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IDENTIFICATION OF MAXIMUM INACCURACY OF TOOLMAKERS MICROSCOPE

Urgency of the research. *There are several types of measurement devices. Industrial practice needs simple, fast and cheap measurement system for inspection of produced parts. There is a need for system like toolmakers microscope.*

Target setting. *Toolmakers microscope is very popular because of its simplicity, but producer often do not provide information about the errors during the measurements.*

Actual scientific researches and issues analysis. *Toolmakers microscope uses two methods of measurements – micrometer head slides in two axes XY and CCD camera for measurements of very small dimensions.*

Uninvestigated parts of general matters defining. *The main problem is with expressing of uncertainty of measurements for both methods of measurements. There is no regulations and recommendation for using of both methods. The question of the probability distribution of measured values and number of minimum required measurements are uninvestigated, because the next research will be focused to this are.*

The research objective. *The aim is to obtain maximum permissible error of explored toolmakers microscope. On the base of this the uncertainty of measurement could be expressed. Uncertainty measurement is non-separable parts of measurement results.*

The statement of basic materials. *Gauge length blocks have been used for calibration of both measurement systems. Maximum permissible error has been estimated as math model for next using.*

Conclusions. *The toolmakers microscope is suitable device for fast and cheap measurement right in industry condition. The producer did not provide information about the accuracy of measurement on this device. Calibration process can be used for estimation of this maximum error achieved during the measurement via using this device. Also this approach can be used for estimation of actual condition of measuring device.*

Keywords: *optical microscope; distance; measurement; uncertainty; gauges.*
Fig.: 10. References: 10.

Introduction. This work will be focused on examination of Toolmaker microscope. A described device is optical measuring microscope for quick measuring of produced parts [1-3]. The microscope is mainly used for miniature parts or completed products. It enables fast measurement of dimensions, angles, deviations of shape and position etc. There are two basic groups of measuring microscopes used in engineering metrology – laboratory measuring microscope and toolmakers microscope (fig. 1). Laboratory microscope is more accurately but also more expensive than toolmakers microscope. The overall price of measurement depends also on price of measurement equipment. Toolmakers microscope is simpler and also cheaper solution. This type of microscope is good alternative in the comparison with the expensive coordinate measurement machines.

Fig. 1. Example of Laboratory measuring microscope (left) and example of Toolmakers microscope (right)

Toolmakers microscope is simple and easy to use. Standard toolmakers microscope (fig. 2) consists of vertical column with optical system with eyepiece and also CCD camera can be included. There are two lights. One is placed on the bottom and one is placed above the measured object. Measured object is placed on XY axis positioning table. The principle of measuring is lied on the precise positioning with table and optical system. Coordinate of position is sensed with micrometer head slide or CCD camera. If object is rotary, then rotary table

can be placed on the XY table for this purpose. Both coordinate X and Y is measured and evaluated for identification of measured dimension.

The main aim of this paper is to identify maximum inaccuracy of the toolmakers microscope. The type and producer of the microscope is not specified because of GDPR and protection of good reputation.

Expressing of all measurement should be coupled with expressing of uncertainty of measurement. Uncertainty is non-separable part of measurement result. The problem is in case, when producer does not express inaccuracy of microscope or it is necessary to verify. Calibration process is needed for this purpose and also it is necessary periodically to inspect if microscope fulfils the inaccuracy declared by producer.

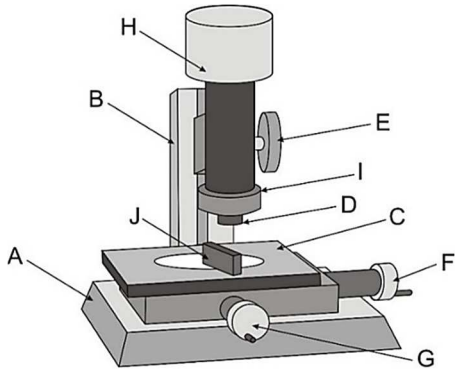

Fig. 2. Basic parts of Toolmakers microscope:
A – Base; B – vertical column; C – XY position table; D – optical system; E – focusing screw; F – micrometer head slide position in X-axis; G – micrometer head slide position in Y-axis; H – CCD measuring camera; I – upper light; J – measured object

1. Description of examined toolmakers microscope. Tested microscope is mainly assigned for measurement in production hall environment. Temperature is non-stable and also moisture can affects the properties of measurement equipment's. Also there is a risk of noise which can influence electrical systems. Signal from digital micrometer slide can be affected.

The tested microscope can be used for dimension measurement and also checking of gears and threaded parts. For these purposes a cross-hair or reticle should be implemented into optical systems, mainly into eyepiece of microscope. Reticles are used for fast checking. The checked thread or gear is compared with pattern on glass shown in eyepiece. This fast checking can be used for fast diagnosis of production processes and reduction of losses. For example, it shows that production device is damaged and it needs the maintenance or adjustment.

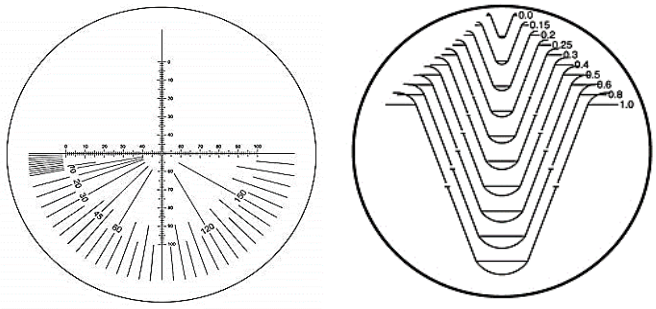

Fig. 3. Microscope cross-hair and microscope reticle for eyepiece

The microscope also enables to measure or inspect the electrical parts or their parts, defects of parts surface, which are not possible to measure with contacts methods. Printed circuits boards (PCB) are frequently checked for defects or mistakes from assembly process and soldered completed boards. Connectors are mechanically stressed and wear can be detected with microscope inspection.

Maximum optical enlargement of microscope can be achieved with combination of optical parts of microscope up to 200 times. Measured on inspected object is placed on XY position table coupled with micrometer slides for obtaining of position of the object in measuring plane. Micrometer slides have range 25mm and resolution 1μm. The inaccuracy of micrometer slides is declared with value of ±0.002 mm.

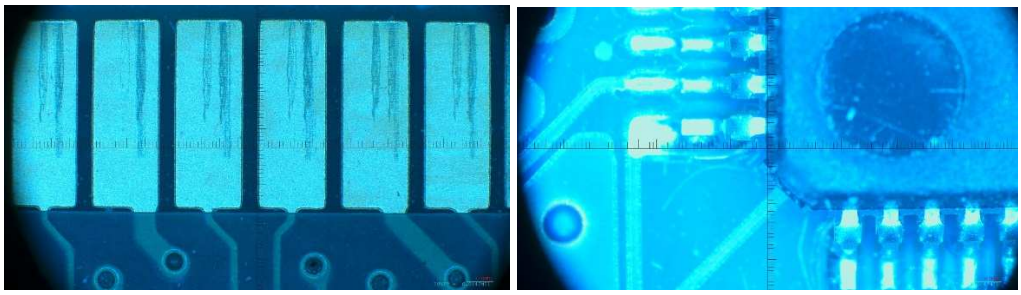

Fig. 4. Printed circuits boards' inspection via using of microscope

Micrometer slides have also digital output for another data processing and evaluation with external data units. Microscope also can be arranged with rotary table with swivel centre for measuring of shafts and threads.

Microscope includes bottom and up LED lights with adjustable intensity of light. In accordance with used light, measurement methods can be divided into these types:

- Measurement via using of transmitted illumination also called as "shadow method", where only bottom light is used. If part is non-transparent, shadow of part is visible in eyepiece and all measurements can be realised only on this shadow.
- Measurement via using of reflected illumination also called as "surface projection method", where up light is used for lighten of measured part.

In some special cases also combination of both these lights is necessary for obtaining of best measurement results.

Mechanical adapter enables to mount the CCD measuring camera with digital output. The provided software enables to measure dimensions, angles, radiuses, diameters etc. The camera provides images or video, where can be saved also moving processes. This system can be used for detection of failure in inspected system. The microscope optical system consists of lenses, optical prisms, mirrors and final visualization is made with CCD camera with any resolution defined in pixels. From the viewpoint of data reading, the microscope enables measuring via using of these methods:

- Measuring with CCD camera, where measurement result is number of image pixels and after calibration it is possible to assign concrete length unit to concrete number of pixels. Measurement can be realized with PC mouse by clicking to desired points on image of part. Range of measurement is limited with maximum dimension, which can be displayed on monitor.

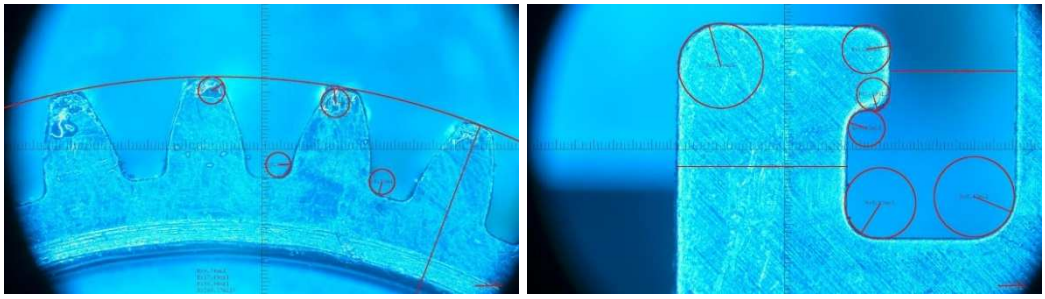

Fig. 5. Measurement by using the CCD camera

- Measurement with micrometric head slides and rotation table, where microscope crosshair is used for localization of required points on part image shown on display screen. The actual position is obtained from both micrometer heads mounted on slide of XY table. Angle value can be obtained from grade on rotation table placed on XY table.

Calibration is needful for both measurement methods. Calibration results give recommendation for using of both measurement systems. Which method is better for which range of lengths.

Fig. 6. Example of XY table with micrometer heads

2. Calibration of optical toolmakers microscope. The calibration process needs any suitable etalons. Microscope micrometer calibration ruler and calibration slide are frequently used in practice, because of simple using and manipulation with them. These etalons consist of length grades, lines with defined width, raster with defined spacing, circles with specified diameter, angles with specified value etc.

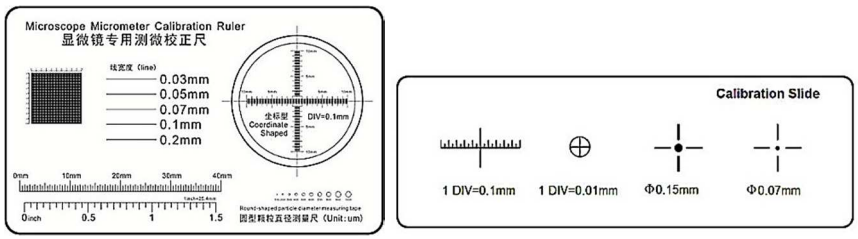

Fig. 7. Calibration ruler and MultiScale Micrometer Glass Slide for Microscope

However engineering metrology is based on calibration where standard is as Set of length gauge blocks. It consist of several blocks made with specified length with defined inaccuracy. Blocks are made from steel or ceramic. These etalons are following up with other superior etalons and there is available certificate about inaccuracy and uncertainty. In accordance with international standards (EALR-R2, ISO 3650), it is possible to use them for calibration of other measurement length devices.

Set of ceramic length gauge blocks have been used for calibration of optical toolmaker microscope. The calibration has been executed with gauges with nominal length in range from 1mm to 25mm with step 1mm.

Fig. 8. Length gauge blocks

Normally, calibration ruler is used for calibration of microscope, but in this work the set of gauge blocks has been used for this purpose as traditional etalon for engineering metrology.

CCD camera method has been calibrated in range from 1 mm to 6 mm and the maximum error was 29μm. Graph of measured values (fig. 9 left) shows growing tendency of measured error from gauge blocks. Reason of these results is probably low resolution of CCD camera system, which was only 0.01 mm. In this moment it is not possible to improve it.

Analogically, the micrometer head slide method has been calibrated with the same set of gauge blocks in range from 1 mm to 25 mm with step 1 mm. Obtained errors (fig. 9 right) have also growing character. The maximum error was 11µm. Mentioned calibrations have been executed only for X-axis and it is assumed that Y-axis will be similar. Resolution of micrometer head is 0.001 mm and it causes the better results than previous method. These results show that CCD camera is useful for dimension range up to 3 mm and for larger distances is better to use micrometer heads system.

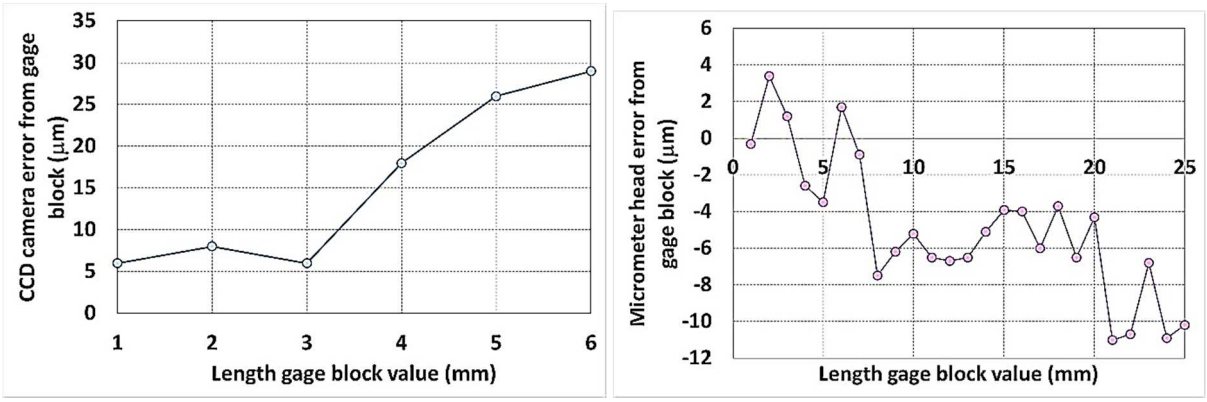

Fig. 9. Calibration of CCD camera measurement method (left) and Calibration of micrometer head measurement method (right)

Error in measurements was also affected by the focusing and identification of searched edge or point on inspected part. This phenomenon is very influenced by the experience of operator. The edge or point detection is the basic principle of the measurement on microscope. The operator has to know detailed information about the dimensional and shape topology of inspected part.

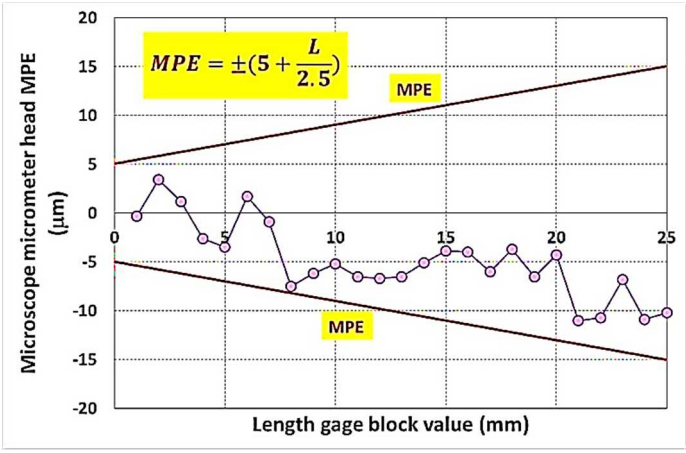

Fig. 10. Maximum permissible error MPE for micrometer head measurement method

The micrometer heads measurements can be assumed for better results obtaining. In accordance with standard ISO 10360 it is possible to use approach for evaluation of maximum permissible error – MPE. MPE describes maximum error which can occurs during the measurement using the equipment. For our microscope MPE is two line, which are borders of our obtained errors from calibration process. Normally it is described with linear model MPE = $A + L/B$, where A and B are constants of line equations (from fig. 10) and L is measured distance (in mm). After approximation and math correction it is possible to obtain math model of maximum permissible error MPE=5+L/2.5.

Conclusion. In practice the frequently used devices are coordinate measuring machines CMM and computer tomography scanners, but measurement on these devices are very precise

and also very expensive. These expensive devices need large place and need the air-conditioned room with special computer and software. Operating costs cannot be neglected.

Production practice frequently needs less precision but cheaper and fast measurements. The toolmakers microscope is suitable device for fast and cheap measurement right in industry condition. The producer did not provide information about the accuracy of measurement on this device. Calibration process can be used for estimation of this maximum error achieved during the measurement via using this device. This information is necessary for uncertainty balance, because every measurement results also include information about uncertainty of measurement.

The inspected part is produced on the base of technical drawing with specified tolerances which are as input requirements for measurements. This information is necessary for selection of measurement device. Operator for checking of the part often select CMM machine without adequate reasons and measurements is very expensive. All these aspects about the measurements and uncertainties have to be taken into consideration with inspection tasks during the production process [4-16].

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References

1. EA-4/02 M:2013 Evaluation of the Uncertainty of Measurement In Calibration. Publication Reference. European Accreditation Laboratory Committee. September 2013 rev 01. cited August, 8th, 2019. Available online: https://european-accreditation.org/wp-content/uploads/2018/10/ea-4-02-m-rev01-september-2013.pdf. EA-4/02 is a mandatory document belongs to Category: Application documents and Technical Advisory documents for Conformity Assessment Bodies.

National translation MSA-L/12 Expression of the Uncertainty of Measurement in Calibration (EA-4/02 M:2013).

2. ISO 3650:1998(E) International Standard, "Length standards – Gauge Blocks," International Organization for Standardization, Geneva, Switzerland.

3. ISO 10360-7:2011 Geometrical product specifications (GPS) -- Acceptance and reverification tests for coordinate measuring machines (CMM) -- Part 7: CMMs equipped with imaging probing systems.

4. KONIAR, D., HARGAS, L., SIMONOVA, A. et al. (2014). *Virtual Instrumentation for Visual Inspection in Mechatronic Applications*. 6th Conference on Modelling of Mechanical and Mechatronic Systems (MMaMS) Location: Vysoke Tatry, SLOVAKIA Date: NOV 25-27, 227-234.

5. TURYGIN, Y., & BOŽEK, P. (2013). Mechatronic systems maintenance and repair management system. *Transfer of innovations*, 26 (2013). 3-5.

6. HARGAS, L., KONIAR, D., SIMONOVA, A., HRIANKA, M., LONCOVA, Z. (2014). Novel Machine Vision Tools Applied in Biomechatronic Tasks. *Procedia Engineering*. Volume 96, 148-156.

7. CHUDÝ, V., PALENČÁR, R., KUREKOVÁ, E., HALAJ, M. (1999). Measurement of technical quantities (in Slovak). Edition of STU, 1st. ed., 1999. ISBN 80-227-1275-2

8. JCGM 100 – Evaluation of measurement data – Guide to the expression of uncertainty in measurement (ISO/IEC Guide 98-3). First edition September 2008. Available online: http://www.iso.org/sites/JCGM/GUM-JCGM100.htm; http://www.bipm.org/en/publications/guides/gum_print.html.

9. WIMMER, G., PALENČÁR, R., WITKOVSKÝ, V. (2001). Stochastic models of measurement. (In Slovak) Graphic Studio Ing. Peter Juriga, Ľ. Fullu 13, 841 05 Bratislava. 1st. ed., 2001. ISBN 80-968449-2-X.

10. KRYACHOK, S. (2019). Researches of criteria for determination of residual systematic errors in the results of double geodetic measurements unequal accuracy. *Technical sciences and technology*. No. 1 (15), 2019. ISSN 2411-5363 (Online) | ISSN 2519-4569 (Print). DOI:10.25140/2411-5363-2019-1(15)-258-266.

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ВИЗНАЧЕННЯ МАКСИМАЛЬНОЇ ПОХИБКИ ІНСТРУМЕНТАЛЬНОГО МІКРОСКОПА

Актуальність теми дослідження. *Існує кілька типів вимірювальних приладів. Промислова практика потребує простої, швидкої та дешевої системи вимірювання для контролю виготовлених деталей. Існує потреба в системі, подібній інструментальному мікроскопу.*

Постановка проблеми. *Інструментальний мікроскоп користується великою популярністю через його простоту, але виробник часто не надає інформацію про похибки, які виникають при вимірюванні.*

Аналіз останніх досліджень і публікацій. *Інструментальний мікроскоп використовує два способи вимірювань – мікрометричну головку, яка переміщується вдовж осей XY та CCD-камеру для вимірювань дуже малих розмірних величин.*

Виділення недосліджених частин загальної проблеми. *Основна проблема полягає у вираженні невизначеності вимірювань для обох методів вимірювань. Немає жодних правил та рекомендацій щодо використання обох методів. Питання ймовірності розподілу вимірюваних значень та кількості мінімально необхідних вимірювань не досліджено, тому наступні дослідження будуть зосереджені саме на цьому.*

Постановка завдання. *Метою є визначення максимально допустимої похибки досліджуваного інструментального мікроскопа. На основі цього може бути представлена невизначеність вимірювання. Невизначеність вимірювання – це невід'ємна частина результатів вимірювань.*

Виклад основного матеріалу. *Калібровані міри довжини були використані для калібрування обох вимірювальних систем. Максимально допустима похибка була визначена як математична модель для подальшого використання.*

Висновки відповідно до статті. *Інструментальний мікроскоп – це підходящий пристрій для швидкого та дешевого вимірювання безпосередньо в умовах виробництва. Виробник не надав інформацію про точність вимірювань на цьому пристрої. Процес калібрування можна використовувати для оцінки максимальної похибки, яка досягається під час вимірювання за допомогою запропонованого пристрою. Також цей підхід може бути використаний для оцінки діючого стану вимірювального приладу.*

Ключові слова: *оптичний мікроскоп; відстань; вимірювання; невизначеність; калібри.*
Fig.: 10. References: 10.

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