IMPLEMENTATION OF COATING FOR FAILURE ELIMINATION OF DIAL GAUGES

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Abstract

One of very important requirements for measuring devices is fact that measured values of observed quantity will be in specific tolerance zone of actual value also after longer period of use. Deviations of actual value can be caused by several factors - improper handling with devices, inadequate maintenance and storing, aging of materials of which they are made and last but not least, by wear of single parts.

The target was to define the way of wear elimination of most faulty parts of dial gauges to obtain the maximum possible lifetime with minimal possible costs. Since, the using of more resistant material for producing of faulty part is difficult economically, for eliminating of wear, there was used the coating method for given part. By experimental results, it was choosen suitable way of coating.

Keywords: Coating, measuring devices, elimination of wear, lifetime

1. INTRODUCTION

Measurement can be defined as a summary of operations whose target is to set the value of a measured quantity. It serves as a source of information for scientific and technical development, process control, quality control of products, international production and economic cooperation. Measuring is a source of objective information and a basis of decision-making, objective assessment of state in all the spheres of society activities. To this purpose are used measuring instruments of all kindsand they serve to assign numbers to measured objects. The fact that measured values of measurands would correspond with the real value even after a longer period of use of measuring instruments within certain tolerances belongs to essential requirements of measuring instruments.

2. MECHANICAL DIAL INDICATOR

Mechanical dial indicators are measuring devices used to accurately measure small distances and angles. Measured linear movements are converted by the transformation mechanism to rotational movements of the pointer of the indicator. There exist several types of dial gauges with a gear, a lever, a pressure spring or a combined mechanism. At present also digital indicators with digital displays started to be used, but simple versions without additional functions as memory or indicators of pointers on display are not a full replacement of the traditional dial indicator. A control of threshold of measured components is much more difficult in case of dial display indicators than in a case of indicators with a pointer. [1,2]

The dial indicator *M2/10S* is the most frequently used in industrial practices.

2.1. Dial Indicator M2/10S

Thanks to the reinforced average of 5 mm of the stem is the type M2/10S particularly stable. **Fig. 1**. That is why it is suitable for special performances with the prolongation of the spindle up to 150 mm. The quality pre-load point protection by means of structurally modified pre-load wheels lowers a risk of damage of gears. Displayed measurements and thresholds represent metrological characteristics in accordance with DIN 878 together with DIN EN ISO 463. Measuring parts together with a clamping screw are produced of durable stainless corrosion-resistant steel. pointer. [3,4]

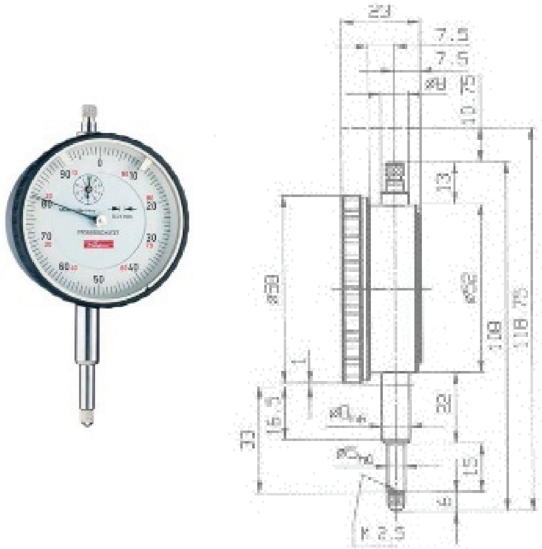


Fig. 1 The design of the dial indicator M2/10S [3]

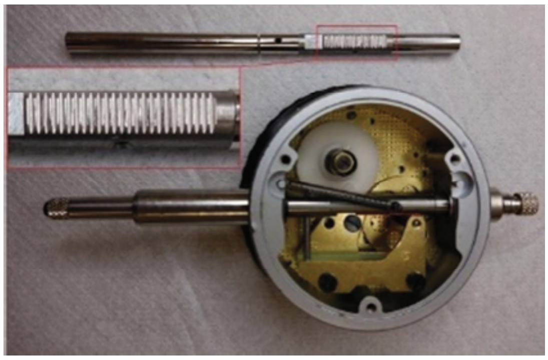


Fig. 2 A damage in the toothing of the measuring rod

3. ANALYSIS OF FAILURE RATE OF INDICATORS M2/10S, CHOICE AND SELECTION OF SUITABLE SOLUTION TO MINIMIZE FAILURE

3.1. Description of most frequent failure

Name of failure: Damaged toothing on the stem **Fig. 2**.

Problem*:* The usage of the measuring instrument causes depreciation of gears of the stem. It occurs in the point of the contact of a gear tooth of the stem with a toothed wheel.Depreciation indicates characteristics of adhesive abrasion. The adhesive abrasion is characteristic of mutually movably connected surfaces. It occurs when elements are scratched out in a sliding movement from one surface and, subsequently, they are moved onto the other surface.The size of abrasion is proportional to loading and the size of displacement and it is inversely proportional to hardness of material; in general, the minimal abrasion can be obtained by means of usage of different materials and hard surfaces. pointer. [5,6]

Type: Hidden failure

Failure demonstration: Abrupt movements of a toothed rod and its interruptions in several parts of the measuring process in haptic testing. It manifests deviations in all the measured parameters during control on calibrators.

Possible failure effects: Inaccurate measurements (confusions of measured pieces, risk of complaints)

Current solution of failure removal: A change of a defected spare part for a new piece from a producer.

3.2. Possibilities to minimize failure origin

Failure cause - Depreciation originates due to used materials of which a measuring rod is produced - the material is soft.

Possibilities - *To produce a new measuring rod* - to measure, design and to produce under contract a new measuring rod, however of different materials with a lower range of abrasion liability. This solution is not optimal from the reason of total high price (a price quotations € 20 ÷ 25Eur/1 pc in the series of 1,000 pcs.)

Modification of an original part purchased from a producer for the purpose of stabilization of surface - to select such a modification of the purchased part, in which there would occur an increase of abrasion resistance while present preservation of parameter accuracy of the toothing. The price of a new piece is ca. € 5 + the price of modification.

3.3. Material analysis

STEEL X6 CrI 7, (Slovak STN 17040)

Ferritic 17% Chromium Stainless *Steel* with fine corrosion resistance, good polishability, deep expansion and bendability. It tends to freeze when forming in temperatures below 20 °C. Its machinability is comparable with alloy carburized steels.

3.4. Choice of suitable technology to increase persistence of researched part

Modification of an original part purchased from the producer, for the purpose of stabilization of surface.

Hardening. Unsuitable - from the standpoint of carbon content and from the standpoint of high working temperatures and the required parameter accuracy.

Cementing Unsuitable - from the standpoint of hight working temperatures and the required parameter accuracy.

Nitriding Suitable - with regard to relatively low working temperatures and the requirement of preservation of high parameter accuracy.

Coating Eifeler TiN (Titanium nitride) Suitable - with regard to relatively low working temperatures, the requirement of preservation of high parameter accuracy, achievement of high hardness value.

The only suitable solutions from the above-stated modifications of the original part with the aim to harden the surface is to have the toothing thermochemically modified and, thus, via the following methods: plasma nitriding or coating based on the basis of titanium nitrade (TiN).

4. EXPERIMENTAL VERIFICATIONS OF PROPOSED ALTERNATIVES

Evaluation of abrasion resistance of materials regarding particular types of abrasion is very difficult due to complex phenomena that occure in abrasive processes. Tests are mostly performed in a special testing instrument in which the essential way of abrasion is simulated by a suitable modification of testing conditions and parameters of a tested body. We measure a weight loss, shape and quality of surface together with a change in parameters of the tested bodies during tests. pointer. [5,7,8]

4.1. Installment of particular measuring rods into dial indicator

The aim of testing is to determine in which type of surface modification of the measuring rod an indicator gauge withstands the highest number of application of repeated load cycles in a testing preparation. The stability of metrologic properties of an indicator gauge is continuously monitored after 30,000 cycles. The test is performed until the indicator gauge exceeds some of prescribed tolerances of measured parameters according to the standards applicable.

4.2. Usage of dial indicator with each measuring rod

Gradually, measuring rods with different surface modifications are installed to the same dial indicator. As the measuring rod is in a direct contact with a toothed wheel and measurement is transferred through a measurement contact, even these parts are constantly changed.

Without coating *Titanium nitride TiN* *Plasma nitriding*

Fig. 3 Surface modifications of measuring rods

4.3. Process of testing

Before testing it is necessary to confirm whether performed adjustments and the related parameter and material changes, e.g., coating thickness or thermal load on the measuring rods did not disrupt anyhow parameters of the toothing and thus the prescribed metrological characteristics.

An original part is tested at first to determine the number of cycles in which there occurs a loss of metrological characteristics of the dial indicator. A pneumatic test preparation was used to test particular formats of the dial indicator, **Fig. 4**. A pneumatic piston in the testing preparation imitates conditions of the usage of the dial indicator in manufacturing processes.

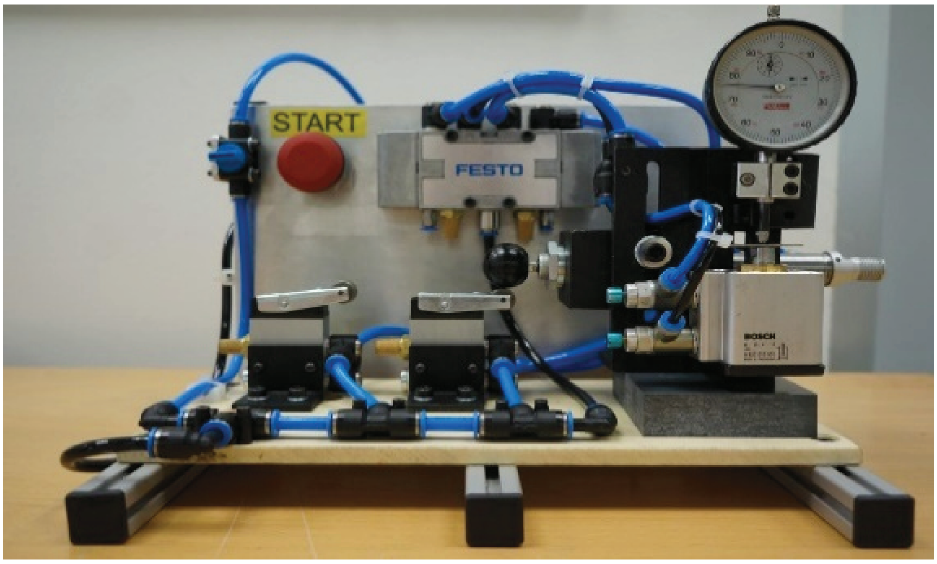


Fig. 4 Testing preparation

4.4. Measurements of metrological characteristics of particular variants of dial indicator during testing

The measuring inspection system MFP100 BV was used to measure and to evaluate prescribed metrological characteristics of the dial indicator, **Fig. 5**. [9,10]

Fully automatic for testing dial gages, dial comparators, lever-type test indicators and incremental and inductive probes. pointer. [9,11]

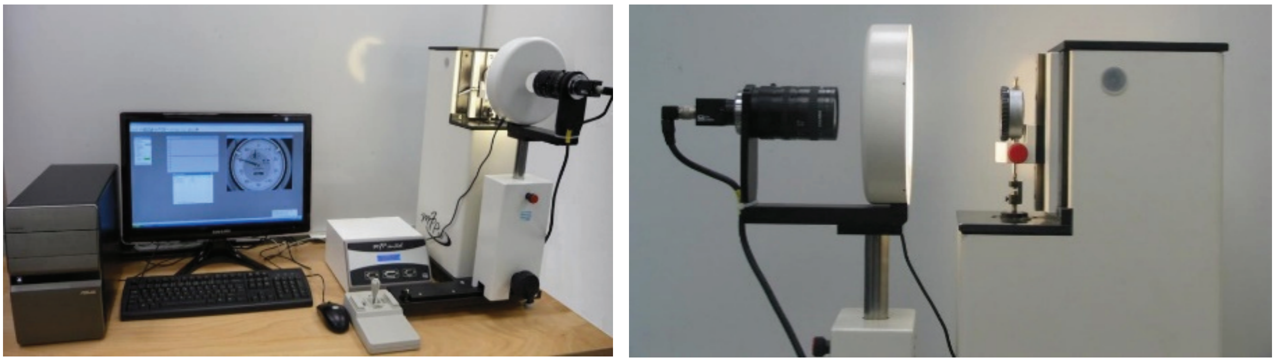


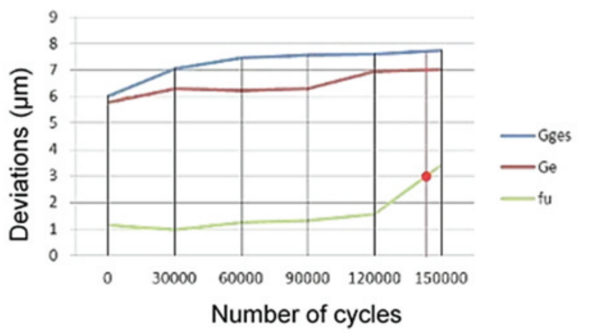
Fig. 5 The measuring inspection system for testing of calibration of dial indicators - MFP100 BV

The individual testing variants of the dial indicator were tested and continuously controlled after every 30,000 cycles until specified tolerances were exceeded, **Fig. 6**.

a)

Without modification (original parts from the manufacturer)	
Title / parameter	*Max. permissible deviation (μm)*
Margin of error at retraction and ejection the measuring pin/ Gges	17
Margin of error at retraction measuring pin / Ge	15
The largest deviation at retraction and ejection the measuring pin/ fu	3

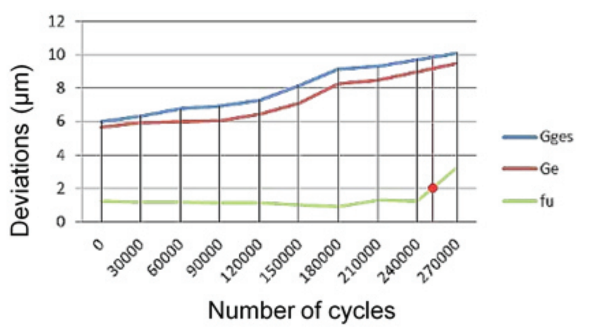
Number of cycles / Measured values (μm)			
0	*6.04*	*5.8*	*1.14*
30000	*7.06*	*6.3*	*0.99*
60000	*7.47*	*6.23*	*1.24*
90000	*7.56*	*6.29*	*1.33*
120000	*7.61*	*6.95*	*1.56*
150000	*7.76*	*7.03*	*3.41*
180000			
210000			
240000			
270000			
300000			



b)

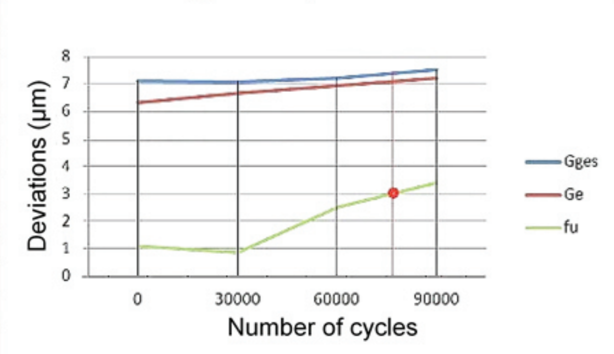
The type of coating measuring stick: plasma nitriding	
Title / parameter	*Max. permissible deviation (μm)*
Margin of error at retraction and ejection the measuring pin/ Gges	17
Margin of error at retraction measuring pin / Ge	15
The largest deviation at retraction and ejection the measuring pin/ fu	3

Number of cycles/Measured values (μm)			
0	*6.01*	*5.68*	*1.28*
30000	*6.35*	*5.98*	*1.22*
60000	*6.77*	*6.02*	*1.21*
90000	*6.93*	*6.04*	*1.18*
120000	*7.28*	*6.43*	*1.16*
150000	*8.18*	*7.14*	*1.04*
180000	*9.17*	*8.25*	*0.92*
210000	*9.3*	*8.52*	*1.33*
240000	*9.72*	*8.99*	*1.29*
270000	*10.1*	*9.48*	*3.24*
300000			



The type of coating measuring stick: TiN	
Title / parameter	*Max. permissible deviation (µm)*
Margin of error at retraction and ejection the measuring pin/ Gges	17
Margin of error at retraction measuring pin / Ge	15
The largest deviation at retraction and ejection the measuring pin/ fu	3

Number of cycles Measured values (µm)			
0	*7.12*	*6.32*	*1.09*
30000	*7.09*	*6.65*	*0.84*
60000	*7.23*	*6.94*	*2.51*
90000	*7.51*	*7.22*	*3.39*
120000			
150000			
180000			
210000			
240000			
270000			
300000			

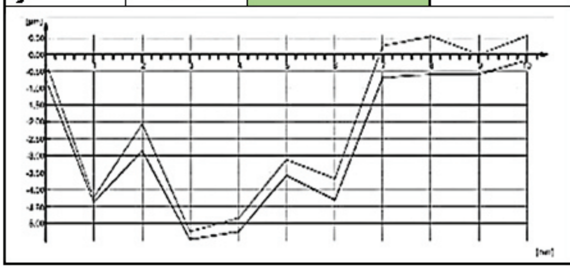


c)

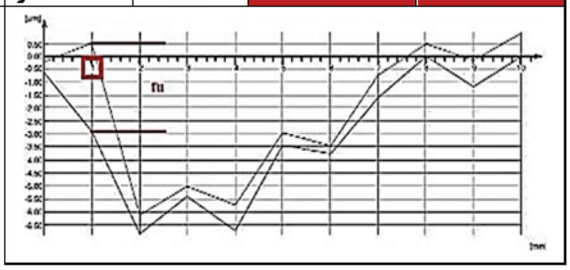
Fig. 6 Measured values for the measuring rod: a - without any adjustment, b - for plasma nitriding, c - for surface modification TiN

Graphs with measured values - before testing (0 cycles) and after testing, **Fig. 7**.

0 cycles			
Parameter	Tolerance	Measurement values (µm)	Divergence
Gges	17.0	6.01	-
Ge	15.0	5.68	-
fu	3.0	1.28	-

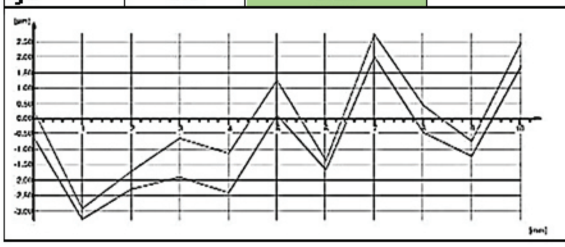


150 000 cycles			
Parameter	Tolerance	Measurement values (µm)	Divergence
Gges	17.0	10.01	-
Ge	15.0	9.48	-
fu	3.0	3.24	0.24

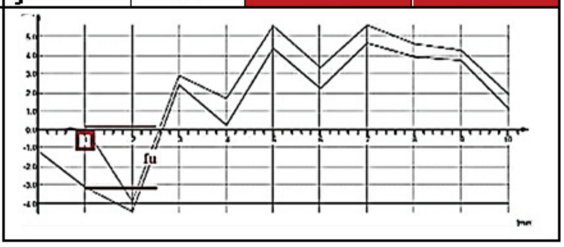


a)

0 cycles			
Parameter	Tolerance	Measurement values (µm)	Divergence
Gges	17.0	6.01	-
Ge	15.0	5.68	-
fu	3.0	1.28	-



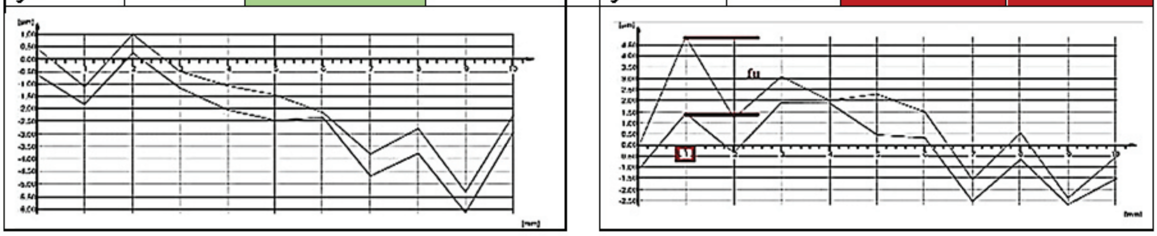
270 000 cycles			
Parameter	Tolerance	Measurement values (µm)	Divergence
Gges	17.0	10.01	-
Ge	15.0	9.48	-
fu	3.0	3.24	0.24



b)

0 cycles			
Parameter	Tolerance	Measurement values (μm)	Divergence
Gges	17.0	7.12	-
Ge	15.0	6.32	-
fu	3.0	1.09	-

90 000 cycles			
Parameter	Tolerance	Measurement values (μm)	Divergence
Gges	17.0	7.51	-
Ge	15.0	7.22	-
fu	3.0	3.39	0.39



c)

Fig. 7 A comparison of graphs of a dial indicator with a measuring rod: a - without any adjustment, b - for plasma nitriding, c - for surface modification TiN

From the stated measurements of the individual variants results the fact that the highest depreciation occured after inserting the measuring rod in the distance of 1 mm in the scale of the indicator and the main reason of a disposal of eligibility was the exceeding of the maximum deviation of a parameter f_u - *reverse range* - the miximum deviation in a measured period of inserting and ejecting (μm).

4.5. Measurement of depreciation of parts

As the toothed measuring rod is in a direct contact with the toothed wheel, the both parts must be measured. The amount of loss of material caused by depreciation on the most corrupted part of the toothing is compared. The *MarSurf XC 20* Contour Measuring *system is used to measure and evaluate the level of depreciation of the toothing,* **Fig. 8**.

Fig. 8 The *MarSurf XC 20* Contour Measuring *system* [12]

Analysis of depreciation of variants

After the **disassembly and control of the both parts we may allege the results stated from the Table 1.**

Table 1 Analysis of depreciation of tested parts

Depreciation analysis	*Toothed measuring rod*	*Toothed wheel*
Variant - without adjustment	the level of depreciation in the area of toothing visually apparent, values of depreciation measurable	the level of depreciation visually not detected, values of depreciation non-measurable by the apparatus
variant - surface modification TiN	the level of depreciation in the area of toothing visually apparent, values of depreciation measurable	the level of depreciation visually apparent, values of depreciation measurable by the apparatus
variant - plasma nitriding	the level of depreciation in the area of toothing visually not detected (black colour), values of depreciation measurable	the level of depreciation visually not detected, values of depreciation non-measurable in the apparatus

5. CONCLUSION

By performing of experimantal verifications, designed alternatives to eliminate of depreciation of a measuring rod of a dial indicator we come to the conclusion that:

1) The measuring rod without any adjustments (an original by its producer): 140,000, 5,000 +/- cycles
2) The measuring rod with the surface modification - TiN: 77,000, +/- 5,000 cycles
3) The measuring rod with the surface modification - plasma nitriding: 250,000, +/- 5,000 cycles.

As stated in the results of measurements of individual adjustments of a tested part of a dial indicator, the level of depreciation varies and, thus, also a number of load cycles in case of each adjustment.

In the total results of testing was found that the surface modification by *plasma nitriding* is the most suitable alternative from the tested ones, as it withstood the highest number of cycles while instant maintaining of a toothed wheel. The toothing of such adjustment of the measuring rod withstands 64,28 %t more cycles than the original part without any adjustment. The result represents a proof of an increase of its durability.

The surface modification of TiN is not suitable due to the present depreciation of the toothed wheel. A potential solution could be to have also the toothing of the wheel coated.

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