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REPEATABILITY AND VALIDITY OF THE MEASUREMENTS MADE ON TOOLMAKERS MICROSCOPE

Urgency of the research. *There are several problems with resulting of measurement result related to validity and repeatability of measurement device. Toolmaker microscope has been verified for these characteristics.*

Target setting. *Toolmakers microscope is as target device which is currently used for fast testing of manufactured prototype. Currently, it is necessary to know information about repeatability and validity of obtained results.*

Actual scientific researches and issues analysis. *Producer did not provide the maximum permissible error MPE, so the aim of this work was to establish the actual MPE for this microscope. Also there is no mention about repeatability of this machine. Normally in accordance with standards, it is required to express results with also with measurement error or uncertainty of measurement.*

Uninvestigated parts of general matters defining. *The main problem is with expressing of validity and repeatability of measurement process. The minimum number of measurement has been established and also maximum permissible error has been identified. Producer provides own microscope etalon as calibration ruler and multiscale micrometer glass slide for microscope. The question of the validity of these etalons are uninvestigated, because the next research will be focused to this problem.*

The research objective. *Too log measurement process will unnecessarily over-price overall costs for measurement process. But insufficient number of measurements will decrease accuracy of measurement and overall uncertainty of measurement. Verification process of microscope has been executed for obtaining the information about maximum error of microscope. This information is also necessary for balance of the uncertainty of measurement made on this microscope.*

The statement of basic materials. *The probability distribution of measured values and number of minimum required number of measurement has been obtained from mentioned analysis.*

Conclusions. *Validity and repeatability of measurement device bring the information how we can believe to measurement process with specified measurement device. Every measurement device should be verified for these metrological properties. Repeatability obtained for examined microscope shows information about the number of measurement needed for effective measurement from the viewpoint of optimized inaccuracy and also from the viewpoint of economic costs. Measurement process is very expensive, so it is necessary to do economy optimization because of ability to be competitive on the market.*

Keywords: *optical microscope; distance; measurement; validity; repeatability.*

Fig.: 6. References: 14.

Introduction. This work tries to solve problem of validity of measurement which are made on Toolmaker microscope. Validity and repeatability are the most important key properties of measurement devices for evaluation of state of the device. Both repeatability and validity evaluate the quality of research. The quality of measurement process is very important for the making of decisions. If there is no quality of measurement, then it is not possible to make good decision.

Repeatability gives information about consistency of measurement results for multiply repeated measurements of any quantity. Repeatability describes the stability of process of finding of the measurement of measurement quantity. Process of the measurement is influenced by the various errors. Systematic and observational errors can be identified and eliminated. But random errors can be reduced only via using of repeated measurements and making the average from many measurements of quantity. But there is a problem, because if we will increase the number of repeated measurement then also overall price of the measurement will rapidly grows. Consequently, there is a question: "How many measurement is necessary to do for the obtaining of the best repeatability of measurement result?" If random error is minimized then measurement result repeatability is very high. It is necessary to find, how many minimum repeating of measurement is necessary to do. It is possible to find it only with detailed analysis of large count measurements. Optimum number of measurement will say about necessary repeating but it depends also on character of measured quantity. For some cases, another increasing of measurement repeating will not improve repeatability but it will increase only the overall costs of measurement. For these reasons it is a key role to identify optimum number of measurement repeating.

Validity responses on the question about the trustfulness of the measurement results for any measured quantity. If systematic errors are minimized then it is possible to say that we have valid measurement result.

If the measurement is not reliable then also it is not valid.

Toolmaker microscope will be analysed in this paper for the reaching of the validity and repeatability of the measurements on this equipment. The microscope is used mainly for the inspection and measurement of machine and electrical (fig.1) or other type of parts (filters and dust particles) (fig. 2). In compare with coordinate measurement machines (CMM), the microscope allows fast measurement with lower price. Also price of the microscope and overall using costs on the microscope are greatly lower than on CMM machines [1-4]. Here is no mention about the type and producer of microscope because of General Data Protection Regulation.
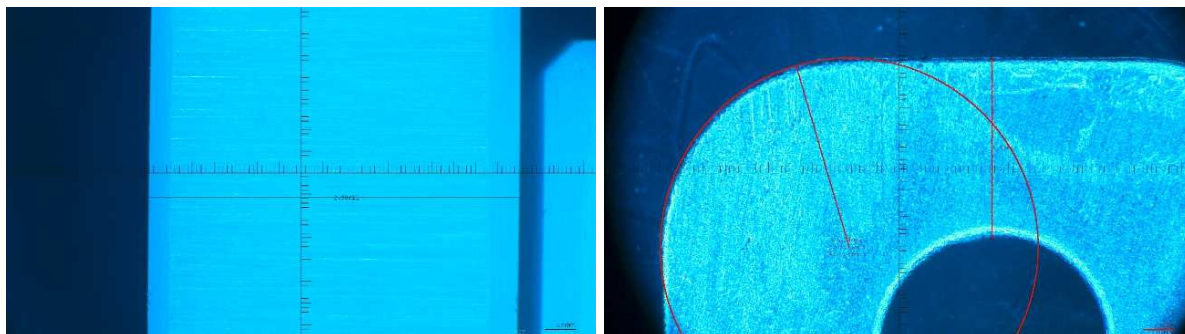

Fig. 1. Measurement of mechanical parts using the toolmakers microscope
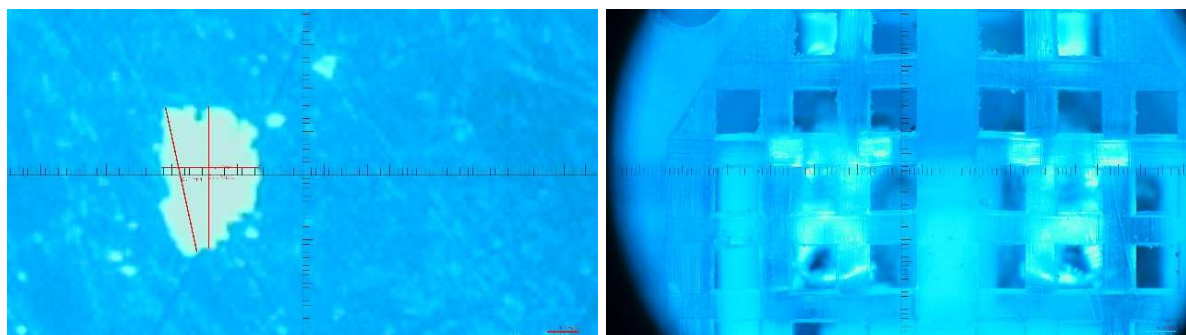

Fig. 2. Measurement of dust particles

Tested microscope is designed for using in laboratory and also in production hall environment. If it will be used for quality checking of parts, it is necessary periodically to check the repeatability of the microscope [4].

1. Measurement repeatability of examined toolmakers microscope. Repeatability of the microscope depends on numbers of measurements. For this reason it is necessary to identify suitable number of measurement. Standard deviation describes variation or disperse of set of measured values. It is a statistical quantity, that is related to average value and it is obtained as square root of the variance through the determination of variation of each value to average value. Variation of measured value is defined as subtraction of measured value from the average value. Every these subtraction is squared and summed. Square root of this sum is searched standard deviation of measured values.

In this work one hundred measurement have been executed for six selected values in all range of microscope. These measured data are analysed via using histograms (fig. 3). Histogram is graphical representation of distribution of measured values. It is as bar graph, which is composed from series of intervals and all values are sorted into these interval with equal size. Bar graph shows a count of values in every interval. Height of bar is proportional to the count or frequency of values, which belong to this interval. Number of interval can be obtained from Sturgess equation [5]:

$$k_{hist} \doteq 1 + \log_2 n_M , \qquad (1)$$

where n_M is a number of values.

Scott equation also respects also disperse and span of values [6]:

$$k_{hist} = \frac{R_R}{3.49 \cdot S_X} \cdot n_M^{\frac{1}{3}}, \qquad (2)$$

where R_R is span of measured values, S_X is standard deviation, n_M is number of measured values.

Histograms show which data distribution law is valid for these measured values. Figure 3 shows, that we can assume the normal (Gaussian) distribution law for obtained values (fig. 4). It is most frequently used continuous probability distribution of measured data representation. Bell curve is characteristic for this distribution shows that most of values are placed close to average.
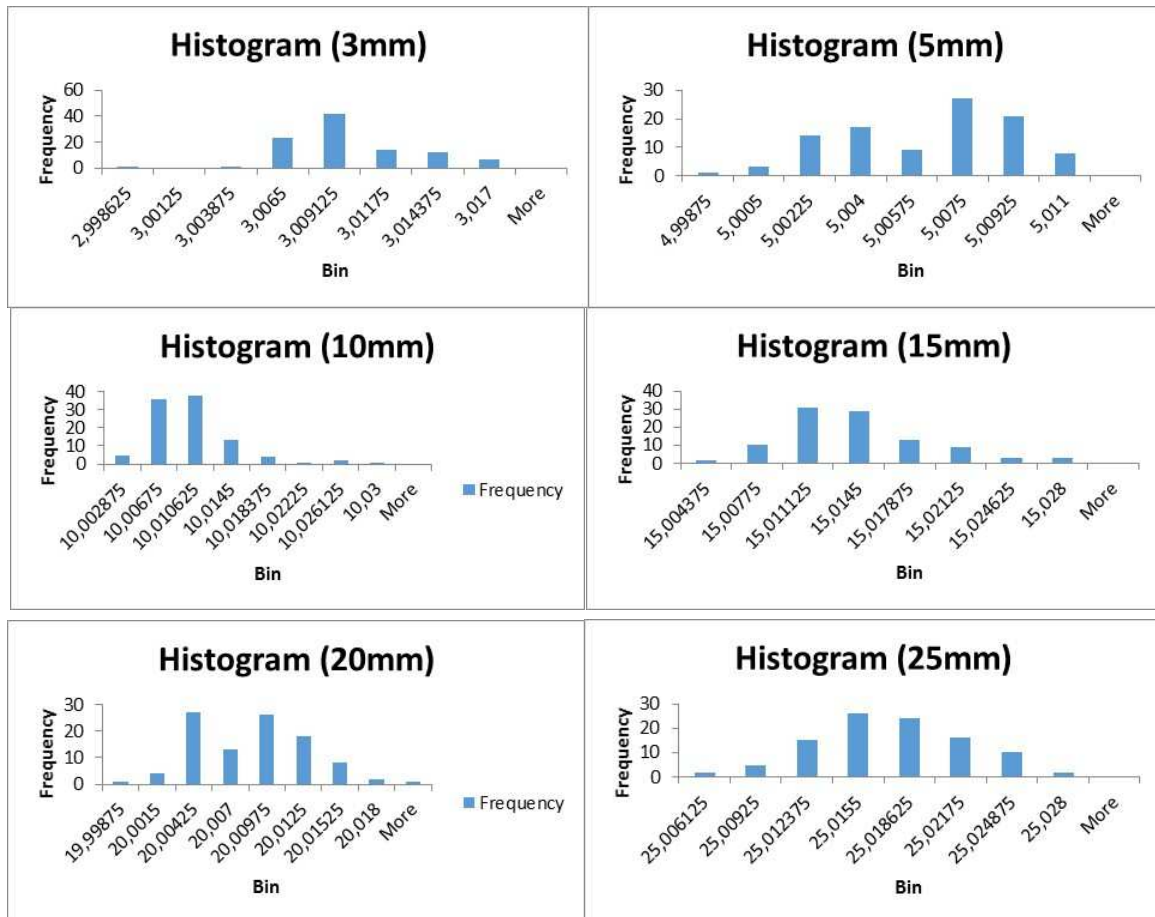

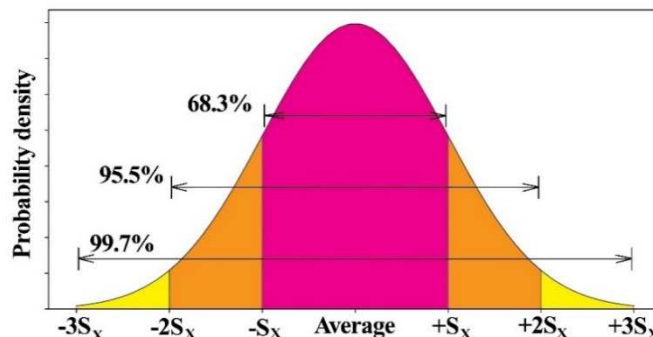Fig. 3. Histograms for selected dimensions

Fig. 4. Probability density for normal Gaussian distribution

Approximately 68% of values are placed inside interval with plus and minus one standard deviation of the average valued. If we assume plus minus two standard deviations interval, then 95% of values become to this interval and if we will take interval plus minus three standard deviations, then 99.7% of values are inside this interval around the average.

Standard deviation from these values have been evaluated (fig. 5). For comparing the cumulative standard deviations are done for first ten measured values, then for first twenty measured values and so on up to the standard deviation of all (hundred) measured values. Consequently, it is possible compare data dispersion when we will add next ten measured values. Figure 5 shows the cumulative standard deviations and it gives answer to question "How many measurement is necessary to execute?" Best repeatability is obtained for 50 measurements. Next measurement do not improve the repeatability of measurement or contribution is only minimally.
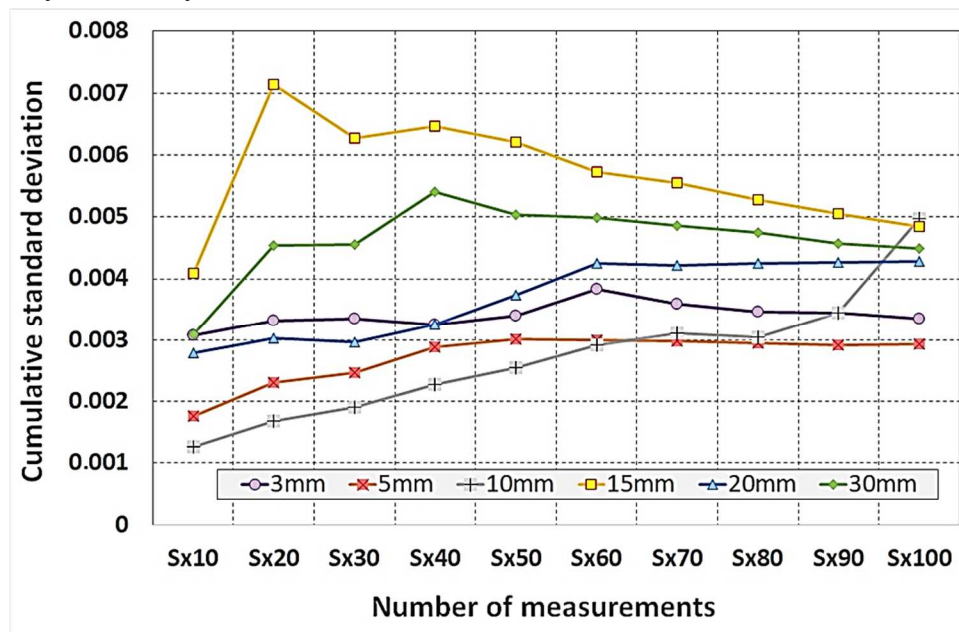

Fig. 5. Cumulative standard deviations for obtained values

2. Measurement validity of examined toolmakers microscope. Validity is an ability of measurement device to return quantity value, which we want to measure. It evaluates whether the measurement process returns accurate measurement result and whether the suitable measurement device have been used.

Calibration process returns the answer about ability of measurement device to measure any quantity with requested accuracy. It means that it is need to do comparison of measured value with value represented on etalon gauge. International standards (EALR-R2, ISO 3650) provides necessary steps for calibration process [7, 8].

Maintenance staff often meet with terms as calibration and verification. International Vocabulary of Metrology (VIM) [9] defines verification as process measurement devices is tested if it is able to fulfil requirements as for example maximum permissible error MPE. Verification checking the calibration results or actual state of measuring machine with specified requirements defined by manufacturer or legal metrology organisation or customer which is as end user.

International Vocabulary of Metrology (VIM) [9] also defines term calibration as process where it is obtained relationship between the value from indicator and value obtained from reference material or etalon.

Maximum permissible error MPE obtained by the ISO10360 is also as evaluation of validity of examined microscope. Maximum permissible error is maximum error normally guaranteed by producer of measurement instruments. But there is a many measurement instruments, where producer does not provides this information. Math model from experimental data (fig. 6) has form MPE=5+L/2.5, where L is measured dimension (mm) and MPE is resulted in μm.
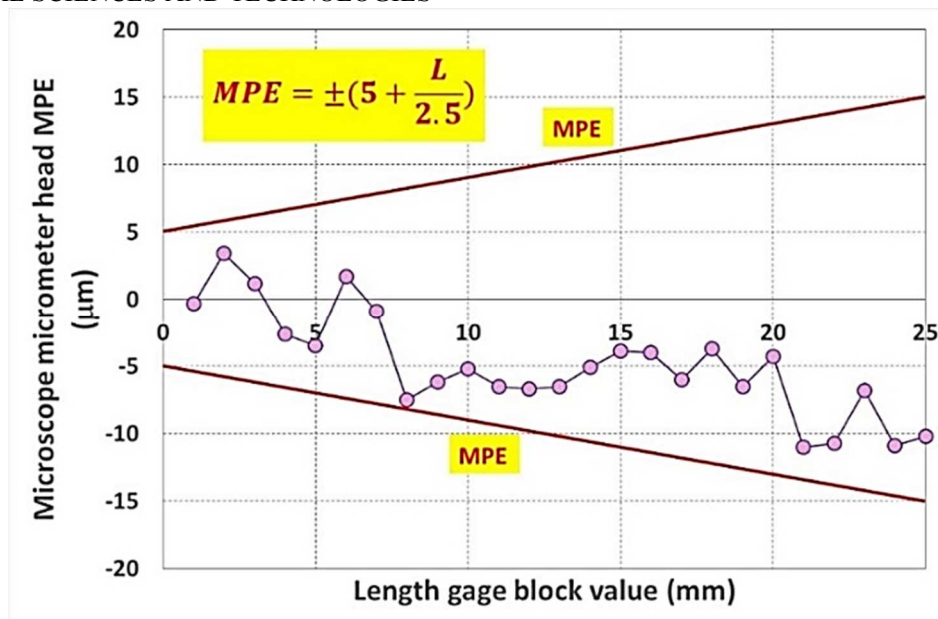
Fig. 6. Maximum permissible error MPE for Toolmaker microscope

Conclusion. Validity and repeatability of measurement device bring the information how we can believe to measurement process with specified measurement device. Every measurement device should be verified for these metrological properties. Repeatability obtained for examined microscope shows information about the number of measurement needed for effective measurement from the viewpoint of optimized inaccuracy and also from the viewpoint of economic costs. Measurement process is very expensive, so it is necessary to do economy optimization because of ability to be competitive on the market. Too log measurement process will unnecessarily over-price overall costs for measurement process. But insufficient number of measurements will decrease accuracy of measurement and overall uncertainty of measurement. Verification process of microscope has been executed for obtaining the information about maximum error of microscope. This information is also necessary for balance of the uncertainty of measurement made on this microscope. Producer did not provide the maximum permissible error MPE, so the aim of this work was to establish the actual MPE for this microscope. The evaluation of MPE also shows, that it has downward trend and it can be partially compensated with separation of systematic error from this error balance. The main advantage of this microscope is fast measurement process and also low overall costs in comparing with coordinate measuring machines [10-17].

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Тетяна Келеменова

ПОВТОРЮВАНІСТЬ І ДОСТОВІРНІСТЬ ВИМІРЮВАНЬ, ЗРОБЛЕНИХ ЗА ДОПОМОГОЮ ІНСТРУМЕНТАЛЬНОГО МІКРОСКОПА

Актуальність теми дослідження. *Проблема оцінки повторюваності та достовірності засобів вимірювальної техніки (ЗВТ) є надзвичайно важливою на даному етапі. Дана робота присвячена оцінці цих характеристик для мікроскопу.*

Постановка проблеми. *Мікроскоп - це пристрій, який використовується для швидкого тестування прототипів. Для достовірності оцінки зразків важливими є метрологічні характеристики цього засобу вимірювальної техніки.*

Аналіз останніх досліджень і публікацій. *Виробник у технічній документації не надавав гранично допустиму похибку ЗВТ, тому метою даної роботи було встановити фактичне значення похибки для цього мікроскопа. Також відсутня інформація щодо повторюваності для цього ЗВТ.*

Виділення недосліджених частин загальної проблеми. *В якості встановлення метрологічних характеристик досліджуваного мікроскопу виробник забезпечує власний еталон як калібрувальну лінійку. Питання про обґрунтованість цих еталонів не досліджено, отже наступне дослідження буде зосереджено на цій проблемі.*

Постановка завдання. *Основними завданнями, які вирішуються в даній роботі є встановлення економічно-обґрунтованої кількості вимірювань, для забезпечення необхідної точності та аналітичного виразу, що характеризуватиме основну інструментальну похибку вимірювання.*

Виклад основного матеріалу. *Проведено аналіз експериментальних даних вимірювань лінійних розмірів за допомогою оптичного мікроскопу. Побудовані гістограми розподілу результатів вимірювань для об'єктів від 3 до 25 мм. Оцінено залежність невизначеності вимірювань лінійних розмірів за типом А від кількості експериментів. На основі представлених залежностей визначено економічно доцільну кількість спостережень, необхідну для отримування результатів із заданою точністю. На основі аналізу експериментальних даних методами лінійної регресії визначено аналітичний вираз для меж інструментальної похибки в залежності від значення лінійних розмірів.*

Висновки відповідно до статті. *На основі експериментальних досліджень визначені характеристики достовірності вимірювань у вигляді аналітичного виразу меж граничної інструментальної похибки. Досліджено повторюваність результатів для цього мікроскопу. Обґрунтовано кількість вимірювань, необхідних для ефективного вимірювання з точки зору оптимізованої точності, а також з точки зору економічних витрат. Процес вимірювання дуже дорогий, тому необхідно здійснювати оптимізацію економічних витрат для можливості бути конкурентоспроможними на ринку.*

Ключові слова: *оптичний мікроскоп; відстань; вимірювання; достовірність; повторюваність.*
Рис.: 6. Бібл: 14.

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