882
10	39.9976727	**20**	39.9976484	**30**	39.9976107	**40**	39.9976323	**50**	39.9976112

5. VERIFICATION OF THE SUITABILITY OF THE MEASURING EQUIPMENT

As mentioned above, we focused on verifying the suitability of the measuring equipment according to a combination of methodologies from Ford and Bosch.

The actual value of the standard must be determined using measuring equipment with an accuracy of an order of magnitude higher. In this case, the nominal value is the calibration ring diameter of 39.9979 mm.

Based on research in the literature, we concluded that it is not recommended to use a method related to the variance of the process. This is because the variance of the process is often not known, especially for new processes and therefore cannot be used, or because of the change in variance during the process. [8]

Therefore, in this case, we use a calculation related to the field width of the specification T. The determined variance of the measured values is compared with a part of the tolerance field, namely 20% of the tolerance field.

The result is the calculation of the values of the coefficients Cg and Cgk, for which the Ford relations indicating the repeatability according to the used variant were used. Measuring equipment is considered suitable if Cg> 1.33 and Cgk> 1.33.

Thanks to the measured values for the fixed and the rotating measuring head, the eligibility indices of the measuring equipment were calculated and the minimum width of the tolerance field when the measuring equipment is still suitable was determined. (see table 3 - 6)

As part of the tests performed, both the width of the one-sided tolerance fields and the width of the two-sided tolerance field were evaluated.

a) Width of one-sided tolerance

Tab. 3: Calculated values for a fixed measuring head VAST GOLD

Fixed head VAST GOLD	
Mean measured value:	**39.99694**
Calculated standard deviation:	**0.00004**
Cg eligibility index:	**8.52982**
Cgk eligibility index:	**1.35401**
Upper tolerance limit:	**39.9979**
Lower tolerance limit:	**39.9865**
Tolerance field width:	**0,0114**

Tab. 4: Calculated values for a rotating measuring head VAST XXT

Rotating head VAST XXT	
Mean measured value:	**39.99765**
Calculated standard deviation:	**0.00003**
Cg eligibility index:	**4.04195**
Cgk eligibility index:	**1.38628**
Upper tolerance limit:	**39.9979**
Lower tolerance limit:	**39.9941**
Tolerance field width:	**0,0038**

b) Width of bilateral tolerance

Tab. 5: Calculated values for a fixed measuring head VAST GOLD

Fixed head VAST GOLD	
Mean measured value:	**39.99694**
Calculated standard deviation:	**0.0004**
Cg eligibility index:	**10.49477**
Cgk eligibility index:	**2.54861**
Upper tolerance limit:	**40.005**
Lower tolerance limit:	**39.991**
Tolerance field width:	**0.014**

Tab. 6: Calculated values for a rotating measuring head VAST XXT

Rotating head VAST XXT	
Mean measured value:	**39.99765**
Calculated standard deviation:	**0.0003**
Cg eligibility index:	**5.31836**
Cgk eligibility index:	**2.66269**
Upper tolerance limit:	**40.001**
Lower tolerance limit:	**39.996**
Tolerance field width:	**0.005**

6. CONCLUSION

The main idea of this article was to determine the minimum width of the tolerance field for fixed and rotating measuring heads, at which the measuring equipment is still suitable. The criteria from Ford and Bosch were used to verify the suitability, corresponding to the repeatability of the variant used. The gauge is considered suitable if Cg> 1.33 and Cgk> 1.33. During the measurement, the following was observed:

- the measurements were carried out by one person
- the measurement was performed with one gauge (measuring head) and it was not replaced during the measurement
- the measurement was performed in one way
- the same environmental conditions were ensured during the measurement

- the measurement took place in a relatively short time interval.

These conditions ensured a minimal effect on the measurement. The constant conditions did not affect the results of measuring. According to the results in the previous section, it is possible to compare the individual minimum widths of the tolerance field for each measuring head.

One-side tolerance. The results for the fixed head VAST GOLD show an upper tolerance limit of 39.9979 mm and a lower tolerance limit of 39.9865 mm. This means that the width of the tolerance field is 0.0114 mm. For the VAST XXT rotating head, the upper tolerance limit is 39.9979 mm and the lower tolerance limit is 39.9941 mm. This means that the width of the tolerance field is 0.0038 mm.

Similar results are obtained for the bilateral width of the tolerance field. The results for the VAST GOLD fixed head show an upper tolerance limit of 40.001 mm and a lower tolerance limit of 39.991 mm. This means that the width of the tolerance field is 0.014 mm. For the VAST XXT rotating head, the upper tolerance limit is 40.001 mm and the lower tolerance limit is 39.996 mm. This means that the width of the tolerance field is 0.005 mm.

Based on these results, it can be said that the VAST XXT rotary head has a tolerance field width 3 times smaller than the fixed VAST GOLD head.

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