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TOLERANCES AND DIMENSIONAL CONTROL

Laboratory works for foreigner students

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Laboratory work no. 1

LINEAR DIMENSIONS CONTROL
WITH GAUGE BLOCKS

Control of external and internal dimensions with gauge blocks.
Control of external and internal dimensions with limitative gauges/ fixed gauges.

Applications to be made at Laboratory work 1:

a. control of linear dimensions with gauge blocks;
b. control of linear dimensions with limitative gauge/fixed gauges.

1. Purpose.

Knowledge of gauge blocks and their use, knowledge of the formation of gauge blocks; the use of this gauges to measure dimensions by the method of direct evaluation.

Knowledge of the constructive types of limitative gauges or fixed gauges for checking the exterior and interior surfaces dimension, knowledge of the use of limit plug gauges, single-jaw snap gauges, double-jaw snap gauges and setting ring gauges; knowledge of how to check exterior and interior surfaces dimension with these limitative/ fixed gauges.

2. Control of linear dimensions with gauge blocks

2.1. General Considerations

Gauge blocks (also known as gage blocks, Johansson gauges, slip gauges, or Jo blocks) are a system for producing precision lengths. The individual gauge block is a metal or ceramic block that has been precision ground and lapped to a specific thickness. Gauge blocks come in sets of blocks with a range of standard lengths. In use, the blocks are stacked to make up a desired length (or height).

Gauge blocks are terminal measures which materializes, between two flat and parallel surfaces, a length; they are rectangular shapes with neatly prepared surfaces, two of them flat and parallel to each other), as work surfaces, SL or active (or measuring).

The length that a gauge blocks it materializes between active areas, as the distance between the working surfaces, measured at their middle represents the median length, lm, and its value is entered in a non-active surface of the gauge block, being his nominal dimension (Fig. 1.).

Gauge blocks are supplied in kits with gauge blocks, in which there are arithmetic series with various ratios:0.001 mm, 0.01 mm, 0.1 mm, 0.5 mm, 1 mm, 10 mm, 25 mm, 100mm, a kit with gauge blocks includes a few series (3-4 series, not to be bulky) so as to afford a larger number of different sizes.

The set with gauge blocks used in laboratory contains 4 arithmetic series(tab.1).

Table 1.

Series	Ratio [mm]	Nominal lengths for gauge blocks [mm]
1	0,001	1,001; 1,002; …………;1,009
2	0,01	1,01; 1, 02;……………; 1,49
3	0,5	0,5; 1; 1,5; 2; 2, 5……….; 9,5
4	10	10; 20; ....…………;90; 100

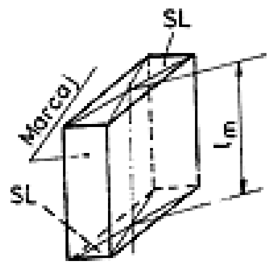


Fig. 1.

Gauge blocks are arranged I sets, thus making it possible to obtain gauge-block combination of any length up to the third decimal within a given range.

Sets of gauge blocks are accompanied by accessory set for gauge blocks (which include: marginal gauge blocks, gauge blocks frames and support staff) needed to measure lengths using direct evaluation method.

In figure 2 is presented the block gauge set with four series, and in figure 3 is a set of the accessories

Figure. 2. Gauges block set
1-series I (ratio 0,001 mm); 2-series II (ratio 0,01 mm);
3-seriesIII (ratio 0,5 mm); 4-series IV (ratio 10 mm)

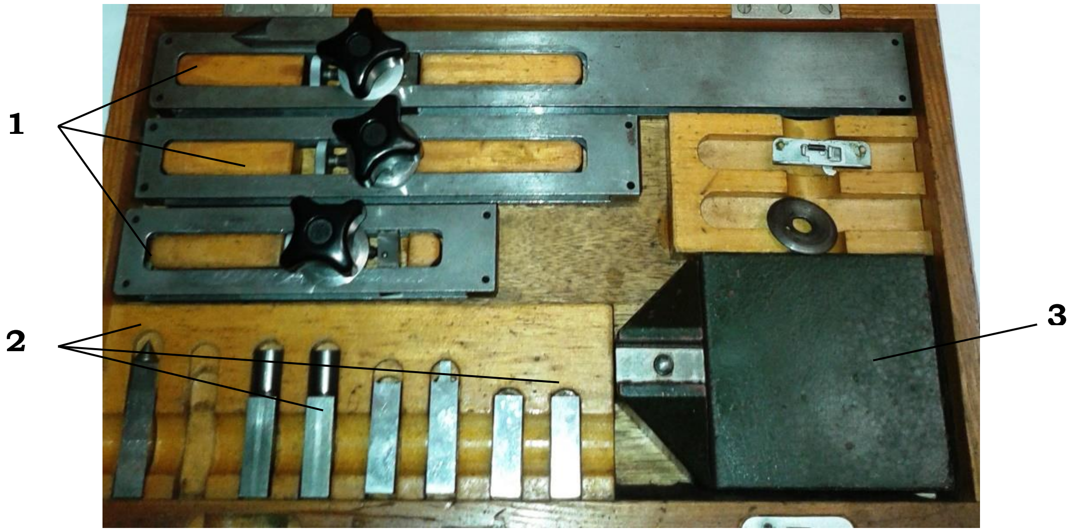


Fig. 3. Gauge block accesories set
1-frames for gauges block;
2- marginalgauge bolcks (flat or cylindrical jaw),
3- suport

2.1.1. Gauge blocks properties

- **high dimensional accuracy**, error which materializes the medianlength of a gauge block is very small (compared with other instruments), micrometer unit to micrometer fractions (depending on the class precision of the gauge block). Depending on error manifestation of median length and deviation from parallelism of the active surfaces, gauge block is divided into five classes precision
- **high dimensional stability**, gauge block retains a long time thedimension materialized between active areas, for it is made of materialsthat have high structural stability in time: stainless steels, carbide and ceramic;
- **wringing ability** is owned by a gauge to accede, with the active surface, to the activesurface of another gauge block with a force large enough to obtain plane-parallel gauge blocks with various dimensions; a gauge block is a combination of plane parallel gauges with surfaces that adhere together by active surfaces, in order to materialize length different than the length of the plane-parallel gauges from kit.

Wringing is the process of sliding two blocks together so that their faces bond. Because of their ultra-flat surfaces, when wrung, gauge blocks adhere to each other tightly. Properly wrung blocks may withstand a 300 N pull. While the exact mechanism that causes wringing is unknown, it is believed to be a combination of:

- Air pressure applies pressure between the blocks because the air is squeezed out of the joint
- Surface tension from oil and water vapor that is present between the blocks
- Molecular attraction that occurs when two very flat surfaces are brought into contact; this force causes gauge blocks to adhere even without surface lubricants, and in a vacuum

2.1.2. Formation of gauge blocks

To form a gauge block to measure means to determine the number of gauge blocks and their size, necessary for the materialization of a given length. The correct formation of this gauge blocks will follow the rules:

- the number of gauge blocks in a combination should be minimal because the deviations from nominal length of gauge blocks are cumulated, itwill use as few gauge blocks (for the same reason do not use more than five-gauge blocks to form a combination).

-determining the necessary dimensions of the gauge blocks is done by subtracting, on turn, from pack size to be formed, the length of each gauge blocks, starting with the gauge block from the series with the lowest ratio (example 1).

- when the decimal value is greater than 0.5, deduct an amount so as to remain decimal 5 (choosing a gauge block from series with ratio0.01 m) in this way we can use then a gauge block from theseries with ratio with 0.5 m (Example 2).

Example 1:	**Example 2:**
178,231 mm −	178,939 mm −
1,001	**1,009**
177,23 −	177,93 −
1,23	**1,43**
176 −	176,5 −
6	**6,5**
170 −	170 −
70	**70**
100	**100**

Conclusions:

• example 1: in order to materialize the dimension with the size of 178.231 mm: 5 flat-parallel gauge blocks are required: 1.001 mm, 1.23 mm, 6 mm, 70 mm and 100 mm;

• example 2: in order to materialize the dimension with the size of 178.939 mm, 5 flat-parallel gauge blocks are required: 1.009 mm, 1.43 mm, 6.5 mm, 70 mm and 100 mm;

2.1.3. Measuring linear dimensions with help of the gauge blocks.

Measuring linear dimensions with gauge blocks may be done in two ways:

- direct measuring method consists in the introduction of the measured value between the areas for measuring and determining the value measured using a gauge block pack of known value

Measurement by this method consists in the formation of a pack of gauge blocks in length equal to the nominal size which is measured and by adding it in a frame from accessories for gauge blocks between two flat or cylindrical jaws (marginal gauge), in this way between the operative surfaces of jaw materializes nominal dimension of the size to be measured. For fixing the amount of effective size, the part is inserted between the operative surfaces of the jaws so that it easy to be entered without game and with a slight friction (fig.4. a.) if the part is complying with this requirement, it may be established that the actual size is equal to the nominal one, reflected the pack of gauge blocks. If the part enters with game, or, instead, does not enter between the jaws, it means that size is different from the nominal value, we change (minus or plus) the size of the block ofgauge until the piece will enter easy, without game between thejaws, time when it is obtained the actual value equal with size of the block of gauge located in the frame. For measuring internal dimensions, it is proceeded in the same way, specifying that in formation of the block of gauge aretaken into account thickness of the cylindrical jaws which is subtracted from nominal value and the resulting size will be materialized by the block of gauges (fig.4.b).

Note: The method is accurate (using only the gauge block with highdimensional accuracy), but it is laborious, several attempts are necessary because of changes in the size of the stack of gauge blocks.

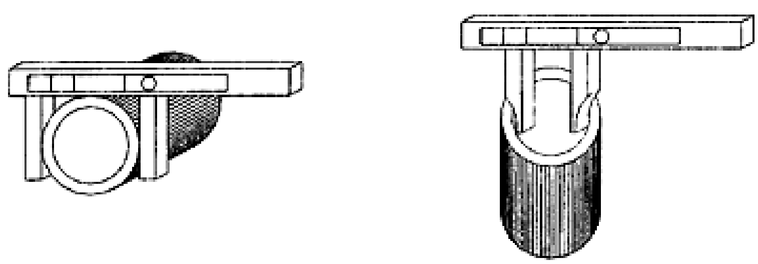


Fig. 4.

- difference method, involves the difference between a measured position and size, measure (length equal with the nominal value of measured size) which is used for zeroing the dial indicator device used.

Note: for difference method in measuring length, the gauges blocks are used only as a means for zeroing dial indicator (is to be seen in paper 2).

3.1.Measurement of linear dimensions with gauge block by the direct evaluation method

This method it is compared the dimension to be measured with a gauge block of known value

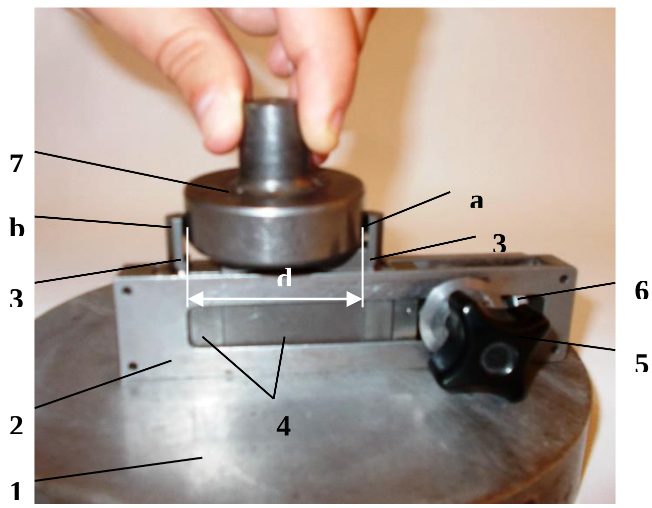
3.1.1.Measurement of external dimensions with gauge blocks

Required equipment and accessories: gauge blocks kit, gauge blocks accessory set, active surface check plate.

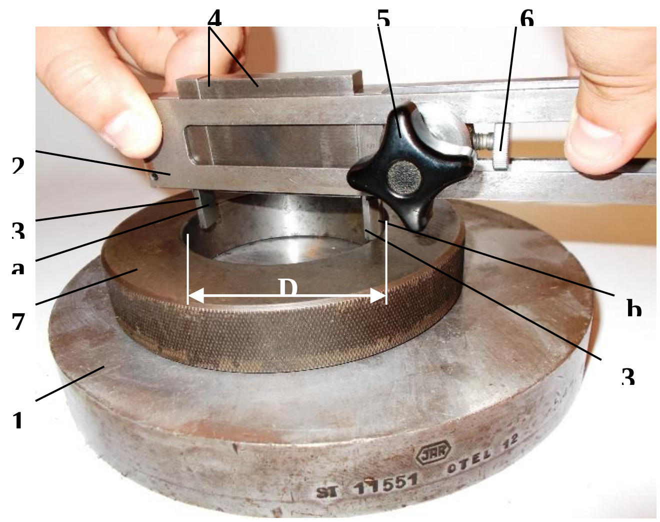
Measurement technique.To measure the diameter *d* of the workpiece 7, a gauge blocks 4 is formed, with a length equal to the nominal value of the dimension to be measured;it is inserted in frame 2, between two flat jaws 3 and, with screws 5 and 6, the blockis locked in frame 2 (fig.5. a.).

In this way, between the plane active surfaces a, of the flat jaws (marginal gauges) 3, the nominal value of the dimension to be measured materializes. The whole assembly is placed on the active surface of the check plate 1.

In order to establish the effective value of the dimension *d*, the part to be controlled is inserted between the active surfaces of the flat jaws, so that it enters easily, without game, with a slight friction (if this condition is observed, it can be estimated that the effective size is equal to the nominal one, materialized by the gauge blocks.



a



b

Figure5. **Dimensional control with the gauge blocks**
a.- external dimension; b- inner dimension

Following these steps, the following situations may occur:

• if is accomplished the condition as the controlled part enters slightly, without game, with a slight friction, between the active surfaces of the flat jaws, it can be considered that the effective size is equal to the nominal one, materialized by the gauge block;

• if the piece comes into with some game between the flat jaws, it means that it has an actual size smaller than the nominal value; then, the size of the gauges block is changed (minus) until the piece enters easily, without game, between the flat jaws, at which point the actual value is obtained, equal to the size of the gauges block in the frame for who complied with the condition;

• if the piece does not fit at all between the flat jaws, it means that it has a size larger than the nominal value; then, the size of the gauges block is changed (in addition) until the workpiece enters easily, without game, between the flat jaws, at which point the actual value is obtained, equal to the size of the gauges block in the frame.

3.1.2.Measurement of inner dimensions with gauge blocks

The measurement technique consists in the materialization of a dimension equal to the nominal value of the dimension to be measured, between the active surfaces of the cylindrical jaws opposite to their flat surfaces.

To measure the interior dimensions, proceed in the same way, specifying that, when forming the gauges blocks, the thicknesses of the cylindrical jaws 3 will be taken into account, which are deducted from the nominal value and the resulting dimension will be materialized by the gauges block 4, between the cylindrical active surfaces b, of cylindrical jaws 3 (fig.5.b). In this way, an external dimension equal to the nominal value of the measured dimension is materialized between the active surfaces of the cylindrical jaws.

The gauge blocks accessory set contains jaws sets with a thickness of 3 mm and 6 mm, respectively.

In order to establish the effective value of the internal dimension, cylindrical jaws are inserted inside the part to be controlled, bringing the active surfaces of the jaws in contact with the cylindrical surface of the part, so that they enter easily, without game, with a slight friction. (fig.5. b.).Next, proceed as for measuring the external dimensions.
Note: The method is accurate (only gauge blocks with high dimensional accuracy are used), but it is laborious because several tests are required to change the size of the block.

4. Checking ISO bores and shafts with limiting gauges or fixed gauges

4.1 General consideration

Fixed gauges are measuring tools without a scale being used to check dimension, form (geometrical condition), and relative position of surfaces of parts. The actual size of the part cannot be obtained with the use of the fixed gauges; their purpose is to determine whether the size lies within the specified limits. In mass production are much more widely used limit gauges

Limit gauges arefixed gauges that are used to verify the dimensions of the parts between operations / phases of their processing, or after their processing, being provided with measuring surfaces of the same shape as the shape of the verified surface.

The advantages of using limit gauges when checking the dimensions are: constructive simplicity, reduced control time, ensuring the interchangeability of parts, at a low-cost price of control.

4.2 Classification

The fixed gauges are classified according to a series of criteria, of which the most important are:

C1. According to the complexity of the controlled surface:
-limit gauges for checking the dimensions of simple shaped surfaces (ISO shafts and bores), namely:
-limit gauges for checking the diameters of cylindrical surfaces;
- limit gauges for checking the dimensions between flat surfaces.
- limit gauges for checking conical surfaces;
-limit gauges for checking threaded surfaces;

-limit gauges for checking grooved surfaces;
- limit gauges for checking the distance between the hole's axes.

C2. By nature of the controlled area:
- limit gauges for checking the external surfaces (shafts);
- limit gauges for checking the interior surfaces (bores).

C3. By destination:
- working gauges, which are new gauges and are used to control parts during their production on machine tools;
- control gauges that are partially worn and used by the controller to check the machined parts in the specially arranged points in the production section or workshop;
- the reception gauges which are used gauges, having the actual dimensions equal to those of the limits, "pass" or "GO", respectively "do not pass" or "NOT GO", being used by controllers (receivers) for the final reception of the products;
- counter-gauges are gauges intended for checking the gauges, being characterized, among others, by their special precision;

C4.By number of component parts of the gauge structure:
- one-piece gauges, a solution used in the case of flat gauges and rig gauges intended for checking parts with controlled surface dimensions below 10 mm; - composite calibers, in several pieces.

C5.After construction:
- simple gauges, having only the passing or GO part or only the not passing part or NOT GO part;
- double gauges, having both the "pass" or GO part and the "do not pass"or NOT GO part.

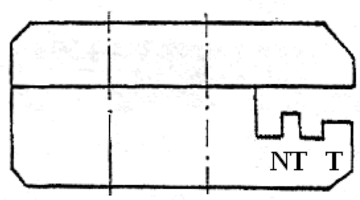
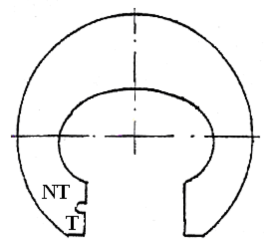
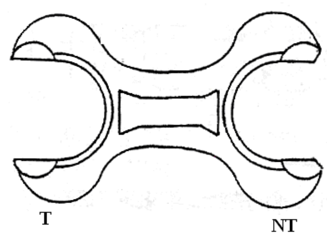
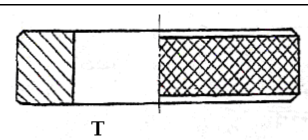
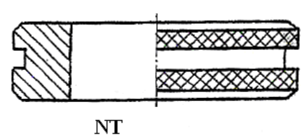
C6. After the possibility to change the verified size range:
- fixed gauges;
- adjustable gauges.

C7. After normalization / standardization:
- standardized gauges;
- non-standard gauges.

In tab. 2 are presented standardized forms of gauges for checking ISO shafts, and in tab. 3, standardized gauge shapes for checking ISO bores/holes are presented

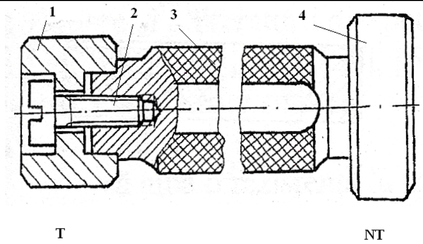
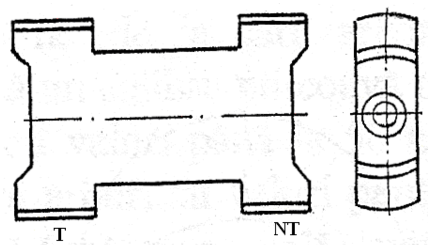
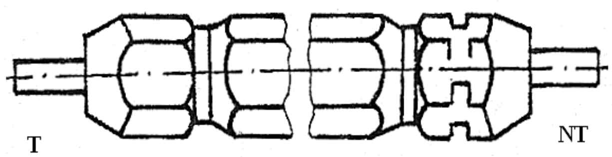
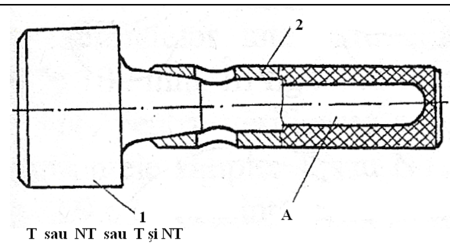
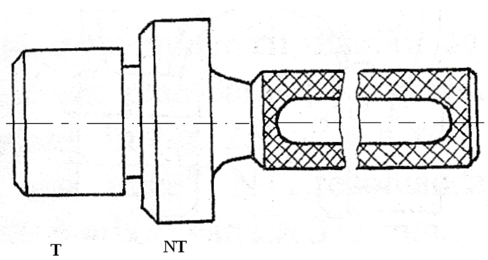
Each form of limitgauges has advantages and disadvantages; in the given practical situation, the optimal solution must be chosen, observing the requirements imposed regarding the proper performance of the control.

Limit gauges for shafts **Table 2**

Type of gauge	**Sketch**	**Observation**
0	**1**	**2**
Assembledsingle-jaw snapgauge T (GO) and NT (NOT GO)		STAS 2991 - 86 Size range: 1 – 3 mm
Double single-jaw snap gaugesT (GO) and NT (NOT GO)		STAS 2991 - 86 Size range: 3 – 180 mm
Wrought double -jaw snap gauge double-end T(GO)and NT (NOT GO)		STAS 3507 - 80 Size range: 3 – 310 mm;
Ring gauge T (GO)		STAS 3938 - 87 Size range: 1 – 315 mm
Ring gaugeNT (NOT GO)		STAS 3938 - 87 Size range: 1 – 315 mm

Limit gauges for holesTable 3

0	**1**	**2**

Plug gaugedouble-ended T (GO) and NT (NOT GO), with fixing screw		STAS 2981 - 88 Size range 30 – 100 mm; 1 – side T/ GO end; 2 –fixing screw; 3. – handle; 4 – side NT/ NOT GO end.
Flat plug gauge double -ended T (GO)and NT(NOT GO)		SR EN 844-2:2000 Size range 18 – 100 mm;
Pin plug double-ended gauge T(GO)and NT (NOT GO)		STAS 2992/2 - 85 Size range Until to 18 mm
Plug gauge with conical tappersingle-ended T or NT ordouble-ended T and NT		STAS 2981/1 - 88 Size range Ultil to 30 mm; 1 – active part; 2 – tapper/handle; A – place for marking
Double-ended T (GO) and NT (NOT GO) conical tapperplug gauge with active parts on the same side of the handle		STAS 2981/2 - 88 Size range: Until to 30 mm

4.3 Checking with limit gauges

The gauges for checking ISO shafts and bores are limited because with their help the two limits of the size to be checked are checked (corresponding to the limits of the prescribed range of values): the maximum material limit and the minimum material limit.

Each of the two limits of the considered dimension is checked with a distinct element of the limit gauge (with a part of it) called thus:

- pass gauge or pass part, used to check the maximum material limit;
- the not pass gauge or the part does not pass, used to check the minimum material limit.

Checking dimensions with limit gauges is simple and easy; also, some deviations of form that are difficult to notice when measuring with universal measuring instruments are highlighted.

When checking with limit gauges, Taylor's principle must be observed: when checking the limit, the entire surface must be covered; the check of the limit is not done in points, in order to identify the deviations of form.

During the verification, it is necessary that:

• the passing or GO part must slide (by its own weight) inside the controlled surface (in the case of holes), (fig. 6.a.), or over the controlled surface (in the case of shafts), (fig. 7, a.);

• the part not pass or NOT GO must not enter inside the controlled surface (in the case of holes), (fig. 6.b.), or exceed the diameter of the controlled surface (in the case of shafts), (fig. 7.b.).

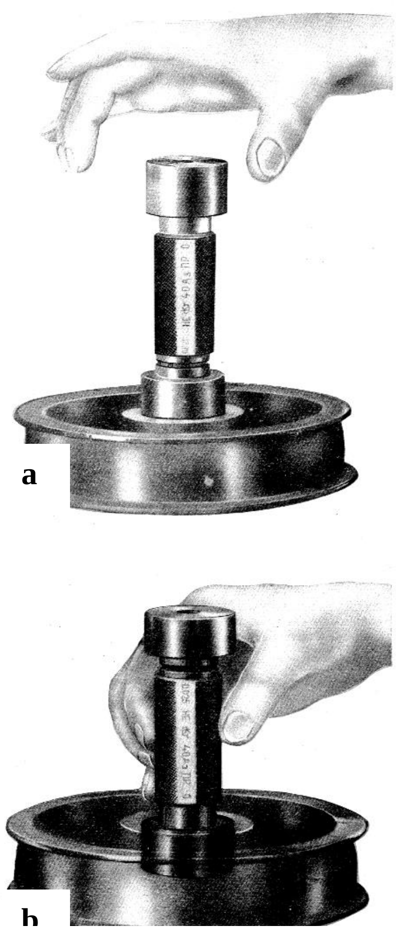


Fig. 6. Checking with plug double-ended gauge

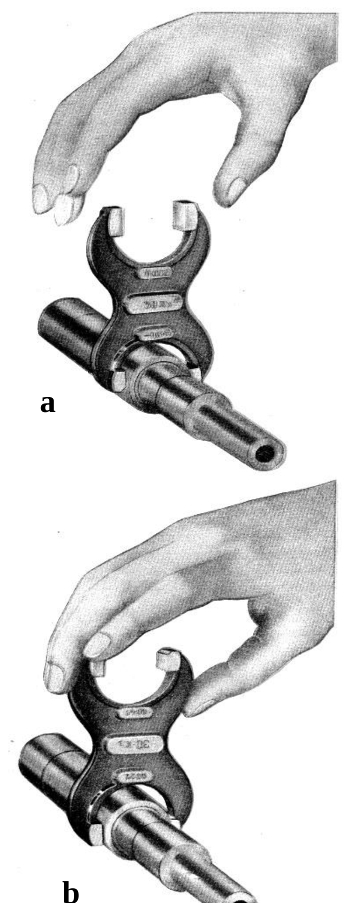


Fig. 7. Checking withdouble -jaw snap double-endedgauge

The measuring pressure and the temperature influence the verification results, especially at the control of the parts executed with restricted tolerances; therefore, the use of gauges is limited to the control of the dimensions for which tolerance 5 - 16 steps are prescribed.

5. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

5.1 To check the dimensions with gauge blocks:

Step no. 1:the execution drawing of the piece to be controlled, will be drawn; on the execution drawing, the tolerance of the dimension tobe measured will be noted.

Step no. 2: the calculation of the limit values and of the tolerance for both tolerated dimensions.

Step no. 3: The gauge block is formed and inserted into the flat-jaws from accessory kit. The gauges block will have the length calculated so that, between the active surfaces of the flat jaws in the frame, the nominal value of the dimension to be measured will be materialized;

Step no. 4: Measure the considered size and obtain the actual value (measured size), *De* (for holes), respectively, *de*(for shafts); go to the control sheet;

Note: if it is necessary to form several gauge blocks, all the calculations made will be entered in the notebook.

Step no 5:the effective value of the measured dimension will be compared with the prescribed tolerance.

Step no. 6: the decision concerning the contolled piece will be made:

- if **Dmin ≤ De ≤ Dmax,** the controlled piece is accepted to be used;
- if **dmin ≤ de ≤ dmax**, the controlled piece is is accepted to be used;
-

5.2. To check the shafts and holes with limit gauges:

Step no. 1: Check the pass or GO and NOT GO limits of an inner cylindrical surface, at a specified number of parts, with plug double-ended gauge

Step no. 2: Check pass or GO and NOT GO limits of an outer cylindrical surface, at a specified number of pieces, with a single -jaw snap double-endedgauge

Step no. 3. The decision is made on each controlled part: the controlled part is allowed for use, or rejected from use (recoverable or non-recoverable).

Laboratory work 2

CONTROL OF LINEAR DIMENSIONS USING DIAL GAUGE TOOLS AS MEASUREMENT INSTRUMENTS

3.1. General considerations

Dial gauge tools as means of measurement are instruments and apparatus used in measuring length with difference method.
They are always adjusted to zero with measures of length (gauge blocks, calipers), or parts model, which materializes, usually, the nominal size to be measured.

3.1.2 Classification of dial gauges or comparators

Classification criteria for for dial gauges are:

C1. After construction:

- With lever movement transmission mechanism: lever minimeter;
- With lever and screw movement transmission mechanism: dial test indicator, also known as a lever arm test indicator or finger indicator;
- gear devices: dial indicator;
- With levers and gear transmission mechanism: multiresolution dial gauge, orthotest, passameter, passimeter;
- devices with elastic elements twisted-band type dial gauge; optical-mechanical devices: optimeter, ultra-optimeter, Abbe device;
- Pneumatic devices.

C.2.After reading accuracy (scale division value parts): 0.01 mm, 0.005mm, 0.002 mm, 0.001 mm, 0.0005 mm, 0.0002 m m.

C.3. After accuracy:

- working dial gauges: are devices used exclusively for measuring lengths;
- benchmark dial gauges are devices used to calibrate other less precise means of measurement.
  Some of mechanical tools, often used in measuring lengths, are given in table. 1.

C4. After the measurement data indication:

- dial gauges with a dial display similar to a clock (with mark scale)
- digital dial gauges

Some of this dial gauges used for linear dimension measurement can be observed in figure 1 and 2.

a **b** **c** **d**

e **f** **g**

Fig. 1. Dial instruments

a- dial indicator, v.d.= 0,01 mm;
b- multirevolution dial gauge, v.d.= 0,001 mm;
c- digital dial indicator/electronic dial gauge, rez.= 0,01 mm;
d- digital dial indicator, rez.= 0,001 mm;
e- dial test indicator; v.d.=0,002/ 0,005 mm; g- passameter v.d.= 0,002 mm;
f- ortotest, v.d.= 0,001 mm;

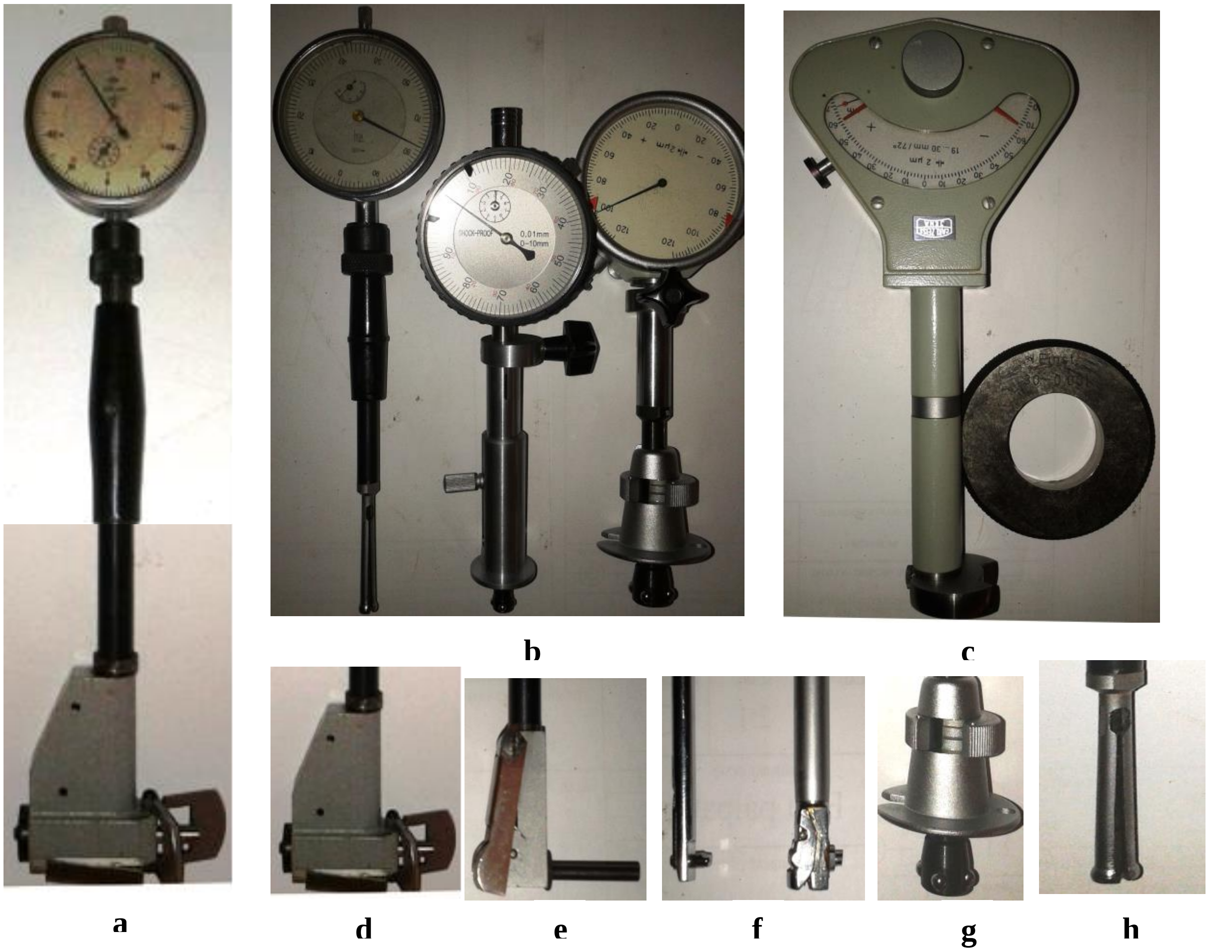


Fig. 2. Inner dial indicators
a, b-dial bore gauge, v.d.= 0,01, 0,002mm;
c- passimeter, v.d.= 0,005, 0,002 mm;
d, e- transmision mechanism with lever;
f- transmision mechanism with conical rod
g- transmision mechanism with calibrated spheres;
h- transmision mechanism with extendible ring.

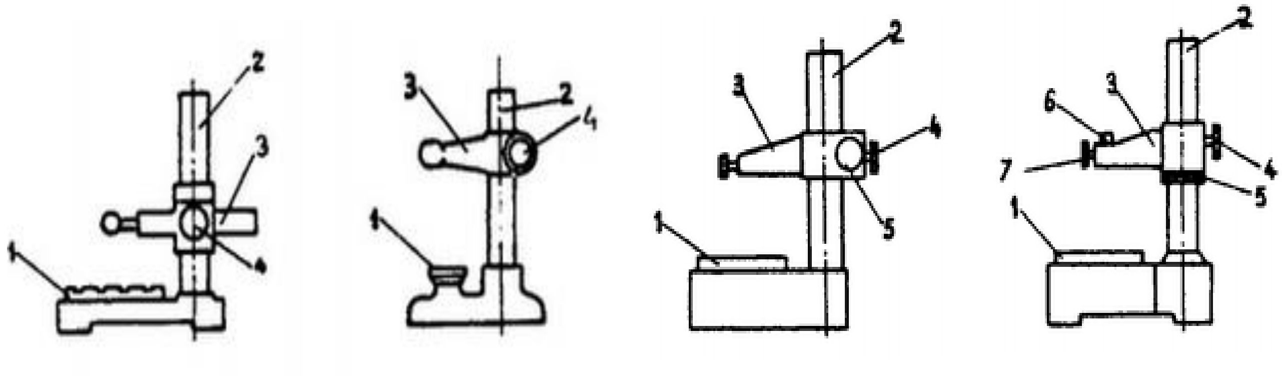
3.1.3. Gauge stands and holders

Dial gauges are set in zero in several type of adjustment (coarse, intermediate, fine), they are providedwith fine adjustment mechanisms, the other levels of adjustment are provided by the stands on which they are fixed.

Stands for dial gauges are constructions consisted from base, a flat table surface 1 (for putting the part to be controlled), column 2, at which is mounted a bracket 3 (which are blocked on the column by the action of wheel 4) on which is fixed the dial instruments (Fig. 3).

Depending on the precision of the comparator means of measurement, their stands (provided with rigidity columns) provide one or two levels of adjustment:

- a single stage of adjustment, coarse adjustment (for the usual precision instruments), moving the console 3 (by hand) on column 2 and lock it with wheel 4 (fig.3.a, b.);
- two levels of adjustment (for instruments with high precision)
  - a rough adjustment, consist in moving the console 3 on column 2, by operating element 5, at which can be: a hand wheel, at flat columns with rack (Figure 3.c.), or a fine milled nut on threaded columns (fig.3. d.)
  - an intermediary adjustment, consist in up / down instrument by driving a cam with element 6 and lock it with bolt 7.



a. b. c. d.

Fig. 3

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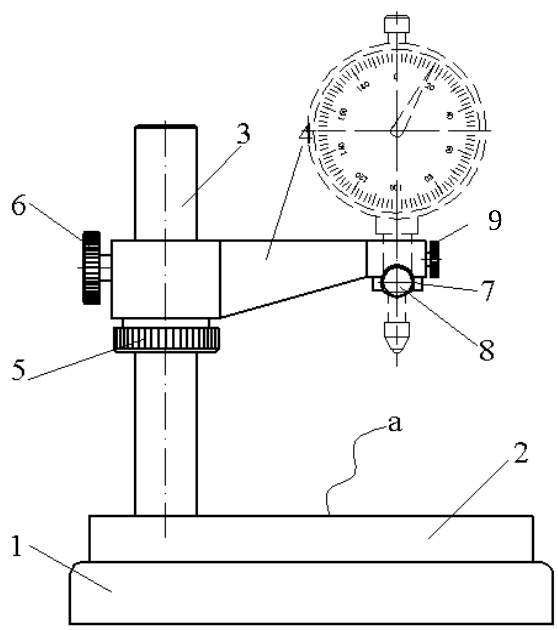


Fig. 4
General structure of a gauge stand

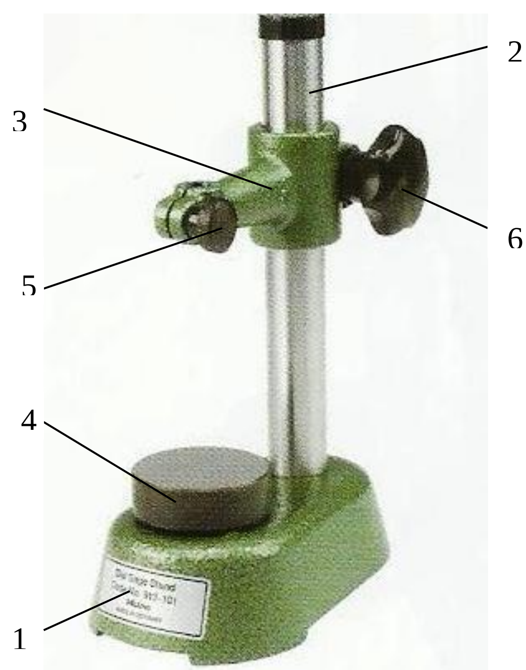


Fig. 5
Atelier holder

3.2. Measuring dimensions with dial indicators

Dial and digital indicators can be used to measure lengths, if they are mounted and fixed to workshop or laboratory supports, depending on their reading accuracy.

Measurement technique: the dial instrument, fixed to a suitable support, is set to zero with a set of gauge blocks with the length equal to the nominal value of the dimension to be measured.

Zero adjustment of the instrument: on the table 1, on the base 2, the set of gauge block 3 is placed (fig. 6.a); lower the bracket 4 (on column 5, of the support), together with the indicator instrument 6, until its measuring tip 7 comes into contact with the free surface of the flat gauge block 3. Continue lowering the instrument by 1 - 2 mm, after which the bracket 5 is locked on column 4 by actuating the handwheel 8. In this position, the indicator tool 6 is set to zero.

Note: the digital dial instruments are provided with a button which, by pressing it, ensures the adjustment to zero; the analog dial instruments (with dial and pointer) are set to zero by rotating the dial and bringing its “0” mark to the pointer.

After zero adjustment, check the stability of the instrument indications as follows: actuate, once, twice, the retracting element of the measuring tip with which the instrument or support is provided: puller, lever or button (in this case, the puller 9) and the indication of the instrument is followed, which must be “0”; if the indication is non-zero, it is set to zero. After zeroing the dial indicator instrument, the measuring tip 7 is retracted, the block of gauge blocks is removed, the instrument being prepared for measurement.

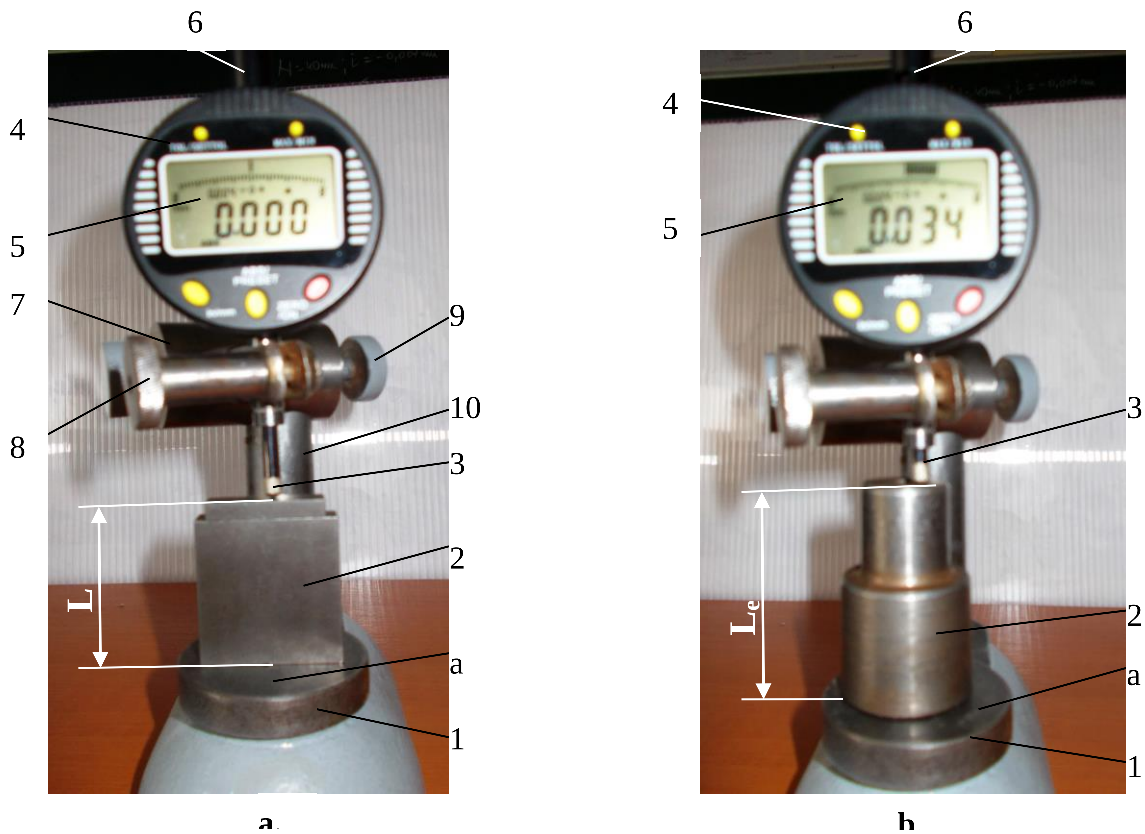


Fig. 6
Measurement of the external dimension with digital dial indicator
a-zero adjustment with gouge bolks; b- measurement of the part

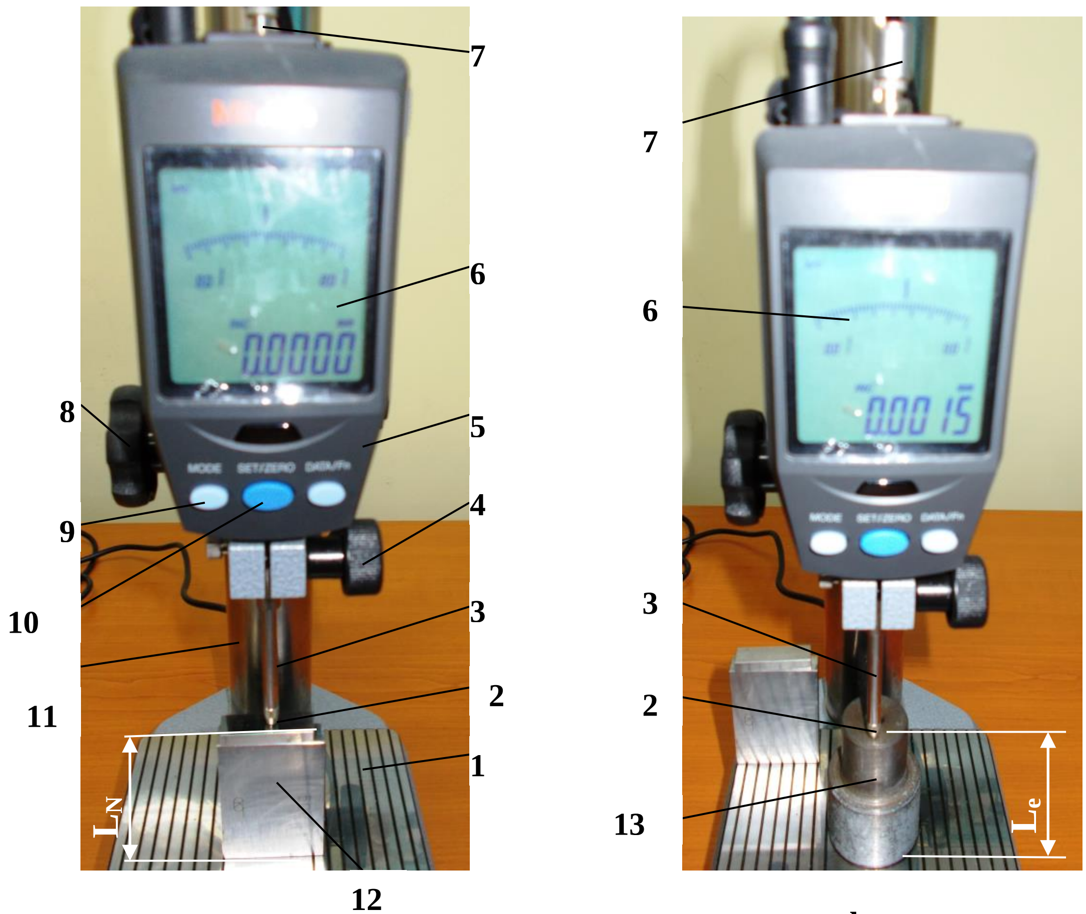
Measuring the size with the dial instrument: to measure the height of the workpiece 10, the measuring tip 7 is raised (by actuating the puller 9) and, instead of the block of gauge blocks used for adjustment, the control workpiece 10 is inserted; return the measuring tip 7, in contact with the free surface of the part (by releasing its retracting element) and note the indication *i* of the instrument (fig. 6.b).

The effective (measured) dimension is obtained as an algebraic sum between the nominal value N and the indication of the dial instrument:

$$\mathbf{d_e = N + i.}$$

3.3. Measurement of external dimensions with precision indicating devices.

Precision indicating devices are measuring devices that have a division value (resolution) of at least 1 μm; are used to measure the dimensions to which very small tolerances are prescribed (of the order of fraction of micrometers).



a. b.

Fig. 7 Measuremnet of a dimension with high precision digital dial indicators
a-zero adjustment with gauge block; b- part measurement

For dimensions measurement with high-precision reading indicators, this dial instruments are mounted and fixed to laboratory supports, provided with two adjustment steps and which have high rigidity.

Measurement technique: the indicator device (with a resolution of 0.0005 mm), fixed to a laboratory support, is set to zero with a gauge block with a length equal to the nominal value of the dimension to be measured.

Zero adjustment of the instrument: on the table 1, of the laboratory support, the gauge block 12 is placed (fig. 7.a); lower the indicator device 5 (on column 11 of the support) until the measuring tip 2 comes into contact with the free surface of the gauge block 12 and locks with the locking wheel 8. Operate the rosette 4, intermediate adjustment, continuing the descent of the measuring tip 2 by about 1 mm (no locking required).

In this position, the indicator device 5 is set to zero by pressing the button 12 (“ZERO”). which must be "0"; if the indication is non-zero, it is set to zero.

Measuring the dimension with tl**2** indicated device: to measure the height of the part 13, raise the measuring tip 2 (by actuating the trigger 7) under which the control part 13 is inserted; the retracting rod 7 is slightly released and the measuring tip 2 is brought into contact with the free surface of the part 13 (fig. 7.b); and note the indication i, of the apparatus which is displayed on display 6.

The effective (measured) dimension is obtained as an algebraic sum between the nominal value N and the indication of the high precision digital dial indicators**:**

$$\mathbf{d_e = N + i.}$$

3.4. Measuring the external dimensions with the passameter or dial snap gauge

Passmeters are dial gauges with levers and gears measuring mechanism and the value division of 0.002 mm. They are used for accurate measurement of external dimensions.

Measurement technique. The passameter, fixed to a suitable support (special support for this type of instruments), is set to zero with a gauge block to the length equal to the nominal value of the measured dimension.

Zero setting of the dial snap gauge or passameter: the passameter 2, fixed to the support 1, is provided with a fixed probe 5 and a movable one 7, with active flat surfaces (fig. 8.a). Loosens the locknut 3 and actuate the nut 4 to move the fixed probe 5 so that the gauge block 6 is inserted between it and the movable probe 6. After inserting the gauge block 6 between the probes 5 and 7, is acting again the nut 4 and bring the two probes into contact with the free surfaces of the gauge block; continue operating the nut 4, until the pointer 8 reaches the mark “0” of the dial 9. The retracting element of the movable probe 7 (button 10) is activated to check the stability of the indications. If the pointer 8 returns to “0”, lock the fixed probe with the locknut 3. Press the button 10, which retracts the movable probe 7 and remove the gauge block. The passameter is set to zero and ready for measurement.

Measuring the external dimension with the passameter: to measure the diameter of the part 11, retract the movable probe 7, by pressing the button 10 and insert the control piece 12, between the probes 5 and 7, supporting it, at the same time, on the stop 11 (to the contact between the probe and the part is ensured, according to its diameter).

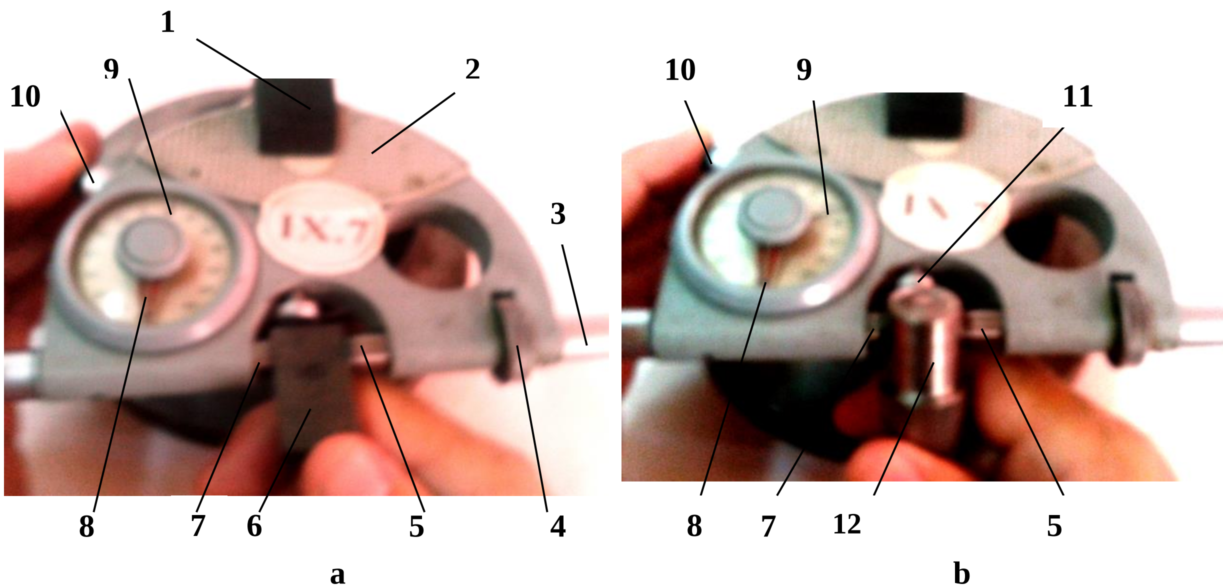


Fig. 8. External dimension measurement with passameter
a-zero adjusment; b- measurement

Release button 10 and note the indication *i* of the instrument (fig. 8.b).

The effective (measured) dimension is obtained as an algebraic sum between the nominal value N and the indication of the dial instrument:

$$\mathbf{d_e = N + i.}$$

3.5 Measurement of inner diameters with dial bore gauge.

The dial bore gauges are instruments used to measure interior dimensions (interior diameters, distances between interior surfaces), and some of them only for measuring the diameters of interior cylindrical surfaces. They are equipped with dial instruments (dial indicator or digital indicators, with a scale division value of 0.01 mm, 0.005 mm, 0.002 mm).

The dial bore gauge are delivered in kits that cover a specified range of dimensions to be measured.

Measurement technique. The dial bore gauge is set to zero with a ring gauge, having a diameter equal to the nominal value of the diameter to be measured (fig. 9).

Zero setting of the dial bore gauge: ring gauge 2, is placed on the active surface of a check plate 1; the body 3 of the instrument is inserted inside the ring gauge, so that its probes 4 and 5 come into contact with the inner cylindrical surface of the gauge (fig. 9.a). Tilt the instrument (holding the handle 6) vertically (movement I) until the point of return of the pointer 8 is obtained, which rotates in front of the dial 7. At that moment, the instrument is adjusted to zero by rotating of the dial 7 (operate the outer part 9 of the dial) and bring the pointer 8 to the mark “0” of the dial 7. Tilt the instrument again (movement I) to check the stability of the indications (indication “0” of to the pointer at its point of return).

Remove the instrument from the ring gauge 2 (by tilting it vertically); the dial bore gauge is set to zero and ready for measurement.

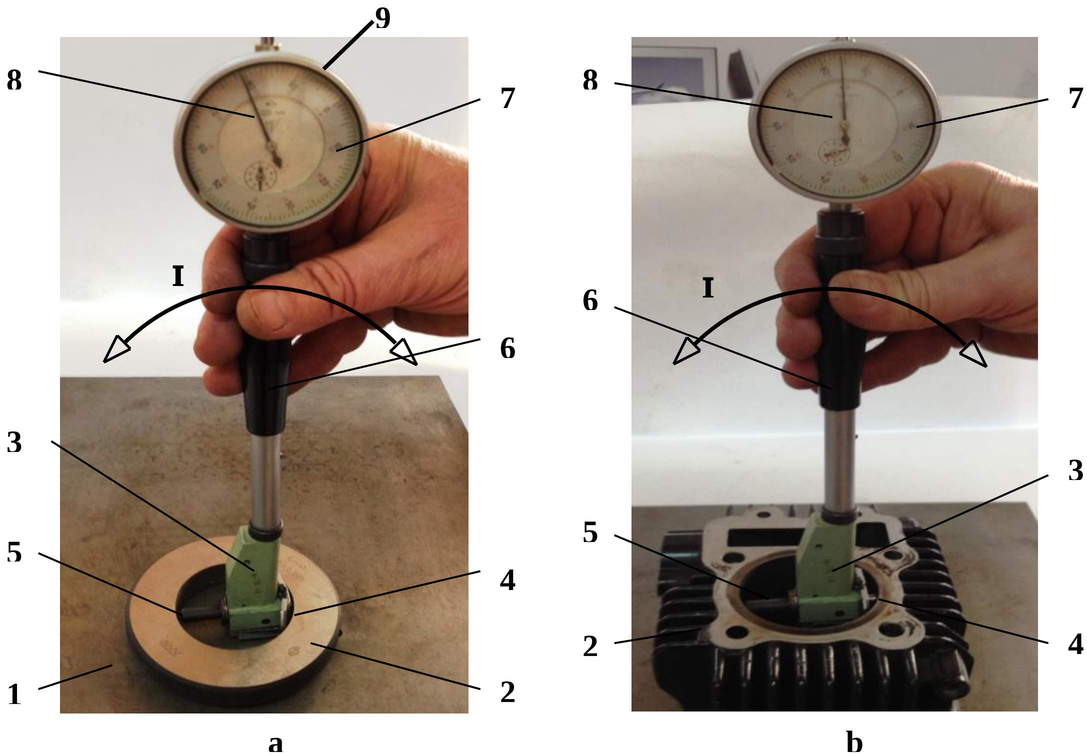


Fig. 9 Measurement with inner dial indicator
a-zero adjustment with ring gauge b- inner dimension measurement

Measuring the inside diameter with the dial bore gauge: to measure the inside diameter of the part 2 (which is placed on the active surface of the check plate 1), insert the body 3, of the instrument inside the part, so that its probes 4 and 5 comes in contact with the inner cylindrical surface of the part (fig. 9.b).

Tilt the instrument (holding the handle 6) vertically (movement I) until the point of return of the pointer 8 is obtained, in front of the dial 7. At that moment, note the indication *i* of the instrument, which represents the deviation diameter of the part compared to its nominal value.

The effective (measured) diameter of the part is obtained as an algebraic sum between the nominal value N and the indication of the dial bore gauge:

$$\mathbf{D_e = N + i.}$$

Note: due to the mechanism for transmitting the movement of the mobile probe 4, at the dial bore gauge, the passameter sign of the reading indication will be changed.

Note: some dial bore gauge (those with lever transmission mechanism) can be set to zero and with gauge blocks inserted into the frame from the gauge accessory kit.

3.6 Measurement of inside diameters with the passimeter.

Passimeters are dial indicator instruments provided with three points of contact with the surface of the part to be controlled: two are fixed and the third corresponds to a movable measuring tip: They are used only for measuring internal diameters and have a division value of 0.005 mm and 0.002 mm.

Unlike dial bore gauge, passimeters have a small measuring range. It is delivered in kits, to cover a specified range of measured dimensions. A kit contains a passimeter and several interchangeable measuring heads; each measuring head is accompanied by the corresponding contact tip and the ring gauge required for zero adjustment.

Measurement technique. The passimeters are set to zero with a ring gauge, contained in the passimeter kit, having a diameter equal to the nominal value of the diameter to be measured (fig. 10).

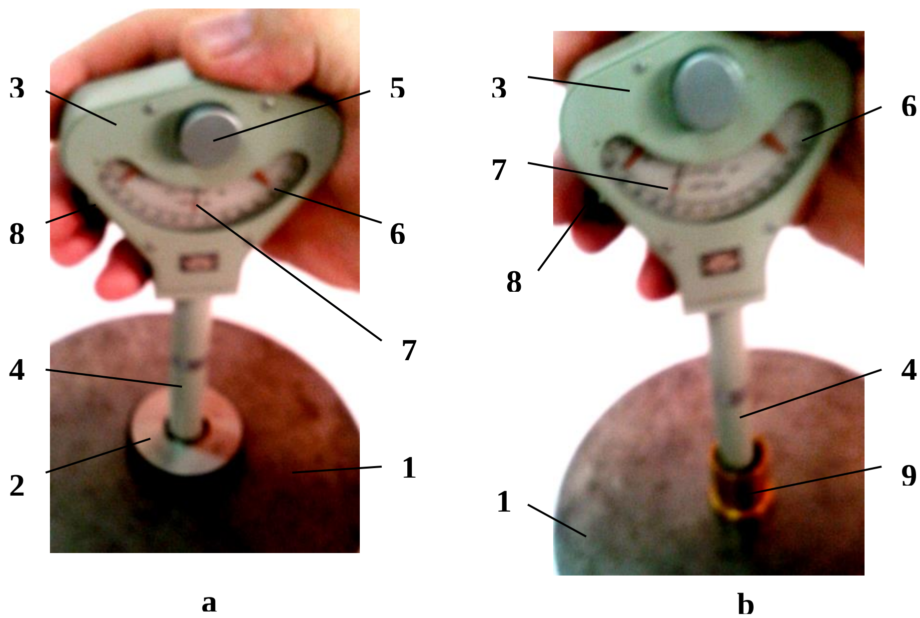


Fig. 10. Measurement with passimeter
a-zero adjusment with ring gauge; b- inside diameter measurement

Zero setting of the passimeter: ring gauge 2, place on the active surface of a check plate 1. Hold the gauge with your right hand on the body 3 and insert the measuring head (located at the end of the cylindrical rod 4) inside the ring gauge 2 (fig. 10.a).

Follow the indication of the pointer 7, on the reference scale 6, of the instrument; if the indication is different from "0", unscrew the cover 5 and, with a special key, operate the mechanism of rotation of the ladder 6 until the mark "0", it reaches the pointer 7. Check the stability of the indications, pressing and releasing, once- twice the button 8, to withdraw the measuring tip; the pointer must return to "0" when the 8 button is released.

Remove the passimeter from the ring gauge and reassemble cover 5; the passimeter is set to zero and ready for measurement.

Measuring the inside diameter with the passimeter: to measure the inside diameter of part 9 (which is placed on the active surface of the check plate 1), proceed as follows: with the passimeter held in the right hand and the button 8 pressed, insert the measuring head (not shown in the figure), inside the part to be controlled (fig. 10.b).

Release the button 8 and note the indication *i* of the instrument, which can be seen on the reference scale 6, next to the pointer 7 and which represents the deviation of the diameter of the part from its nominal value.

The effective (measured) diameter of the part is obtained as an algebraic sum between the nominal value N and the indication of the dial instrument:

$$\mathbf{D_e = N + i.}$$

4. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

Step no. 1: the execution drawing of the piece to be controlled, will be drawn; on the execution drawing, the tolerance of the dimension to be measured will be noted.

Step no. 2: the calculation of the limit values and of the tolerance for both tolerated dimensions.

Step no. 3: Measure the considered size and obtain the actual value (measured size), *De* (for holes), respectively, *de* (for shafts); go to the control sheet;
Note: if it is necessary to form several gauge blocks, all the calculations made will be entered in the notebook.

Step no 4: the effective value of the measured dimension will be compared with the prescribed tolerance.

Step no. 6: the decision concerning the controlled piece will be made:

- if **Dmin ≤ De ≤ Dmax,** the controlled piece is accepted to be used;
- if **dmin ≤ de ≤ dmax**, the controlled piece is accepted to be used;

Laboratory work no. 3

EXTERNAL AND INTERIOR DIMENSIONS CONTROL WITH LINEAR VERNIER INSTRUMENTS

Applications to be performed for laboratory work no. 3:

- measuring the exterior and interior dimensions with exterior callipers;
- measuring heights with height callipers;
- measuring depths with depth callipers.

1. Purpose

Knowledge of the construction of ordinary callipers (exterior, height, depth); knowledge of how to measure external and internal dimensions with regular calipers.

Know how to read the measured part with a vernier callipers.

2. General consideration

Linear vernier instruments are instruments that have in their construction a small scale of marks called vernier, with the help of which the millimeter fractions are read. Linear vernier instruments are commonly known as calipers.

A caliper (calipers) is a device used to measure the dimensions of an object. Many types of calipers permit reading out a measurement on a ruled scale, a dial, or a digital display. The tips of the caliper are adjusted to fit across the points to be measured and the dimension read by measuring between the tips with another measuring tool, such as a ruler.

2.1. Classification of linear vernier instruments

Linear vernier instruments are classified according to a number of criteria:

C.1. By the size category it measures:

• standard calipers, used for regular measurements (fig. 1):

- exterior calipers, for measuring external and internal dimensions (fig. 1.a, b, c);

- vernier height calipers, for measuring heights (fig. 1.e);

- vernier depth gauges, for measuring depths (fig. 1.d).

• special calipers, used to measure certain linear dimensions. Example: caliper for gears

C.2. After the value of the upper measurement limit L:

L = 150; 200; 300; 500; 800; 1000; 1500; 2000 mm.

C.3. According to the value of the vernier division:

- calipers with the value of the vernier division of 0,1 mm;
- calipers with the value of the vernier division of 0,05 mm;
- calipers with the value of the vernier division of 0,02 mm.

C.4. According to the measured size indication:

- vernier caliper (fig. 1.a);
- dial caliper (fig. 1.b);
- digital caliper (fig. 1.c).

C 5. By accuracy class:

- calipers from precision class 1;
- calipers from precision class 2.

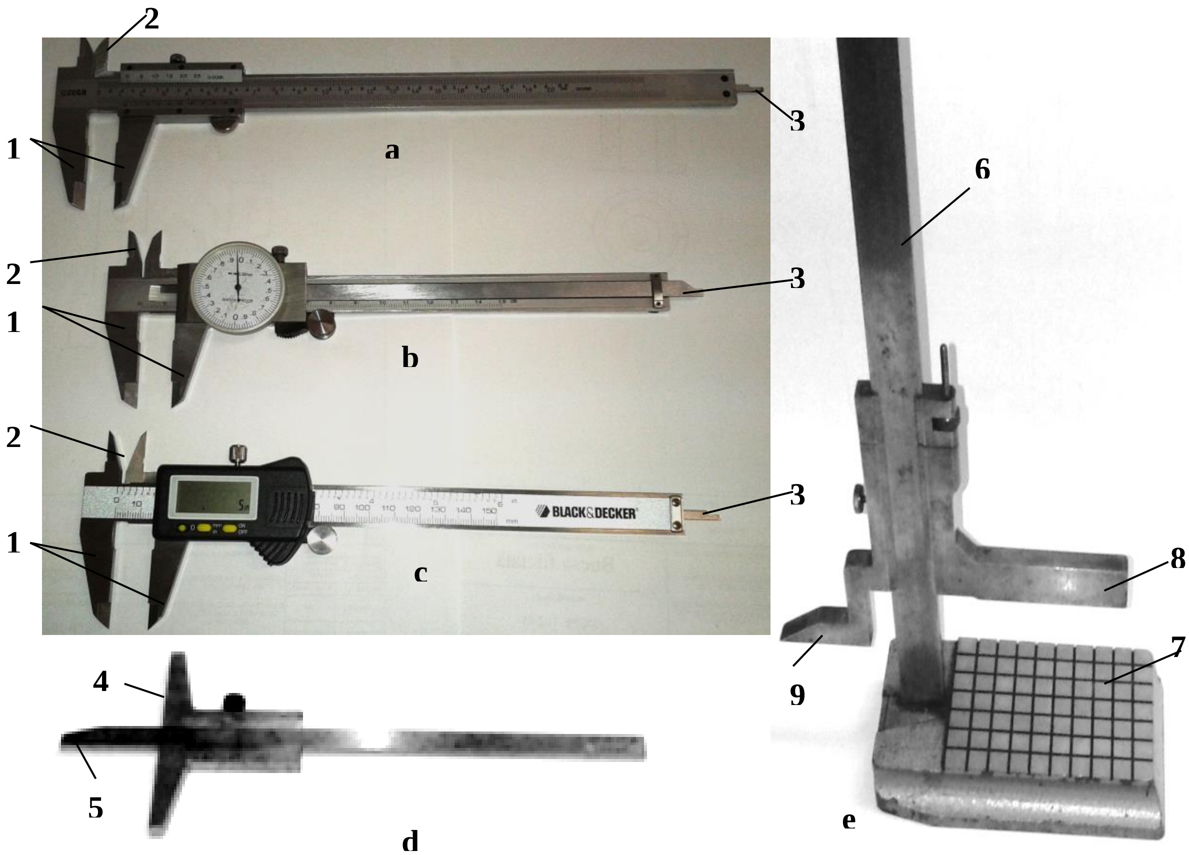


Fig. 1. Regular calipers
a.-vernier caliper; b.- dial caliper;
c.-digital caliper; d.- depth caliper; e.- hight caliper

1.2. General construction of a linear vernier instrument

In fig. 2, a regular caliper (caliper for outer or inner surfaces) is shown; it has the following components: ruler 1, of the caliper, on which is the main *scale* marked every mm 7, with divisions with the value of 1 mm numbered every 10 divisions and which has at its end the long-fixed jaw 3 and short fixed jaw 2.

On the ruler 1, move the cursor 4, provided with a long jaw 5 (adjustable jaw) and a short jaw 6 (adjustable jaw) and on which the linear vernier 8 is drawn, with divisions with the value of 0.1 mm or 0.05 mm or 0.02 mm.

The caliper is provided with a fine feed slider 10 with the fine feed mechanism consisting of the screw 11 and the nut 12; sliders 4 and 10, can be locked on the ruler 1, of the caliper, with the locking screws 9.

The long jaw has on the inside a flat measuring surface a, (for measuring the external dimensions), and on the outside, a portion of a cylindrical surface b, (for measuring the internal dimensions); the short jaws have an edge c each, for measuring the inside diameter of the screws.

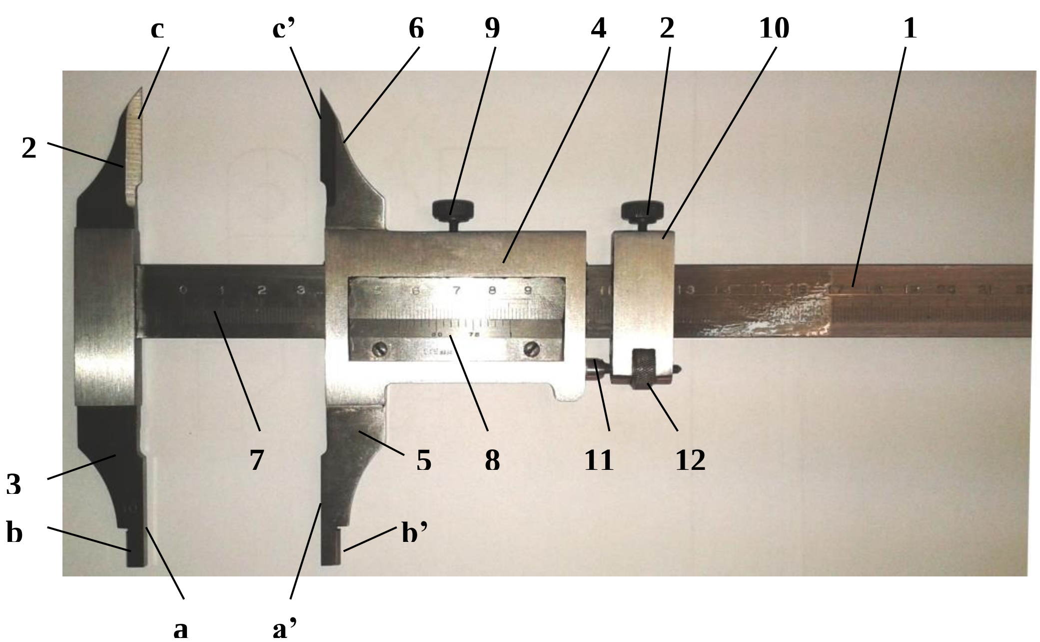


Fig. 2. Caliper construction

Note: calipers with an upper measuring limit of 150 mm, of accuracy class 2, have long jaw 1, with a flat active surface for measuring outer dimensions, and short jaws 2, with active edges for measuring inner dimensions. They also have in their construction, a depth rod 3, for measuring the depths (fig. 1.a, b., c).

The depth calipers have attached to the slider, a base 3, with a flat active surface, and, at the end of the depth rod 5, is the second active flat surface (fig. 1.d).

For height calipers, the caliper ruler 6 is mounted on the table 7, provided with a flat active surface (on which the control piece is placed); and the jaw 8 has, at the bottom, a second active surface (fig. 1.e). To measure the height of large parts, a second jaw 9 with a lower active flat surface is mounted on the height caliper slider.

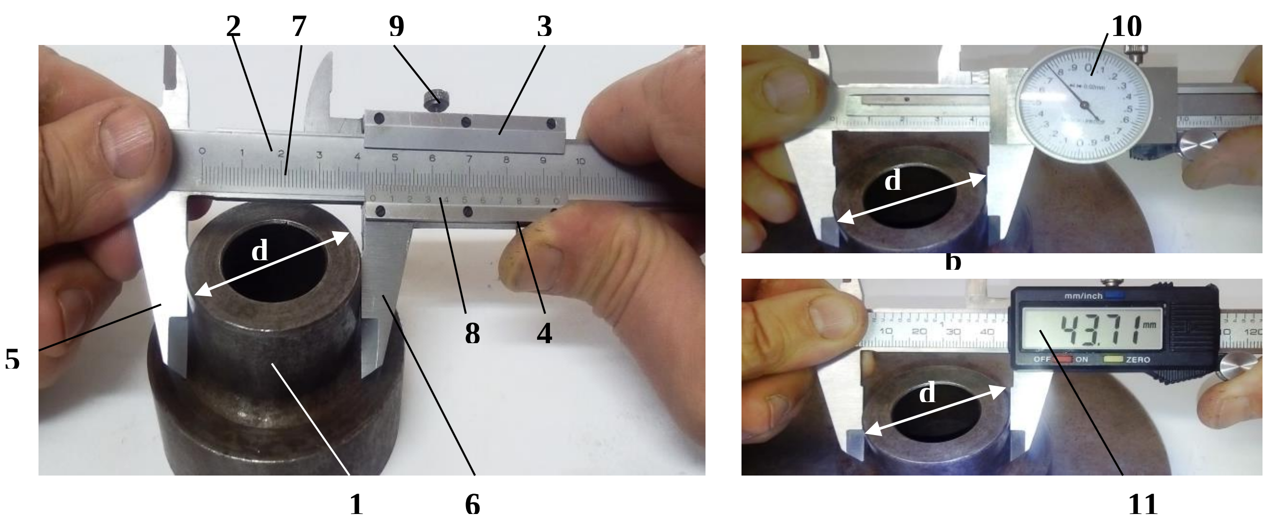
3. Measurement of linear dimensions with linear vernier instruments

When the linear dimensions are measured with instruments with linear vernier, the method of direct evaluation is applied. This method consists in introducing the measured part between the measuring surfaces of the instrument and obtaining the measured value on its reference scale. The direct evaluation method is an absolute method of measurement, because the actual value of the measured dimension is obtained directly by applying it.

3.1. Measurement of external dimensions

The external dimensions (external diameters, distances between flat or other external surfaces) are measured with calipers provided, at the long jaw, with flat active surfaces, between which the control part is inserted (fig. 3).

Measurement technique: to measure the outer diameter *d* of the part to be controlled 1, proceed as follows: hold the caliper, with the left hand on the right end of the ruler 2, and with the right hand also on the ruler, immediately after the slider 3, so that the thumb is on the retainer 4, at the bottom of the cursor 3; In this way, it is possible to move, easily, the cursor 3, on the ruler 2, in both directions (fig. 3.a). Remove the long jaws 5 and 6, wrap the control piece 1 with them and approach the jaws, bringing their flat surfaces into contact with the surface of the part. When the correct contact has been made between the surface of the part and the active flat surfaces of the caliper, the reading of the measured size is taken, on the two scales: 7, on the ruler and 8, on the slider 3.



a **c**

Fig. 3 External dimension caliper measurement

a.-vernier caliper measurement;b.- dial caliper measurement;
c.-digital caliper measurement

The same measuring technique will be applied to any type of caliper, regardless of the type of element with which it is provided for reading the measured dimension: vernier, reference scales 7 and 8, for linear vernier calipers (fig. 3.a), dial 10, for dial calipers (fig. 3.b), display 11, for digital calipers (fig. 3.c).

If it is necessary to maintain the effective size between the measuring surfaces, move the screw 9, locking the slider 3, on the ruler 2 of the caliper.

<u>Note</u>: if the part to be controlled can be held in the hand, for measuring, hold the caliper only with the right hand and operate the cursor with the thumb, also applying the measurement technique presented.

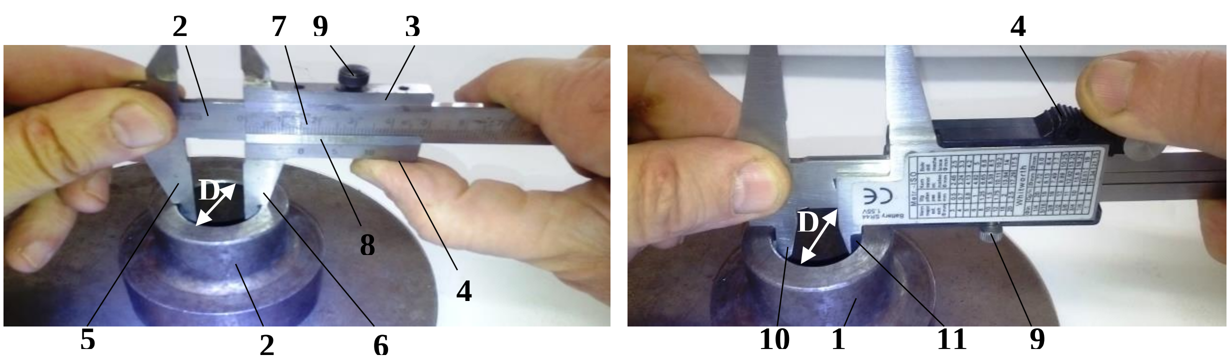
3.2. Measurement of interior dimensions.

Interior dimensions (interior diameters, distances between flat or other interior surfaces) are also measured with previous calipers, the active elements which come into contact with the inner surface to be controlled may be:

• incomplete cylindrical surfaces, located on the long jaws, in the opposite part of the flat surfaces (fig. 4.a);

• active edges, located on the short jaws of the caliper (fig. 4. b).

Measurement technique: for measuring the inner diameter D, of the part to be controlled 1, proceed as follows: hold the caliper, with the left hand on the right end of the ruler 2, and with the right hand also on the ruler, immediately after the slider 3, so that the thumb is on the retainer of the bottom of the cursor; In this way, it is possible to move, easily, the cursor 3, on the ruler 2, in both directions (fig. 4.a). Remove the long jaws 4 and 5, insert them inside the part to be controlled, remove the jaws (by pulling the cursor to the right), bringing their active surfaces (incomplete cylindrical surfaces) in contact with the surface of the part. When the correct contact has been made between the workpiece surface and the active surfaces of the caliper, the measured dimension is read on the two scales (on the ruler and on the slider 3).



a b

Fig. 4 Inner dimension measurement with caliper

a.- measurement of inner surfaces with incomplete cylindrical surfaces of caliper;
b.- caliper measurement with the active edges

<u>Note:</u> when the incomplete cylindrical surfaces of the long jaws are used for measuring the internal dimensions, must add twice the thickness of the jaws.

The same measuring technique is applied when the active elements are active edges, except that the caliper must be inserted with the short jaws 6 and 7, inside the centering part 1 (fig. 4.b); to read the measured size, remove the short jaws 6 and 7, from inside the workpiece, turn the caliper to bring the reading element (reference scale, dial, display) in front of the eyes and take the reading.

Note: If the part to be controlled can be held in the hand, for measurement, the caliper is held only with the right hand and the cursor is operated with the thumb, applying, as well, the measurement technique presented.

3.3. Height measurement.

For measuring the heights, height calipers are used, which have in their structure a base 2, to which is mounted the ruler 3 of the caliper, on which the slider 4 moves, with the reference scale 8 (fig. 5). Attached to the slider 4 is the jaw 5, which has an active flat surface at the bottom; the second active surface is the upper surface 2 ', on which the control piece is placed.

Measurement technique: for measuring the height L, of the part 1, this is placed on the active flat surface 2 ', of the base 2 (fig. 5.a). Lower the slider 4 on the ruler 3 until the flat active surface of the jaw 5 comes into contact with the free surface of the control piece 1. When the correct contact has been made, read the dimension measured on the scales 6 and 7 of the instrument. For a correct reading of the measured size, with the help of the locking screw (not shown in the figure), lock the slider 4, on the ruler 3, remove the piece between the measuring surfaces and orient the instrument to bring it to a convenient position.

To measure the height of parts with large dimensions, which cannot be placed on the active surface of the base 2, the parts are placed on the active surface of a check plate; to the slider 4, a second jaw 8 is attached, with a flat surface active also at the bottom, which comes into contact with the free surface of the part to be controlled, the caliper being, in turn, supported by the lower surface of the base 2, on the check plate.

3.4. Depth measurement.

The depths are measured with the vernier depth gauge, provided with a base 2, located in the extension of the slider 3 (fig. 5.b); the base 2, has a flat active surface, by means of which the instrument rests on the part to be controlled, and the measuring rod 4, has at the lower end the second flat active surface.

Measurement technique: for measuring the depth *H*, of the part to be controlled 1, the base 2 is supported, with its lower flat active surface, on the upper surface of the part 1 (fig. 5. b); lower the measuring rod 4 and bring its lower end into contact with the other (lower) surface of the part. Using the locking screw 5, lock the measuring rod 4 to the slider 3 and lift the instrument, orienting it so that the measured value can be read correctly (on scales 6 and 7).

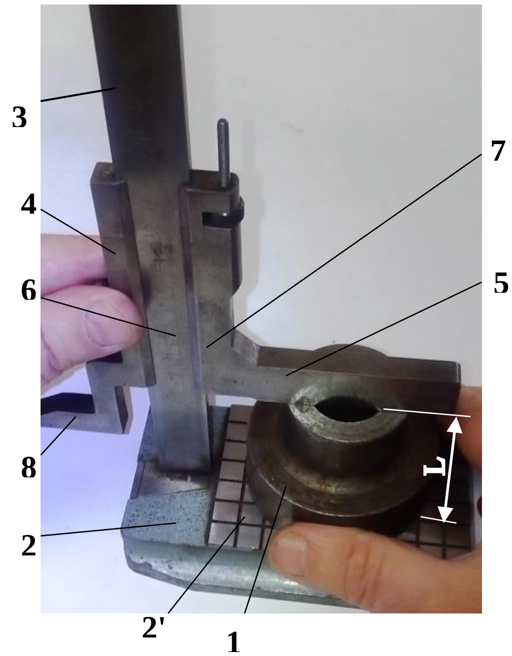
3.5. Reading the measured value with linear vernier instruments

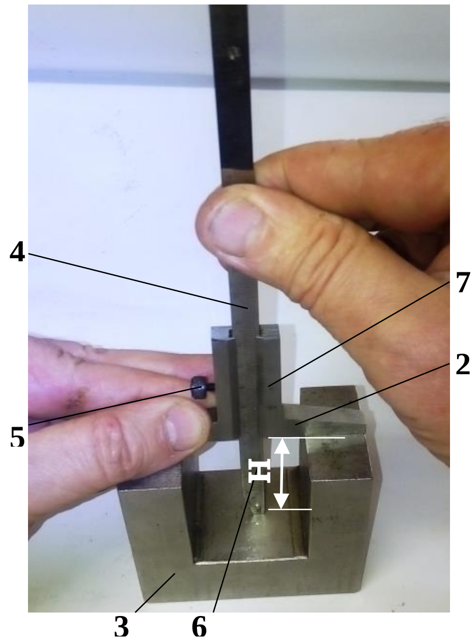
Reading the value of the measured part with vernier calipers.

Regardless of the value of the vernier division, the reading of the value of a dimension measured with the vernier caliper is performed as follows (fig. 6.a, b, c, d):

- ***reading the number of millimeters:*** the number of millimeters is read on the millimeter scale, observing its closest reference to the zero mark of the vernier;
- ***reading the millimeter fractions***: it is observed which landmark on the vernier coincides (it is in extension) with a landmark (regardless of which) on the millimeter scale; multiply the number of divisions on the vernier up to that

inclusive landmark, with the value of the division of the vernier, obtaining the fractions of a millimeter





a b

Fig. 5 Caliper measurement

a-height measurement with vernier height caliper

b- depth measurement with vernier depth gauge

Note: in the case of verniers with 20 divisions (with a value of 0.05 mm), or 50 divisions (with a value of 0.02 mm), reading the fractions of a millimeter by counting the mark in the extension of a mark on the caliper ruler is difficult; therefore, the divisions on the vernier are grouped in a number of divisions so fixed as to ensure a quick reading of the millimeter fractions, as follows:

- for calipers with a division value of 0.05 mm, the divisions are grouped either by 5 divisions: 5x0.05 = 0.25 mm (fig. 6.b), or by two divisions: 2x0.05 = 0.1 mm (fig. 6.c);

- for calipers with a division value of 0.02 mm, the divisions are grouped into 5 divisions: 5x0.02 = 0.1 mm (fig. 6.d).

Reading the value of the measured part with dial calipers.

The number of millimeters is read on the scale 1, of the caliper ruler: the marker on the caliper ruler closest to the left edge of the vernier is observed (fig. 7).

The millimeter fractions are read on the dial 2, next to the pointer 3. For the quick reading of the millimeter fractions, the divisions on the dial 2 of the caliper were grouped as 5: 5x0.02 = 0.1 mm, and the divisions that indicate tenths of a millimeter are numbered on the dial too.

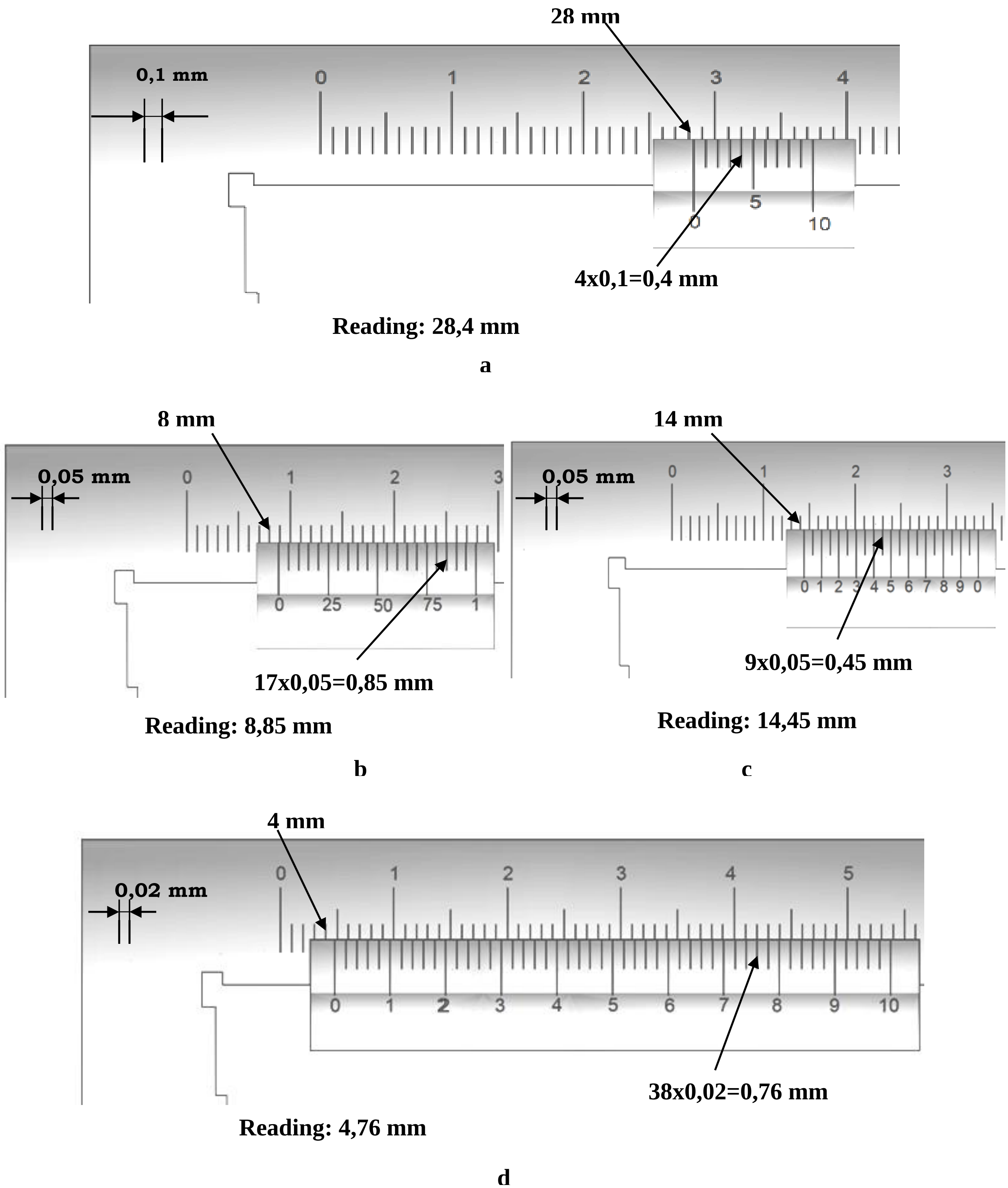


Fig. 6. Reading the measured dimensiun with vernier caliper

a.-vernier caliper with v.d.=0,1 mm; b., c.- vernier caliper with v.d.=0,05 mm (with divisions grouped differently); d.- vernier caliper with v.d.=0,02 mm.

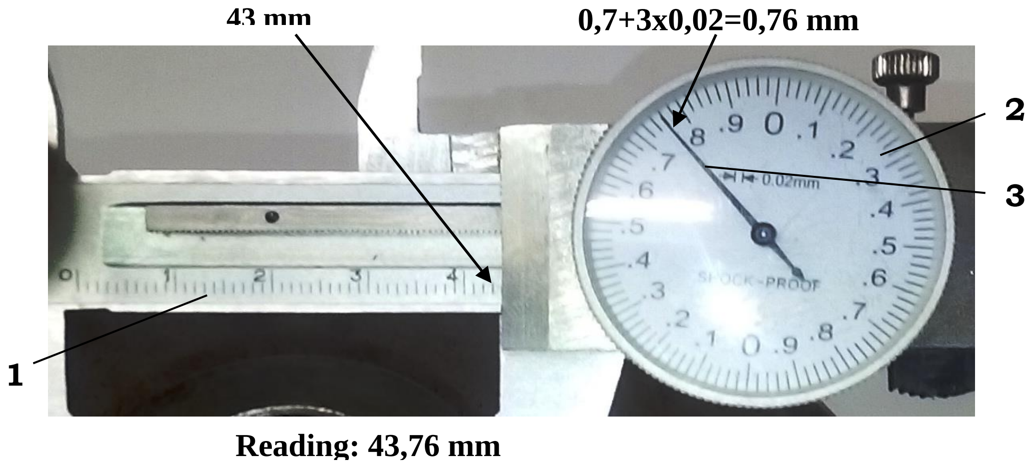


Fig. 7 Reading with dial caliper

In the example of fig. 7, it is observed that the pointer 3, is between 0.7 and 0.8 mm, next to the third division, according to the mark indicating 0.7 mm; so, at 0.7 mm, add 3x0.02 = 0.06 mm, obtaining the fraction 0.76 mm, which is added to the reading of the number of millimeters.

5. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed**:**

Step no. 1: the execution drawing of the piece to be controlled, will be made; on the execution drawing, the tolerance of the dimension to be measured will be noted.

Step no. 2: the calculation of the limit values and of the tolerance for both tolerated dimensions will be made.

Step no. 3: Measure the considered size and obtain the actual value (measured size), *De* (for holes), respectively, *de* (for shafts); go to the control sheet;

Step no 4: the effective value of the measured dimension will be compared with the prescribed tolerance.

Step no. 6: the decision concerning the controlled piece will be made:

- if Dmin **≤ De ≤ Dmax (for holes),** the controlled piece is accepted to be used;
- if dmin **≤ de ≤ dmax (for shafts)**, the controlled piece is accepted to be used;

Laboratory work no. 4

EXTERNAL AND INTERIOR DIMENSIONS CONTROL WITH MICROMETRIC SCREW INSTRUMENTS (MICROMETERS)

- **Applications to be performed for laboratory work no. 4:**

• measuring the external dimensions with external micrometers;

• measuring the internal dimensions with internal micrometers with beaks and with “holtest” type instruments;

• measuring depths with depth micrometers.

1.Pourpose

• knowledge of the construction of regular micrometers; knowledge of how to measure with outside micrometer, caliper jaw inside micrometer, depth micrometers etc.

• knowledge of how to read the workpiece measured with the micrometer

2. General consideration

Instruments with micrometric screw are universal measuring means which have in the construction of the measuring mechanism the threaded screw-nut joint with a pitch of 0.5 mm, in which the micrometric screw performs an axial displacement proportional to the pitch and the number of rotations performed; these instruments are known as micrometers.

2.1. Micrometer classification

Micrometric screw instruments (micrometers) are classified according to a series of criteria, such as:

C.1. By the type of dimension measured:

- Regular micrometers used for regular measurement: exterior or interior dimension (fig. 1):
  - outside micrometers;
  - caliper jaw inside micrometer (fig. 1.a),
  - tubular inside micrometer (fig. 1.b),
  - depth micrometer (fig. 1. c),
  - wire micrometer (fig. 1. d),
  - dial type sheet metal micrometer (fig. 1.e),
  - spherical anvil and spindle type micrometer.
- Special micrometers used to measure some specific dimension of the workpieces.

<u>Example</u>: fixed anvil type screw thread micrometer; tooth thickness micrometer (for gear), etc.

C.2. By micrometer type:

- light type micrometers, with a diameter of the micrometric screw rod of 6 mm and the upper limit of measurement up to 200 mm;

• heavy type micrometers, with a diameter of 8 mm micrometric screw and lower limit of measurement over 200 mm.

C3. By the reading type
• micrometers with reference scale;
• digital micrometers.

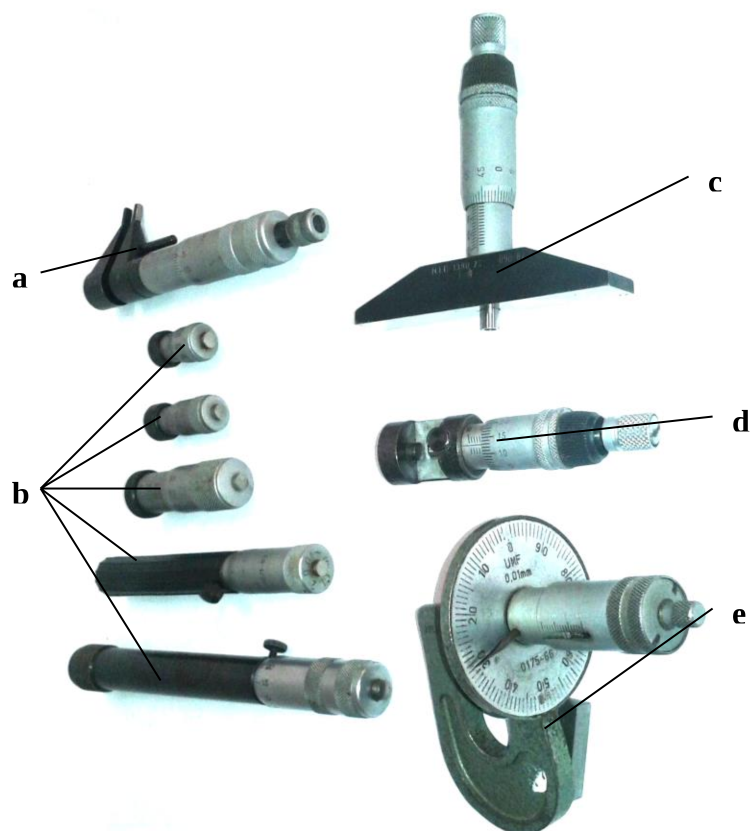


Fig. 1. Standard micrometers
a.- caliper jaw inside micrometer, b.- tubular inside micrometer;
c.- depth micrometer; d.- wier micrometer;
e.- dial type sheet metal micrometer.

C4. By measuring range:

• micrometers with measuring range 0-25 mm;

• micrometers with a multiple measuring range of 25 mm: 25 - 50, 50 - 75, 75 - 100 mm, etc.

C5. By number of feelers:

- micrometers with two feelers, one fixed and one mobile during the measurement;
- instruments with micrometric screw provided with three mobile feelers, “holtest” type.

2.2. General construction of a micrometer

In fig. 2 is presented an outside micrometer (has the most complete structure of the instruments with micrometric screw), which is composed of the following components: frame 1, which has, at one end the anvil 2, with a fixed measuring surface a, and at the other end 3, sleeve 4 of the micrometer, inserted pressed into the frame. In the sleeve 4, there is the nut, in which the micrometric screw is rotated, by actuating the thimble 6; the micrometric screw continues with the spindle 5, at the end of which is the movable measuring surface b.

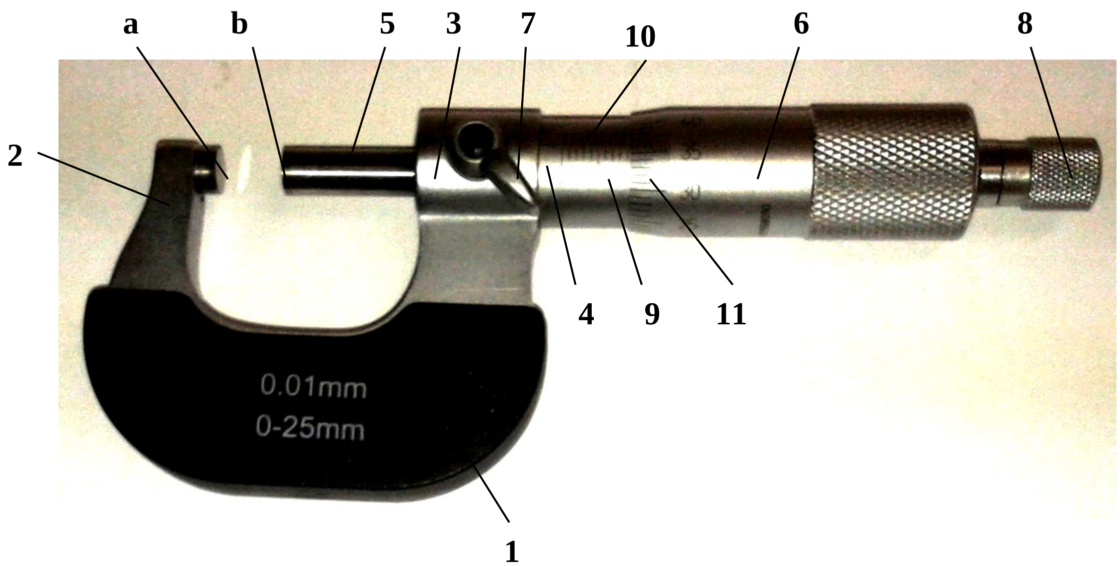


Fig. 2. Outside micrometer

The micrometer is provided with a locking mechanism of the micrometric screw (with the role of materializing, between the measuring surfaces, a given period of time, a certain size), actuated by the lock nut 7 and a mechanism for limiting the measuring force (at a specified value, with the role of protecting the micrometer against vibration and damage of the threaded mechanism), actuated by the last element on the thimble (ratchet stop 8, located at the end of the sleeve 4). The ratchet is itself a small device which is used to provide a limited applied force, it is installed at the right end of screw gauge, ratchet acts as a safety device for instruments and also adds more precision in measurement. Final adjustment is made by a making three turns of ratchet.

În order to read the measured size, the micrometer has three reference scales:

- scale 9, the scale of millimeters, with divisions with the value of 1 mm and numbered every 5 mm, drawn on the sleeve, along its generatrix;
- scale 10, the scale of half a millimeter, also arranged on the sleeve, but separated from the first by a line drawn along its generator; the second scale has divisions with a value of 1 mm, but unnumbered and offset by half division from those on the millimeter scale;
- circular scale 11, the scale of fractions of a millimeter (circular vernier) drawn on the circumference of the thimble, having 50 divisions, with the value of 0.01 mm, numbered every 5 units.

Due to the fact that the measuring mechanism of the micrometers is the pair of screw - nut with fine pitch, of 0.5 mm, the travel of the micrometric screw is limited to the value of 25 mm. Therefore, in order to measure dimensions larger than 25 mm, the micrometers are executed with multiple measuring ranges of 25 mm: 0 - 25 mm, 25 - 50 mm, 50 - 75 mm, 75 - 100 mm, 100 - 125 mm, and so on

The micrometers with the lower limit of measurement over 25 mm, are adjusted (calibrated) by means of cylindrical gauges (cylindrical rods with active flat surfaces) which materialize, between the flat surfaces of the ends, the lower limit of measurement.

3. Measurement of linear dimensions with micrometers

When measuring the linear dimensions with micrometers, the direct evaluation method is applied. In order to prevent the measurement errors due to elastic and contact deformations (of the active surfaces of the instrument, respectively of the controlled part), during the measurement, the pressing force will be limited by using the pressure limiting mechanism in the construction of most micrometers.

3.1. Measurement of external dimensions with outside micrometers

The external dimensions (external diameters, distances between flat or other external surfaces) are measured with outside micrometers provided with flat active surfaces, between which the control part is inserted (fig. 3).

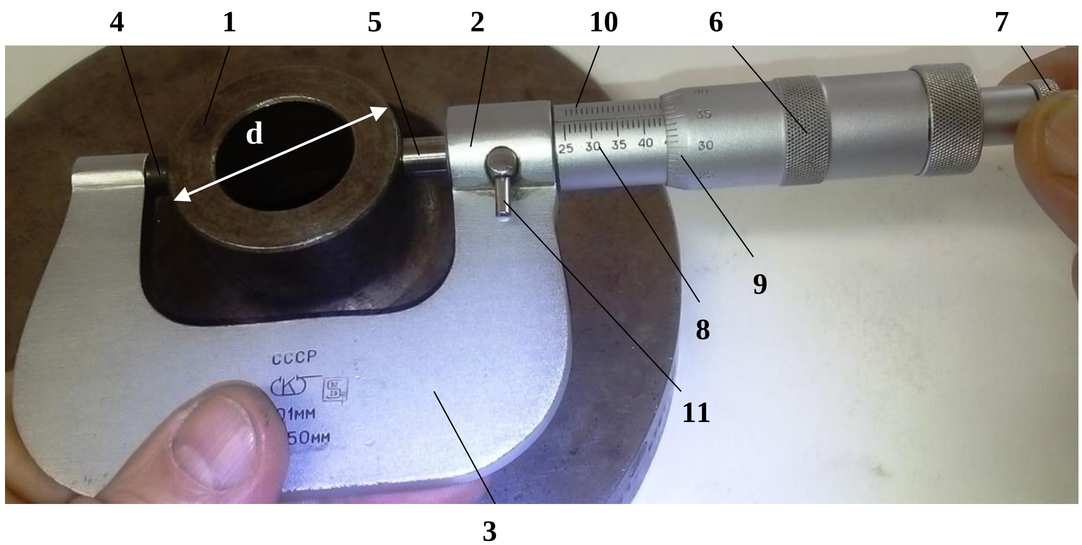


Fig. 3.
Measurement of the dimimension

Measurement technique: to measure the diameter d of the workpiece 1, with the outside micrometer 2, proceed as follows (fig. 3): hold the micrometer, with the left hand, on the frame 3 (in this position one can see all three instrument scales) and insert the control part 1, between the active surfaces 4 and 5, of the micrometer; with the right hand, rotate the thimble 6, to bring the measuring surfaces 4 and 5 closer to the surface of the workpieces, then fine adjustment can be made always rotating the outside micrometers ratchet stop 7, from the end of the thimble 6 (which will operate the mechanism of pressure limitation).

When the ratchet stops 7 turns with no load, it means that the correct contact has been made between the workpiece and the measuring surfaces and the reading of the measured value on the scales 8, 9 and 10 of the instruments can be taken.

If it is necessary to materialize, between the active surfaces 4 and 5, the measured dimension, the lever 11 is actuated to block the rotation of the thimble 6.

Note: outside micrometers can be fixed in micrometer holders, the measurement technique being the same.

3.2. Measurement of interior dimensions with micrometers.

Two distinct categories of micrometric screw instruments are used to measure interior dimensions (interior diameters, distances between flat or other interior surfaces):

- micrometers with two rods, one fixed and one mobile during the measurement, namely:
  - tubular inside micrometer, with spherical active surfaces;
  - caliper jaw inside micrometer, with cylindrical active surfaces;

- instruments with micrometric screw provided with three mobile feelers, “holtest” type.

3.2.1. Measurement of interior dimensions with tubular inside micrometer

Tubular inside micrometer (fig. 1. b), have the shape of cylindrical rods, provided at the ends with spherical active surfaces (part of a spherical surface) which are brought into contact with the inner surface to be controlled.

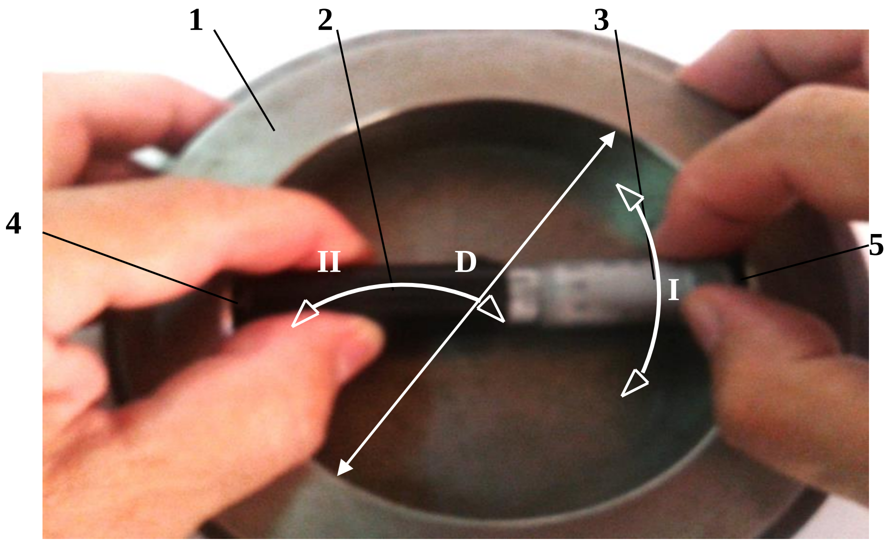


Fig. 4.
Measurement with tubular inside micrometer

Measurement technique: to measure the inner diameter D, of the part to be controlled 1, proceed as follows (fig. 4): insert the micrometer 2, inside the cylindrical surface and actuate the thimble 3, to bring the active surfaces 4 and 5 into contact, with the inner cylindrical surface to be controlled.

To ensure the contact between the active surfaces of the micrometer and the workpiece surface, according to its diameter, tilt the micrometer rod in the normal plane on the workpiece axis (movement I) and in the axial plane (movement II). When the correct contact has been made, the measured dimension is read on the instrument's reference scales.

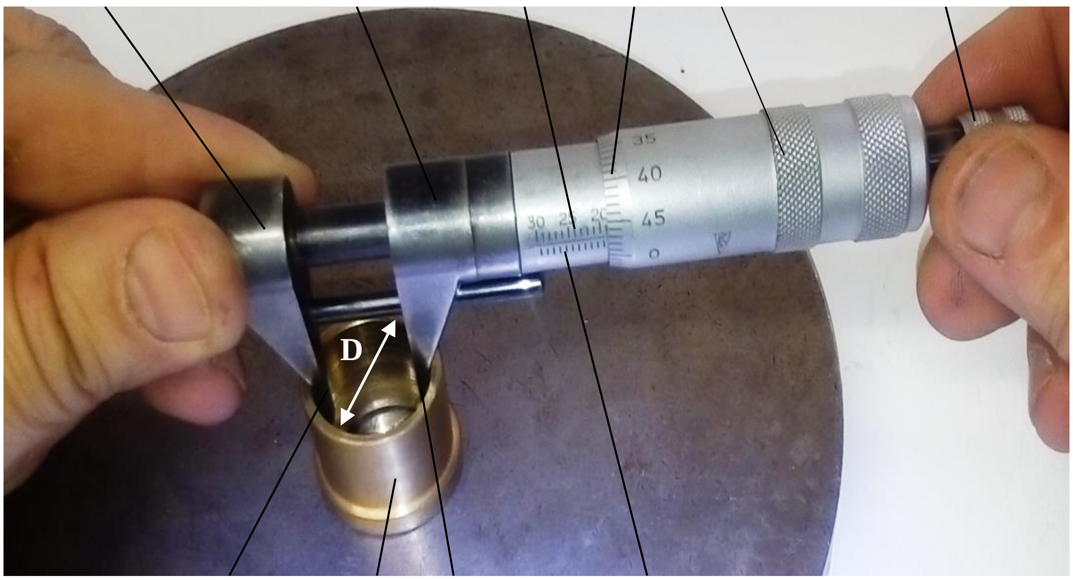
Note: the tubular inside micrometer is not provided with a mechanism for limiting the pressing force; therefore, it will only be used to measure interior dimensions if no other dial bore gauges are available.

3.2.2. Measurement of interior dimensions with caliper jaw inside micrometer

Caliper jaw inside micrometer (fig. 1. a), are provided with two jaws (one fixed during the measurement and the other movable) which have opposite cylindrical active surfaces (part of a spherical surface) which come into contact with the inner surface to be controlled.

Measurement technique: to measure the inner diameter D of the workpiece to be controlled 1, proceed as follows (fig. 5): hold the micrometer, with the left hand, on the upper part of the fixed jaw 3 and, with the right hand, rotate the thimble 3, to bring the jaws 2 and 4 closer together.

3 2 8 9 4 7



5 1 6 10

Fig. 5. Measurement of interior dimensions with caliper jaw inside micrometer

Insert the jaws 2 and 4 into the cylindrical surface and rotate the thimble 3 (in the opposite direction) to bring the measuring surfaces closer to the surface of the workpiece, then bring them in contact always rotating the ratchet 7 at the end of the thimble 3 (which will actuate the pressure limiting mechanism).

When the ratchet 7 turns with no load, it means that the correct contact has been made between the workpiece and the measuring surfaces (5 and 6) and the reading of the measured value on the scales 8, 9 and 10 of the instruments can be taken.

Note: at the caliper jaw inside micrometer the millimeter scale is numbered inversely compare to the outside micrometers (divisions are numbered from right to left).

Therefore, this particularity will be taken into account, in order to take a correct reading of the measured dimension.

3.2.3. Measurement of interior dimensions with micrometers "holtest" type.

The holtest they differ from the other micrometers (which have two active surfaces) in that they have three active surfaces with which they come into contact with the inner surface to be controlled. For this reason, these instruments are adjusted (calibrated) using ring gauges, which materialize one of the limits of the measuring range of the instrument.

Fig. 6. Holtest set
a.- micrometers; b.- ring gauge set; c.- extender

The instruments with micrometric screw type "holtest" (also known as devices for direct measurement of bores) are delivered in kits, which include three instruments, along with the ring gauges used for calibration (Fig. 6). In this way, a "triobor" type tool kit can cover a size range of 30 - 45 mm.

Measurement technique: for measuring the inside diameter of the workpiece 6 (fig. 7.c), the instrument is adjusted whit a ring gauge from the kit with an inside diameter equal to one of the limits of the measuring range of the instrument.

Hold the instrument, with the left hand, by its rod 2 and insert the measuring head 3, inside the ring gauge 1 (fig. 7.a); with the right hand, rotate the thimble 4, by actuating the ratchet 7, to bring the measuring surfaces 5 into contact with the inner cylindrical surface to be controlled and adjust the instrument as follows: if the marker "0" of the circular scale on the thimble 4, does not coincide with the mark on the scale of millimeters corresponding to the nominal value of the diameter of the ring gauge used, the locknut 11 is actuated to allow the rotation of the rod 2 of the instrument; rotate the rod 2, at a very small angle, then lock it in the rotated position with the locknut 11. Repeat the operation until the instrument is adjusted.

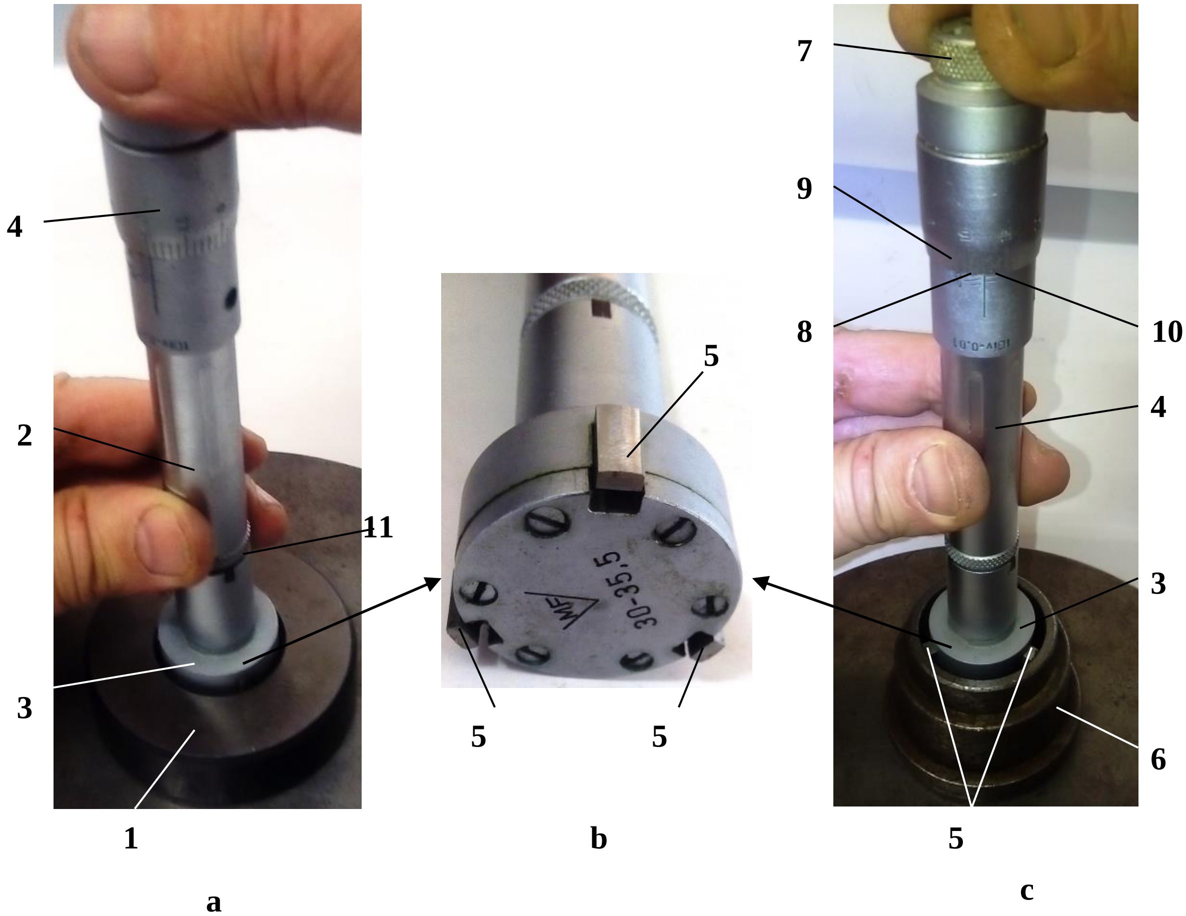


Fig. 7. Measurement with holdtest
a.- reglarea la zero a instrumentului; b.- capul de măsurare (detaliu); c.- măsurarea diametrului interior

After adjusting the instrument, the measuring head 2 is removed from inside the ring gauge 1 and inserted inside the control workpiece 6 (fig. 7.c). Always rotate the ratchet 7 at the end of the thimble 4 (which will actuate the pressure limiting mechanism) and make contact between the active surfaces 5 and the inner surface to be controlled.

When the ratchet 7 turns with no load, it means that the correct contact has been made between the workpiece and the measuring surfaces and the reading of the measured value on the scales 8, 9 and 10 of the instruments can be taken

3.3. Depth measurement with depth micrometers.

The depth measurements are made with depth micrometers (fig. 8.c), which have in their construction a base, provided with an active flat lower surface, through which the instrument rests on the control piece, and the micrometer measurement rod has at the end the second flat active surface.

Measurement technique: for measuring the depth H, of the workpiece to be controlled 1, the base 2, of the depth micrometer with its lower flat active surface, is supported on the upper surface of the workpiece 1 (fig. 8); rotate the thimble 3 and bring the lower end of the measuring rod 5, of the micrometric screw, close to the other (lower) surface of the part. To make contact, ***always*** rotate the thimble ratchet 4 (which will actuate the pressure limiting mechanism).

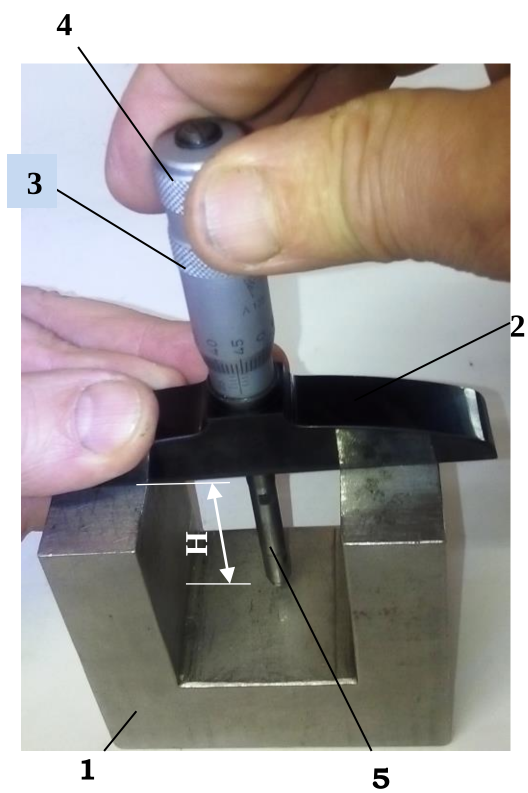


Fig. 8. Depth measurement with depth micrometers.

When the ratchet 7 turns with no load, it means that the correct contact has been made between the workpiece and the measuring surfaces and the reading of the measured value on the instrument scales can be taken

4. Reading the measured value with the micrometer

The reading of the value of a dimension measured with the micrometer is taken in the following sequence (fig. 9):

- **millimeter reading:** the number of millimeters is read on the millimeter scale on the sleeve of the micrometer, observing its closest reference to the edge of the thimble;
- **reading the millimeter fractions**: it is observed which landmark on the circumference of the thimble is in the extension of the line that separates the two scale on the sleeve; multiply the number of divisions on the thimble by the value of the division, obtaining the fraction of millimeter: 12 mm + 2 x 0.01 mm = 12 + 0.02 = 12.02 mm (fig.9a.);
- **half-millimeter reading:** if between the millimeter reading mark and the thimble edge, a half-millimeter scale mark (located on the micrometer sleeve and opposite the millimeter scale) is observed, at the indication obtained previously, 0.5 mm is added: 35 mm + 27 x 0.01 mm + 0.5 mm = 35.77 mm (fig. 9.b.).

Note: the micrometric screw, having a pitch of 0.5 mm, moves axially by 1 mm when performing two complete rotations; on the thimble (there are 50 divisions x 0.01 mm = 0.5 mm) the fractions for each of the two rotations of the micrometric screw on the interval of 1 mm will be read. When the mark on the half-millimeter scale is observed, the value 0.5 mm will be added to the reading (the micrometric screw is in the second rotation, respectively in the second half of the millimeter).

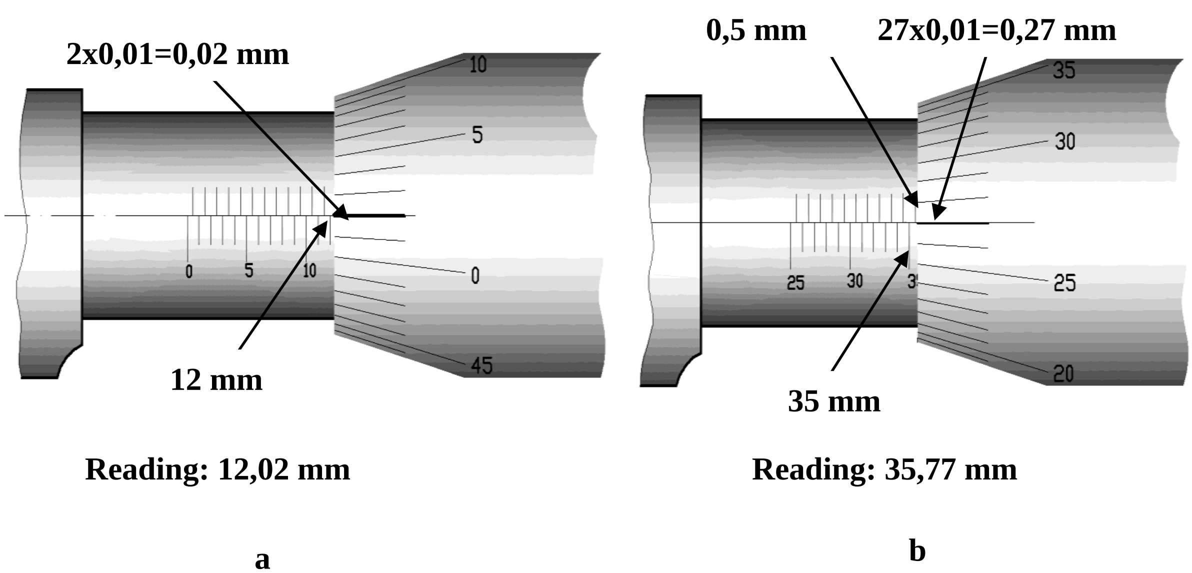


Fig. 9. Reading with micrometer

a.- dimension range 12 - 12,5 mm;
b.- dimension range 35,50 - 36 mm.

5. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed**:**

Step no. 1: the execution drawing of the piece to be controlled, will be made; on the execution drawing, the tolerance of the dimension to be measured will be noted.

Step no. 2: the calculation of the limit values and of the tolerance for both tolerated dimensions will be made.

Step no. 3: Measure the considered size and obtain the actual value (measured size), *De* (for holes), respectively, *de* (for shafts); go to the control sheet;

Step no 4: the effective value of the measured dimension will be compared with the prescribed tolerance.

Step no. 6: the decision concerning the controlled piece will be made:

- if Dmin **≤ De ≤ Dmax (for holes),** the controlled piece is accepted to be used;
- if dmin **≤ de ≤ dmax (for shafts)**, the controlled piece is accepted to be used.

Laboratory work no. 5

DIMENSIONAL TOLERANCES FOR SIMPLE FORM PIECES

Applications to be made at laboratory work no. 5:

a - calculation with dimensional tolerances;
b – graphical representation of the tolerance zone of a tolerated size;
c – calculation of the limit clearances or interference in a fit and of the fit's tolerance.

1. General considerations

The inaccuracy processing causes deviations of sizes and geometry of the manufactured pieces. In order to ensure product performance are established tolerances for dimensional and geometric parameters which are indicated on the work drawings as technical execution conditions.

That's why the designers have to know the graphical symbols, the literaly symbols and the numerical symbols (which are known as specifications); the main terms used in the area of dimensional and geometrical tolerances, are given in table no. 1.

2. Dimensional tolerances

2.1. Tolerated dimensions.

A tolerated dimension is a dimension with limit deviations (to which it is prescribed a tolerance).

For the mounting dimensions (which form fits in the joints of parts) individual tolerances are established by the SR EN 20286-1: 1997 and SR EN 20286-2: 1997 standards.

For the nonfunctional dimensions (which do not form fits in ensembles) general tolerances are established by the SR EN 22768- 1: 1995 standard.

A tolerated dimension is completely characterized if are known the following elements:

- the nominal value of the dimension;
- the tolerance class (combination of fundamental deviation and tolerance grade).

With these elements can be determined:

- the values of the limit deviation;
- the value of the dimensional tolerance;
- the limit values of the dimension considered.

In order to calculate with dimensional tolerances shall be known the basic terms, given in table no. 1

Table no. 1

The term	Definition	Relation to calculation
0	**1**	**2**
Size/ dimension	Number expressing the unit set, the numerical value of a length or an angle.	
Quota	Dimension stated on the drawing.	
Shaft (outer dimension)	Dimension of an outer surface, even if it is not cylindrical.	
Hole (inner dimension)	Dimension of an inner surface even if it is not cylindrical	
Nominal size, N	Dimension with the value obtained from functional reasons or from resistance to forces.	
Theoretically exact size (framed)	The dimension which has no tolerance.	
Actual size	The dimension that is obtained from part machining	
Effective size	The dimension is obtained by measuring the actual size	
Functional dimensions	The dimensions which values are resulting from calculus, in order to ensure the right operation of the parts.	
Mounting dimensions	The dimensions which are forming fits in the joints of parts (they may coincide with the functional dimensions). The mounting dimensions receive individual tolerances.	
Nonfunctional dimensions	The dimensions which do not form fits in ensembles and there are not very important for the right operation of the parts. The nonfunctional dimensions receive general tolerances.	

Table no. 1 (continuance)

0	1	2
Maximum size	The biggest size of the size range: - for shaft: ***dmax*** - for holes: ***Dmax***	d_{max} = N + es; D_{max} = N + ES.
Minimum size	The smallest of the size of the size range: - for shaft: ***dmin*** - for holes: ***Dmin***	d_{min} = N + ei D_{min} = N + EI
Limit deviations	The differences between the limit and the nominal dimension.	
Upper deviation	The difference between the maximum size and nominal size: - for shafts: **es** - for holes: **ES**	es = d_{max} – N ES = D_{max} – N
Lower deviation	The difference between the minimum size and nominal size: - for shafts: **ei** - for holes: **EI**	ei = d_{min} – N EI = D_{min} – N
Dimensional tolerance	The difference between the limit dimensions (maximum size and minimum size) or the difference between limit deviations. It is note: - for shafts: **ITa** - for holes: **ITA**	ITa = d_{max} – d_{min} = es – ei ITA =D_{max} – D_{min} = ES – EI
Zero line	The line corresponding to the nominal size, conventional, chosen to define the limit deviations of the dimension.	
Tolerance zone (tolerance area)	Area between the lines of the limit deviations.	
Fundamental deviation	The limit deviation which is nearest to the zero line	
Fundamental tolerance	A tolerance that belongs to the standardized system of tolerances and fits.	
Tolerance grade	A number that expresses the precision degree of required for the actual size.	
Class of tolerance	Combining fundamental deviation a nd tolerance grade.	

Table 1 (continuance)

0	1	2
Fit	A relationship referring to the difference, before mounting between the effective dimensions of the joint.	
Maximum clearance	The difference, before mounting, between the maximum hole and the minimum shaft in a joint.	$\mathbf{J_{max} = D_{max} - d_{min} = ES - ei}$
Minimum clearance	The difference, before mounting, between the minimum hole and the maximum shaft in a fit.	$\mathbf{J_{min} = D_{min} - d_{max} = EI - es}$
Maximum interference	The difference, before mounting, between the maximum shaft and the minimum hole in a fit.	$\mathbf{S_{max} = d_{max} - D_{min} = es - EI}$
Minimum interference	The difference, before mounting, between the minimum shaft and the maximum hole in a fit.	$\mathbf{S_{min} = d_{min} - D_{max} = ei - ES}$.
Tolerance of the fit	Shaft and bore tolerances sum.	$\mathbf{IT_{aj} = IT_a + IT_A}$.
	Tolerance of the clearance fit:	$\mathbf{IT_{aj} = J_{max} - J_{min}}$.
	Tolerance of the interference fit:	$\mathbf{IT_{aj} = S_{max} - S_{min}}$
	Tolerance of the transition fit:	$\mathbf{IT_{aj} = Jmax + S_{max}}$
Basis shaft, **h**	The shaft taken as a base in the shaft- basis system of fit.	
Basis hole **H**	The hole taken as a base in the hole-basis system of fit.	
Shaft-basis system of fits	All fits obtained by associating a unique shaft called basis shaft to all the holes of the considered system	
Hole -basis system of fits	All fits obtained by associating a unique hole called basis hole to all the shafts of the considered system	
System of fits	Assembly of fits were the clearances and the clamping are obtained by combination of shafts and holes tolerances of the same system.	
General tolerances	Tolerances for nonfunctional dimensions and surfaces.	
General dimensional tolerances	Dimensional tolerances prescribed to the nonfunctional sizes, according to EN 22768-1: 1995	
General geometrical tolerances	Geometric tolerances (for characteristics of form, orientation and relative position) prescribed for nonfunctional surfaces, according to EN 22768-2: 1995	

3. Calculations with tolerated dimensions.

3.1. Calculation of the limits of the dimension.

The two limits of a tolerated dimension are calculated with the formulas:

for shaft (outer size): | *for holes (inner size):*

$\mathbf{d_{max} = N + es}$ (1) | $\mathbf{D_{max} = N + ES}$ (3)

$\mathbf{d_{min} = N + ei}$ (2) | $\mathbf{D_{min} = N + EI}$ (4)

3.2. Calculation of the dimensional tolerance.

The dimensional tolerance is calculated with two equivalent formulas:

for shaft (outer size): | *for holes (inner size):*

I: $\mathbf{ITa = d_{max} - d_{min}}$ (5) | *I:* $\mathbf{ITA = D_{max} - D_{min}}$ (7)

II: $\mathbf{ITa = es - ei}$ (6) | *II*: $\mathbf{ITA = ES - EI}$ (8)

3.3. The graphical representation of the tolerance zone of a tolerated dimension

The tolerance zone is represented as a rectangle having the (width equal to the tolerance of the dimension (figure 1)

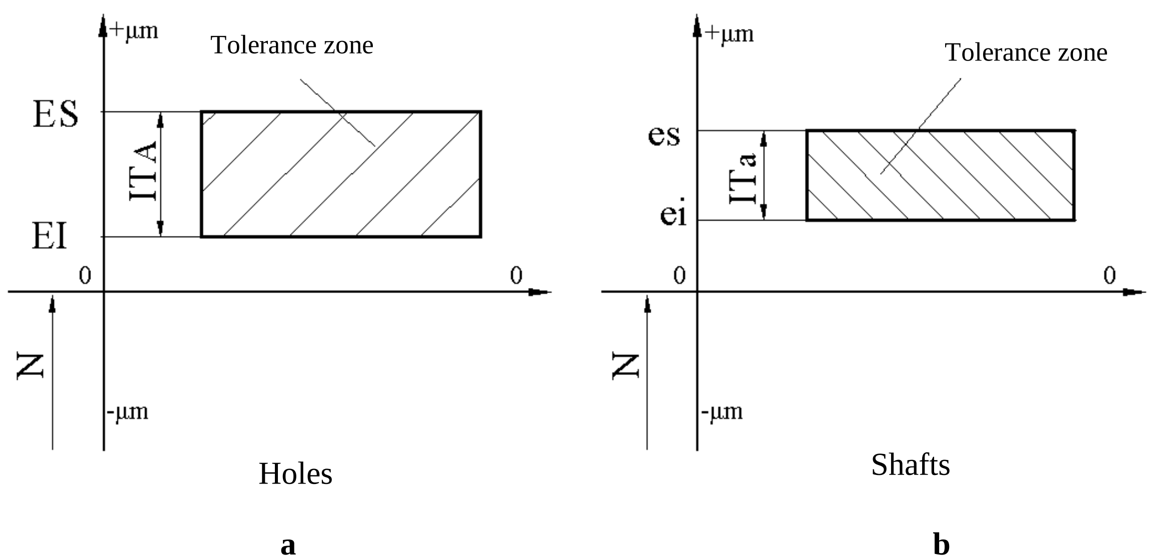


Fig. 1.
Garphical representation of the tolerance zone
a.- for a hole; b.- for a shaft

3.4. Establishing the limit deviations using the SR EN 20286- 2: 1997 standard.

In SR EN 20286-2: 1997 standard are presented the limit deviations for all the shafts and all the holes specified in the ISO system of tolerances and fits.

Two examples are presented in this work, in order to show the working mode.

<u>Example no. 1.</u> Is required to establish the limit deviations of the **30g6** dimension.

In order to resolve this issue, a number of steps are followed:

Step no.1: the elements of the tolerated size are identified:

- the nominal value of size: **N = 30** mm;
- the tolerance class: **g6**.

Step no.2: in ANNEX I: the column of the tolerance class g6 is identified (figure 2).

Step no. 3: in the same ANNEX I: the row corresponding to the range of sizes which includes the nominal size N= 30 mm (over 18 until 30 mm).

Step no.4: in the intersection box (column of g6 and row of N= 30 mm) there are two numerical values one above the other. The value on top is the upper deviation, es and the bottom value is the lower deviation, ei. Both values are given in micrometers.

ANNEX NO.1

Limit deviations for shafts

Values in µm

Dimensiuni nominale [mm]		e			f			g				
Intervale principale	Intervale secundare	5	6	7	5	6	7	5	6	7	4	5
Până la 3 [1)]		-14 -18	-14 -20	-14 -24		-6 -10	-6 -12	-2 -6	-2 -8	-2 -12	0 -3	0 -4
(3 - 6]		-20 -25	-20 -28	-20 -32		-10 -15	-10 -18	-4 -9	-4 -12	-4 -16	0 -4	0 -5
(6 - 10]		-25 -31	-25 -34	-25 -40		-13 -19	-13 -22	-5 -11	-5 -14	-5 -20	0 -4	0 -6
(10 - 18]		-32 -40	-32 -43	-32 -50		-16 -24	-16 -27	-6 -14	-6 -17	-6 -24	0 -5	0 -8
(18 - 30]		-40 -49	-40 -53	-40 -61		-20 -29	-20 -33	-7 -16	-7 -20	-7 -28	0 -6	0 -9
	(30 - 40]	-50 [illegible]	-50 [illegible]	-50 [illegible]	-25 [illegible]	-25 [illegible]	-25 [illegible]	-9 [illegible]	-9 [illegible]	0 [illegible]	0 [illegible]	0 [illegible]

Fig. 2

Conclusion: the limit deviations of the tolerated dimension 30 g6, founded in the standard, are: **= -7 µm, ei = -20 µm**.

Example no. 2. Is required to establish the limit deviations of the **30H7** dimension.

In order to resolve this issue, a number of steps are followed:

Step no.1: the elements of the tolerated size are identified:

- the nominal value of size: **N = 30** mm;
- the tolerance class: **H7**.

Step no.2: in ANNEX I: the column of the tolerance class H7 is identified (figure 3).

Step no. 3: in the same ANNEX I: the row corresponding to the range of sizes which includes the nominal size N= 30 mm (over 18 until 30 mm).

Step no.4: in the intersection box (column of H7 and row of N= 30 mm) there are two numerical values one above the other. The value on top is the upper deviation, ES and the bottom value is the lower deviation, EI. Both values are given in micrometers.

ANNEX NO.2

Values in µm

Limit deviations for holes

Dimensiuni nominale [mm]		E			F			G			H				
Intervale principale	Intervale secundare	6	7	8	6	7	8	6	7	8	5	6	7	8	9
Până la 3 1)		+20 +14	+24 +14	+28 +14	+12 +6	+16 +6	+20 +6	+8 +2	+12 +2	+16 +2	+4 0	+6 0	+10 0	+14 0	+25 0
(3 - 6]		+28 +20	+32 +20	+38 +20	+18 +10	+22 +10	+28 +10	+12 +4	+16 +4	+22 +4	+6 0	+8 0	+12 0	+18 0	+30 0
(6 - 10]		+34 +25	+40 +25	+47 +25	+22 +13	+28 +13	+35 +13	+14 +5	+20 +5	+27 +5	+6 0	+9 0	+15 0	+22 0	+38 0
(10 - 18]		+43 +32	+50 +32	+59 +32	+27 +16	+34 +16	+43 +16	+17 +6	+24 +6	+33 +6	+8 0	+11 0	+18 0	+27 0	+43 0
(18 - 30]		+53 +40	+51 +40	+73 +40	+33 +20	+41 +20	+53 +20	+20 +7	+28 +7	+40 +7	+9 0	+13 0	+21 0	+33 0	+52 0
	(30 – 40)	+66 [illegible]	+75 [illegible]	+89 [illegible]	+41 [illegible]	+50 [illegible]	+64 [illegible]	+25 [illegible]	+34 [illegible]	+48 [illegible]	+11 [illegible]	+16 [illegible]	+25 [illegible]	+39 [illegible]	+62 [illegible]

Fig. 3

Conclusion: the limit deviations of the tolerated dimension 30 H7, founded in the standard, are: **ES = +21 µm, ei = 0 µm**.

Using the limit deviations, the two tolerated dimensions can be written as is followed:

The shaft: $30g6=30^{-0,007}_{-0,020}$ mm

The hole: $30H7=30^{+0,021}_{0}$ mm

4. Fits. Types of fits.

The fit is a relationship resulting from the difference, before mounting, between the effective dimensions of the joint: the fit is referring to the size of the clearance or of the clamping between two assembled parts.

The main characteristics of the fit are the followings:

- ***the nominal size of the fit:*** is the common nominal size of the conjugated parts;
- ***the fit tolerance***, IT_{aj}: the sum of the hole and shaft tolerances:

$$IT_{aj} = IT_a + IT_A. \qquad (9)$$

4.1. Types of fits. Graphical representation of the fits.

There are the following types of fits in the joints of parts:

- clearance fits;
- interference/tight fits;
- transition fits.

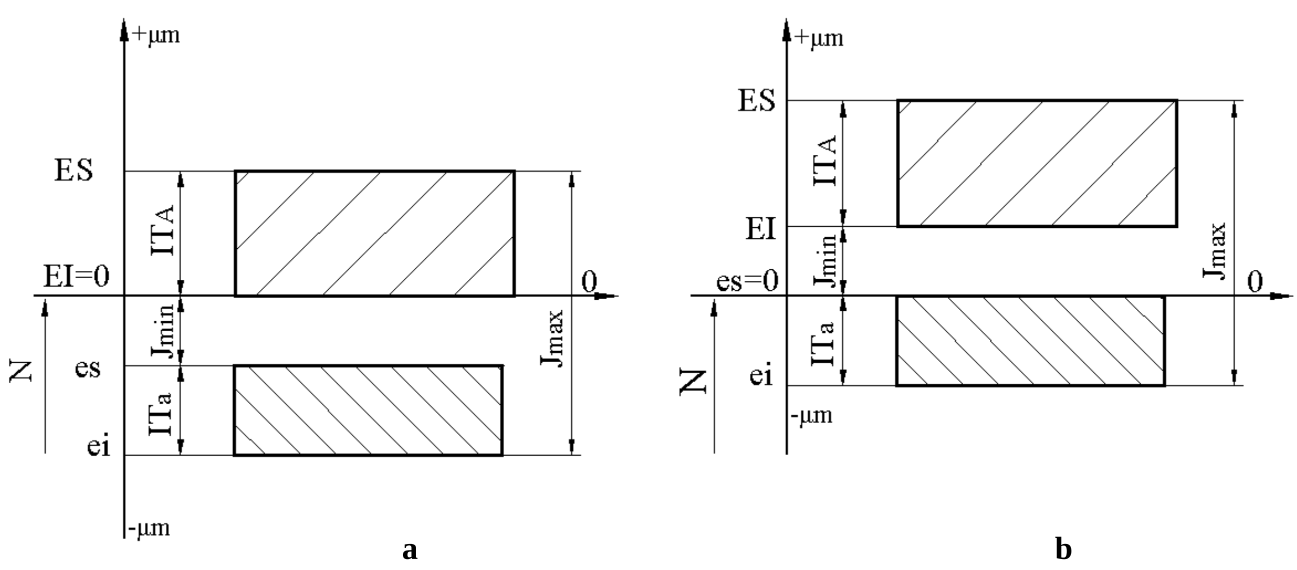


Fig. 4.
Graphical representation of a clearance fit
a.- in hole-basis system of fits; b.- in shaft-basis system of fits.

a. <u>Clearance fits</u>: the fits which always ensure a clearance in the joint of parts. In graphical representation of the clearance fit, the tolerance zone of the hole is situated over the tolerance zone of the shaft, apart minimum clearance one to each other (figure no. 4).

The maximum clearance is the difference, before mounting, between the maximum hole and the minimum shaft in a fit:

$$\mathbf{J_{max} = D_{max} - d_{min} = ES - ei.} \tag{10}$$

The minimum clearance is the difference, before mounting, between the minimum hole and the maximum shaft in a fit:

$$\mathbf{J_{min} = D_{min} - d_{max} = EI - es.} \tag{11}$$

The clearance fit tolerance $\boldsymbol{IT_j}$, is calculated as follows (starting with formula no. 9):

$$\mathbf{IT_{aj} = IT_j = IT_A + IT_a = ES - EI + es - ei = (ES - ei) - (EI - es)}$$

$$\mathbf{IT_{aj} = J_{max} - J_{min}.} \tag{12}$$

b. <u>Interference/ tight fits</u>: the fits which always ensures an interference in the fit of parts. In graphical representation of the interference fit, the tolerance zone of the hole is situated under the tolerance zone of the shaft, apart minimum interference one to each other (figure no. 5.).

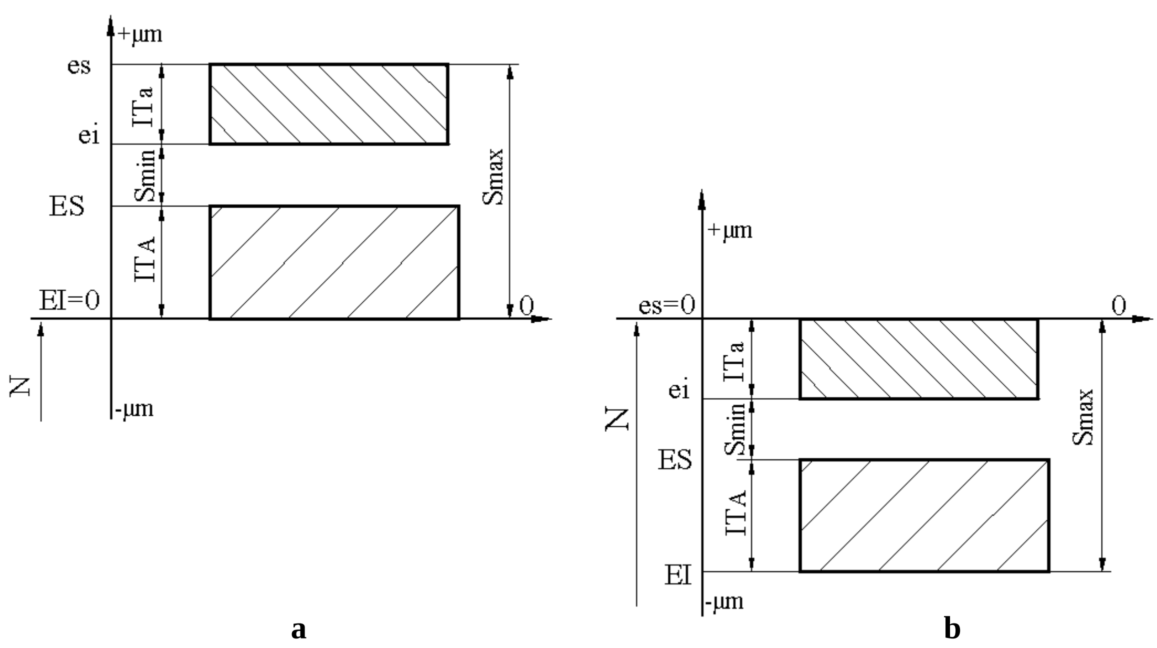


Fig. 6.
Graphical representation of a interference/tight fit
a.- in hole -basis system of fits; b.- in shaft -basis system of fits.

The maximum interference is the difference, before mounting, between the maximum shaft and the minimum hole in a fitment:

$$\mathbf{S_{max} = d_{max} - D_{min} = es - EI.} \quad (13)$$

The minimum interference is the difference, before mounting, between the minimum shaft and the maximum hole in a fitment:

$$\mathbf{S_{min} = d_{min} - D_{max} = ei - ES.} \quad (14)$$

The interference fit tolerance IT_s, is calculated as follows (starting with formula no. 9):

$$\mathbf{IT_{aj} = IT_s = IT_A + IT_a = ES - EI + es - ei = (es - EI) - (ei - ES)}$$

$$\mathbf{IT_{aj} = IT_s = S_{max} - S_{min}} \quad (15)$$

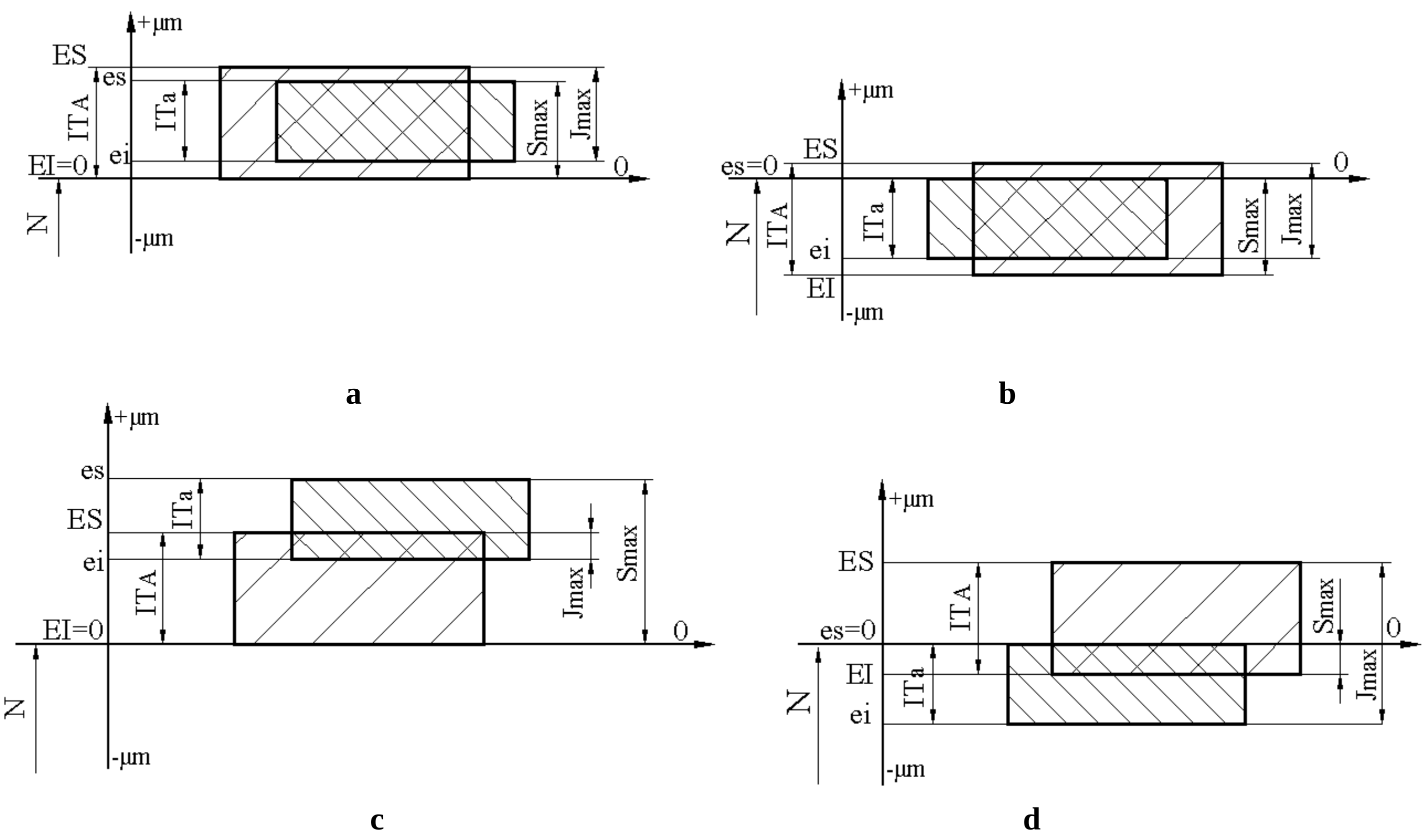


Fig. 7.
Graphical representation of an transition fit
a, b- in hole -basis system of fits; c, d.- in shaft basis system of fits.

c. <u>Transition fits</u>: the fits which ensures a small clearance or a small interference in the fit of parts. In graphical representation of the transition fit, the tolerance zone of the hole and the tolerance zone of the shaft, are totally superimposed (figure no. 7.a and b), or partial superimposed (figure no. 7.c and d).

The intermediary fit is characterized by maximum clearance and maximum clamping.

The transition fit tolerance IT_i, is calculated as follows (starting with formula no. 9):

$$\mathbf{IT_{aj} = IT_A + IT_a = ES - EI + es - ei = (ES - ei) - (ei - ES)}$$

$$\mathbf{IT_{aj} = J_{max} + S_{max}.} \qquad (16)$$

5. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

Step no. 1: the establishing of the limit deviations of a tolerated hole and a tolerated shaft, using SR EN 20286-2: 1997 standard.

Step no. 2: the calculation of the limit values and of the tolerance for both tolerated dimensions.

Step no. 3: the graphical representation of the tolerance zone of both tolerated dimensions.

Step no. 4: shall specify the type of fit and the system of fits for the considered fitment (for the fit settled with the both tolerated dimensions).

Step no. 5: the calculation of the limit clearances/ limit interference and of the fit tolerance.

Laboratory work no. 6

DIMENSIONAL CHAINS

Applications to be made at the laboratory work no. 3:

a. solving the direct problem of the dimensional chains applying the algebraic method;

b. solving the direct problem of the dimensional chains applying the maximum and the minimum method.

1. General considerations

A dimensional chain represents all the linear dimensions and / or the angular dimensions which form a closed contour and determine the size, shape, orientation and relative position of the surfaces of parts or of a part in an assembly/ subassembly.

In an dimensions chain there are two types of sizes:

a. primary sizes or component sizes: the dimensions which are obtained by processing the parts;

b. closing size or resultant size: the dimension which is indirectly obtained after the execution of the primary dimensions.

A dimensions chain can have a minimum of two primary dimensions and one closing dimension; the closing dimension is not quoted on the drawing.

2. Conventional representation of a dimensional chain.

In order to resolve more convenient, the problems of dimensional chains, a conventional representation (schematically) of them it is used: the conventional representation is made using quota lines and auxiliary lines.

Example: the conventional representation of the dimensional chain of the part from figure no. 1.a, is presented in figure no. 1.b.

In the conventional representation of a dimensional chain, the dimensions are noted as follows:

- the primary dimensions are noted with uppercase, having as an index the serial number of dimension in dimensions chain: $\mathbf{A_1, A_2, A_3 \ldots, A_n}$, or $\mathbf{B_1, B_2, B_3 \ldots, B_n}$, etc;
- the closing dimension is noted with R letter, having as an index the letter which the primary dimensions received: $\mathbf{R_A}$ or $\mathbf{R_B}$, etc.

3. The classification of the dimensional chains

The chain dimensions are classified according to several criteria, most important being:

C.1. belonging to a part or to an assembly/ subassembly:

- dimensions chain of a single part (figure 1);
- assembly dimensions chain (figure 2);

C.2. the dimensions type from dimensions chain:

- linear dimensional chain: all the dimensions of the chain are linear sizes (figure 1);

- angular dimensional chain: all the dimensions of the chain are angular sizes (figure 3);
- mixed dimensional chain: the dimension of the chain is both linear and angular;

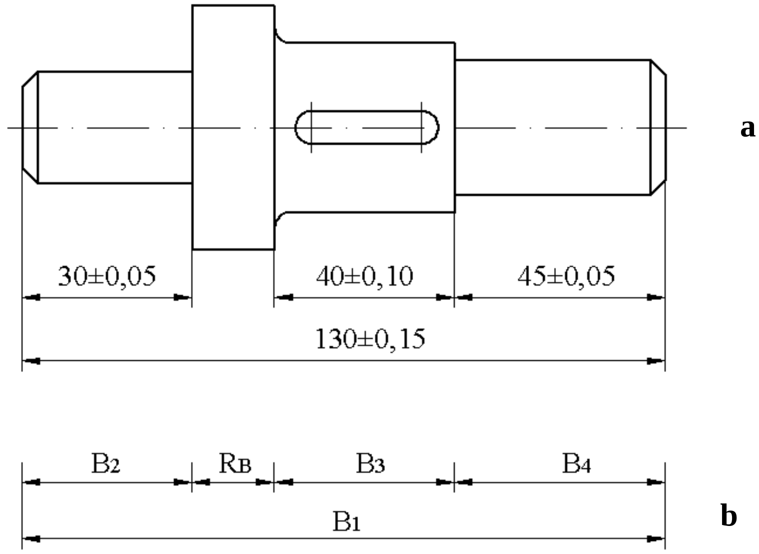


Fig. 1
The dimensional chain of a part
a.- representation on the drawing of the part;
b.- convenţional representation of the chain.

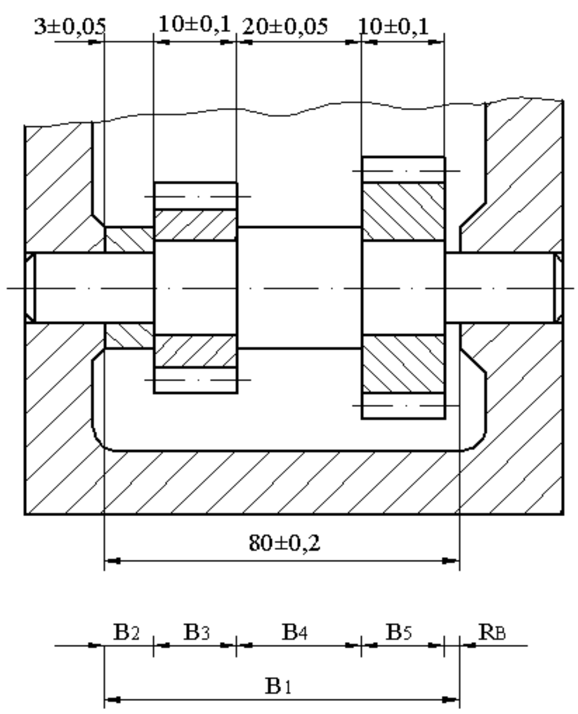


Fig. 2
Assembly dimensional chain
a.- representation on the drawing of the assembly;
b.- conventional representation of the chain.

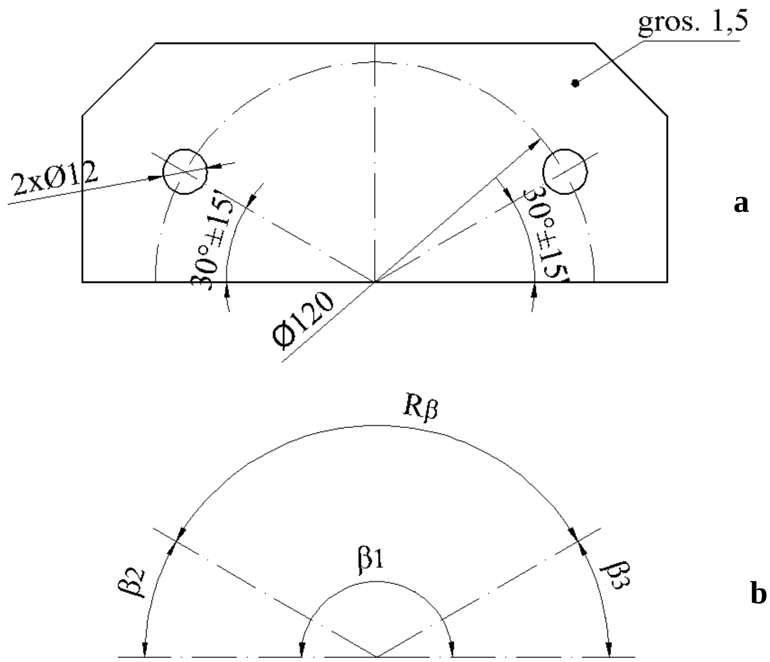


Fig. 3
Angular dimensional chain
a.- representation on the drawing of the part;
b.- convenţional representation of the chain

C.3. **position in space of the sizes from chain dimensions:**

- dimensional chain in plane (figure 4);
- dimensional chain in space;

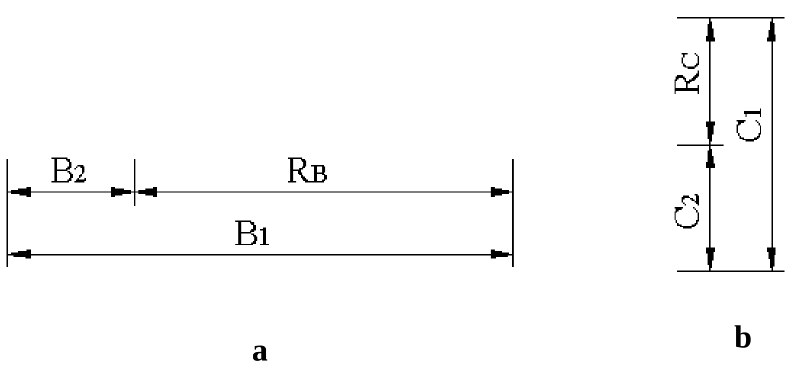


Fig. 4
Dimensional chain in plain with parallel sizes
a.- in the horizontal direction; b.- in the vertical direction

C.4. the complexity of the dimensional chain:

- simple dimensional chain (the dimensions of a chain are independent of the dimension of another chain), see figure 5;
- complex dimensional chains (the dimensional chains which have common dimensions), see figure 6;

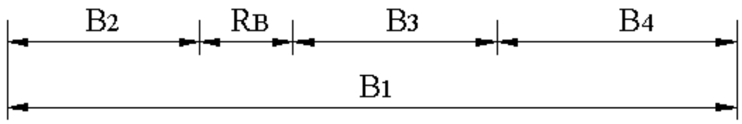


Fig. 5
Simple dimensons chain

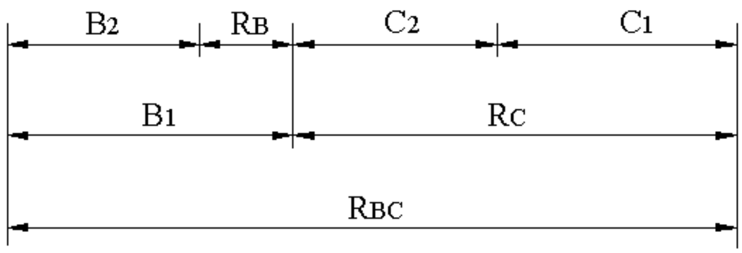


Fig. 6
Complex dimensional chains

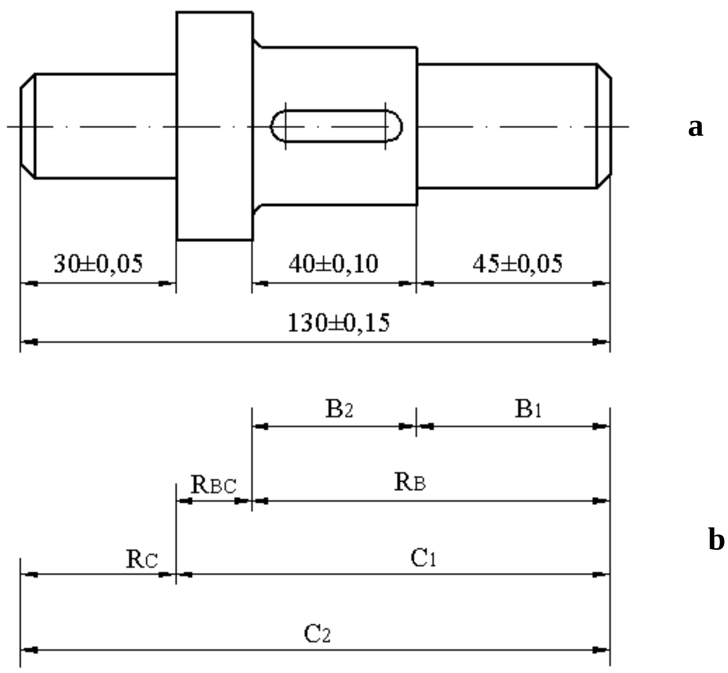


Fig. 7
Dimensional chain in parallel
a.- representation on the drawing of the part;
b.- convenţional representation of the chain

C.5. how to quote the dimensions in the dimensional chains:

- dimensional chains in series (with different quota bases), see figure 4;
- dimensional chains in parallel (with a unique quota base), see figure 7;
- dimensional chains with mixed quota (with two quota bases), see figure 8.

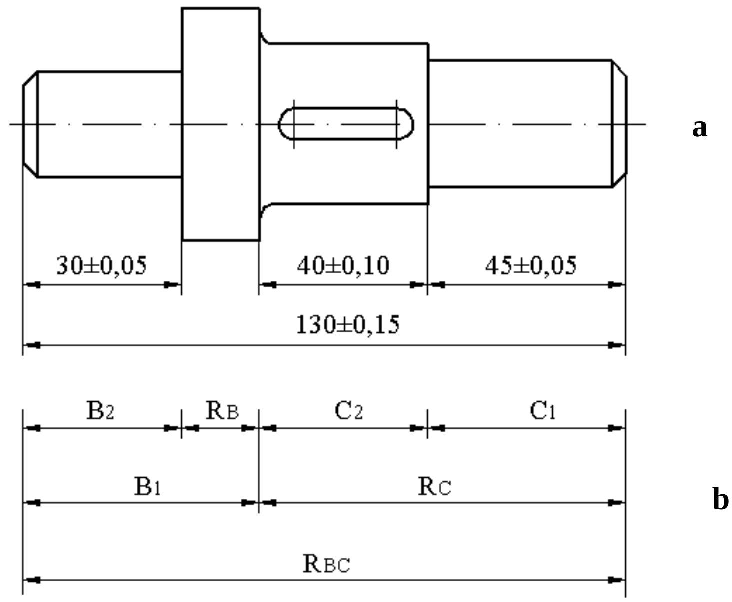


Fig. 7
Dimensional chain with mixed quota bases
a.- representation on the drawing of the part;
b.- convenţional representation of the chain

4. Solving the dimensional chains

When solving a dimensional chain two distinct cases appear:

1. the direct problem which consists in determining the nominal value and limit deviations values of the closed size, when nominal values and limit deviations of the primary dimensions are known;

2. the inverse problem which consists in determining the tolerances and limit deviations of the primary dimensions, when nominal values of them and the closed dimension are known.

Methods to solve the direct problem of dimensional chains:

a. The algebraic method.

The algebraic method of solving the direct problem of dimensional chains, consists in obtaining the closed dimension by simultaneous determination of its nominal value and its limit deviations.

In order to solve the dimensional chain, by applying the algebraic method, follow the steps:

Step no. 1: making the conventional representation of the dimensional chai, considered and establishes a starting point, O and a direction to followed;

Step no. 2: writing the equation of the dimensional chain; in order to write the equation, is established an origin (at any point in the chain dimensions) and a sense to go. In the equation of the dimensions which are going through in the chosen direction, shall receive the „+”, sign and the dimensions which are going through in counter direction shall receive the „-” sign.

Step no. 3: writing the formula of the closing size, from the equation of the dimensions.

Step no. 4: in the formula of the closing size the literal symbols of the dimensional chain shall be replaced with the nominal values and the limit deviations. Then, shall make the calculations with thw same kind of terms.

Note: in an equation, the „-” sign of a dimension, generates the following transformations:

- the change of the sign of the considered size;
- the change of the sign and type of the limit deviation; that means that the upper deviation becomes lower deviation with „-” sign, and the lower deviation becomes upper deviation with „-” sign.

The property of the tolerance of the closing dimension.

The tolerance of the closing dimension is equal to the sum of the tolerances of the primary dimensions of the chain.

$$IT_{RB} = \sum_{i=1}^{n} IT_{Bi} \qquad (1)$$

b. The maximum and minimum method.

The maximum and minimum method of solving the direct problem of dimensional chains, consists in obtaining the closed dimension by calculating its nominal value and its limit deviations one by one.

In order to solve the dimensional chain, by applying the maximum and minimum method, follow the steps:

Step no. 1: making the conventional representation of the dimensional chain.

Step no. 2: establish the increasing sizes and the reducing sizes of the dimensional chain.

An increasing dimension (size) is the primary dimension which, if it is growing determine also, the increasing of the closing size, when the other primary dimensions remain constant.

A reducing dimension (size) is the primary dimension which, if it is growing determine the reduction of the closing size, when the other primary dimensions remain constant.

Step no. 3: calculation of the nominal value of the closing size, by applying the formula:

$$N_{R_B} = \sum_{i=1}^{m} N_{B_i} - \sum_{j=m+1}^{n} N_{B_j}, \tag{2}$$

where:

$\sum_{i=1}^{m} N_{B_i}$ represents the sum of the nominal values of the increasing sizes;

$\sum_{j=m+1}^{n} N_{B_j}$, represents the sum of the nominal values of the reducing sizes.

Step no. 4: calculation of the limit deviations of the closing size:

- ***the upper deviation***:

$$ES_{R_B} = \sum_{i=1}^{m} ES_{B_i} - \sum_{j=m+1}^{n} EI_{B_j}. \tag{3}$$

- ***the lower deviation***:

$$EI_{R_B} = \sum_{i=1}^{m} EI_{B_i} - \sum_{j=m+1}^{n} ES_{B_j}. \tag{4}$$

In the no. 3 and no. 4 formulas, the meanings of the terms are:

$\sum_{i=1}^{m} ES_{B_i}$ represents the sum of the upper deviations of the increasing sizes;

$\sum_{j=m+1}^{n} EI_{B_j}$, represents the sum of the lower deviations of the reducing sizes;

$\sum_{i=1}^{m} EI_{B_i}$ represents the sum of the lower deviations of the increasing sizes;

$\sum_{j=m+1}^{n} ES_{B_j}$, represents the sum of the lower deviations of the reducing sizes;

5. How to perform the laboratory work

The laboratory work consists in the solving of a dimensional chain of a part by applying the algebraic method and the maximum and minimum method (the drawing of the part is given).

To carry out the laboratory work the following steps shall be completed:

Step no. 1: shall execute the drawing of the part (hand drawing)

Step no. 2: shall calculate the nominal value and the limit deviations by applying the algebraic method.

Step no. 3: shall calculate the nominal value and the limit deviations by applying the maximum and minimum method.

Step no. 4: shall verify the property of the closing size tolerance.

Step no. 5: shall specify the type of fit and the system of fits for the considered fit (for the fit settled with the both tolerated dimensions).

Note: the conventional representation of the dimensions chain is compulsory no matter what method is applied.

Laboratory work no. 7

THE INDICATION OF THE DIMENSIONAL AND GEOMETRICAL TOLERANCES ON THE DRAWINGS.

Applications to be made at the laboratory work no. 7.

- the indication of the dimensional tolerances on the landmark drawing;
- the indication of the fits on the assembly drawings;
- the indication of the geometrical tolerances on the landmark drawing;
- the indication of the roughness parameters geometrical tolerances on the landmark drawing.

1. General considerations.

The dimensions and the geometry of the parts integrated in the mechanical structures are obtained using divers manufacturing processes, based on the technical conditions which are established by the designers, in order to ensure the accurate function of the assemblies.

These technical conditions are the following:

- dimensional tolerances with and whitout individual indication (general tolerances);
- geometrical tolerances (of form, orientation and relative position) with and whitout individual indication (general tolerances);
- maximum allowed values for the roughness parameters with and whitout individual indication;
- other technical conditions: thermal treatment, values for the hardness parameters of the part material, metal coating, and so on.

The dimensional and geometrical tolerances are indicated on the drawings using graphical, literal and numerical symbols named specifications, which are regulated by standards.

2. The indication of the dimensional tolerances on the execution drawing (dimensional tolerances with individual indication).

There are two distinct categories of the specifications used to indicate the dimensional tolerances on the execution drawing

- basic apecifications;
- additional specifications.

Note: in the laboratory work will be presented the basic specifications.

3.1. Basic specifications used to indicate the dimensional tolerances.

The basic specifications are graphical, literal and numerical symbols used to direct indications of the dimensional tolerances

These basic specifications are compulsory and shall be positioned after the nominal value of the tolerated dimension.

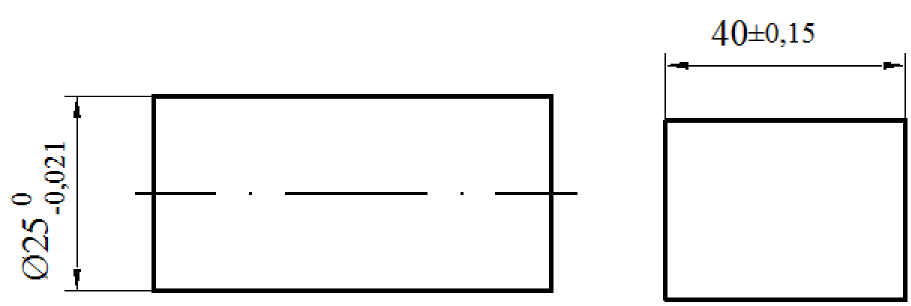
The basic specifications are presented in table no. 1.

Note: the value of the dimension and the values of the limit deviations are given in milimeters.

Basic specifications for tolerated dimensions. **Table no. 1**

No.	Type of tolerance	Description	Exemples	Fig. No.
1.	Tolerances with individual tolerance	Nominal valueN, followed by the limits deviations.	$40^{0}_{-0,025}$; $40^{+0,025}_{-0,015}$ $40\pm0,03$.	1.a, b
2.		Nominal valueN, followed by the tolerance class.	**40 h7;**	2
3.		Nominal valueN, followed by the tolerance class and the limit deviations (in parenthesis).	$40h8\left(^{0}_{-0,025}\right)$	3
4.		Limit values positioned one under the other.	Φ40 Φ39,975	4.a
5.		Limit values positioned one after the other.	Φ40 max. Φ39,975 min	4.b

The exemples of the indication of the dimensional tolerances on the execution drawing are presented in figures no. 1 to 4.



a **b**

Fig. no. 1

Indication of the dimensional tolerance through the limit deviations

a. unequal limit deviations ; b- symmetrical limit deviations

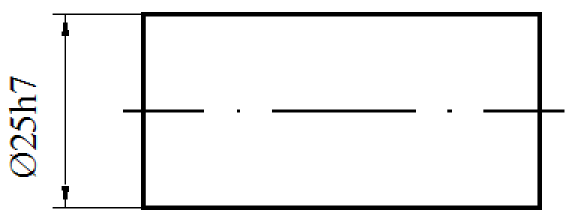


Fig. no. 2
Indication of the dimensional tolerance through the tolerance class

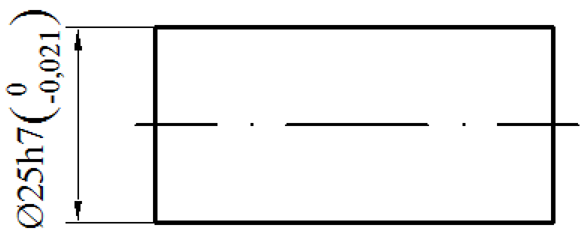


Fig. no. 3
Indication of the dimensional tolerance through the tolerance class and the limit deviations.

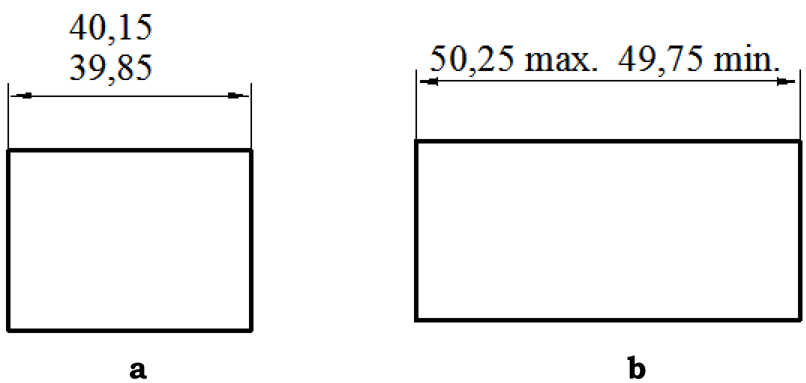


Fig. no. 4
Indication of the dimensional tolerance through the limit values of the dimension
a. limit values one under the other; b. limit values one after the other.

3. The indication of the fits on the assembly drawing.

The fits are indicated on the assembly drawings through two distinctive ways:

- ***using a single quota line:*** it' s using the quota line of the common dimension; above the quotq line it will be written the value of nominal dimension followed by the tolerance classis of the hole and shaft (as a fraction);

Note: the nominal value is written once; the hole' s tolerance class is written as a numinator and the shaft' s tolerance class is written as a denuminator.

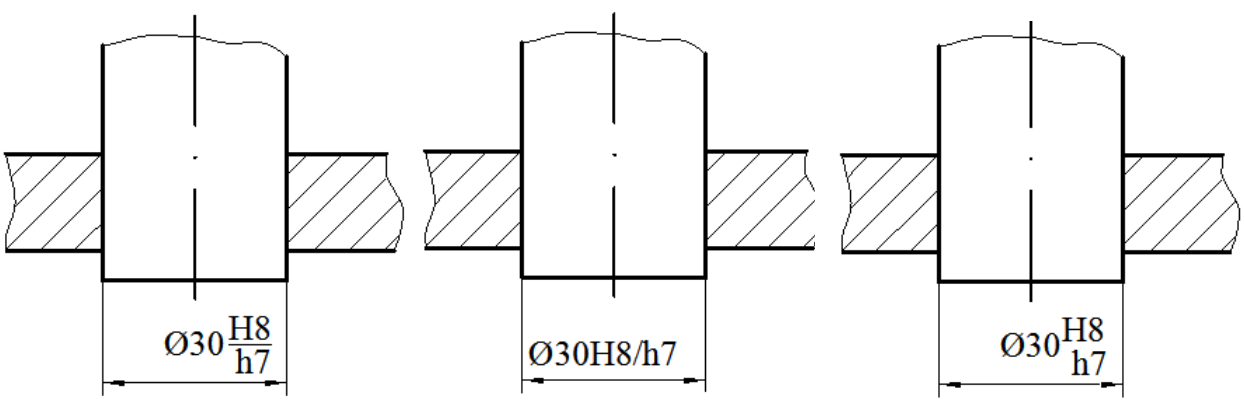
- ***using two quota lines:*** for each dimension it will use a quota line; the first quota line will correspond to the hole and the second quota line will correspond to the shaft.

The specifications used to indicate the fits on the assembly drawings are presented in table no. 2.

The exemples of the indication of the fits on the assembly drawings are presented in figures no. 5 and 6.

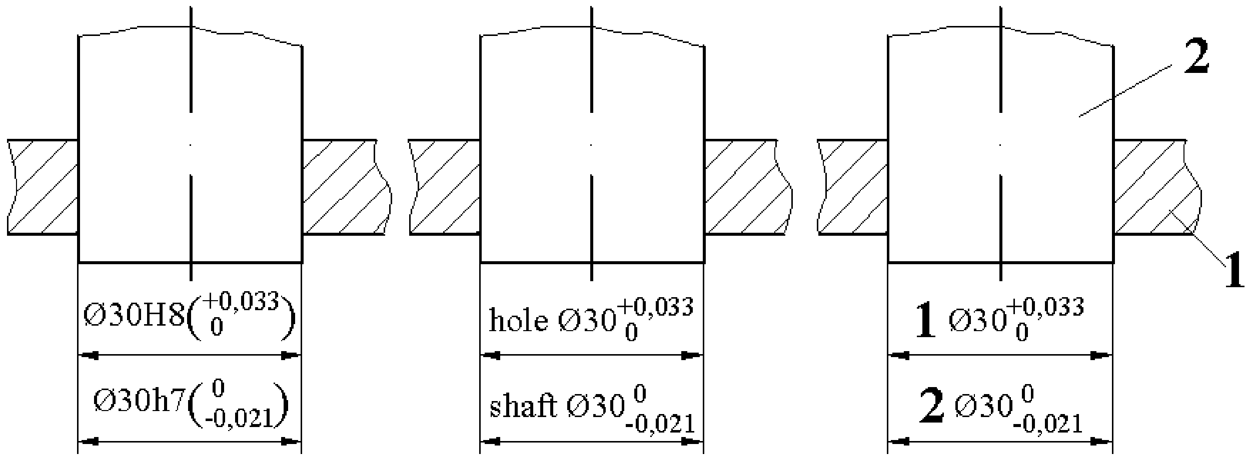
Specifications used to indicate the fits **Table no. 2**

No.	Description		Exemples	Fig. No.
1.	Using a single quota line	Nominal value N, of the fit followed by the tolerances classes of the both dimensions as a fraction.	$30\frac{H8}{h7}$; 30H8/h7	5.a,b
2.		Nominal value N, of the fit followed by the tolerances classes of the both dimensions written one under the other.	30^{H8}_{h7}	5.c
3.	Using two quota lines	For each quota line: nominal value N, of each dimension, followed by the tolerance class and the limit deviations written in brakets.	$40H8\left(^{+0,033}_{0}\right)$ $40h7\left(^{0}_{-0,021}\right)$	6.a
4.		For each quota line: type of dimension (hole or shaft) followed by nominal value N, of each dimension and by the limit deviations.	$hole40^{+0,033}_{0}$ $schaft40^{0}_{-0,021}$	6.b
5.		For each quota line: nominal value N, of each dimension and by the limit deviations; before them, the position of the part in the assembly will be written.	$1\ 40^{+0,033}_{0}$ $2\ 40^{0}_{-0,021}$	6.c



a b c

Fig. no. 5.
Indicating the fits using a single quota line



a b c

Fig. no. 6.
Indicating the fits using a two quota line

4. The indication of the geometrical tolerances on the execution drawing (geometrical tolerances with individual indication).)

The geometrical specifications indication used to indicate the geometrical tolerances give the following types of informations to the user of the drawing:

- the geometrical characteristic which is tolerated: the form, the orientation, or, the relative position;
- the geometrical element of the part which is tolerated;
- the tolerance zone: it' sise and it' s form;
- the geometrical element of the part which is specified as datum;
- additional informations (reference length, when it is not equal to element' s lenght, material conditions, partial datums, and so on).

There are two distinct categories of the specifications used to indicate the geometrical tolerances on the execution drawing

- basic apecifications;
- additional specifications.

Note: in the laboratory work will be presented the basic specifications.

The elements of the geometrical specification indication are the following fig. no. 7):

- the tolerance indicator;
- the plane and feature indicator;
- adiacent indication area, for additional specifications.

Note: the geometrical specification indication is aplied both at 2D drawngs and 3D drawings.

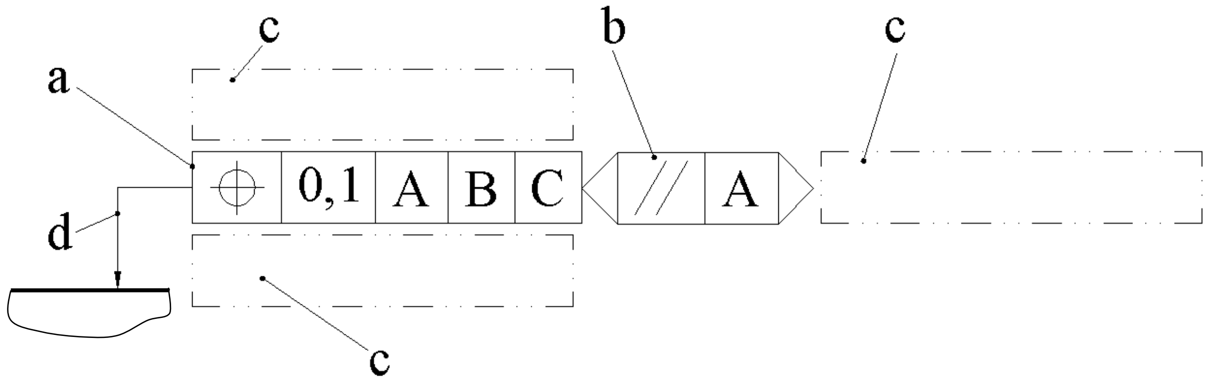


Fig. No.7.
The geometrical specification indicator

a- the tolerance indicator; b- the plane and feature indicator; c- the adiacent indication area;
d- the indication line with an arrow.

The tolerance indicator is a rectangular frame which is divided in two or three sections; the sections are allways arranged frpm left to right (figure no. 8.):

- ***first section (the symbol section)*** contains the symbol for the geometrical characteristic;
- ***second section (the zone feature and characteristic section)*** contains literal and numerical symbols for the shape, width and extent specification elements;
- ***third section (the datum section)*** may contanins one, or two or three boxes for the literal symbols of the singular datums.

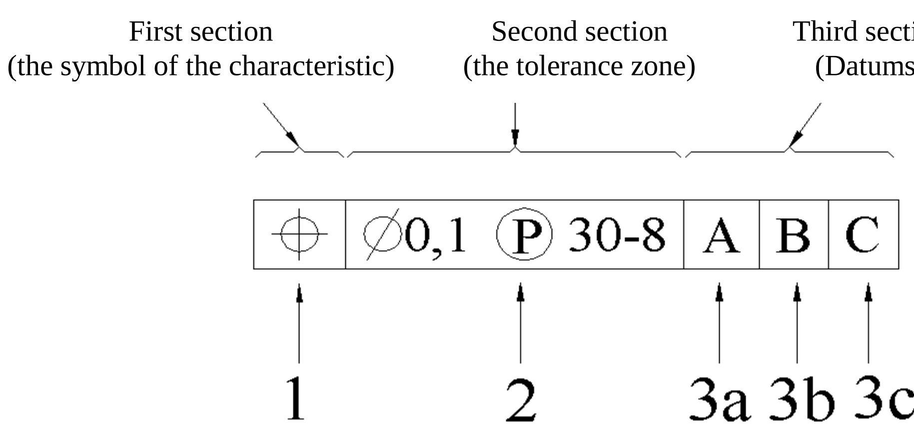


Fig. no. 8
The tolerance indicator

1. first section: the symbol section; 2. second section: the zone feature and characteristic section; 3.- third section: the datum section; 3a – primary datum; 3b- secundary datum; 3c- tertiary datum.

The plane and feature indicator gives additional informations about the tolerated element: it' s direction, or it' s orientation relative to the datum or datums system.

4.1. Basic specifications used to indicate the dimensional tolerances.

The basic specifications are compulsory and shall be positioned in the corresponding section of the tolerance indicator.

Note: the value of the geometrical tolerance are given in milimeters.

The graphical symbols for the geometrical characteristics which shall be positioned in the first section are given in table no. 3.

Symbols for the geometrical characteristics **Table no. 3**

Geometrical characteristic		**Symbol**	**Datum**	**Figure no.**
Macrogeometrical form characteristics	Straightness	⏤	No	9, 10, 11
	Flatness	⏥	No	12
	Roundness	○	No	13.a; 13.b
	Cylindricity	⌭	No	14
	Line profile	⌒	No/ Yes	16.a; 16.b
	Surface profile	⌓	No/ Yes	15
Microgeometrical form characteristics	Surface roughness	Complete graphical symbol		34, 35
Orientation characteristics	Parallelism	∥	Da	17.a; 17.b;18
	Angularity	∠	Da	19
	Perpendicularity	⊥	Da	20.a, b; 21.a, b
Location characteristics	Pozition	⌖	Yes/ No	22.a, b; 23
	Concentricity (for centre points)	◎	Yes	30
	Coaxiality (for median lines)	◎	Yes	31
	Simmetry	⌯	Yes	32
	Circular run- out	↗	Yes	33.a
	Total run- out	⌰	Yes	34.a

4.2. Indication of the form tolerances

Exemples for indication of the form tolerances are given in figures no. 9 to 16.

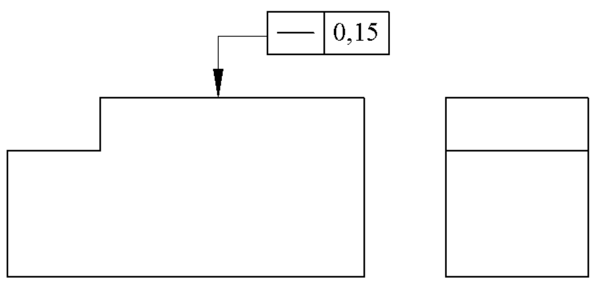


Fig. no. 9
Straightness indication of a line contained in a surface

Meaning: the straightness tolerance 0,15 mm, applied to the each line contained in the plane surface.

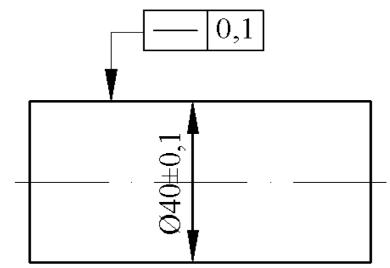


Fig. no 10
Straightness indication of generators

Meaning: the straightness tolerance 0,1 mm, applied to the cylindrical surface generators. Each line contained in the plane surface.

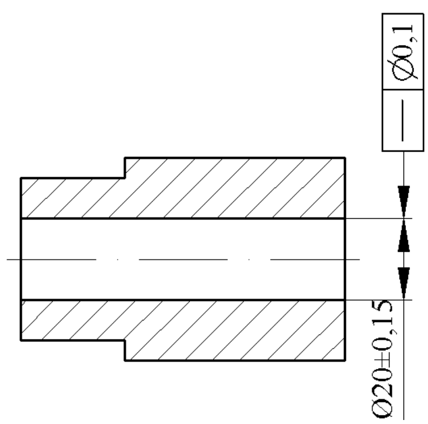


Fig. no 11
Straightness indication of a median line

Meaning: the straightness tolerance 0,1 mm, applied to the inner cylindrical surface median line.

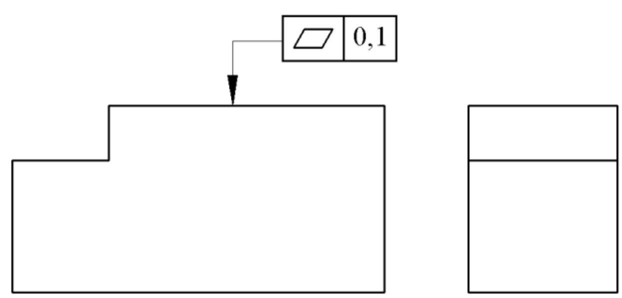
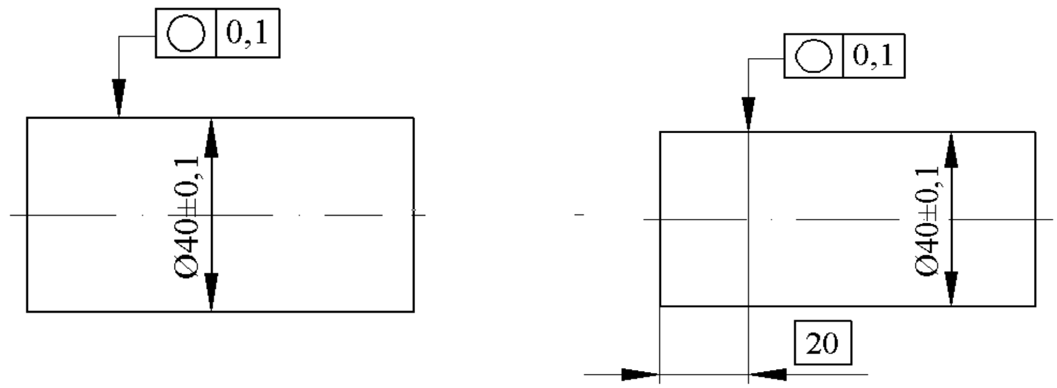


Fig. no 12
Flatness indication

Meaning: the flatness tolerance 0,1 mm, applied to the upper plane surface.



a. **b.**

Fig. no 13.
Roundness indication

a.- the toleranced element is a complete element;
b.- the toleranced element is a part of the element.

***Meaning* (figure no. 13.a):** the roundness tolerance 0,1 mm, applied to the each cross section of the cylindrical surface.

***Meaning* (figure no. 13.b):** the roundness tolerance 0,1 mm, applied to the cross section of the cylindrical surface located at 20 mm (TED) from the left side.

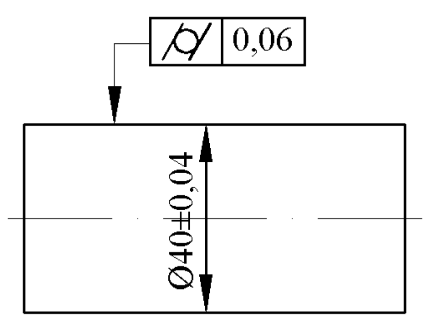


Fig. no. 14
Cylindricity indication

Meaning: the cylindricity tolerance 0,06 mm, applied to the cylindrical surface.

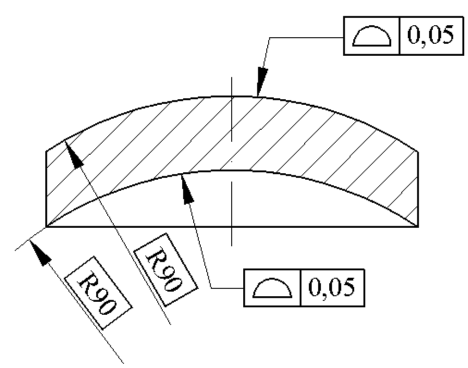
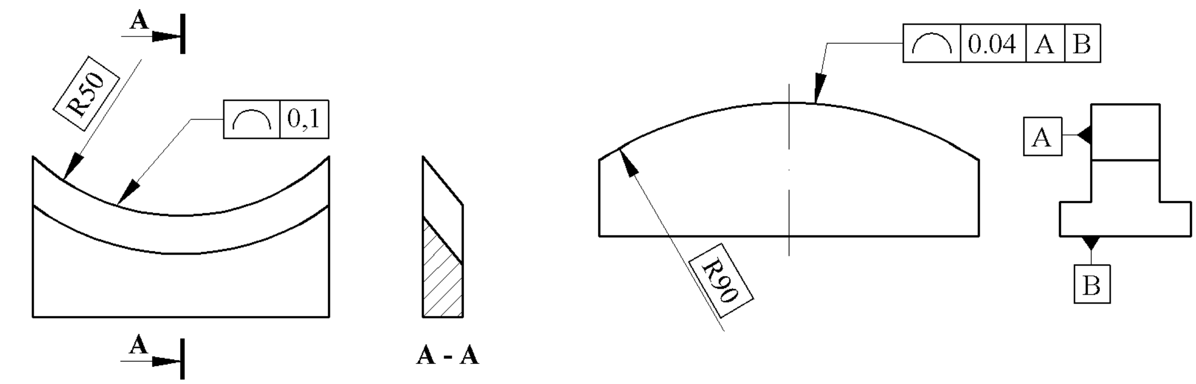


Fig. no. 15

Indication of the tolerance on the given shape of the surface

Meaning: the surface profile tolerance 0,05 mm, applied to the both profiled surfaces.



a. **b.**

Fig. no. 16
Line profile indication

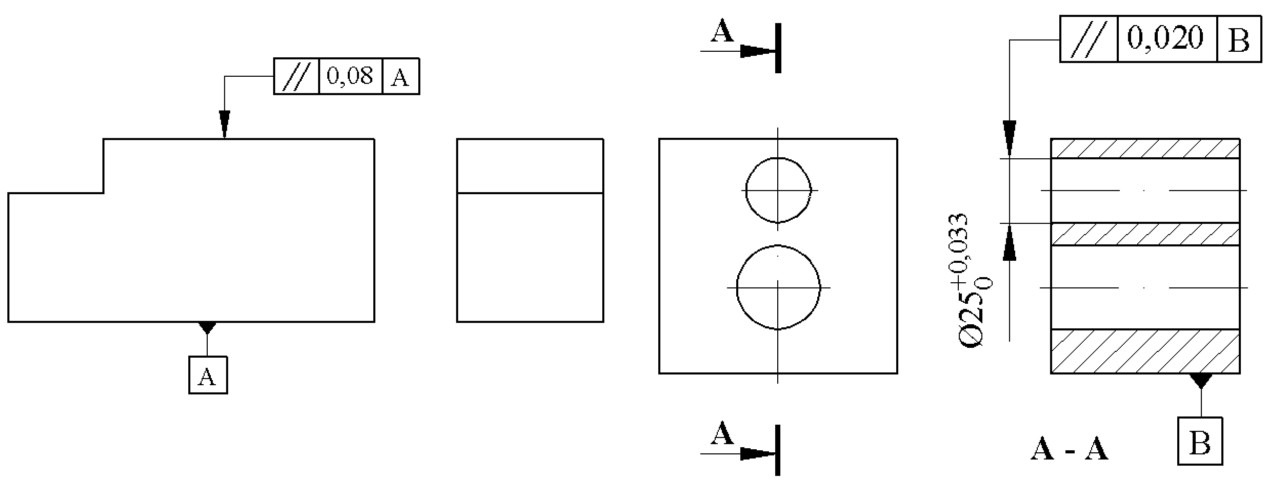
a.- datum is not necessary;
b.- datum is necessary.

***Meaning* (figure no. 16.a):** the line profile tolerance 0,1 mm, applied to the profiled edge.

***Meaning* (figure no. 16.b):** the line profile tolerance 0,04 mm, applied to the each profiled line included in intersection planes related to the datum system A, B.

4.3. Indication of the orientation tolerances

Exemples for indication of the orientation tolerances are given in figures no. 17 to 21.



a. **b.**

Fig. no 17
Parallelism indication

a.- parallelism specification of a plane related to a datum plane;
b.- parallelism specification of a line related to a datum plane;

***Meaning* (figure no. 17.a):** the parallelism tolerance 0,08 mm, applied to the upper plane related to the datum plane B.

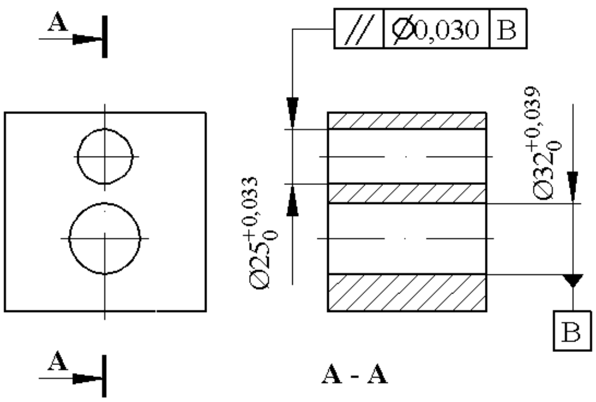


Fig. no. 18
Paralelism indication (line related to an axix datum)

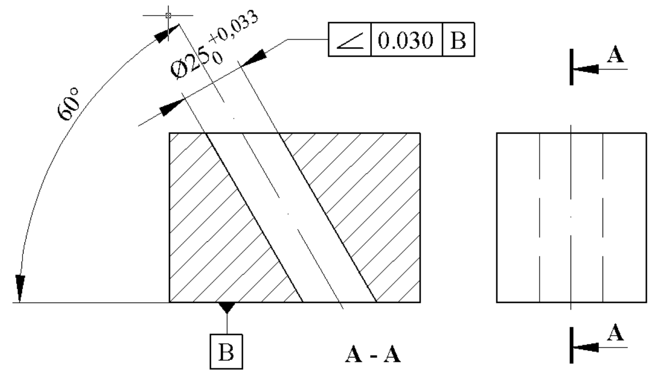
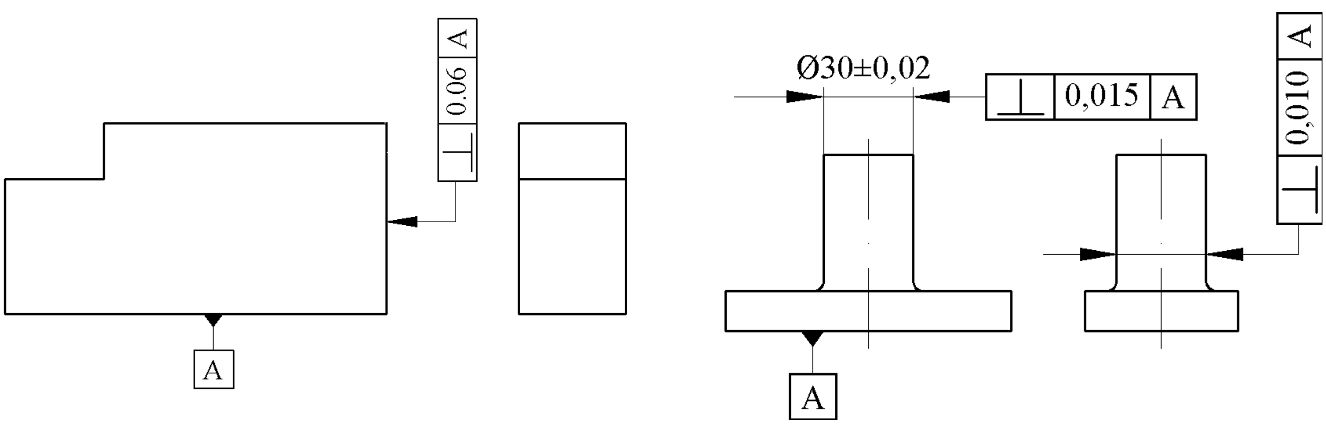


Fig. no. 19.
Angular indication

***Meaning* (figure no. 17.b):** the parallelism tolerance 0,02 mm, applied to the median line of the cylindrical surfaces with N= 25 mm, related to the datum plane B.

***Meaning* (figure no. 18):** the parallelism tolerance 0,030 mm, applied to the median line of the cylindrical surface with N= 25 mm, related to the axis of the the cylindrical surface with N= 32 mm, specified as datum axis B; the tolerance is prescribed in any direction.

***Meaning* (figure no. 19):** the angular tolerance 0,03 mm, applied to the median line (axis) of the inner cylindrical surface related to the datum plane B.



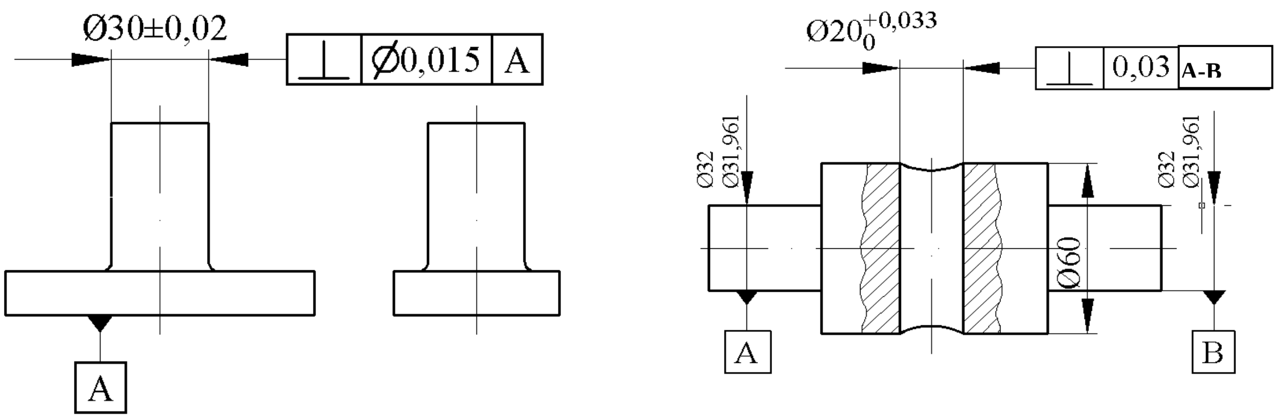
a. **b.**

Fig. no. 20
Perpendicularity indication I

a.- perpendicularity of a plane related to a datum plane;
b.- perpendicularity of a line related to a datum plane prescribed to one direction.

***Meaning** (figure no. 20.a):* the perpendicularity tolerance 0,06 mm, applied to the plane surface from the right side, related to the datum plane A;

***Meaning** (figure no. 20.b):* the perpendicularity tolerance 0,02 mm, applied to median line of the cylindrical surface with N= 30 mm, related to the datum plane A; the tolerance is prescribed in one direction.



a. **b.**

Fig. no. 21.Perpendicularity indication II

a.- perpendicularity of a line related to a datum plane, prescribed to any direction.;
b.- perpendicularity of a line related to a datum axis

***Meaning** (figure no. 21.a):* the perpendicularity tolerance 0,02 mm, applied to the median line of the cylindrical surface with N= 30 mm, related to the datum plane A; the tolerance is prescribed in any direction.

***Meaning** (figure no. 21.b):* the perpendicularity tolerance 0,023 mm, applied to median line of the cylindrical surface with N= 20 mm, related to the datum axis A.

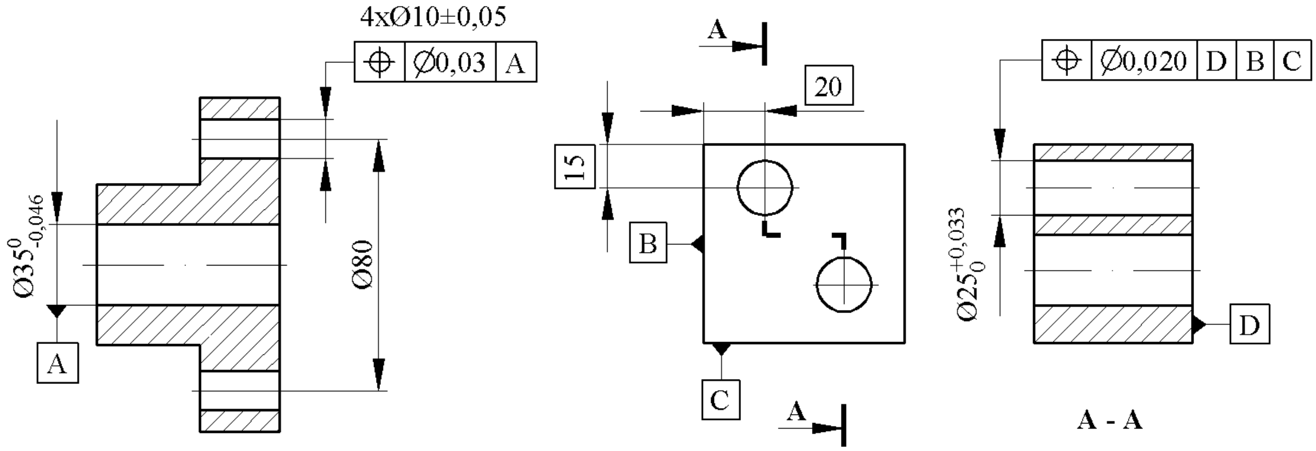
4.4. Indication of the location tolerances

Exemples for indication of the location tolerances are given in figures no. 22 to 28.

***Meaning** (figure no. 22.a):* the position tolerance 0,03 mm, applied to the median lines of the four cylindrical surfaces with N= 10 mm, related to the datum axis A; the tolerance is prescribed in any direction.

***Meaning** (figure no. 22.b):* the position tolerance 0,020 mm, applied to the median line of the cylindrical surface with N= 25 mm, related to the datum system; the tolerance is prescribed in any direction.

***Meaning** (figure no. 23):* the position tolerance 0,030 mm and 0,020 mm, applied to the median line of both cylindrical surfaces with N= 10 mm, related to the datum system A, B, C; the tolerance is prescribed in two perpendicular directions one on each other.



a. **b.**

Fig. no. 22
Position indication I
a.- position of a line related to a datum axis, prescribed to one direction;
b.- position of a line related to a datum system, prescribed to any direction;

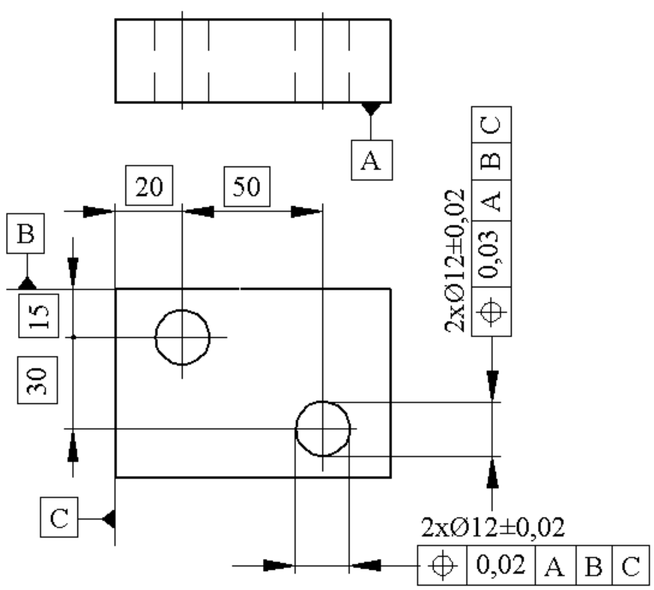


Fig. no 23
Position indication (a median line relative to a datum system); tolerance prescribed in two perpendiculary directions)

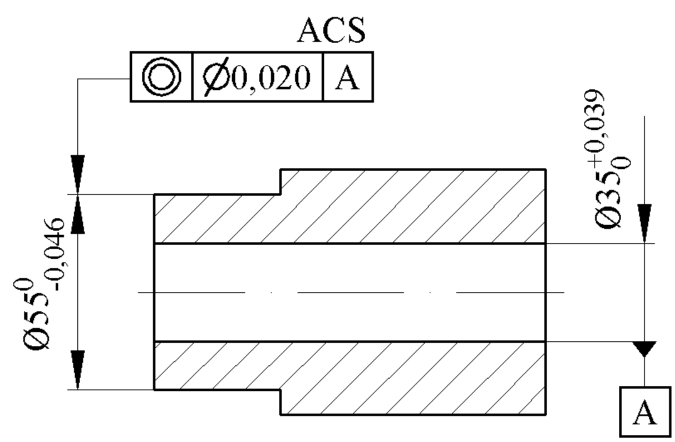


Fig. no 24
Concentricity indication

***Meaning* (figure no. 24):** the concentricity tolerance 0,020 mm, applied to the center of any cross section of the cylindrical surface with N= 55 mm, related to the datum axis A.

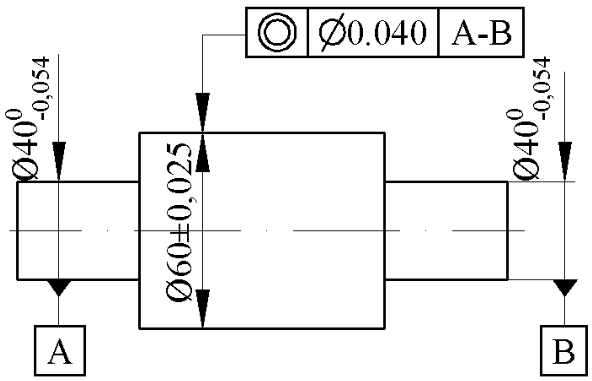


Fig. no. 25
Coaxiality indication

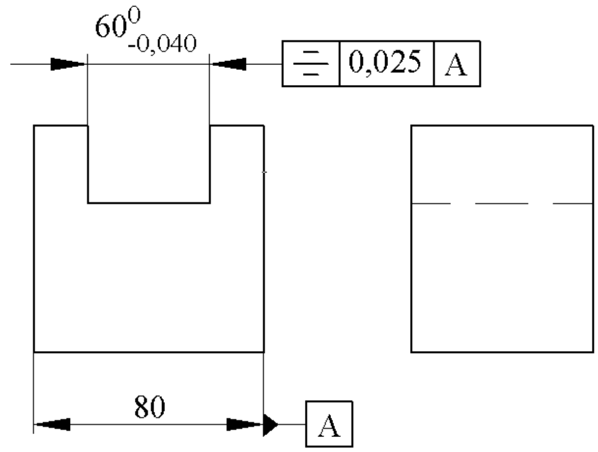
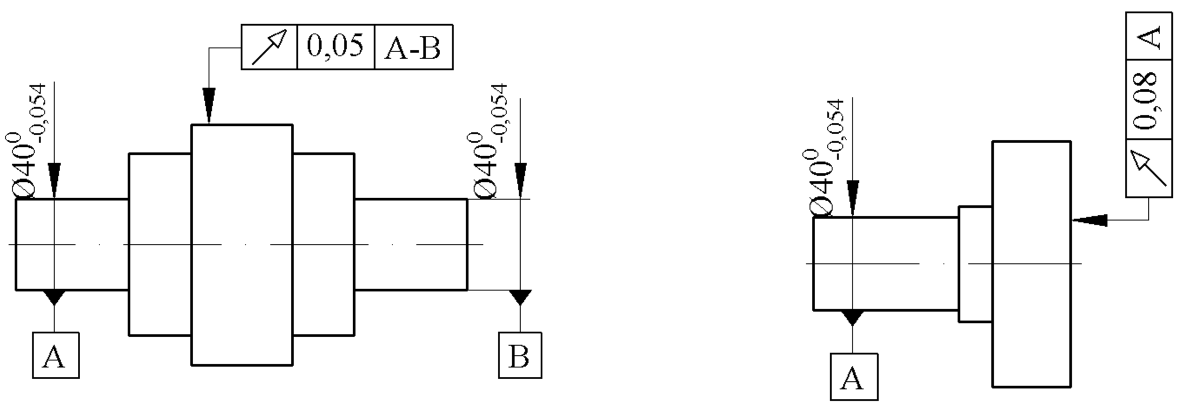


Fig. no. 26
Simmetry indication

***Meaning** (figure no. 25):* the coaxiality tolerance 0,040 mm, applied to the median lines of the cylindrical surface with N= 60 mm, related to the common datum axis A- B; the common datum axis A- B, is the result of the reunion of the singular axes of the cylindrical surfaces with N= 40 mm.

***Meaning** (figure no. 26):* the symmetry tolerance 0,025 mm, applied to the median plane of the channel with width N= 60 mm, related to the symmetry datum plane



a. **b.**

Fig. no. 27
Circular run- out indication

a.- circular run- out of a cylindrical surface;
b.- circular run- out of a frontal surface;

***Meaning* (figure no. 27.a):** the circular run- out tolerance 0,05 mm, applied to the cylindrical surface from the middle, related to the common datum axis A- B; the common datum axis A- B, is the result of the reunion of the singular axes of the cylindrical surfaces with N= 40 mm.

***Meaning* (figure no. 27.b):** the circular run- out tolerance 0,08 mm, applied to the frontal surface on the right side, related to the datum axis A.

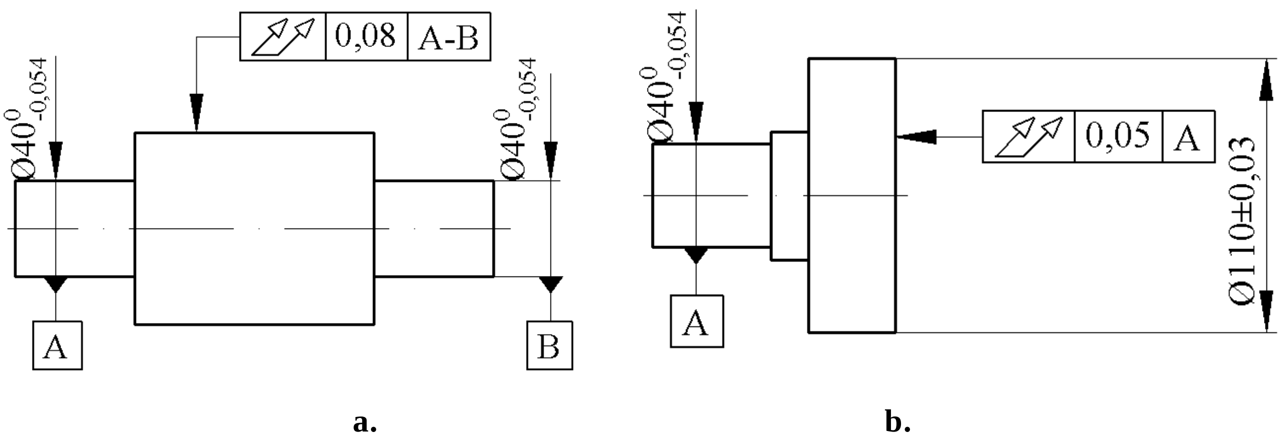


Fig. 28
Indication of the total run-out tolerance
a.- radial run-out; b.- frontal run-out

***Meaning* (figure no. 28.a):** the total run- out tolerance 0,08 mm, applied to the cylindrical surface from the middle, related to the common datum axis A- B; the common datum axis A- B, is the result of the reunion of the singular axes of the cylindrical surfaces with N= 40 mm.

***Meaning* (figure no. 28.b):** the total run- out tolerance 0,05 mm, applied to the frontal surface on the right side, related to the datum axis A.

4.5. Indication of the roughness parameters

The most used roughness parameters are the following:

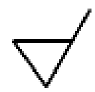
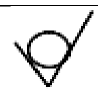
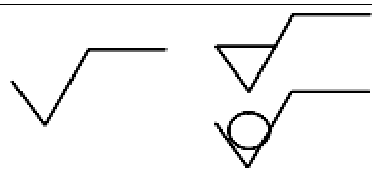
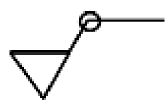
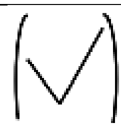
- the arithmetic mean depth of the rougness Ra;
- the average depth of the rougness Rz;
- the maximum depth of the rougness Rt;
- the total depth of the rougness Rmax.

Graphical symbols used for the roughness parameters indication

In order to indicate the requirements for the surfaces rougness on the drawings, dedicated specifications (graphical, literaly and numerical symbols) are used.

The graphical symbols used to indicate the limit values of the roughness parameters are presented in table no. 4.

Graphical symbols used to indicate roughness requirements **Table no. 4**

No.	Name	Representation	Meaning
1.	Basic graphicals ymbol		The way of obtaining the surface is not indicated.
2.	Extended graphical symbols		The material removal is allowed.
3.			The material removal is forbidden.
4.	Complete graphical symbols		The menings from current point no. 1, 2, 3.
5.	Graphical symbol for all surfaces		The same conditions are prescribed for all surfaces.
6.	Simplified graphical symbol		Simplified indication: the same conditions are prescribed for most of the surfaces.

The locations reserved to inscribe the roughness conditions on the complete graphical symbol are presented in table no. 5.

Position and orientation of the specifications.

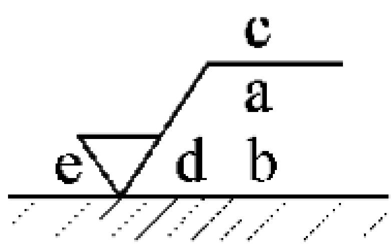
The condition for the surface roughnes is indicated once for a specific surface and, if it is posible, on the same drawing projection which includes the dimensional tolerances or the geometrical tolerances, or both.

In order to be a correctly reading of the roughness specifications, the graphical symbol shall be orientated as is presented in the figure no. 29.

The simplified indication of the surface rougnes conditions.

In order to indicate that the same condition of roughness is specified to most of the surfaces of the part, the graphical symbol shall be placed nearby area of the indicator of the drawing (fig. no. 30).

The locations for the roughness conditions on the graphical symbol **Table no. 5**

<table>
<tr><th colspan="3">The locations around the complete graphical symbol</th></tr>
<tr><td colspan="3">
</td></tr>
<tr><th rowspan="2">Location</th><th colspan="2">The roughness condotions</th></tr>
<tr><th>The description of the conditions</th><th>Examples</th></tr>
<tr><td rowspan="4">a</td><td rowspan="4">The first condition of rougness:
• the symbol of the roughness parameter;
• the limit value of the roughness parameter in µm;
• the transmission band (optional);
• the basic lenght (if it in not equql to the standard value).</td><td>-0,8/ Rz 6,8</td></tr>
<tr><td>0,0025- 0,8/ Rz 6,8</td></tr>
<tr><td>0,008- 0,5/16/R 10</td></tr>
<tr><td>Ra 1,6</td></tr>
<tr><td>b</td><td>The second condition of rougness.
If the third condition is necessary, the graphical symbol shall be extended in vertical direction.</td><td>Ra 1,6
Rz 15</td></tr>
<tr><td rowspan="3">c</td><td rowspan="3">The fabrication process, the thermal treatment process or, other conditions to obtain the surface.</td><td>Molded</td></tr>
<tr><td>Milling</td></tr>
<tr><td>Rectified</td></tr>
<tr><td>d</td><td>The orientation of the irregularities.</td><td>Table no. 6</td></tr>
<tr><td>e</td><td>The value for the cutting depth in mm.</td><td>0,2</td></tr>
</table>

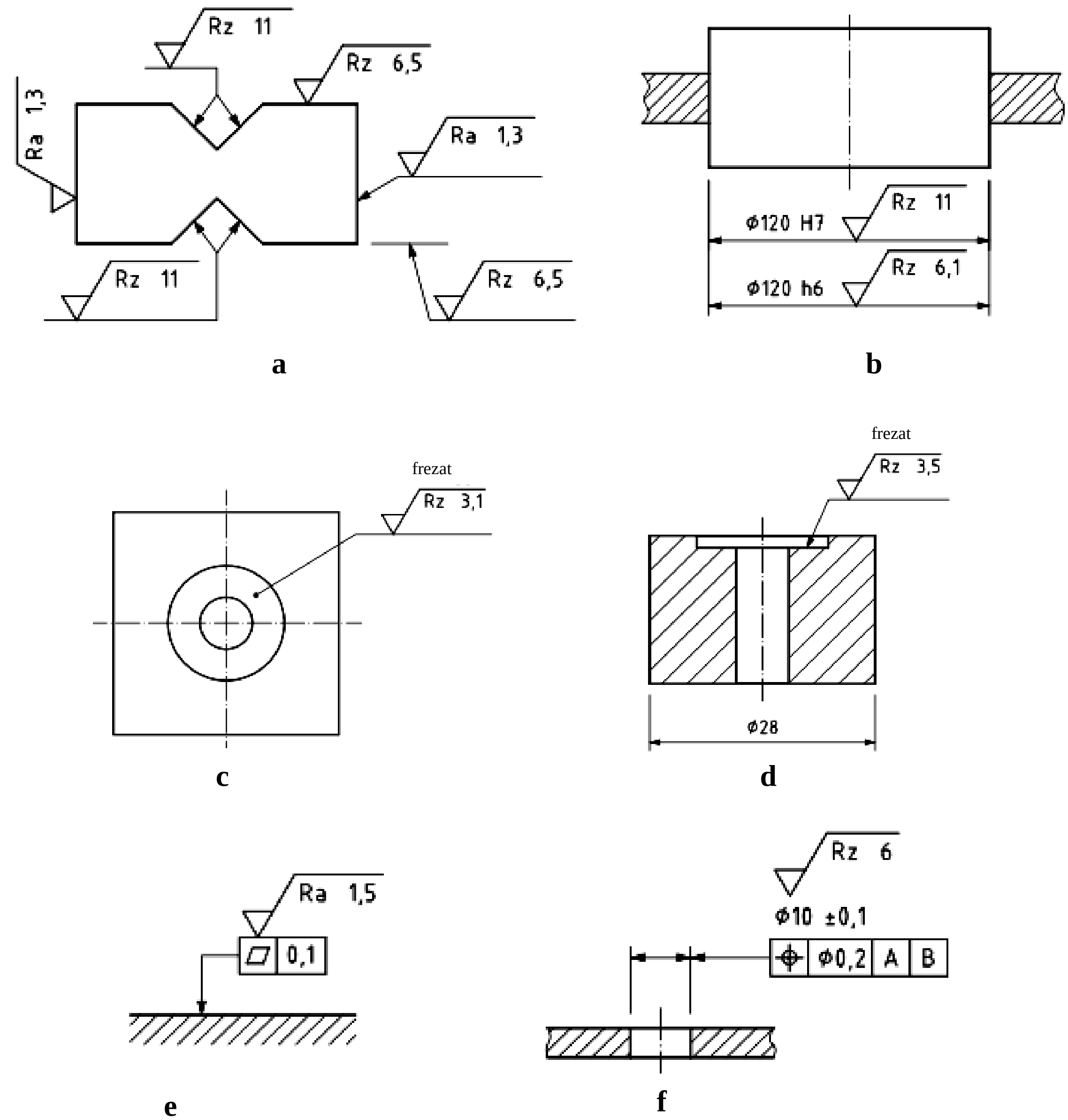


Fig. no 29

Position and orientation of the specifications.

a. location: on the contour line or added line;
b. location: on the quota line;
c. location: on the indication line with arrow;
d. location: pe linie de indicație cu punct;
a. location: over the tolerance indicator;
b. location: over the tolerance indicator and over the tolerated dimension.

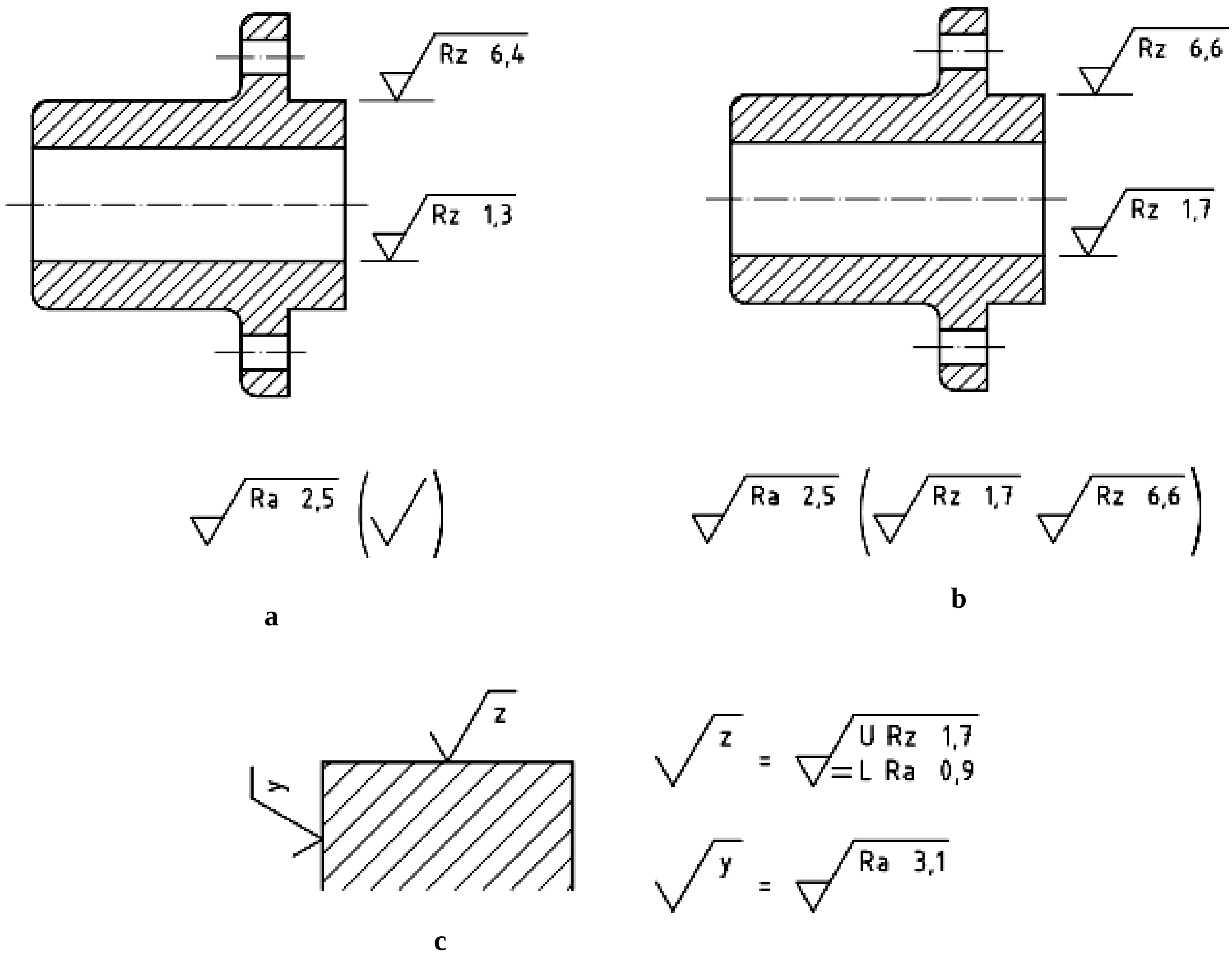


Fig. no. 30
The simplified indication of the rougness conditions.
a, b. when the same roughness condition is prescribed to several surfaces;
c. when it is no space on the drawing.

5. Indication of the general tolerances on the execution drawings (dimensional and geometrical tolerances without individual indication)

In order to economic manufacturing of the nonfunctional dimensions and surfaces, higher tolerances are required. These tolerances are known as general dimensional and geometrical tolerances.

Dimensional tolerances without individual indication.

The general tolerances for the nonfunctional dimensions are classified in four tolerance classes which are symbolized with lowercase:

the tolerance class **f** (fine execution);
the tolerance class **m** (medium execution);
the tolerance class **c** (coarse execution);
the tolerance class **v** (rough execution);

The tolerance class prescribed to a part shall be aplied to all nonfunctional dimensions of the part.

Geometrical tolerances without individual indication.

The general tolerances for the nonfunctional surfaces (form tolerances, orientation tolerances, location tolerances) are classified in three tolerance classes which are symbolized with uppercase:

the tolerance class **R** (fine execution);
the tolerance class **K** (medium execution);
the tolerance class **L** (coarse execution);

The tolerance class prescribed to a part shall be aplied to all nonfunctional surfaces of the part.

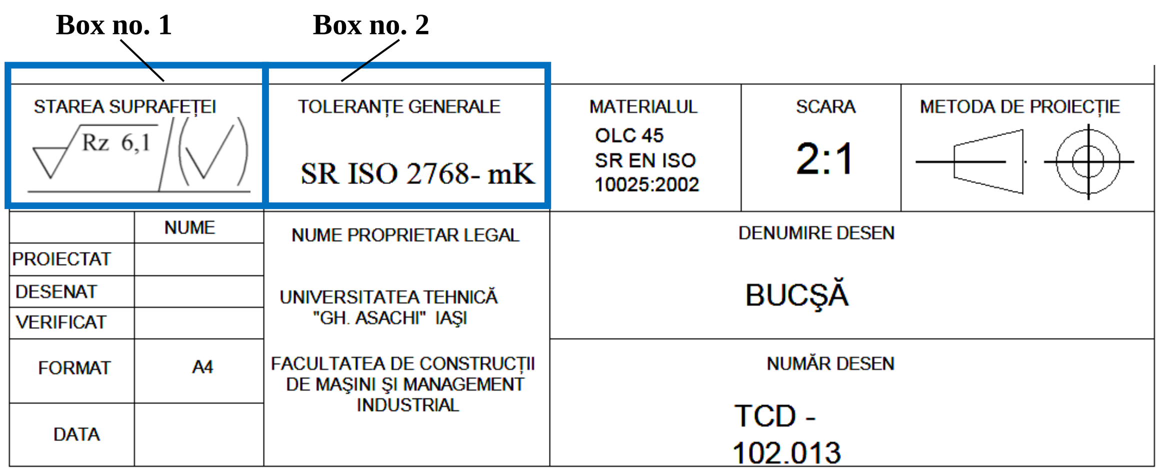


Fig. no. 31
The indication of the general tolerances and of the general roughness conditions on the execution drawing

In order to indicate the general tolerances on the execution drawing, the both symbols of the classes tolerance (for the dimensional tolerances and for the geometrical tolerances) shall be inscribed in the second box of the indicator of the drawing; the following order shall be kept: the symbol of the general dimensional tolerances and the symbol of the general geometrical tolerances (figure no. 31).

6. How to perform the laboratory work

The laboratory work consists in numerical applications to the tolerances part of the course: how to indicate the execution conditions on the execution drawing (as a constructive designer) and how to indentify the technical conditions indicated on the execution drawings.

To carry out the laboratory work the following steps shall be completed:

Step no. 1: shall analyse the execution drawing of a part and shall identify the technical conditions on the drawing.

Step no. 2: shall execute the execution drawing of a part (as a hand sketch) and the given technical conditions shall indicate on the drawing.

Laboratory work no. 8

CONTROL OF THE SURFACES MACROGEOMETRICAL FORM USING UNIVERSAL MEASURING INSTRUMENTS

Applications to be made at the laboratory work no. 8:

a. verifying straightness by applying the slit light method.
b. measuring of straightness deviation with an indicator.
c. measuring of flatness deviation with an indicator.
d. measuring of roundness deviation to outer cylindrical surfaces with the passameter or dial snap gauge and the orthotest.
e. measuring of roundness deviation to inner cylindrical surfaces with inner indicator and passimeter.

1. General considerations

The form deviations of the surfaces are differences between the form of the processed surfaces and the theoretical form of the same surfaces. The form deviations of the parts surfaces are generated by the inaccuracy of the manufacturing process.

The main form deviations of the parts surfaces are:

- the straightness deviation;
- the flatness deviation;
- the roundness deviation;
- the cylindricity deviation;
- the form deviation of the profile;
- the form deviation of the surface.

2. Methods applied to control the form deviations of the surfaces.

In order to measure the form deviations of the surfaces, two main methods are applied:

- usual measuring methods which use universal means for lengths measuring, control devices and accessories;
- special measuring methods.

Any method applied to measure a geometrical deviation includes the following elements:

- ***the measuring scheme***, which is a graphical representation indicating: the part to be measured, it’s orientation- position and clamping, the instrument’s orientation relative to the part, the movements of the mobile elements;

- ***equipment’s and accessories***, which are the measuring means (gauges, calibers, measuring instruments for linear and angular dimension) and accessories (supports for the measuring instruments, v- blocks, control dowels and mandrels, checking rulers, control plates, clamping elements, etc.);
- ***the measurement technique*** describes the steps to go in order to measure the geometrical deviation.

3. Checking the straightness by applying the slit light method.

The necessary equipment’s and accessories: check ruler with an active edge, control plate, light source.

The verification scheme: is presented in figure no. 1.

The verification technique: the part 1, is placed on the active surface of a control plate 2. In order to check every line which is included in the controlled surface **a**, the active edge **b**, of the check ruler 3, is placed on the **a** surfaced and shall observe if there in slit light between the elements **a** and **b**; in the same time, the ruler shall be moved along the width of a surface.

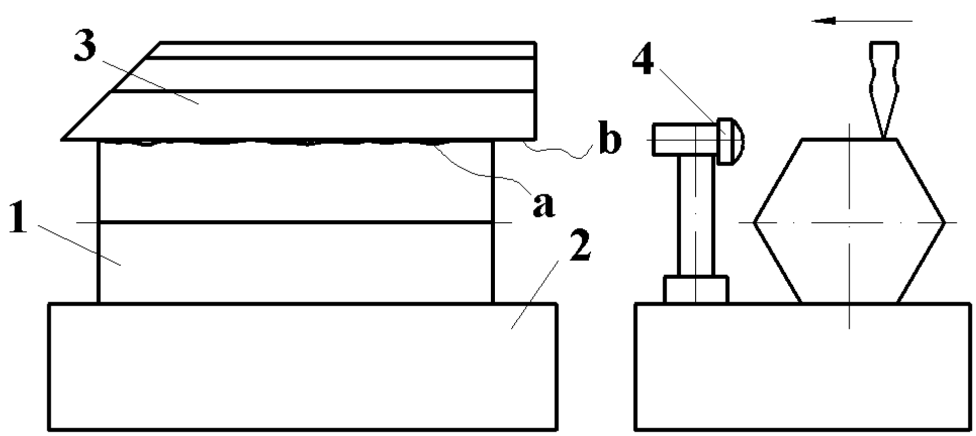


Fig. no. 1
Checking of the straightness

Shall proceed in the same way, for all the lateral surfaces of the part.

Conclusion: if it is seen the light between the ruler’s edge b and the part’s surface, that’ s means that the checked surface has straight deviation.

4. The measurement of the straightness deviation using an indicator.

In the execution drawing of the piece a form tolerance is noted (figure no. 2.a).

The meaning of the geometrical tolerance is: 0,06 mm is the value of the straightness tolerance of each edge of the piece.

In order to measure the straightness deviation of an edge of the piece to be controlled a dial indicator will be used.

The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,01 mm, indicator support, check plate with active surface, adjustable racks, spacer ruler.

The measurement scheme: in order to measure the edge's straightness deviation of a part, the measurement scheme is presented in figure no. 2.

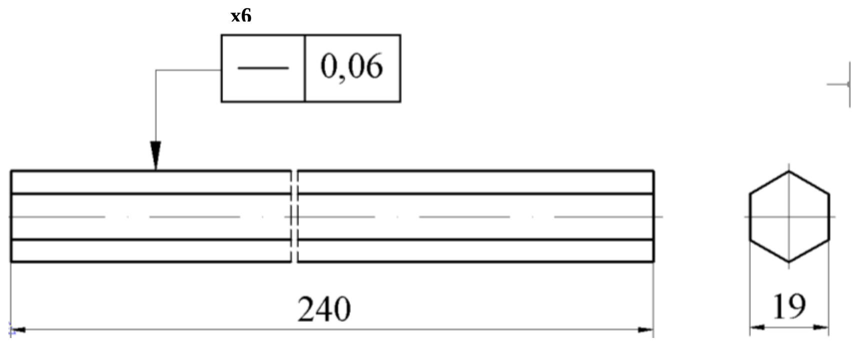
The measurement technique: the part to control 1, is placed on two V- blocks 3, of the adjustable supports under form of straight prism with hexagon base, rests, through prisms 3, on two adjustable racks 2, the dial indicator 6, is fixed to the support 5. All these assemblies are placed on the active surface **a**, of the check plate 4. The measuring peak of the indicator is having an edge c, which shall be brought in contact to the edge of the part.

In order to proceed to the measurement, it must to materialized a virtual straight line parallel to the active surface a, in two points of the part's edge, first; therefor, the edge c, of the measurement peak is brought in contact to the part's edge at an end point of the part (A position). In this point, the indicator will be calibrated to „0" value. Then, the support 5, is moved to the other end point of the part, where indication of the instrument is observed (B position); if the indication is not zero, adjust the support height corresponding at B position, until the „0" indication; then the indicator is moved in A position (again), where it's indication is observed; if the indication is not zero, adjust the support height corresponding to A position, until the „0" indication.

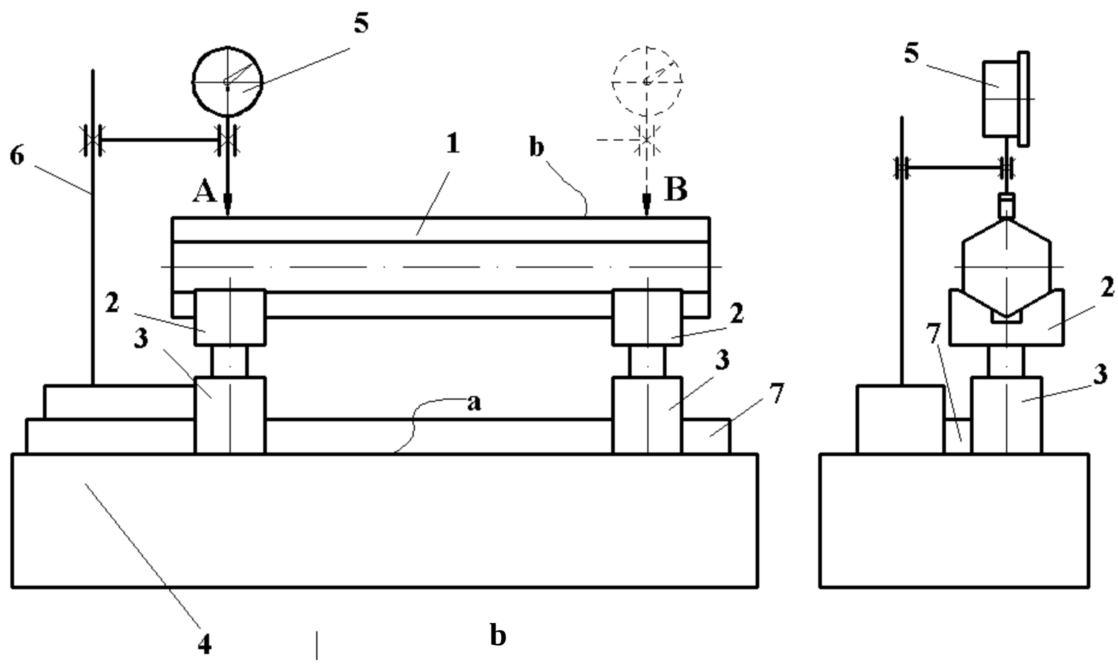
This operation shall be repeated the until the indications of instrument in both A and B points will be „0"; so, it can be considered that through points A and B, from the part's edge, pass a straight line (a virtual line) which is parallel with the active surface a of the control plate.

In order to measure the straightness deviation of the edge **a**, the indicator 5, shall be moved from A point to B point (the measuring peak **b**, shall be in permanent contact with edge **a**); for rectilinear movement of the instrument 5, its support 6, will be permanent maintained in contact with spacer 7. During the movement' s indicator, shall note the minimum and maximum indications of instrument.

The algebraic difference of measured extreme indications represents the straightness deviation of the edge **a**.



a



b

Fig. no. 2
The measurement of the straightness deviation using an indicator.
a.- indication the straightness tolerance on the drawing;
b.- the measurement scheme.

5. The measurement of the flatness deviation using an indicator.

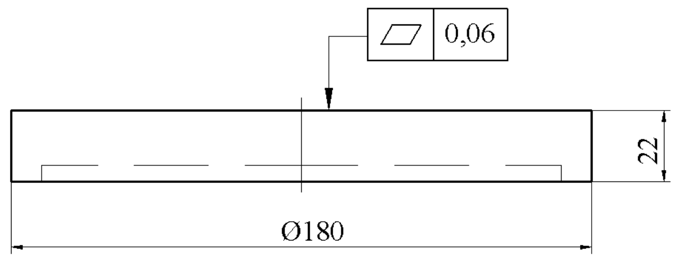
In the execution drawing of the piece a form tolerance is noted (figure no. 3.a).

The meaning of the geometrical tolerance is: 0,06 mm is the value of the flatness tolerance of the top plane surface of the piece.

In order to measure the flatness deviation of an edge of the piece to be controlled a dial indicator will be used.

<u>*The necessary equipment's and accessories*</u>: dial indicator with the reading accuracy: 0,01 mm, indicator support, check plate with active surface, three adjustable racks.

<u>*The measurement scheme:*</u> in order to measure the flatness deviation of a plane surface, the measurement scheme is presented in figure no. 3.



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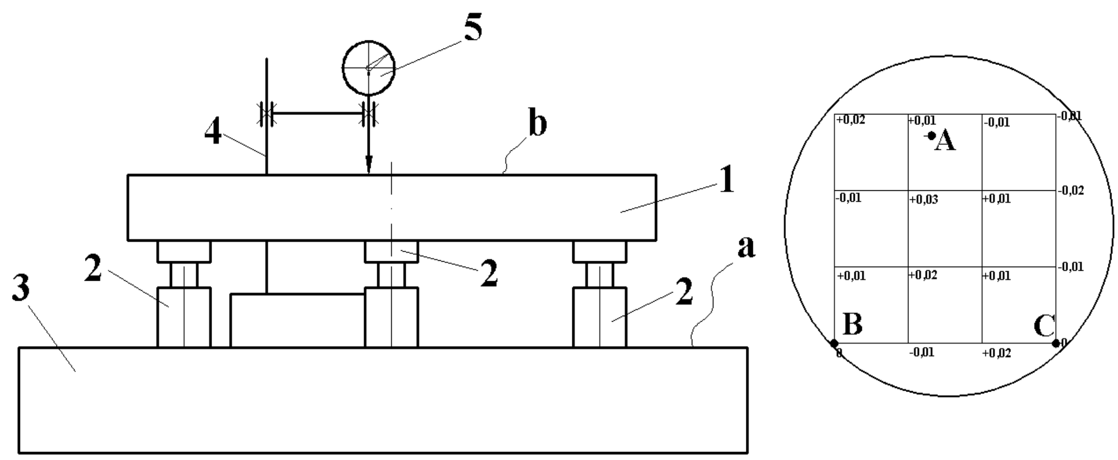


b

Fig. no. 3

The measurement of the flatness deviation using an indicator.

a.- indication the flatness tolerance on the drawing;
b.- the measurement scheme.

<u>*The measurement technique:*</u> the part to control 1, is placed on three adjustable supports 2; the dial indicator 5, is fixed to the support 4. All these assemblies are placed on the active surface **a**, of the check plate 4. The measuring peak of the indicator shall be brought in contact to the plane surface **b**, of the part. In order to proceed to the measurement, it must to materialized a virtual plane parallel to the active surface **a**; the measurement peak of the instrument shall be brought in contact to the plane b, in A point, first. In this point, the indicator will be calibrated to „0" value. Then, the support 4, with the indicator 5, shall be moved to the B point where indication of the instrument is observed; if the indication is not zero, adjust the support height corresponding to B position, until the „0" indication; then the indicator is moved in C point and the same operation shall be made (it is necessary that the A, B, C points to be not collinear).

If the values of the instrument's indications, will be „0" it can be considered that a virtual geometrical plane is materialized by the three points.

In order to measure the flatness deviation of the plane surface **b**, the measuring peak of the instrument 5, shall be brought in contact to the plane **b**, in every nods of the network (which was drawn on the considered plane) and the indications of the instrument 5, will be noted.

The algebraic difference of the minimum and maximum indications represents the deviation flatness of the measured plane surface.

6. The measurement of the roundness deviations to cylindrical surfaces.

6.1. General considerations.

The cross sections of the cylindrical and conical surfaces are characterized by two particular forms of the roundness deviation (figure no. 4):

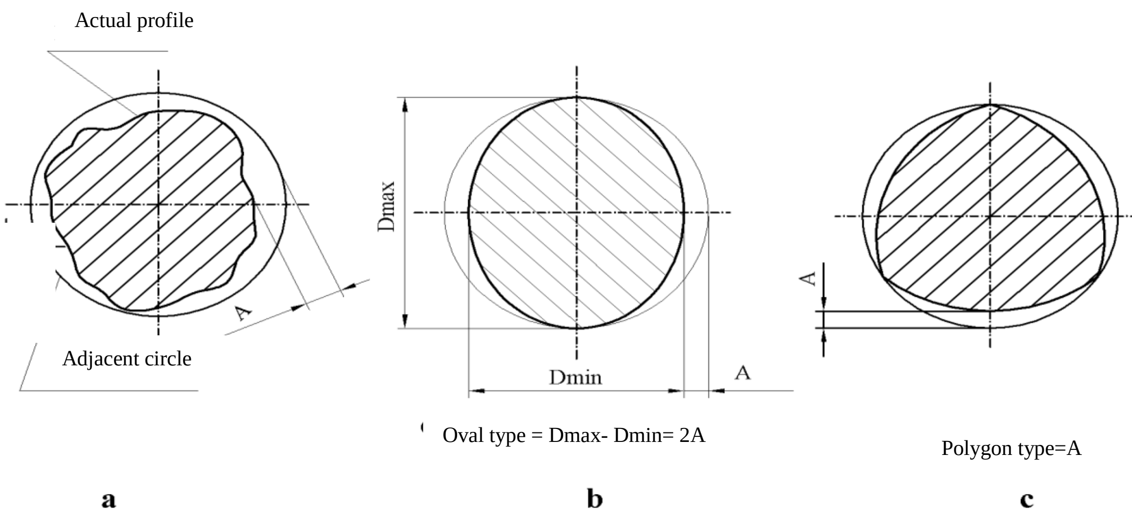


Fig. no. 4
The particular forms of the roundness deviation
a.- the definition scheme of the roundness;
b.- the oval type deviation
c.- the polygon type deviation

- ***oval type deviation*****:** is characterized by the maximum and minimum diameters of the actual cross section which is elliptical; is measured by introducing the piece to control between flat surfaces;

- ***polygon type deviation*****:** is characterized by a closed polygon of the actual cross section, composed of at least three connected arcs of a circle; is measured by positioning of the piece on prismatic surfaces.

Each form of the roundness deviation is measured by specific methods concerning the measurement technique and the way to obtain the roundness deviation. The most common method applied to measure the two particular forms of the roundness deviations are (figure no. 5):

- ***two contact points method***: the piece to be controlled 1, will be introduced between two plane surfaces; in this way, in a cross section of the piece will be materialized two contact points **a** and **b** (figure no. 5.a). The measurement instrument 5 (a dial indicator), will calibrated using a gauge block having the length equal to the nominal value of the diameter (it can also be used a plug gauge), or, directly on the surface to be controlled. Then, will be measured in the considered cross section, four diameters; will be obtained four measured values. The roundness deviation A, will be calculated with the math formula:

$$A = \frac{dmax - dmin}{2} = \frac{\delta max - \delta min}{2}, \quad (1)$$

Note: in math formula (1), will be considered the difference of the diameters (dmax- dmin) when the measured values were obtained by applying the direct evaluation method; will be considered the difference of the deviations (δmax- δmin) when the measured values were obtained by applying the difference method of measuring.

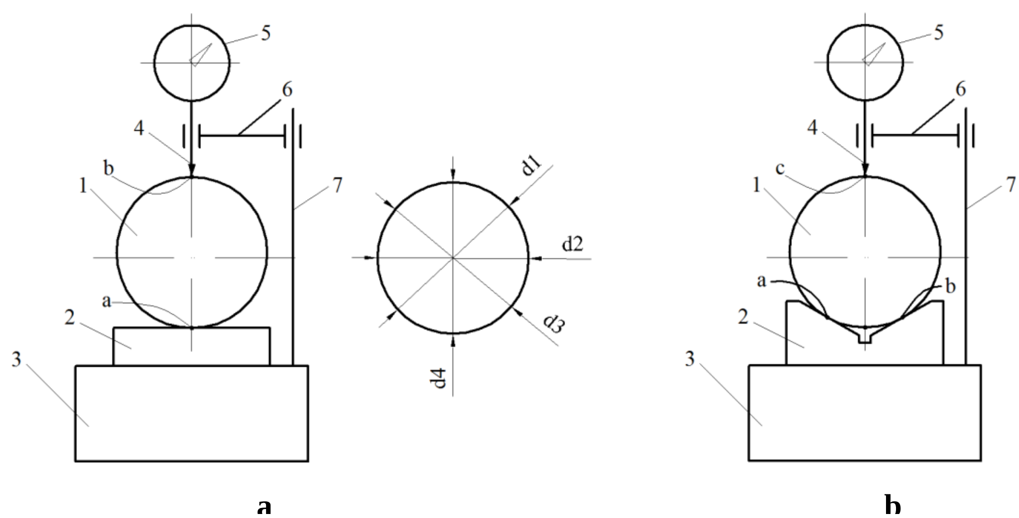


Fig. no. 5
Measurement scheme of the roundness deviations
a. two contact points method: b. three contact points method.

- ***three contact points method:*** the piece to be controlled 1, will be placed on a v- block, so, will be materialized two contact points **a** and **b** and the third contact point **c**, with the measuring peak 4, of the indicator 5 (figure no. 5.b). The measurement instrument 5 (a dial indicator), will calibrated directly on the surface to be controlled; then, the piece 1, will be rotated being in permanent contact with the measuring peak 4. During rotation, the extreme values of the dial indicator will be noted. The roundness deviation A, will be calculated with the math formula:

$$A = \delta max - \delta min \,, \qquad (2)$$

6.2. The measurement of the roundness deviations to outer cylindrical surfaces.

- ***The measurement of ovality using a dial instrument.***

In the execution drawing of the piece a form tolerance is noted (figure no. 6.a).

The meaning of the geometrical tolerance is: 0,040 mm is the value of the roundness tolerance of each cross sections of the cylindrical surface having nominal diameter equal to N= 20 mm.

In order to measure the roundness deviation in a cross section of the cylindrical surface, the two-contact points method is applied.

The necessary equipment's and accessories: passameter with the reading accuracy: 0,002 mm, passameter support, gauge blocks.

The measurement scheme: in order to measure the ovality of an outer cylindrical surface, the measurement scheme is presented in figure no. 6.b.

Measurement technique: the passameter 1, is fixed in the support 2; the instrument will be calibrated with a gauge block having the length equal to the nominal value of the diameter, N= 20 mm. Then, by pressing the button 5, the mobile probe **a**, is released and the gauge block will be remoted with the piece to be controlled 6; when the cylindrical surface **c**, of the piece 6, comes in contact with the active plane surfaces of the mobile probe **a** and the fix probe **b**, the first indication of the instrument will be noted (the indication corresponds to the diameter d_1). In this way, four diameters in the same cross section of the cylindrical surface **c,** will be measured, being obtained four indications of the passameter: δ_1, δ_2, δ_3, δ_4 (figure no. 6.c).

Obtaining the effective value of the roundness deviation: the roundness deviation A_e, in the measured cross section will be calculated with the math formula no. 1.

The effective roundness deviation A_e, will be compared with the prescribed roundness tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

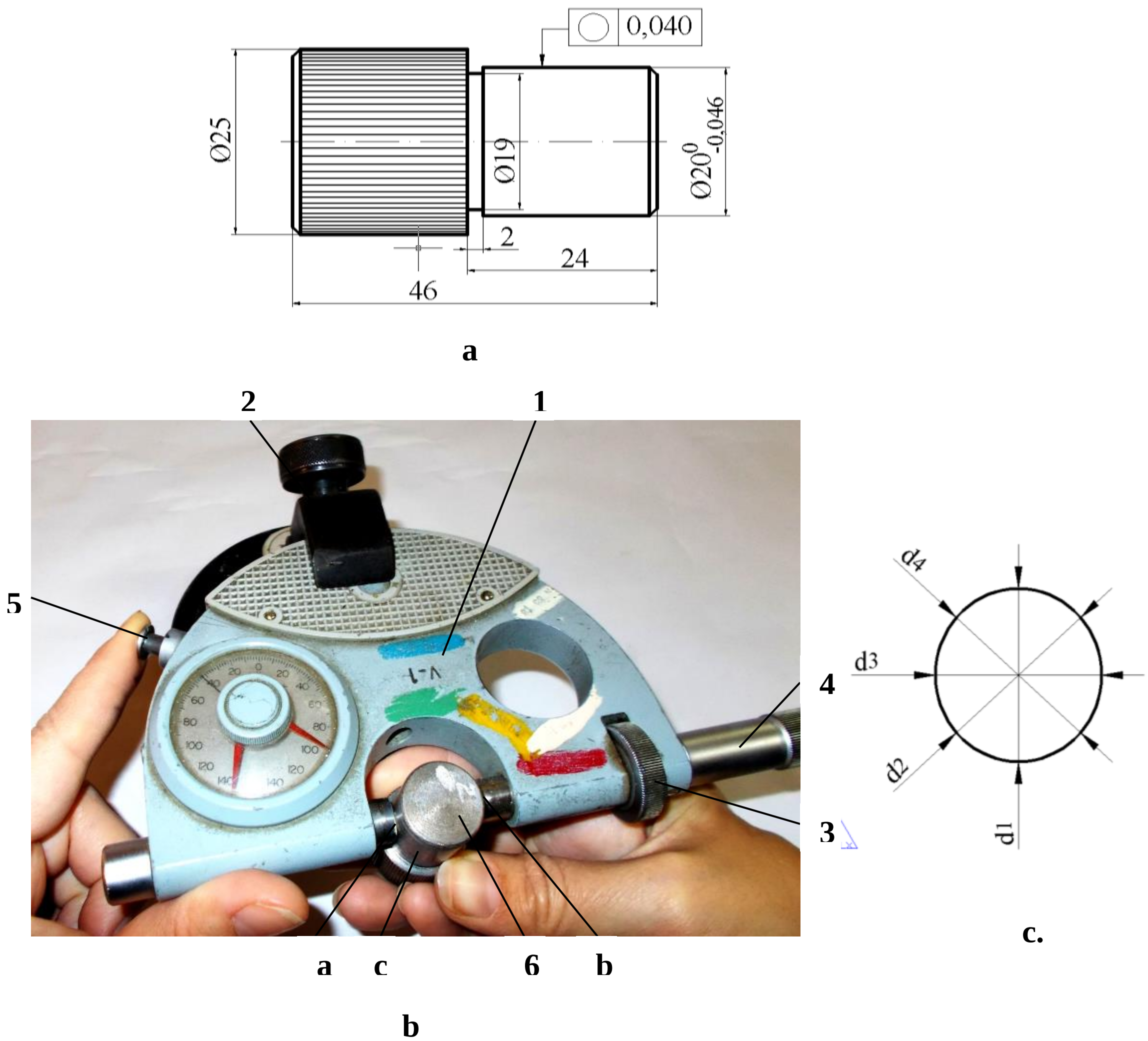


Fig. no. 6
The ovality measurement using a passameter
a.- indication the roundness tolerance on the drawing;
b.- the measurement scheme; c.- the disposing of the measured diameters.

- ***The measurement of polygon type deviation using a dial indicator.***

In the execution drawing of the piece a form tolerance is noted (figure no. 7.a).

The meaning of the geometrical tolerance is: 0,010 mm is the value of the roundness tolerance of each cross sections of the cylindrical surface having nominal diameter equal to N= 16 mm.

In order to measure the roundness deviation in a cross section of the cylindrical surface, the three-contact points method is applied.

The necessary equipment's and accessories: orthotest with the reading accuracy: 0,001 mm, laboratory support for the instrument, v- block.

The measurement scheme: in order to measure the polygon type of an outer cylindrical surface, the measurement scheme is presented in figure no. 7.b.

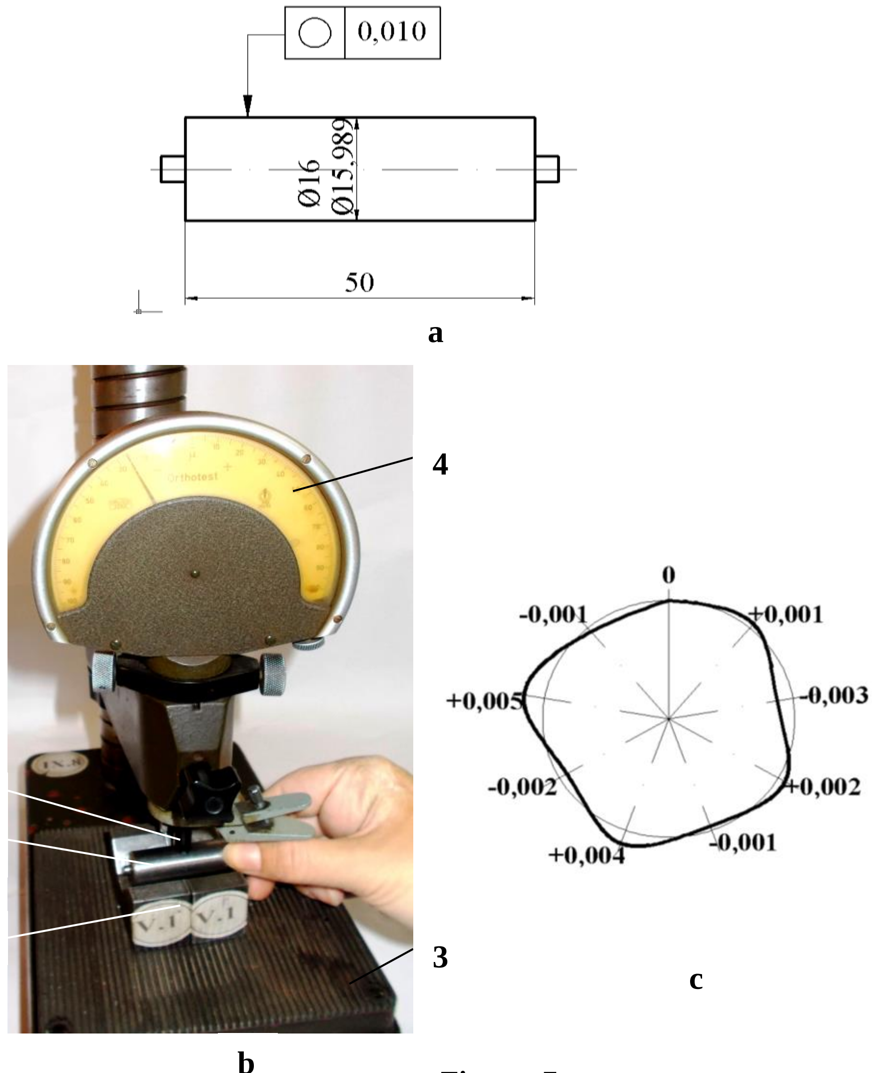


Fig. no. 7
The poligonity measurement using a passameter
a.- indication the roundness tolerance on the drawing;
b.- the measurement scheme.
c.- graphical representation of the actual circular profile (in polar coordinates).

Measurement technique: the piece to be controlled 1, is seated, with the cylindrical surface **a**, on the v- block 2; the probe 5 (with active edge) is brought in contact to **a** surface. Then, the instrument will be calibrated; after this action, the piece 1, will be rotated being in permanent contact with the instrument's probe. During a complete rotation of the piece, the extreme values of the dial indicator 4, will be noted: δ_1, δ_2, ..., δ_n.

The measured values δ_1, δ_2, ..., δ_n, can be used to make the graphical representation of the actual profile of the measured cross section (figure no. 7.c).

Obtaining the effective value of the roundness deviation: the roundness deviation A_e, in the measured cross section will be calculated with the no. 2 math formula.

The effective roundness deviation A_e, will be compared with the prescribed roundness tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

6.3. The measurement of the roundness deviations to inner cylindrical surfaces.

- ***The measurement of ovality using a dial instrument for inner sizes.***

In the execution drawing of the piece a form tolerance is noted (figure no. 8.a).

The meaning of the geometrical tolerance is: 0,08 mm is the value of the roundness tolerance of each cross sections of the inner cylindrical surface having nominal diameter equal to N= 57 mm.

In order to measure the roundness deviation in a cross section of the cylindrical surface, the two-contact points method is applied.

The necessary equipment's and accessories: dial indicator for inner sizes with the reading accuracy: 0,01 mm, ring gauge.

The measurement scheme: in order to measure the ovality of an inner cylindrical surface, the measurement scheme is presented in figure no. 8.b.

Measurement technique: the dial indicator for inner sizes will calibrated with a ring gauge having the diameter equal to the nominal value: N= 57 mm. After the calibration, the dial indicator 1, will be inserted inside the inner surface of the piece to be controlled until its bottom is seated on the vertical support 6 and the active surfaces of the probes 4 and 5 of the instrument are in contact with the inner surface in the cross section determined by the height of the vertical support 6. In the specified section will be measured four diameters uniform disposed on the circumference: D_1, D_2, D_3, D_4 (figure no. 8.c).

In the same way, will be measured another two cross sections disposed on the length of the inner surface (figure no. 8.c).

Obtaining the effective value of the roundness deviation: the roundness deviation A_{e1}, A_{e2}, A_{e3}, in the each measured cross section will be calculated with the no. 1 math formula.

The effective roundness deviation A_e, of the controlled inner surface will be the maximum value of the three effective deviations; this value will be compared with the prescribed roundness tolerance IT; if Ae ≤ IT, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

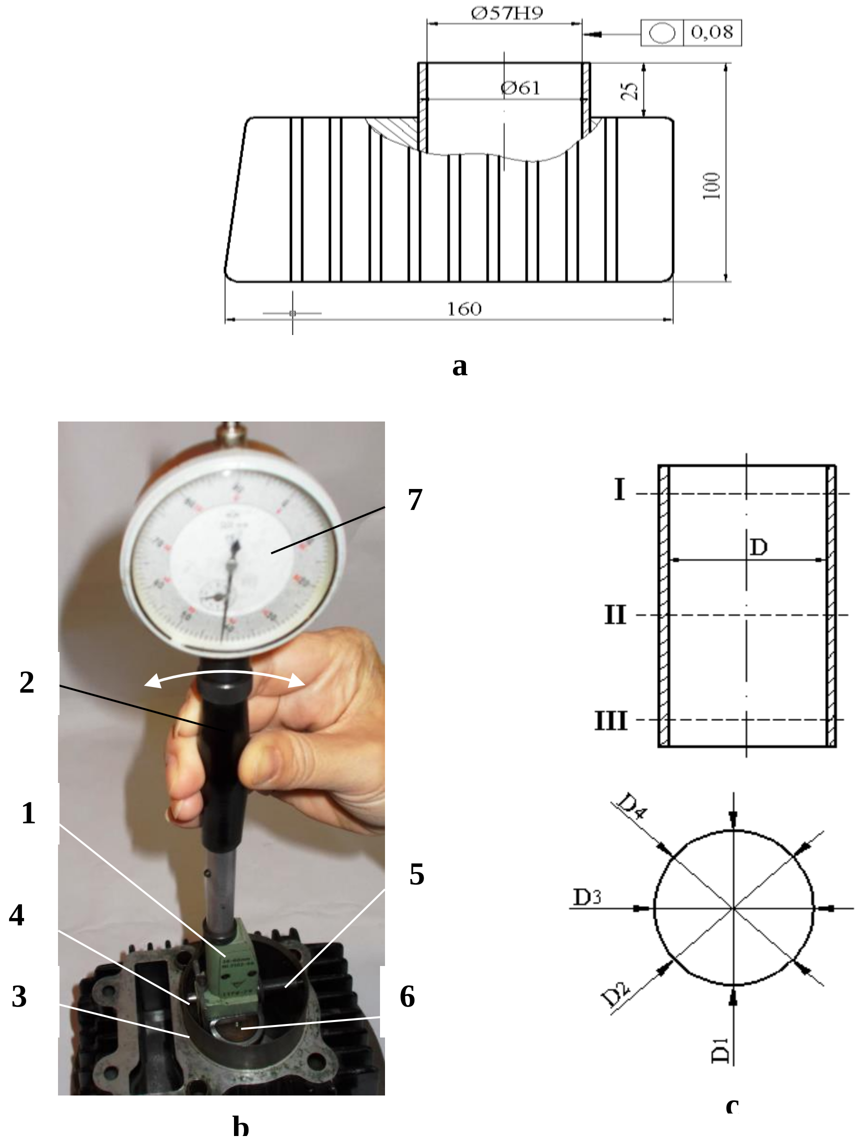


Fig. no. 8

The measurement of the roundness deviation using an inner indicator

a.- indication the roundness tolerance on the drawing;

b.- the measurement scheme; c.- the disposing of the measured sections and diameters.

- ***The measurement of polygon type deviation using a passimeter.***

In the execution drawing of the piece a form tolerance is noted (figure no. 9.a).

The meaning of the geometrical tolerance is: 0,024 mm is the value of the roundness tolerance of each cross sections of the inner cylindrical surface having nominal diameter equal to N= 20 mm.

In order to measure the roundness deviation in a cross section of the cylindrical surface, the two-contact points method is applied.

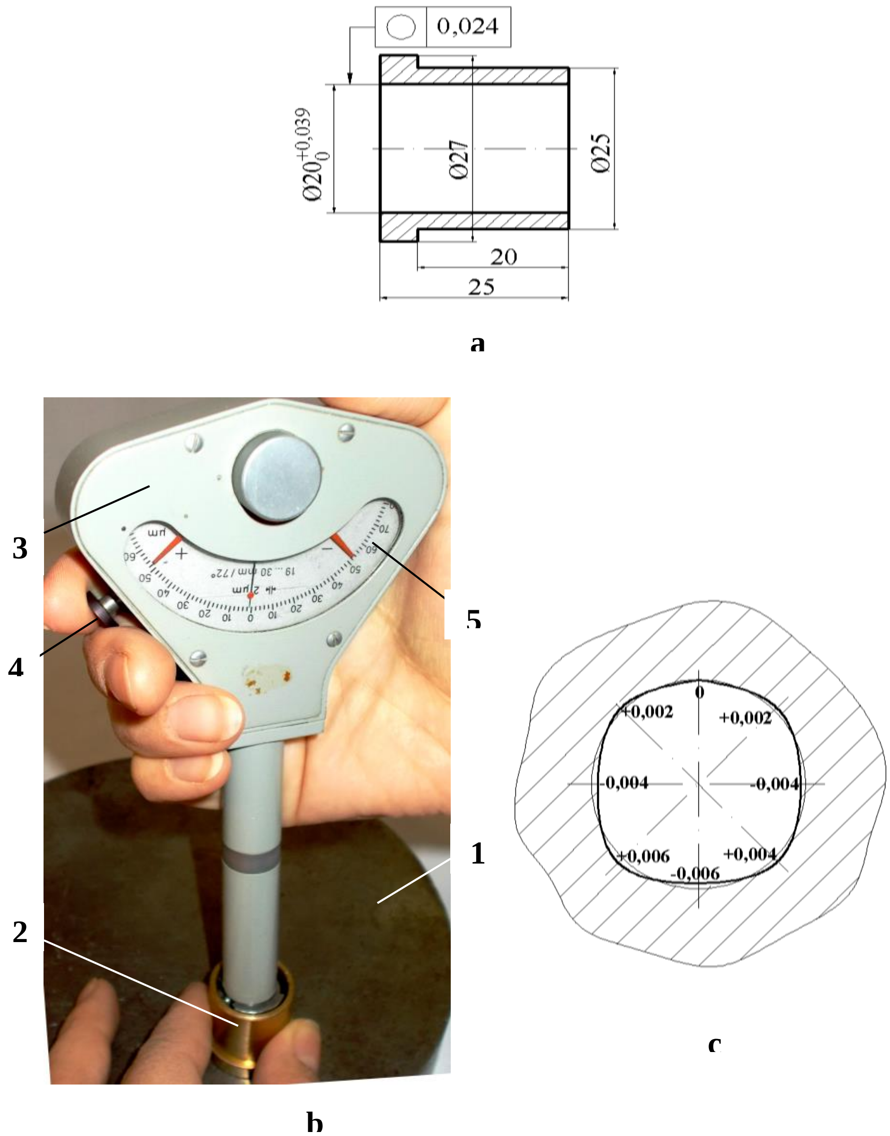


Fig. no. 9

The measurement of the roundness deviation using a passimeter

a.- indication the roundness tolerance on the drawing;

b.- the measurement scheme; c.- graphical representation of the actual circular profile (in polar coordinates).

<u>*The necessary equipment's and accessories*</u>: passimeter with the reading accuracy: 0,002 mm, ring gauge.

The measurement scheme: in order to measure the ovality of an inner cylindrical surface, the measurement scheme is presented in figure no. 9.b.

Measurement technique: the passimeter will calibrated with a ring gauge having the diameter equal to the nominal value: N= 20 mm. After the calibration, the passimeter 4, will be inserted inside the inner surface of the piece to be controlled 2 (this action will be made with the button 4 pressed); then, by releasing the button 4 and when the mobile probe comes in contact to the inner surface, the instrument will be rotated inside the inner surface in the same cross section. During rotation, the extreme values of the dial indicator4, will be noted: δ_1, δ_2, ..., δ_n.

The measured values δ_1, δ_2, ..., δ_n, can be used to make the graphical representation of the actual profile of the measured cross section (figure no. 9.c).

Obtaining the effective value of the roundness deviation: the roundness deviation A_e, in the measured cross section will be calculated with the no. 2 math formula.

The effective roundness deviation A_e, will be compared with the prescribed roundness tolerance IT; if Ae ≤ IT, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

7. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

Step no. 1: on the execution drawing of the piece to be controlled, the form tolerance will be identified and the form deviation to be measured will be established.

Step no. 2: the form deviation will be measured by applying the specified measuring method.

Step no. 3: the effective form deviation will be calculated.

Step no. 4: the effective form deviation will be compared with the prescribed form tolerance.

Step no. 5: the decision concerning the controlled piece will be made:

- if Ae ≤ IT, the controlled piece is accepted to be used;
- if Ae > IT, the controlled piece is rejected from use.

Laboratory work no. 9

CONTROL OF ORIENTATION AND RELATIVE POSITION DEVIATIONS USING UNIVERSAL INSTRUMENTS

Applications to be made at the laboratory work no. 9:

a. measuring of parallelism deviation between two plane surfaces;
b. measuring of parallelism deviation of an axis relative to a plane surface;
c. verifying the coaxiality of the inner cylindrical surfaces;
d. measuring of concentricity deviation to outer cylindrical surfaces;
e. measuring of symmetry deviation using a dial indicator;
f. measuring of radial run- out and of axial run- out.

2. General considerations

The orientation and relative position deviations of the surfaces are differences between the orientation/ relative position of the processed surfaces and the theoretical orientation/ relative position of the same surfaces. The orientation and relative position deviations of the parts surfaces are generated by the inaccuracy of the manufacturing process.

The main orientation and relative position deviations of the parts surfaces are:

- ***orientation deviations:***
    - parallelism deviations;
    - angular deviations;
    - perpendicularity deviations;
- ***relative position deviations:***
    - position deviations;
    - coaxiality deviation;
    - concentricity deviation;
    - symmetry deviation;
    - circular radial run- out;
    - total radial run- out deviation;
    - circular axial run- out;
    - total axial run- out.

6. Methods applied to control the orientation and relative position deviations of the surfaces.

In order to measure the orientation and relative position deviations of the surfaces, two main methods are applied:

- usual measuring methods which use universal means for lengths measuring, control devices and accessories;
- special measuring methods.

Any method applied to measure a geometrical deviation includes the following elements:

- ***the measuring scheme***, which is a graphical representation indicating: the part to be measured, it's orientation- position and clamping, the instrument's orientation relative to the part, the movements of the mobile elements;
- ***equipment's and accessories***, which are the measuring means (gauges, calibers, measuring instruments for linear and angular dimension) and accessories (supports for the measuring instruments, v- blocks, control dowels and mandrels, checking rulers, control plates, clamping elements, etc.);
- ***the measurement technique*** describes the steps to go in order to measure the geometrical deviation.

7. The measurement of the parallelism deviation of a surface relative to a datum plane.

In the execution drawing of the piece a geometrical tolerance is noted (figure no. 1.a).

The meaning of the geometrical tolerance is: 0,08 mm is the value of the parallelism tolerance of the top plane surface relative to the datum plane A (which is the bottom plane surface).

In order to measure the parallelism deviation of the plain surface of the piece to be controlled a dial indicator will be used.

The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,01 mm, indicator support, check plate with active surface, check ruler with active surface.

The measurement scheme: in order to measure the parallelism deviation of the plain surface of the piece, the measurement scheme is presented in figure no. 1.b.

The measurement technique: the part to control 1, is placed, with the bottom plane surface **b**, on the active surface of the check plate 2; on the top plane surface **a**, a check ruler 3, is placed. The dial indicator 4 (which is fixed to the support 5) will be moved in order to bring its measuring pick on the top active surface **c**, of the check ruler 3, to an extremity of the piece's surface (position I); in this point the instrument will be calibrated (setting to zero).

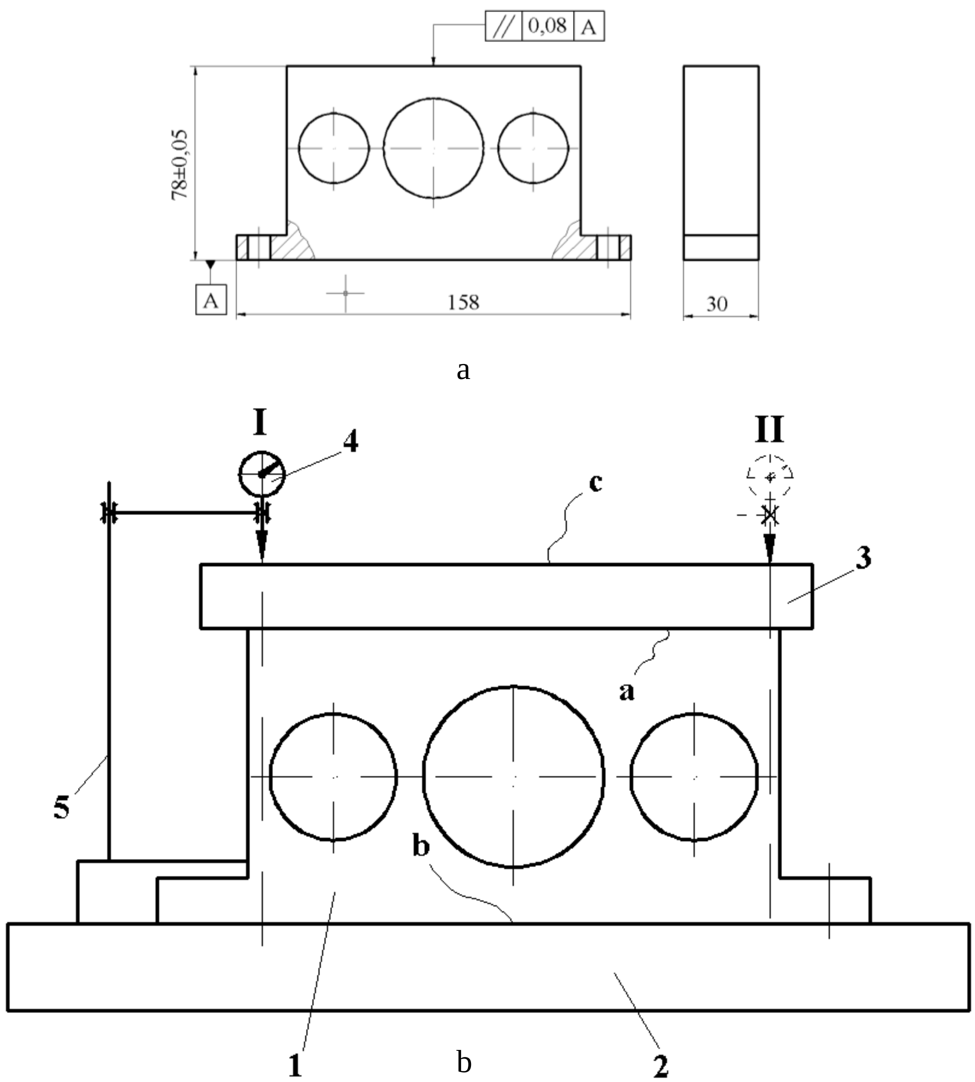


Fig. no. 1
The measurement of the parallelism deviation
(the case of a plain surface relative to a datum plane)

a.- indication the parallelism tolerance on the drawing;
b.- the measurement scheme.

With the measurement pick in the position picked up, the instrument 4, will be moved to the other extremity of the piece's surface (position II); in this position, the indication δ, of the instrument 4, will be noted.

Obtaining the effective value of the parallelism deviation: the measured parallelism deviation A_e, represent the absolute value of δ.

The effective parallelism deviation A_e, will be compared with the prescribed parallelism tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

8. The measurement of the parallelism deviation of an axis relative to a datum plane.

In the execution drawing of the piece a geometrical tolerance is noted (figure no. 2.a).

The meaning of the geometrical tolerance is: 0,10 mm is the value of the parallelism tolerance of the axis of the inner cylindrical surface having the nominal value of the diameter N= 27 mm, relative to the datum plane A (which is the bottom plane surface).

In order to measure the parallelism deviation of the axis of the piece to be controlled a dial indicator will be used.

The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,01 mm, indicator support, check plate with active surface, control mandrel ∅26 x ∅27 x 400 mm, measuring ruler.

The measurement scheme: in order to measure the parallelism deviation of the axis of the piece's inner surface, the measurement scheme is presented in figure no. 2.b.

The measurement technique: the part to control 1, is placed, with the bottom plane surface **a** (the datum plane), on the active surface **b**, of the check plate 2. In order to materialize the axis **c**, of the inner cylindrical surface, a control mandrel 3, is introduced inside the inner surface. The dial indicator 4 (which is fixed to the support 5) will be moved in order to bring its measuring pick on the highest point of the mandrel to an extremity of it (position I); in this point the instrument will be calibrated (setting to zero).

Note: the contact of the measuring pick with the highest point of the mandrel corresponds to maximum value of the instrument' s indication.

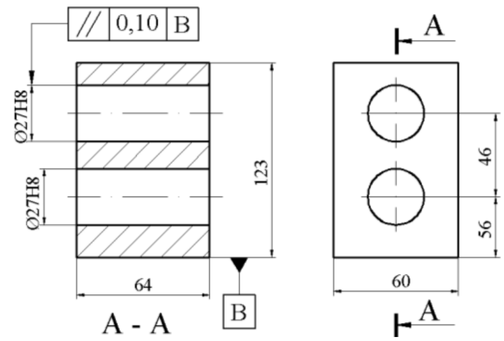
The instrument 4 will be moved in order to bring in order to bring its measuring pick on the highest point of the mandrel to other extremity of it (position II). in this position, the indication δ, of the instrument 4, will be noted.

The distance Lm, between the positions I and II, will be measured using a measuring ruler.

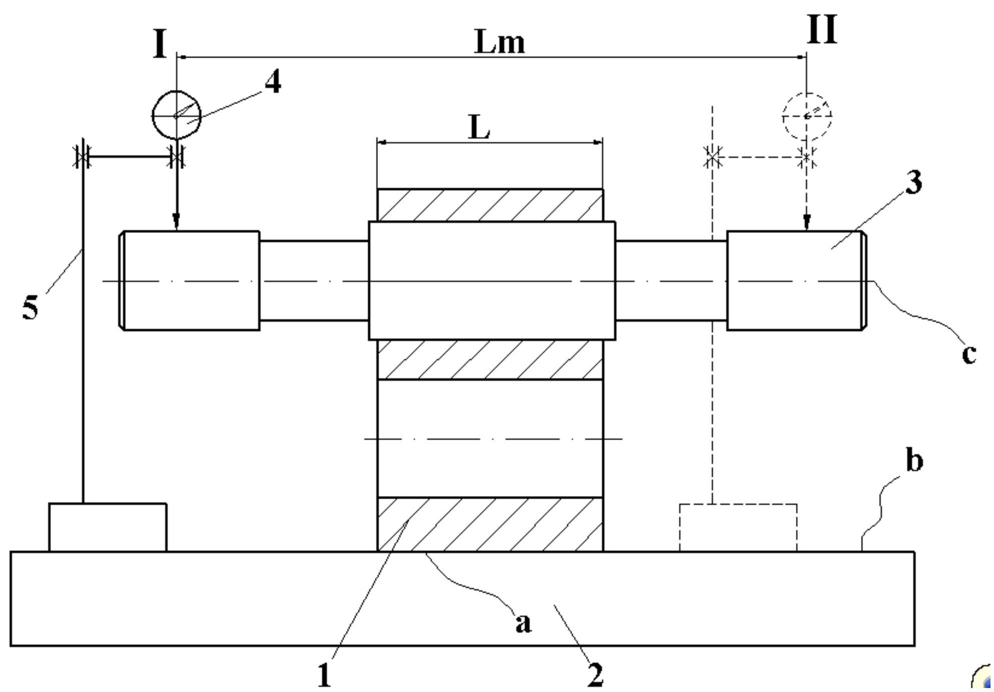
Obtaining the effective value of the parallelism deviation: the measured parallelism deviation A_e, will be calculated with the no 1 math formula:

$$A_e = |\delta| \cdot \frac{L}{Lm} \qquad (1)$$

L represents the reference length, which is the length of the inner cylindrical surface.



a



b

Fig. no. 2
The measurement of the parallelism deviation
(the case of an axis relative to a datum plane)

a.- indication the parallelism tolerance on the drawing;
b.- the measurement scheme.

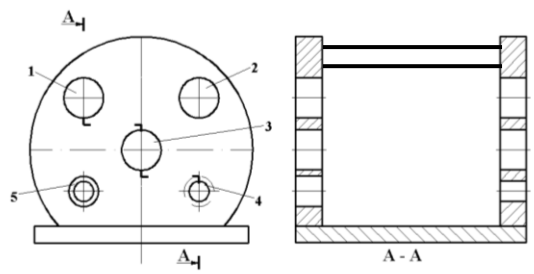
The effective parallelism deviation A_e, will be compared with the prescribed parallelism tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

9. Checking the coaxiality using control mandrels.

The piece presented in figure no. 3.a, is a case having five pairs of inner cylindrical surfaces; it must be checked the coaxiality of these surfaces.

In order to check the coaxiality of each pair of inner surfaces, control mandrels will be used.

The necessary equipment's and accessories: truncated control mandrel: ∅14 x ∅16 x 200 mm, polished control mandrel: ∅27 x 280 mm.



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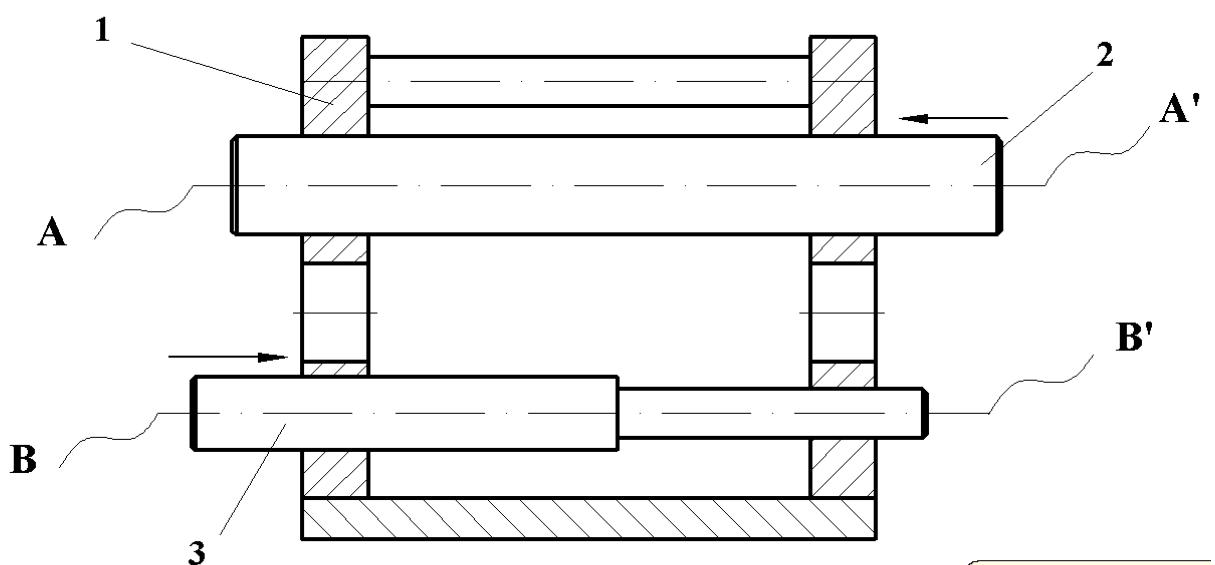


b

Fig. no. 3
Checking the coaxiality using control mandrels

a.- the drawing of the piece to be cecked;
b.- the checking scheme.

The verification scheme: is presented in figure no. 3.b.

The verification technique: in order to check the coaxiality of two inner cylindrical surfaces having the same value of diameter (example: the inner surfaces A and A'), will be used a polished control mandrel 2; the control mandrel 2, will be introduced in the inner surface A and it is moved to the inner surface A'. If the control mandrel will enter both inner surfaces A and A', can be considered that the checked surfaces are coaxial or, their coaxiality deviation fits in the coaxiality tolerance.

The same way to check the coaxiality will be used for all the pairs of inner cylindrical surfaces.

Note: when the diameters values of the inner cylindrical surfaces to be checked are not equal, a truncated control handle will be used.

10. The measurement of the concentricity deviation of two outer cylindrical surfaces

In the execution drawing of the piece a geometrical tolerance is noted (figure no. 4.a).

The meaning of the geometrical tolerance is: 0,040 mm is the value of the concentricity tolerance of each cross section of the truncated control outer cylindrical surface having the nominal value of the diameter N= 25 mm, relative to the datum A (which is the axis of the outer cylindrical surface having the nominal value of the diameter N= 50).

In order to measure the concentricity deviation of a cross section of the piece to be controlled a dial indicator will be used.

The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,002 mm, indicator support, check plate with active surface, long v- block.

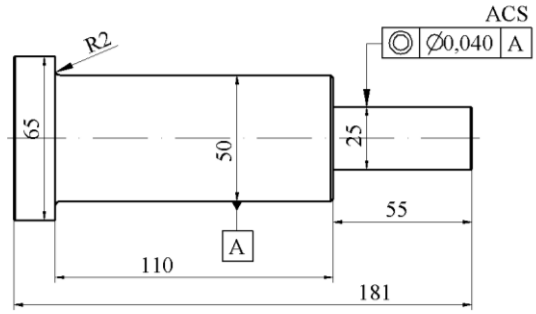
The measurement scheme: in order to measure the concentricity deviation, the measurement scheme is presented in figure no. 4.b.

The measurement technique: the piece to be controlled 1, is seated, with the cylindrical surface **a** (the datum A), on the v- block 2; the v- block 2, is placed on the active surface **c**, of the check plate 3. The probe of the instrument 4, is brought in contact to surface to be controlled **b**, on the highest point of the surface.

Then, the instrument will be calibrated, after this action, the piece 1, will be rotated being in permanent contact with the active edge of the probe 5. During a complete rotation of the piece, the extreme values of the dial indicator 4, will be noted: δ_{max}, δ_{min}.

Obtaining the effective value of the concentricity deviation: the measured concentricity deviation A_e, will be calculated with the no 2 math formula:

$$A_e = \frac{\delta_{max} - \delta_{min}}{2}. \quad (2)$$



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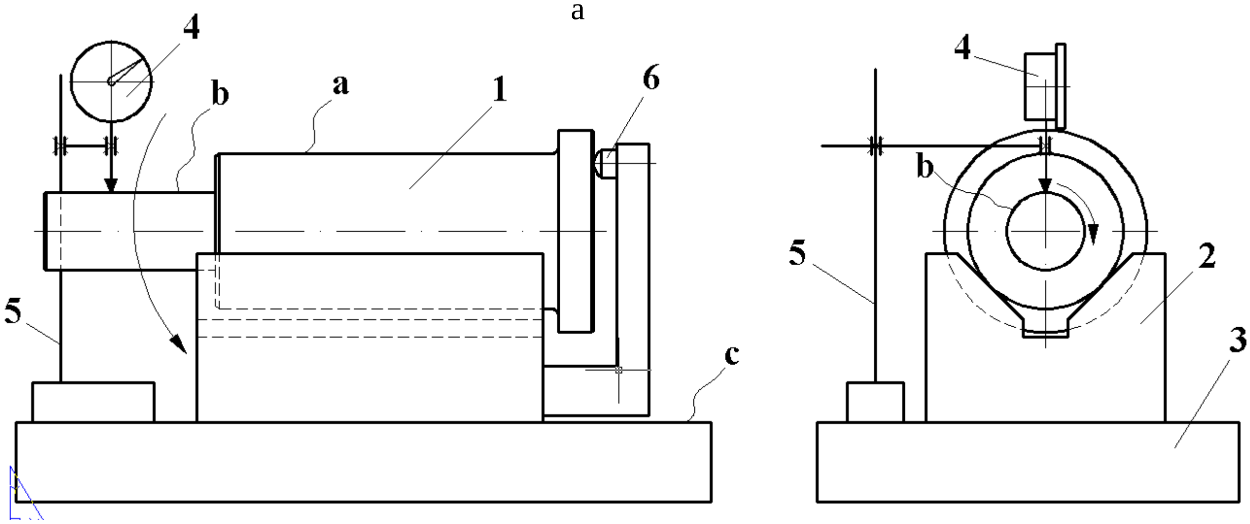


b

Fig. no. 4
The measurement of the concentricity deviation

a.- indication the concentricity tolerance on the drawing;
b.- the measurement scheme.

The effective concentricity deviation A_e, will be compared with the prescribed concentricity tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

Note: in order to ensure the rotation of the piece without its axial displacement, a spacer 6, is used.

11. The measurement of the symmetry deviation of two plane surfaces

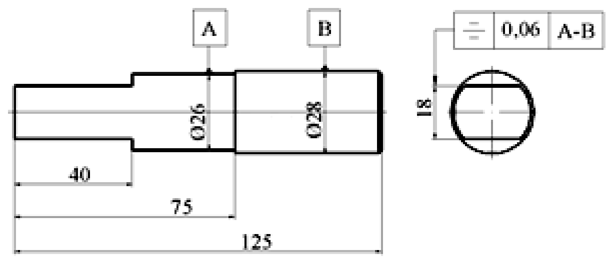
In the execution drawing of the piece a geometrical tolerance is noted (figure no. 5.a).

The meaning of the geometrical tolerance is: 0,06 mm is the value of the symmetry tolerance of the median plane of the plane surfaces apart 18 mm, relative to the common datum A- B (which is formed by the reunion of both single datums A and B).

In order to measure the symmetry deviation of the piece to be controlled a dial indicator will be used.

<u>*The necessary equipment's and accessories*</u>: dial indicator with the reading accuracy: 0,01 mm, indicator support, device with centering peaks.

<u>*The measurement scheme:*</u> in order to measure the symmetry deviation, the measurement scheme is presented in figure no. 5.b.



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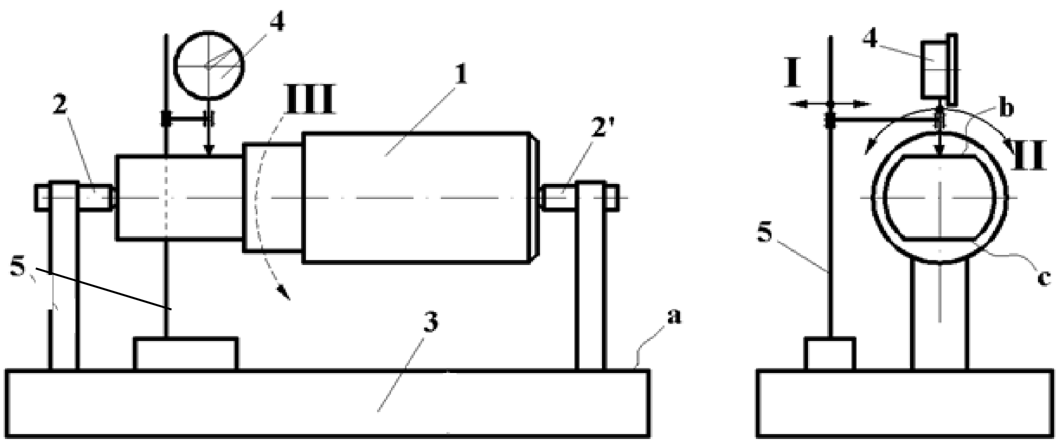


b

Fig. no. 5
The measurement of the simmetry deviation
a.- indication the simmetry tolerance on the drawing;
b.- the measurement scheme.

<u>*The measurement technique:*</u> the piece to be controlled 1, is introduced between the centering peaks 2 and 2', of the device 3. On the active surface **a**, of the check plate 3, the support 5, of the indicator 4, is seated. The probe of the instrument 4, is brought in contact to plane surface **b**, in the vertical plane of the axis line (move I). Then, by move II, in order to obtain the minimum value of instrument's indication; in this position the instrument will be calibrated. After this action, the piece will be rotated (move III) 180 degrees (first, the probe will be raised) and the probe will be brought in contact to the plane surface **c**.

Using, again, the move II, will find the minimum value δ of the instrument indication.

Obtaining the effective value of the symmetry deviation: the measured symmetry deviation A_e, will be the absolute value of δ indication.

The effective symmetry deviation A_e, will be compared with the prescribed symmetry tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

12. The measurement of the circular radial run- out.

In the execution drawing of the piece a geometrical tolerance is noted (figure no. 6.a).

The meaning of the geometrical tolerance is: 0,03 mm is the value of the circular radial run- out tolerance applied to the cylindrical surface, having the nominal value of the diameter N= 94 mm, relative to the common datum A- B (which is formed by the reunion of both single datums A and B).

In order to measure the radial run- out of the piece to be controlled a dial indicator will be used.

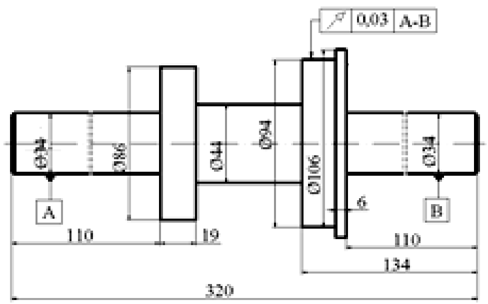
The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,01 mm, device with centering peaks.

The measurement scheme: in order to measure the radial run- out, the measurement scheme is presented in figure no. 6.b.

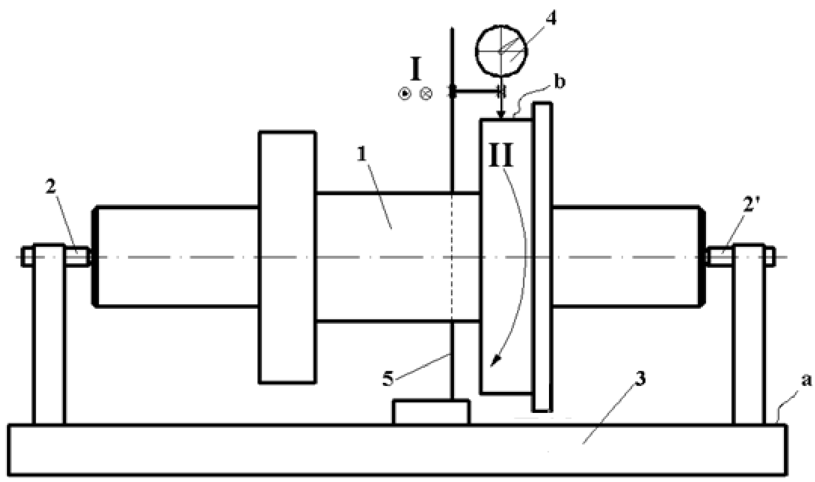
The measurement technique: the piece to be controlled 1, is introduced between the centering peaks 2 and 2', of the device 3. On the active surface **a**, of the check plate 3, the support 5, of the indicator 4, is seated. The probe of the instrument 4, is brought in contact to plane surface **b**, in the highest point of the cylindrical surface (move I); in this position the instrument will be calibrated. Then, the piece 1, will be rotated being in permanent contact with the instrument's probe. During a complete rotation of the piece, the extreme values of the dial indicator 4, will be noted: δ_{max}, δ_{min}.

Obtaining the effective value of the radial run- out: the measured radial run- out A_e, will be calculated with the no 3 math formula:

$$A_e=\delta_{max}-\delta_{min} \quad (3)$$



a



b

Fig. no. 6
The measurement of the circular radial run- out
a.- indication the radial run- out tolerance on the drawing;
b.- the measurement scheme.

The effective radial run- out A_e, will be compared with the prescribed tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

13. The measurement of the circular axial run- out.

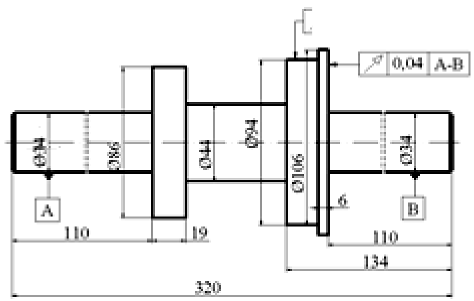
In the execution drawing of the piece a geometrical tolerance is noted (figure no. 7.a).

The meaning of the geometrical tolerance is: 0,04 mm is the value of the circular axial run- out tolerance applied to the frontal surface on the right side, relative to the common datum A- B (which is formed by the reunion of both single datums A and B).

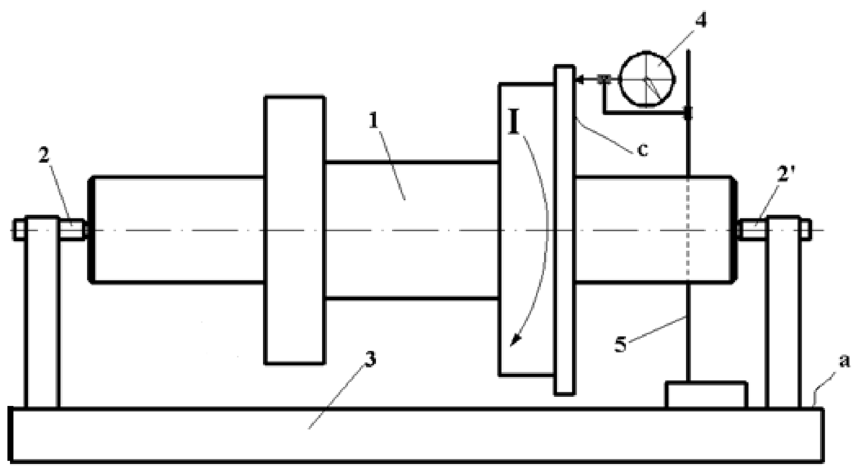
In order to measure the axial run- out of the piece to be controlled a dial indicator will be used.

The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,01 mm, device with centering peaks.

The measurement scheme: in order to measure the axial run- out, the measurement scheme is presented in figure no. 7.b.



a



b

Fig. no. 7
The measurement of the circular radial run- out

a.- indication the axialrun- out tolerance on the drawing;
b.- the measurement scheme.

The measurement technique: the piece to be controlled 1, is introduced between the centering peaks 2 and 2', of the device 3. On the active surface **a**, of the check plate 3, the support 5, of the indicator 4, is seated. The probe of the instrument 4, is brought in contact to frontal surface **c**, close to surface edge; in this position the instrument will be calibrated. Then, the piece 1, will be rotated being in permanent contact with the instrument's probe. During a complete rotation of the piece, the extreme values of the dial indicator 4, will be noted: δ_{max}, δ_{min}.

Obtaining the effective value of the axial run- out: the measured axial run- out A_e, will be calculated with the no 3 math formula:

The effective axial run- out A_e, will be compared with the prescribed tolerance IT; if $Ae \leq IT$, the decision concerning the controlled piece will be: the controlled piece is accepted to be used.

14. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

Step no. 1: on the execution drawing of the piece to be controlled, the geometrical tolerance will be identified and the geometrical deviation to be measured will be established.

Step no. 2: the geometrical deviation will be measured by applying the specified measuring method.

Step no. 3: the effective geometrical deviation will be calculated.

Step no. 4: the effective geometrical deviation will be compared with the prescribed form tolerance.

Step no. 5: the decision concerning the controlled piece will be made:

- if $Ae \leq IT$, the controlled piece is accepted to be used;
- if $Ae > IT$, the controlled piece is rejected from use.

Laboratory work no. 10

CONTROL OF ANGLES BETWEEN PLANE SURFACES.
CONTROL OF OUTER AND INNER CONES

Applications to be made at the laboratory work no. 10:

1. control of angles between plane surfaces:

a. measuring of the angles using universal rapporteur;
b. measuring of the angles on measuring microscope;
c. measuring of the right-angle deviation using an indicator;
d. measuring of the angles to a rectangular part;
e. measuring of the angles applying sin method;

2. control of outer and inner cones:

a. checking of the inner cones using conical plug gauges;
b. measuring of the angle to an outer cone on the measuring microscope.

3. Control of angles between plane surfaces.

a. General considerations

In order to control the angles between plane surfaces, three distinct categories of measuring methods are applied:

- goniometric measuring methods; when these applied, means for measuring angles are used: rapporteurs, measuring microscopes, goniometers;
- measuring methods with angle measures;
- trigonometric measuring methods.

b. Measuring angles using universal rapporteur.

The rapporteurs are mechanical instruments having active plane surfaces used to measure angles between plane surfaces; the value of the measured angle is given on a graduated scale in angle units (degree and minutes).

The universal rapporteur is an instrument having a circular graduated scale 0- 360º and a circular vernier with reading accuracy equal to 5 minutes (figure no. 1). It consists of a fix ruler with disk 1; on the fix disk 1, a mobile assembly is mounted containing a rotating disk 2, a mobile ruler 3 with its guide 4 and locking screws 5 and 6. On the circumference of the fix disk 1, a circular scale is marked; the circular scale is divided in 4 circular sections having divisions from 0º to 90º. On the mobile disk 2, a circular vernier is marked; the circular vernier is a bilateral scale with 12 divisions on the left side of the „0” mark and other 12 divisions on the right side of the „0” mark. The value of the vernier’s division is 5 minutes.

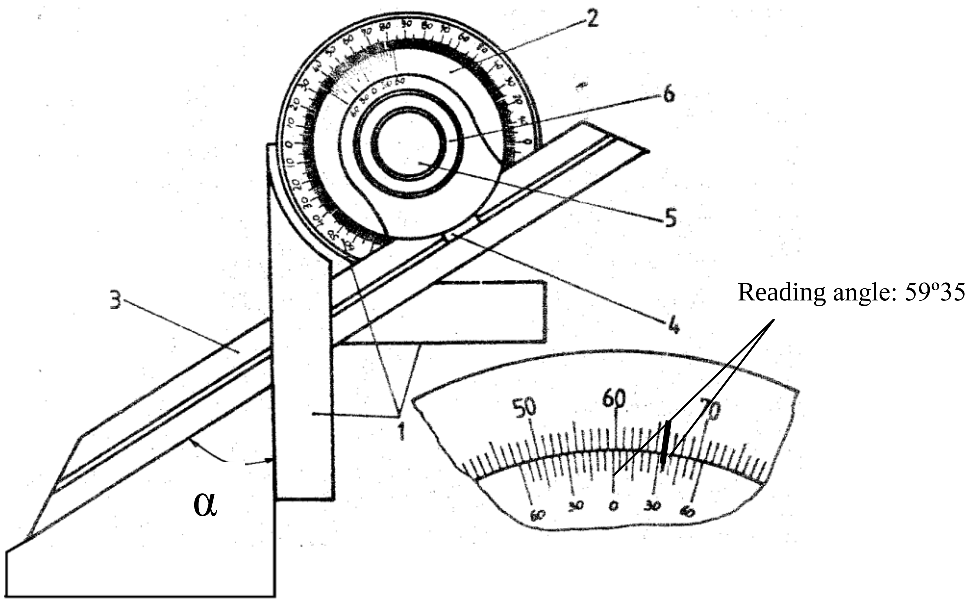


Fig. no. 1.
The universal rapporteur

The measurement technique: in order to measure the α angle between the plane surfaces, the piece 1 is introduced between the fix and mobile rules and, when the full contact between the pieces’ surfaces and the rulers is accomplished, the mobile ruler is blocked with the screw 6. On the circular scale the effective value of the measured angle will be read.

The mechanical dial rapporteur is an instrument without circular vernier; the effective value of the measured angle is read on the circular scales next to an index (figure no. 2). In the instrument’ s structure is a fixed ruler with disk 1, which the mobile assembly is mounted; the mobile assembly contains the rotating disk 4 and the mobile ruler 2 which can be fixed with the lever 8.

On the fix disc 1, a circular scale is marked; the division’ s value of the scale is 10°. Each division of the circular scale can be seen in a small window 5. On the mobile disc 4, another circular scale is marked; the division’ s value of this scale is 5 minutes the effective value of the angle can be read next the index 6.

The mobile assembly (the mobile disk 4 and the mobile ruler 3) can be blocked in the measurement position with the lever 7.

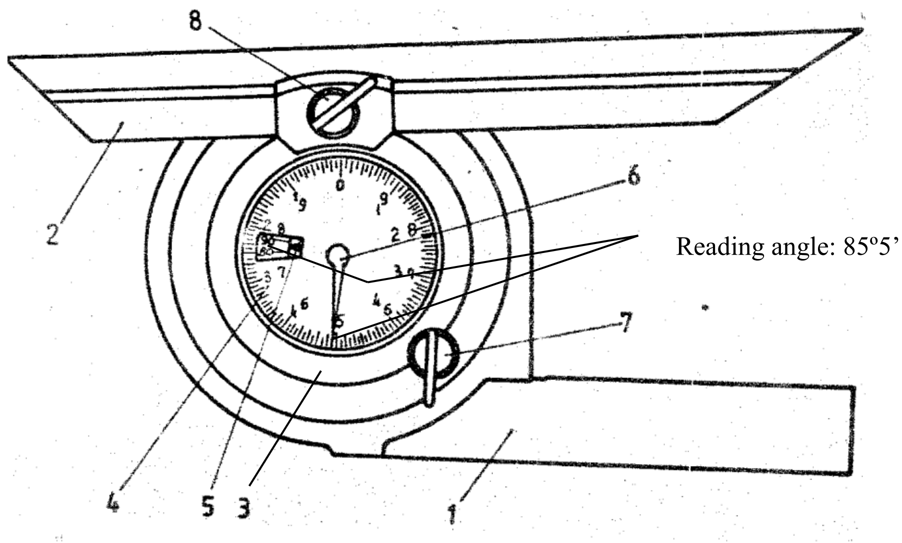


Fig. no. 2.
The mechanical dial rapporteur

The measurement of angles between two plane surfaces with the mechanical dial rapporteur is doing the same with the universal rapporteur. The reading of the effective value of the measured angle is different (see the example in figure no. 2): in the window 5, the tens of degrees (80°) will be read; on the circular scale 4, next the index 6, the units of degrees (5°) and the minutes (5') will be read.

c. Measuring angles on the measuring microscope FM.

The measuring microscope is an optical- mechanical apparatus used to measure linear and angular dimensions with accuracy.

The structure of a measuring microscope, the following systems contains:

- mechanical system;
- optical system;
- the lighting system.

The mechanical system ensures the position of the piece to be controlled, the movements of the piece and the sustaining of the optical system (figure no. 3).

The base 21 stands up the column 9 (with the console 11) and the assembly of two sleighs 20 (which moves on direction X by rotating the wheel 18) and 26 (which moves on direction Y by rotating the wheel 27). On the slight 26, a glass plate is mounted; on the glass piece the piece to be controlled will be seated.

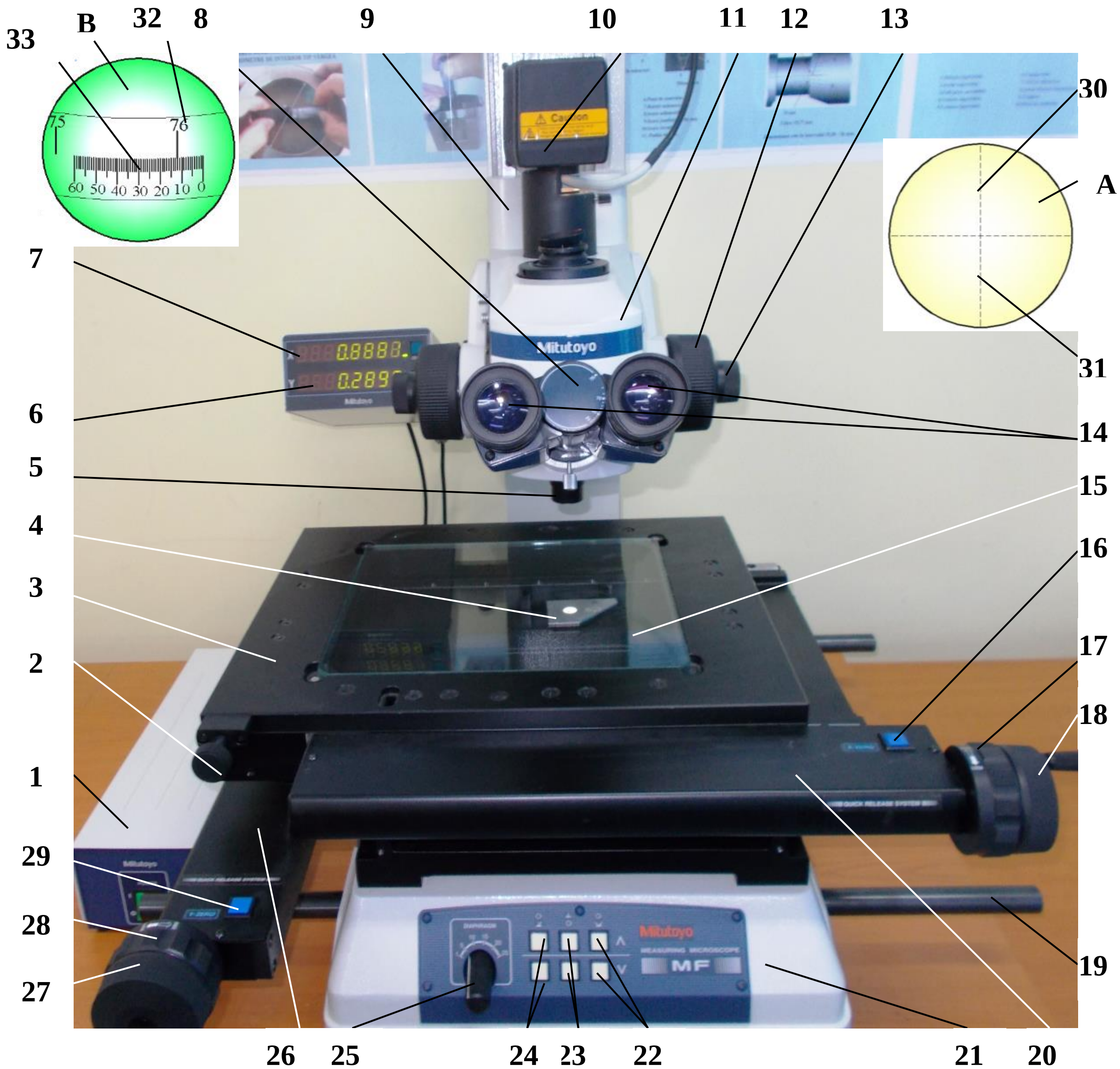


Fig. no. 3

Measuring microscope FM- Mitutoyo

1-power unit; 2- table inclination screw; 3- table of the microscope; 4- piece to be controlled; 5- objectif; 6- display X axis; 7- display Y axis; 8- eyepiece setting wheel; 9- column; 10- lighting lamp 11- console; 12- fast moving wheel; 13- fine movement screw of the console; 14- eyepieces head; 15- glass plate; 16- reset button X axis; 17- lock- unlock on X axis wheel; 18- fine movement wheel on X axis; 19- microscope lifting bar; 20- X axis sleigh; 21- base; 22- up to down lighting setting butons; 23- down to up lighting setting butons; 24- lighting setting butons; 25- contrast setting wheel; 26- Y axis sleigh 27- fine movement wheel on Y axis; 28- lock- unlock on Y axis wheel; 29- reset button Y axis.

The optical system takes the image of the controlled piece an transmits it to the eyepiece. The optical system is the optical head 14 (which is mounted on the console 11); it contains the objective 5 and the eyepieces 14. Looking through the eyepieces 14, can be seen the image of the piece and two linear perpendicular reticles 30 and 31 (see the detail **A**).

At the microscope an optical head can be mounted; this optical head contains a transparent lined plate with two scale (see detail **B**): a circular scale having 360 divisions, value equal 1º and a circular vernier having 60 division, value equal 1 minute.

The transparent lined plate can be rotated in order to measure angles.

The lighting system ensures the lighting the piece to be controlled, in order to be seen through the eyepiece. Two ways of lighting the piece can be used:

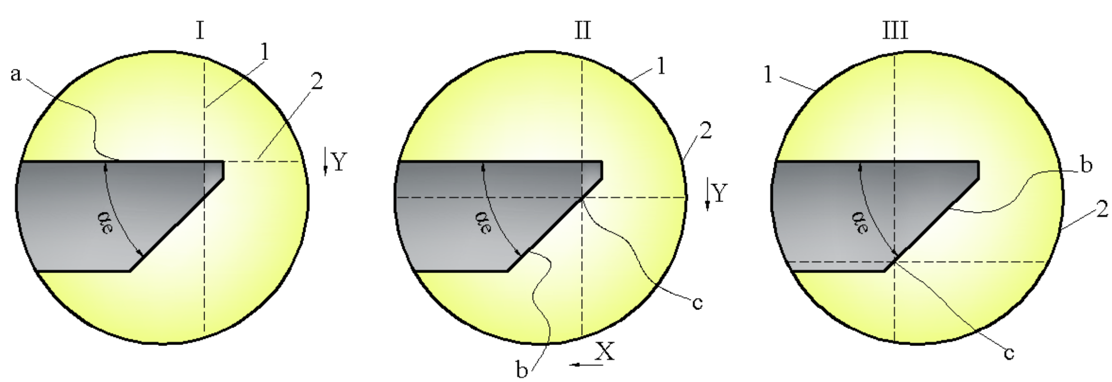
- lighting from down to up, with a lamp mounted in the base 21;
- lighting from up to down, with a lamp mounted at the console 11.

In order to measure angular dimensions on the measuring microscope, two measuring methods are used:

- the indirect measuring method: linear dimensions will be measured and a trigonometric formula will be applied;
- the direct method: the angle between plane surfaces will be measured directly.

The indirect method is applied when microscopes without the rotating transparent lined plate are used.

<u>The measurement technique:</u> in order to measure the angle with the nominal value α_N= 45º, between the plane surfaces of the piece 4, the piece is seated on the transparent table 15 (figure no. 3); the lighting mode from down to up is applied. So, in the eyepiece of the microscope, the black contour on the yellow background will be seen (figure no.



a **b** **c**

Fig. 4
The idirect method to measure the angle.

4).

The table 3, of the microscope will be moved (on the both axis X and Y) until the horizontal reticle 2 (figure no. 4.a) overlaps on side **a**, of the piece (position I); then, the sleigh on Y axis will be moved until the intersection point **c**, of the reticles 1 and 2, overlaps on the other side **b**, of the piece (figure no. 4.b). When the overlap is accomplished (position II), the reset buttons 16 and 29 (on both axis X and Y) will be pressed; on the X and Y displays 6 and 7, will appear the „0” value.

After the setting of the „0” value on the axis X and Y, the table 3, of the microscope will be moved (on the both axis X and Y) until the intersection point **c**, overlaps on the same side **b**, of the piece, but, in a different position III (figure no. 4.c)

The values indicated on the displays 6 and 7, will be noted:

— the indication on the X axis display will be noted L_X;

— the indication on the Y axis display will be noted L_Y.

The effective value of the measured angle will be calculated with the math formula 1:

$$\alpha_e = \text{arctg}\frac{L_Y}{L_X}. \qquad (1)$$

The direct method is applied when the measuring microscope contains the rotating transparent lined plate which ensure the direct measuring of the angle and the getting of the effective value of the angle in angle units directly.

<u>*The measurement technique:*</u> in order to measure the angle with the nominal value α_N= 45º, between the plane surfaces of the piece 4, the piece is seated on the transparent table 15 (figure no. 3); the lighting mode from down to up is applied. So, in the eyepiece of the microscope, the black contour on the green background will be seen (figure no. 5).

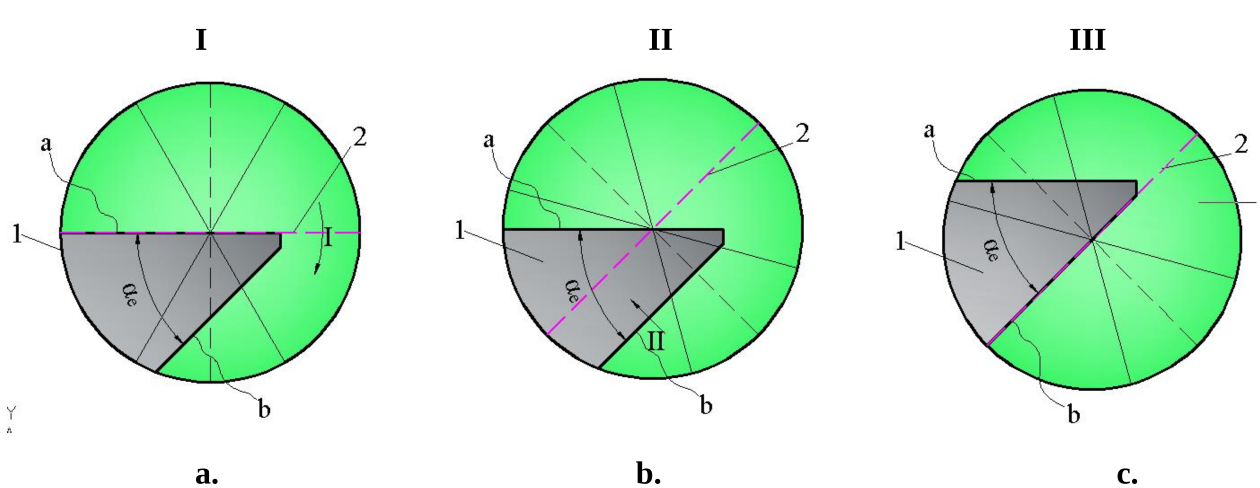


Fig. 5
The direct method to measure the angle.

The table 3, of the microscope will be moved (on the both axis X and Y) until the horizontal reticle 2 (figure no. 5.a) overlaps on side **a**, of the piece (position I); in this position will be read the first value $C_{1\alpha}$, on the circular scales of the rotating transparent lined plate.

Then, the rotating transparent lined plate will be rotated until the reticle 2 will be parallel to the other side b, of the piece, in position II (figure no. 5.b); after this action, the piece will be moved in Y axis, until the reticle 2, will overlaps on the side **b**, of the piece (figure no. 5.c); after the complete overlap will be accomplished (position III), will be read the second value $C_{2\alpha}$, on the circular scales of the rotating transparent lined plate.

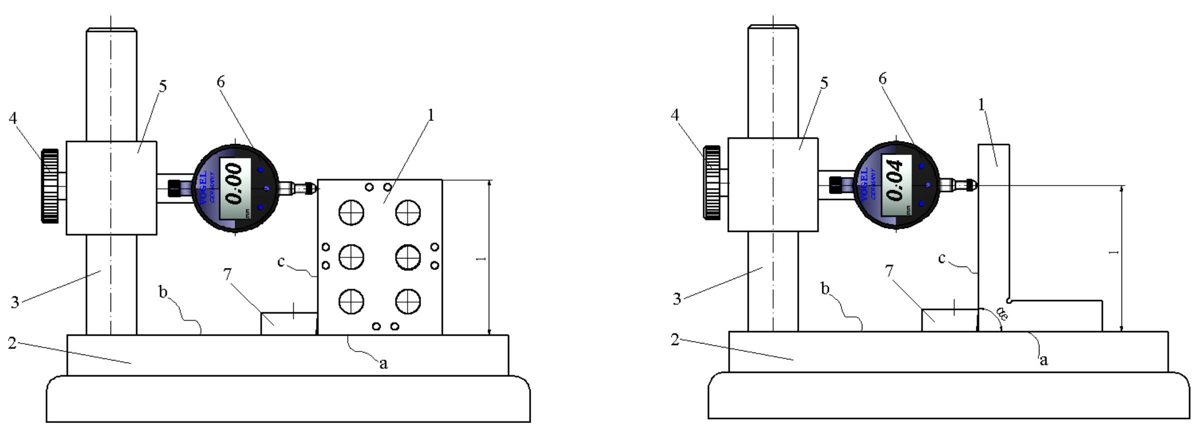
The effective value of the measured angle will be calculated with the math formula 2:

$$\alpha_e = \left| C_{1\alpha} - C_{2\alpha} \right|. \quad (2)$$

d. **Measuring angle deviation from 90º using a dial indicator.**

In order to measure the angle deviation to a square whose nominal angle is $\alpha_N = 90^o$, an angular gauge is use.

<u>*The necessary equipment and accessories*</u>: dial indicator with the reading accuracy: 0,01 mm, indicator support, angular gauge with 90 degree.



a **b**

Fig. no. 6

The measurement of the angle deviation using an angular gauge.

a. The calibration of the indicator (setting to “0”); the measuring scheme.

<u>*The measurement scheme:*</u> in order to measure the angular deviation of the outer angle of a square, the measurement scheme is presented in figure no. 6.

The measurement technique: first, it will calibrate the dial indicator. In order to calibrate the instrument 6, an angular gauge 1 is used (figure no. 6.a). The angular gauge 1, is seated with one of the active surfaces **as**, on the active surface **b**, of the base 2; then, the angular gauge 1, is moved to the stopper 7, until it will be realized the contact of the other active surface **c**, both with the stopper 7 and the measurement contact point of the instrument 6. The distance from the contact point of the measurement contact point and the surface **a**, will be measured using a measurement ruler. In this position the instrument 6 will be calibrated (will be settled to „0" value of its indication).

After calibration, the angular gauge will be removed with the square to be controlled 1, which will be brought in the same position as the angular gauge was brought (figure no. 6.b); in this moment, the indication of the instrument 6, will be noted.

Obtaining the effective value of the angular deviation: the indication of the instrument represents the linear deviation Δh, corresponding to the angular deviation Δα.

The angular deviation Δα (given in seconds units) will be calculated with the math formula 3:

$$\Delta\alpha = \frac{\Delta h}{l} 206{,}264'' \pm \Delta\alpha_m \,, \qquad (3)$$

where:

- Δh is the indication of the measuring instrument; units: mm;
- l is the length of the longer side of the controlled square; units: mm;
- $\Delta\alpha_m$ is the angular deviation of the angular gauge; units: seconds.

e. **Measuring angles to parallelepiped pieces using a dial indicator.**

In case of parallelepiped pieces, it is possible to measure all the four angles of a side of the piece, using a dial indicator only.

The necessary equipment's and accessories: dial indicator with the reading accuracy: 0,01 mm, indicator support.

The measurement scheme: in order to measure the angles α, β, γ and ε, of the piece to be controlled 1, the measurement scheme is presented in figure no. 7.

The measurement technique: first, it will calibrate the dial indicator 6, on the piece to be controlled 1, directly; in order to calibrate the indicator 6, one of the four angles will be chosen as reference angle (example: α angle, between the sides **a** and **c** of the piece). The piece to be controlled 1, is seated with the side **a**, on the active surface **b**, of the base 2; then, the piece 1, is moved to the stopper 7, until it will be realized the contact of the other active surface **c**, both with the stopper 7 and the measurement contact point of the instrument 6 (figure no. 7.a). In this position the instrument 6 will be calibrated (will be settled to „0" value of its indication) for the α angle as reference.

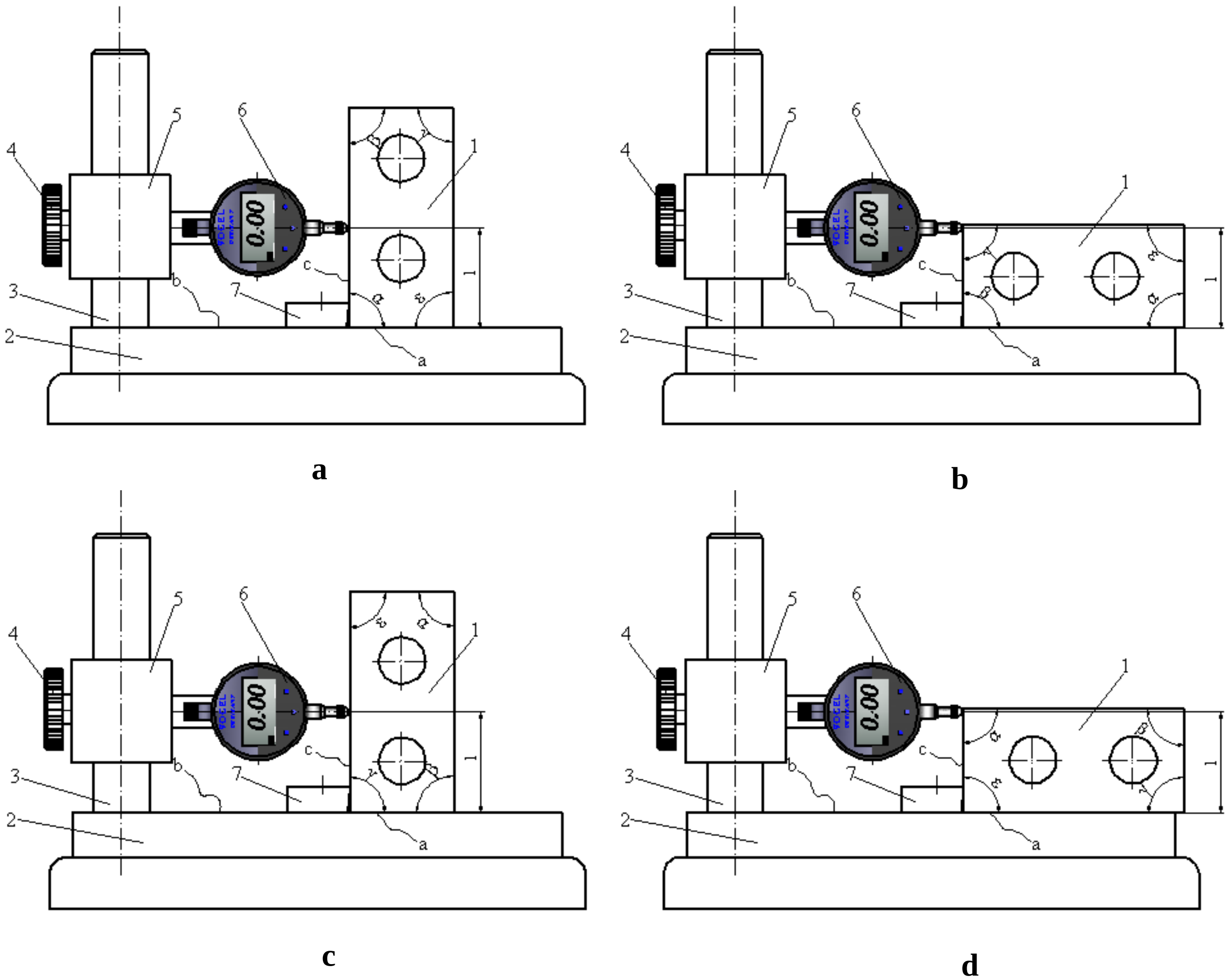


Fig. no. 7
The measurement of the angles to parallelipipedic pieces using a dial indicator

After calibration, the piece 1 will be rotated the piece 1, such that the side of β angle will be brought in contact to the instrument contact point (figure no. 7.b); in this position the indication of the instrument 6, will be noted.

It will proceed with the γ angle (figure no. 7.c) and the ε angle (figure no. 7.d).

The indications of the instrument 6, will represent the following parameters:

— the indication for β angle represents the linear deviation Δh_{β}, corresponding to the angular deviation Δβ, of the β angle;
— the indication for γ angle represents the linear deviation Δh_{γ}, corresponding to the angular deviation Δγ, of the γ angle;
— the indication for ε angle represents the linear deviation Δh_{ε}, corresponding to the angular deviation Δε, of the ε angle.

Obtaining the effective value of the measured angles: the linear deviations Δh_β, Δh_γ, Δh_ε, will be transformed in angular deviations, using the math formula 3:

$$\Delta\beta = \frac{\Delta h_\beta}{l} 206{,}264, \quad (4)$$

$$\Delta\gamma = \frac{\Delta h_\gamma}{l} 206{,}264, \quad (5)$$

$$\Delta\varepsilon = \frac{\Delta h_\varepsilon}{l} 206{,}264, \quad (6)$$

were l, is the length of the shorter side of the controlled piece; units: mm.

After the calculation of the angular deviations, a system of four equations will be formed:

$$\begin{aligned} &\beta = \alpha + \Delta\beta; \\ &\gamma = \alpha + \Delta\gamma \\ &\varepsilon = \alpha + \Delta\varepsilon; \\ &\alpha + \beta + \gamma + \varepsilon = 360° \end{aligned} \quad (7)$$

Note: the parallelepiped workpieces have the property: the sum of the side surfaces is equal to 360º.

f. **Measuring angles applying the sinus method.**

The sinus method is one of the trigonometric measuring methods (sinus method and tangent method) applied to the measuring of angles using trigonometric functions.

In order to applied the sinus method, a special accessory is necessary: sinus ruler or sinus plate; the effective value of the measured angle results from sinus trigonometric function, after linear dimensions were measured.

The necessary equipment's and accessories: sinus plate, gauge block set, surface plate, dial indicator with the reading accuracy: 0,01 mm, indicator support.

The measurement scheme: in order to measure the angle between two plane surfaces of a piece by applying the sinus method, the measurement scheme is presented in figure no. 8.

The measurement technique: two calibrated roll 2 and 10, are mounted at both ends of the sinus plate 4; one of the calibrated rolls (roll 2) is seated on the active surface **a** of the surface plate 1 and the other calibrated roll (roll 10) is seated on the block gauge 11, having the height H.

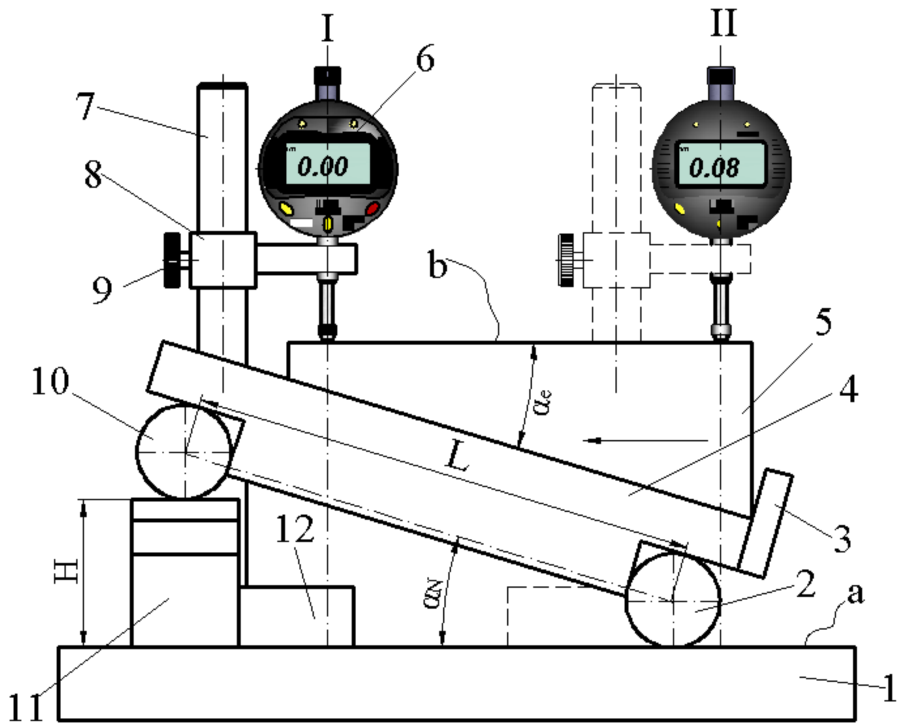


Fig. no. 8
The measurement of the angles by applying the sinus method.

The piece to be controlled 5, is seated on the active surface of the sinus plate 4; the sinus plate 4, is inclined with nominal angle α_N, by introducing under the calibrated roll a gauge block 11; the height H, of the gauge block is calculated with math formula:

$$H = L.\sin \alpha_N, \tag{8}$$

where L is the distance between the axis of the calibrated roll: L= 100± 0,001 mm.

If the effective angle of the piece 5, is equal to the nominal value ($\alpha_N = \alpha_e$), the upper surface **b**, of the piece is parallel to the active surface of the surface plate 1; the parallelism of these surfaces will be checked using a dial indicator 6, which is mounted at the support 7.

The instrument 6 will be calibrated (settled to „0”) in position I, then it is moved to position II, where the indication of the instrument will be observed.

If the effective angle of the piece 5, is not equal to the nominal value ($\alpha_N \neq \alpha_e$), the upper surface **b**, of the piece will be not parallel to the active surface of the surface plate 1 and the indication of the instrument 6 will be not „0”. In order to obtain the effective value of the angle, will modify the height of the gage block 11, until the indication of the instrument 6, in position II will be „0”. When the instrument 6, will indicate „0” value (in the position II), the corresponding height H’, of the gage block 11, will be noted.

Obtaining the effective value of the angular deviation: the effective value α_e, of the measured angle will be calculated with the math formula:

$$\alpha_e = \arcsin \frac{H'}{L}. \tag{9}$$

4. Control of cones.

a. Checking cones with conical gauges.

The gauges used to check the polished conical surfaces are limiting gauges since a conical gauge checks both limits of material of the cone:

- the maximum limit of material is checked by the „GO” gauge;
- the minimum limit of the material is checked by the „ NO GO” gauge.

Two distinct categories of conical gauges are used to check the polished cones (figure no. 9):

- conical plug gauges GO and NO GO, used to check the inner cones, having different constructive forms:
  - conical plug gauge with two lines (streaks) (figure no. 9.a and b);
  - conical plug gauge with one line (streak) (figure no. 9.c and d);
  - conical plug gauge with two clearances (figure no. 9.e and f);
  - conical plug gauge with one clearance (figure no. 9.g and h);
- conical ring gauges GO and NO GO, used to check the outer cones, having two constructive forms:
  - conical ring gauge (figure no. i and j);
  - conical plate gauge (figure no. k).

i. Checking outer cones using conical ring gauges.

In order to check the outer cones, the piece to be controlled 1, will be introduced inside the conical ring gauge; after this action the position of the small or large base of the piece relative to the limits of the gauge will be observed (figure no. 10).

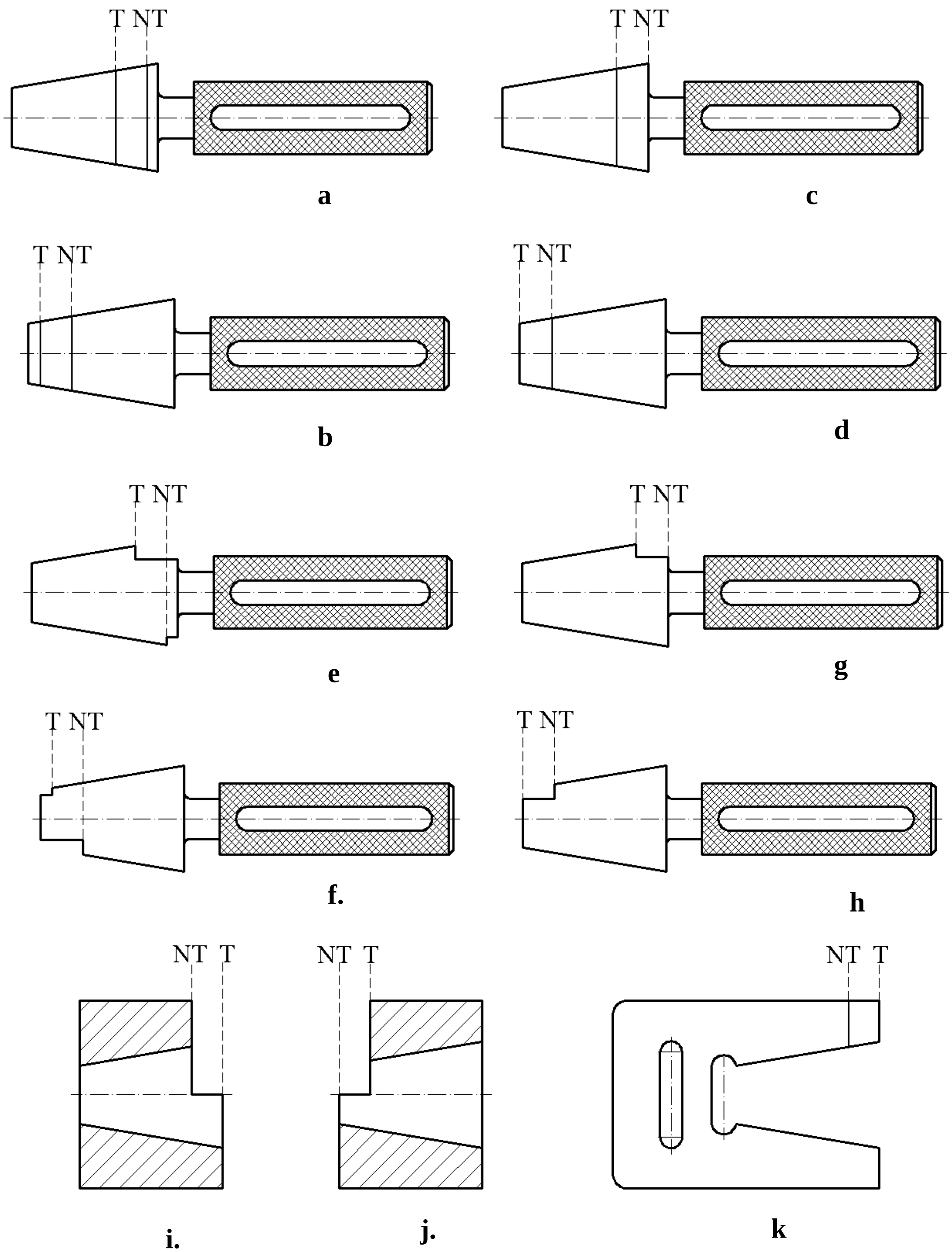
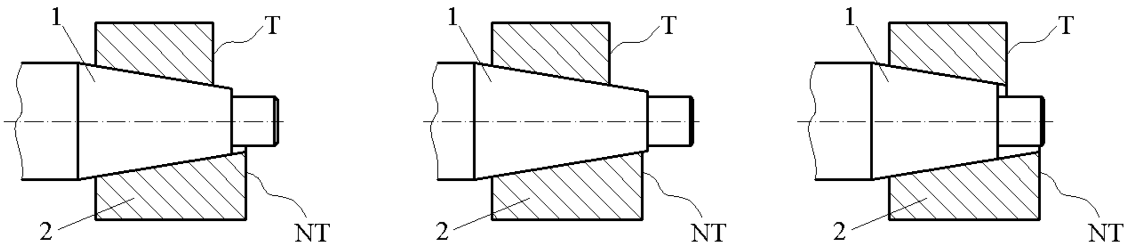
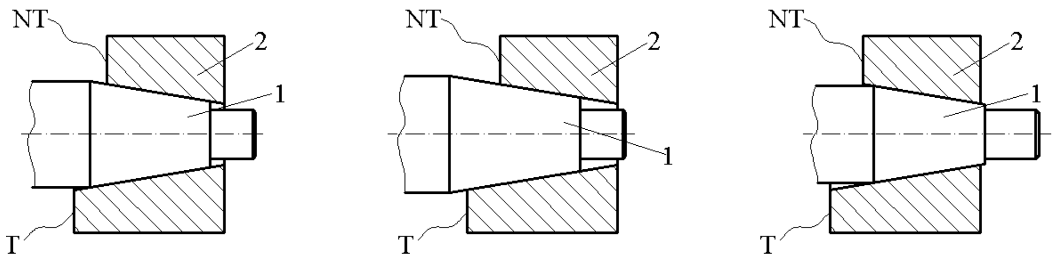


Fig. 9
Limiting conical gauges

a- h- conical plug gauges for checking inner cones
i- k- conical gauge for checking the outer cones.



a

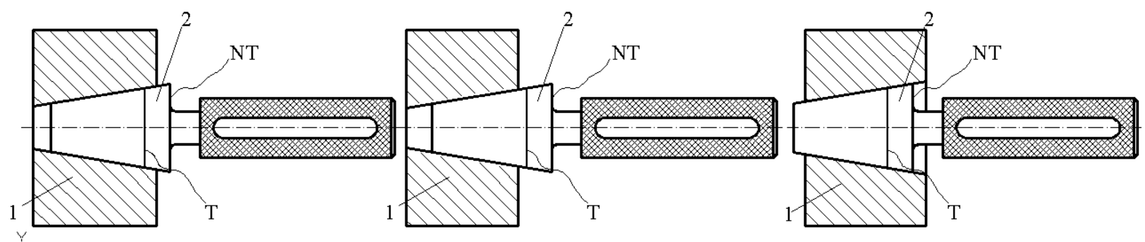


b

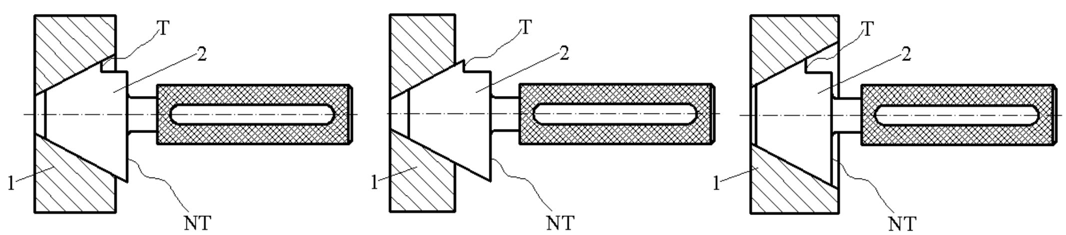
Fig. no. 10

Checking the outer cones using conical ring gauges

a- checking the outer cones relative to the small base of the cone;
b- checking the outer cones relative to the large base of the cone.



a



b

Fig. no. 11

Checking the inner cones using conical plug gauges

a- checking the inner cones using conical plug gauges with streaks;
b- checking the inner cones using conical plug gauges with clearances.

When the checking is made relative to the small base of the cone to be controlled, the following possible situations can occur (figure no. 10.a):

- the small base of the cone is between the GO and NO GO limits of the gauge; that means: the controlled cone is admitted to be used;
- the small base of the cone comes after the NO GO limit of the gauge; that means: the controlled cone is rejected from use;
- the small base of the cone comes before the GO limit of the gauge; that means: the controlled cone is rejected from use.

When the checking is made relative to the large base of the cone to be controlled, the following possible situations can occur (figure no. 10.b):

- the large base of the cone is between the GO and NO GO limits of the gauge; that means: the controlled cone is admitted to be used;
- the large base of the cone comes before the GO limit of the gauge; that means: the controlled cone is rejected from use;
- the large base of the cone comes after the NO GO limit of the gauge; that means: the controlled cone is rejected from use.

ii. Checking inner cones using conical plug gauges.

In order to check the inner cones, the conical plug gauge 2, will be introduced inside the piece to be controlled 1; after this action the position of the small or large base of the piece relative to the limits of the gauge will be observed. It will occur the same three situations as well as when checking outer cones (figure no. 11a and b).

b. Measuring outer cones on the measuring microscope FM.

In order to measure the angle of an outer cone, on the measuring microscope presented in figure no. 3, a centering device is used as an accessory; this accessory (which is not shown in the figure no. 3) is seated on the plate of the microscope.

The measurement scheme: is presented in figure no. 12.

The measurement technique: in order to measure the angle α_e, of the outer cone 1, the cone will be introduced between the two centering tips 3. It is applied the projection method (the piece to be controlled is illuminated from down to up); so, in the eyepiece of the microscope the black contour on the yellow background **c**, will be seen (see the detail from figure no. 12).

The table of the microscope (with the cone 1) will be moved on X and Y axis, until the intersection point **b**, of the vertical and horizontal reticles, will overlap on the top line **a**, of the cone (position I); in this position, the reset button on Y axis will pe pressed (on the Y display will appear the „000,000” value).

Then, the piece will be moved on the Y axis (move MI) until the will intersection point **b**, will overlap on the bottom line of the cone (position I); in this position, the reset button on X axis will pe pressed (on the X display will appear the „000,000” value). In the same time, the value $C1_Y$, on the Y display will be noted.

The piece will be moved on the X axis (move MII) until the X display will indicate a no decimals value (example 10,000 mm); the indicated value, $C1_X$, on X display will be noted (position III).

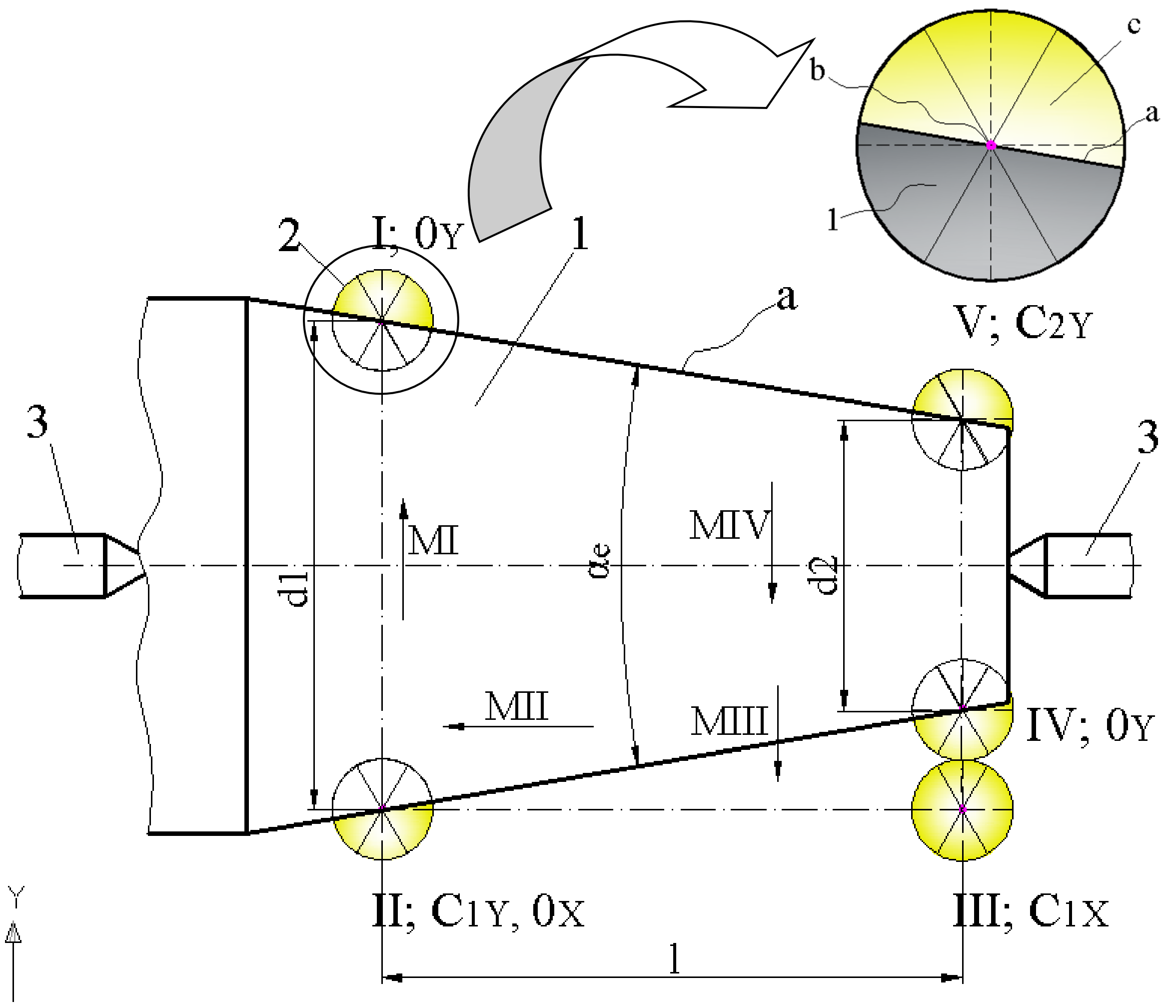


Fig. no. 12.
Measuring the angle of an outer cone on the measurement microscope

Then, the piece will be moved on the Y axis (move MIII) until the no decimals intersection point **b**, will overlap on the bottom line of the cone (position IV); in this position, the reset button on Y axis will pe pressed (on the Y display will appear the „000,000” value). After this action, the piece will be moved allows, on the Y axis (move MIV) until the allows intersection point **b**, will overlap on the top line **a**, of the cone (position V); in this position, the value $C2_Y$, on the Y display will be noted.

The numerical values noted on the X display and Y display will be used to calculate the following linear dimensions of the controlled cone:

- the diameter d_1, of the cone: $d_1 = |C1_Y|$;
- the diameter d_2, of the cone: $d_2 = |C2_Y|$;
- the distance between the sections with d_1 and d_2 of the cone: $l = |C1_X|$.

<u>Obtaining the effective value of the measured angle:</u> the effective value of the angle of the measured cone will be calculated with the math formula:

$$\alpha_e = 2 \cdot \operatorname{arctg} \frac{d_1 - d_2}{2l}. \tag{10}$$

In the math formula 10, the terms d_1, d_2 and l, represent the diameters of two sections apart at distance l, of the controlled cone.

5. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

Step no. 1: the execution drawing of the piece to be controlled, will be drawn; on the execution drawing, the tolerance of the dimension to be measured will be noted.

Step no. 2: the specified dimension will be measured by applying the specified measuring method.

Step no. 3: the effective value of the measured dimension will be calculated.

Step no. 4: the effective value of the measured dimension will be compared with the prescribed tolerance.

Step no. 5: the decision concerning the controlled piece will be made:

- if $Ae \leq IT$, the controlled piece is accepted to be used;
- if $Ae > IT$, the controlled piece is rejected from use.

Laboratory work no. 11

CONTROL OF OUTER AND INNER THREADS

Applications to be made at the laboratory work no. 11

a. checking the inner threads using threaded plug gauges;
b. measuring the outer and the inner diameters to a screw using the caliper;
c. measuring the pitch diameter to a screw using thread micrometer and three calibrated wires;
d. measuring the pitch diameter to a screw on the measuring microscope;
e. measuring the pitch to a screw on the measuring microscope;
f. measuring the angle of the flanks to a screw on the measuring microscope.

1. Checking the inner threads using threaded plug gauges.

1.1. General considerations.

The inspection of the threaded surfaces using threaded gauges is a complex checking method due to the fact that all the dimensional elements of the threaded surface are checked; the threaded gauge used to this inspection are limiting gauges which will check the material limits of the threaded surfaces:

- the maximum limit of material is checked by the „GO” gauge;
- the minimum limit of the material is checked by the „ NO GO” gauge.

Two distinct categories of threaded gauges are used to check the threaded surfaces (figure no. 1):

- threaded plug gauges GO and NO GO, used to check the inner threads (figure no. 1.a);
- threaded ring gauges GO and NO GO, used to check the outer threads (figure no. 1.b).

Both types of gauges contain of two distinctive parts, each of them verifying a limit of material of the threaded surface:

- a GO threaded gauge, having full profile on thread height;
- a NO GO threaded gauge, having truncated profile on thread height.

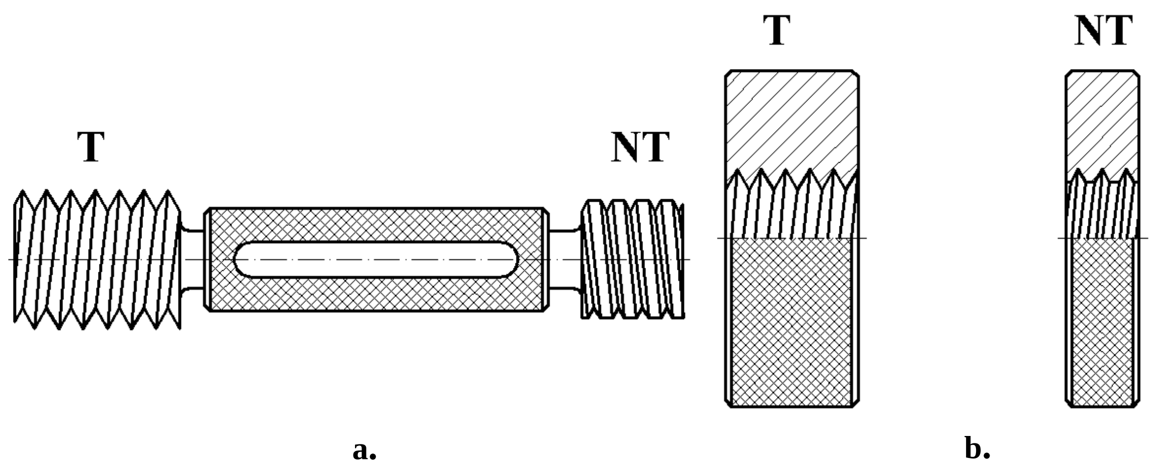


Fig. no.1
Limiting thraded gauges
a- GO/ NO GO threaded plug gauge; b- GO/ NO GO ring gauge;

1.2. Checking the inner threaded surfaces using threaded plug gauge.

In order to check the inner threads a GO and NO GO threaded plug gauge will be used; each part of the threaded plug gauge 2, will be screwed in the treaded piece to be controlled 1 (figure no. 2).

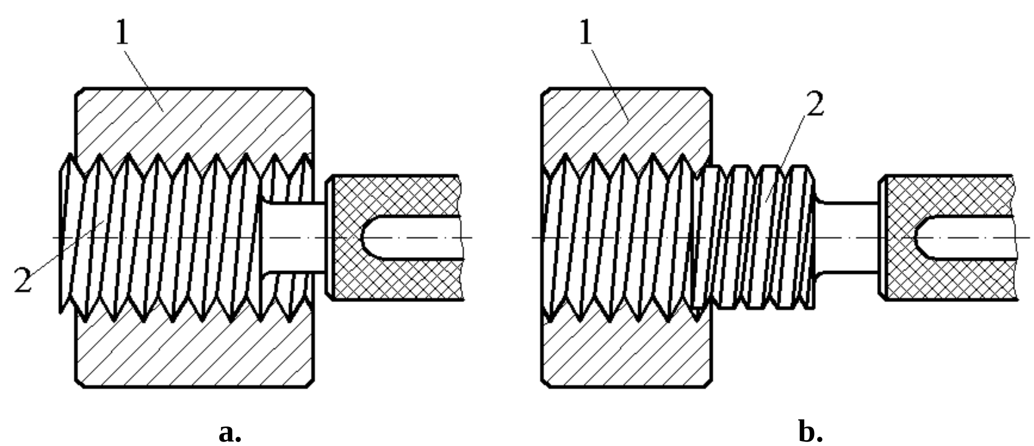


Fig. no. 2
Checking the inner threads using threaded plug gauge
a- checking the maximum limit; b- checking the minimum limit

During the checking, the following possible situations can occur:

- the GO plug gauge is screwed in the threaded piece on entire length of its threads (figure no. 2.a) and the NO GO plug gauge is screwed maximum one complete rotation (figure no. 2.b); that means: the controlled threaded piece is admitted to be used;

- the GO plug gauge is screwed in the threaded piece on one portion of length of its threads and the NO GO plug gauge is not screwed in the threaded piece; that means: the controlled threaded piece is rejected to use;
- the GO plug gauge is screwed in the threaded piece on entire length of its threads and the NO GO plug gauge is screwed more than one complete rotation; that means: the controlled threaded piece is rejected to use.

2. Measuring of the outer thread's dimensions.

2.1. Measuring the outer diameter using calipers and micrometers.

In the cases when a high measuring precision is not required, the outer diameter of a screw, can be measured using outside calipers or outside micrometers.

The measurement technique: the measurement of the outer diameter of the screw using calipers and micrometers is made in the same way as in the case of the measurement of the outer diameters at cylindrical polished surfaces.

2.2. Measuring the inner diameter using outside caliper.

The necessary equipment's and accessories: outside caliper with short jaws.

The measurement scheme: in order to measure the inner diameter d_1, of the screw 1, using outside caliper, the measured scheme is presented in figure no. 3.

The measurement technique: the active edges of the short jaws 2, of the caliper, will be brought in contact to the threaded surface at the level of the inner diameter (figure no. 3); in this moment, the measured value will be read on the caliper's scales.

Obtaining the effective value of the inner diameter: the inner diameter d_1, of the measured screw, will be calculated with the math formula:

$$d_1 = M - \frac{p^2}{8M} \qquad (1)$$

where:

- M is the measured value indicated by the caliper; units: mm;
- p is the nominal value of the screw pitch; units: mm.

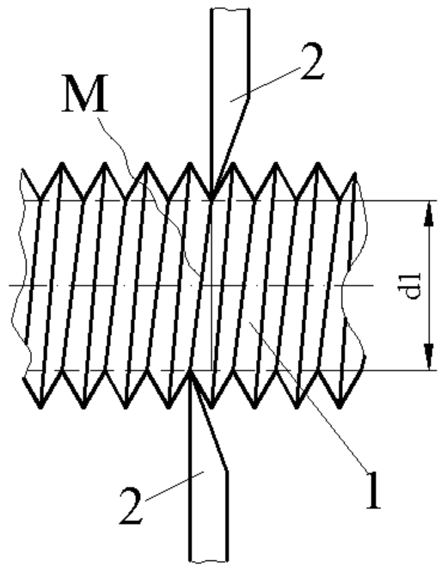


Fig. no. 3
Measuring the inner diameter to a screw using a caliper

2.3. Measuring the pitch diameter to a screw, using thread micrometer.

The necessary equipment's and accessories: thread micrometer with V- block and cone as active surfaces, support for micrometers.

The measurement scheme: in order to measure the pitch diameter d_2, of the screw 3, using thread micrometer, the measured scheme is presented in figure no. 4.

The measurement technique: first the probes with active surfaces V- block 2 and cone 3, corresponding to the pitch of the screw to be controlled, will be chosen and will be mounted to the micrometer 1 (figure no. 3.a). Then, the screw 3, will be introduced between the two probes 4 and 5 of the micrometer 1. When it will be realized the contact between the treaded surface of the screw and the active surfaces (V- block and cone) of the probes, the measured value will be read at the micrometer's scales.

Obtaining the effective value of the inner diameter: using a tread micrometer to measure the pitch diameter, a direct method will be applied; so, the effective value of the measured pitch diameter will be the value indicated by the instrument.

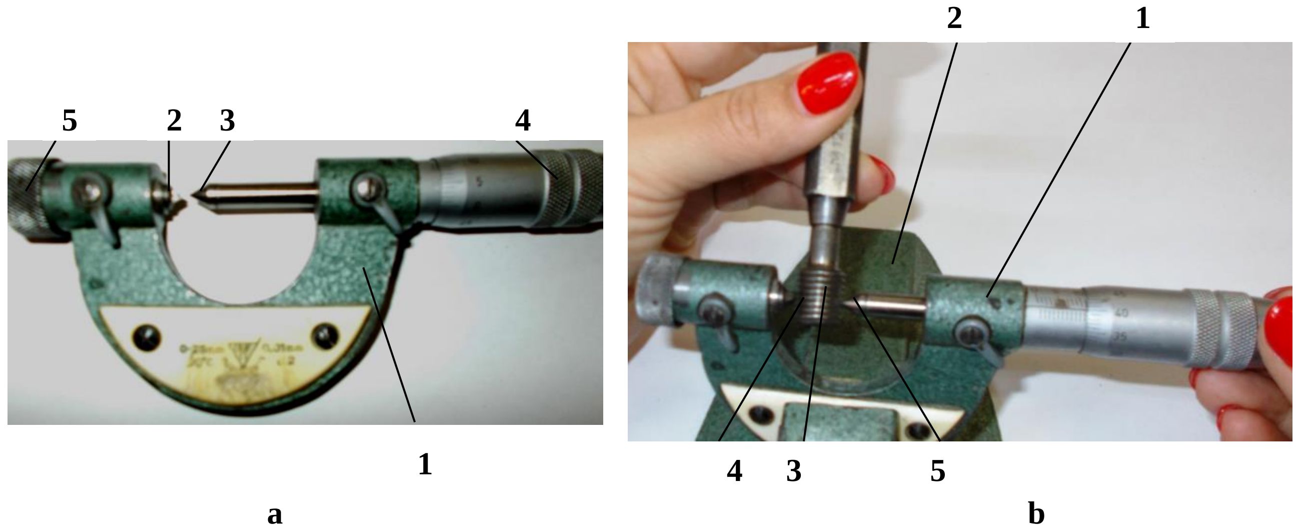


Fig. no. 4
Measuring the pitch diameter using the thread micrometer
a- the thread micrometer; b- the measurement scheme.

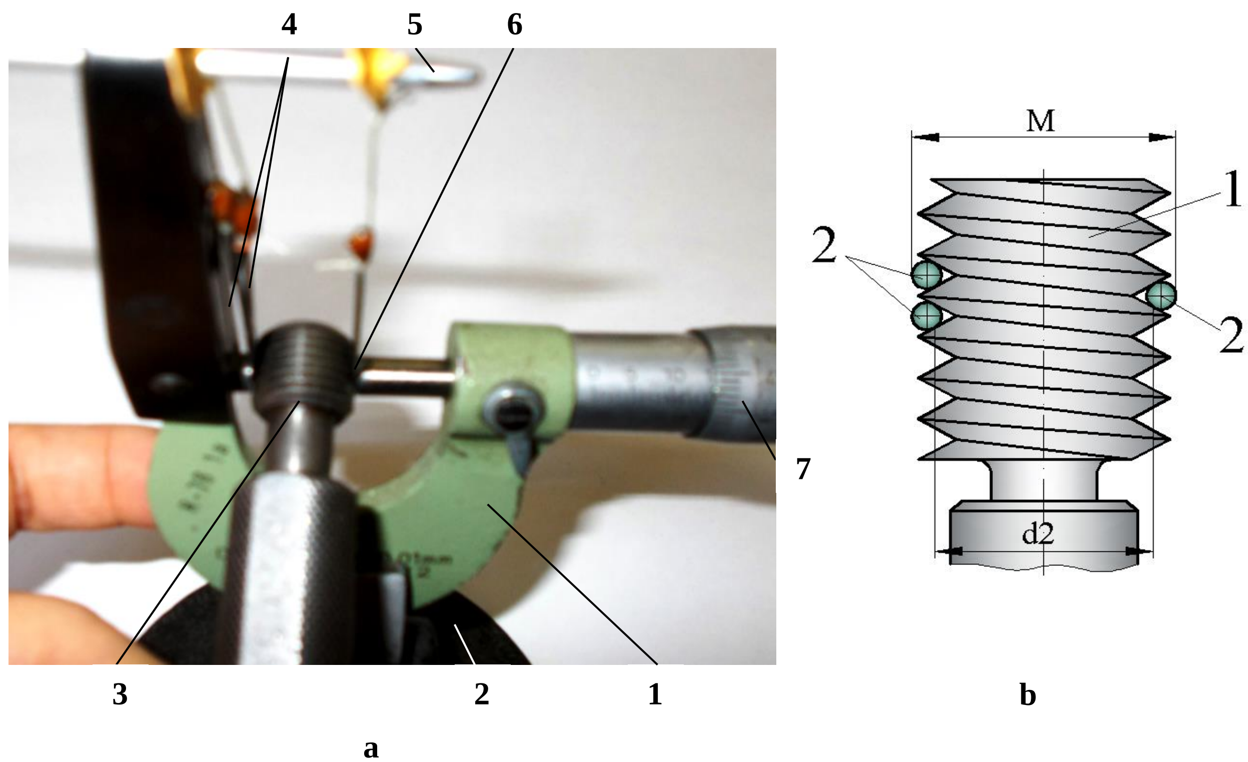


Fig. 5
Measuring the pitch diameter using three calibated wires
a- the measurement scheme; b- the calibrated wires arrangement scheme

2.4. Measuring the pitch diameter to a screw, applying the calibrated wires method.

This measurement method is applied when a higher accuracy of the measurement is required; some special accessories are used: calibrated wires, whose diameter has a very low tolerance (about 1 μm). Several variants of the calibrated wires method are applied: with one calibrated wire, with two calibrated wires, with three calibrated wires.

The necessary equipment's and accessories: outside micrometer, three calibrated wires, support for micrometers.

The measurement scheme: in order to measure the pitch diameter d_2, of a screw using an outside micrometer and three calibrated wires, the measured scheme is presented in figure no. 5.

The measurement technique: first the three calibrated wires will be chosen from the calibrated wires set; the choice of the calibrated wires will be chosen depending on the value of the pitch of the screw to be controlled. The diameter ds, of the calibrated wires is calculated with math formula:

$$d_s = \frac{p}{2\cos\alpha/2}, \qquad (2)$$

where:

- p is the pitch of the thread to be controlled; units: mm;
- α is the angle of the thread flanks; units: degrees.

The three calibrated wires 4 and 6, will be attached to the special support 5 of the micrometer 1 (figure no. 5.a). Then, the screw to be controlled 3, will be brought between the active surfaces of the micrometer such that the three wires to be positioned as it is shown in figure no. 5.b; in this position of the calibrated wires, the quota M, will be measured with the micrometer 1.

Obtaining the effective value of the inner diameter: using the three calibrated wires to measure the pitch diameter, an indirect method will be applied; so, the effective value of the measured pitch diameter will be calculated with the math formula:

$$d_2 = M - d_s\left(1 - \frac{1}{\sin\alpha/2}\right) + \frac{p}{2}\mathrm{ctg}\,\alpha/2. \qquad (3)$$

where:

- M is the value measured of the quota over the wires; units: mm;
- D_s is the diameter of the calibrated wires; units: mm;
- p is the pitch of the controlled thread; units: mm;
- α is the angle of the thread flanks; units: degrees.

2.5. Measuring the thread dimensions on the workshop measuring microscope.

The workshop measuring microscope is an optical- mechanical apparatus used to measure linear and angular dimensions with accuracy.

The structure of a measuring microscope, the following systems contains:

- mechanical system;
- optical system;
- the lighting system.

The mechanical system ensures the position of the piece to be controlled, the movements of the piece and the sustaining of the optical system (figure no. 6).

The base 1 stands up the column 13 and with the console 11, which can be moved in vertical direction by rotating the wheel 12 and can be locked with the screw 11. On the base 1, an assembly of two sleighs is mounted; the two sleighs can move on two perpendicular directions. Each sleigh is moved by means of a micrometric screw. On the top sleigh a rotating plate 4, is mounted; it can be rotated with the wheel 3. The rotating plate 4, is provided with a transparent glass plate used to seat the piece to be controlled.

When shafts with centering holes are controlled, a special centering device is used.

The optical system takes the image of the controlled piece an transmits it to the eyepiece. The optical system 17, is mounted on the console 11; it contains the optical head 14 and the objective (not figured on the figure).

The optical head 14 contains the central the eyepiece 15 and the peripheral eyepiece 16; looking through the central eyepiece 15, can be seen the image of the piece and the transparent lined plate. On the transparent lined plate linear reticles are drawn; also, on the circumference of the transparent lined plate a circular scale with 360 divisions, value equal 1^{o}, is drawn. Looking through the peripheral eyepiece 16, can be seen one division 20, of the circular scale and a circular vernier 21, having 60 division, value equal 1 minute.

The transparent lined plate can be rotated in order to measure angles.

The lighting system ensures the lighting the piece to be controlled, in order to be seen through the eyepiece. Two ways of lighting the piece can be used:

- lighting from down to up, with a lamp mounted in the base 1;
- lighting from up to down, with a lamp 18, at the bottom of the optical system 17.

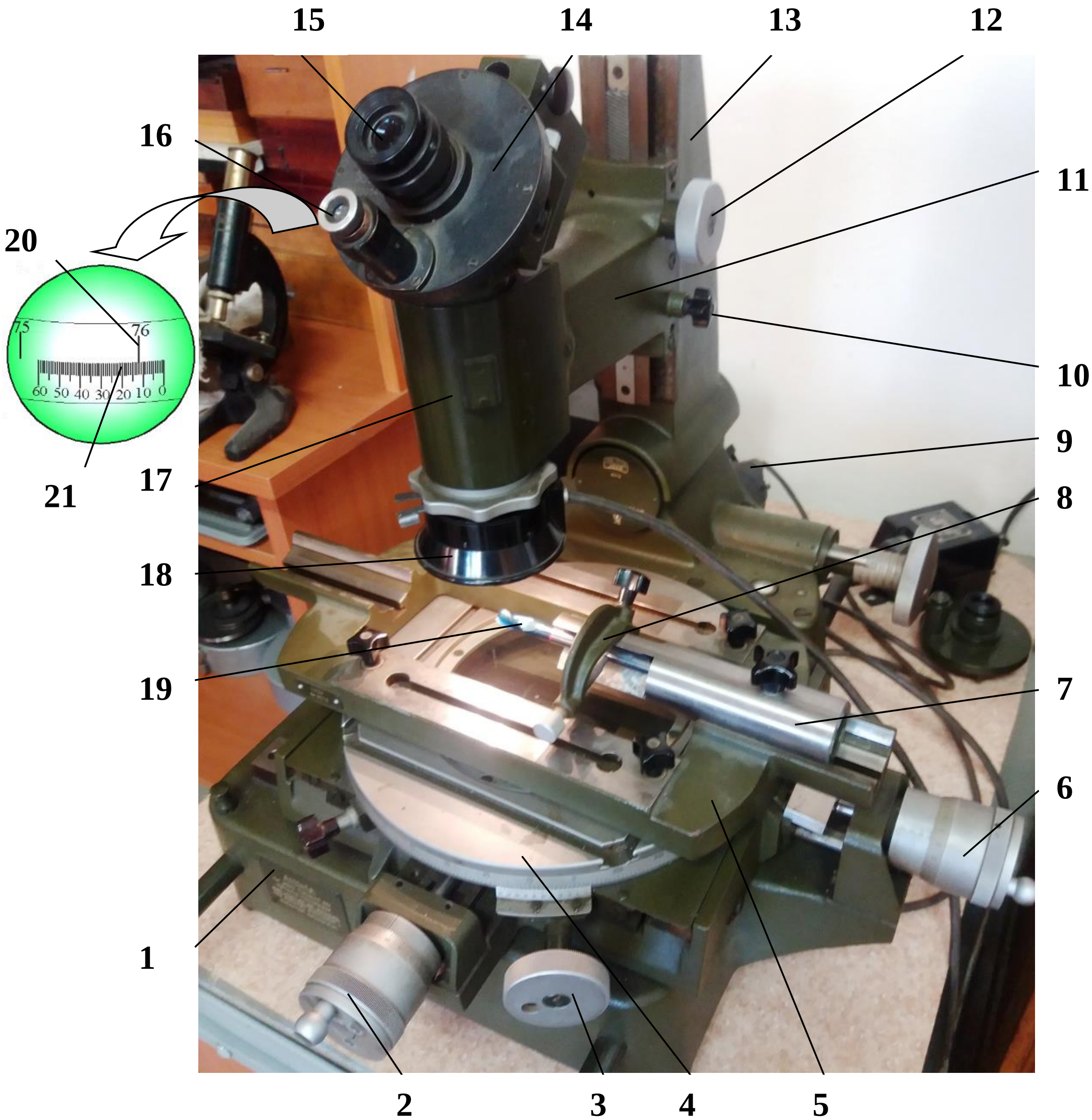


Fig. no. 6
The workshop measuring microscop

1-base; 2- micrometric screw of the transversal sleigh, 3- wheel to rotate rotating plate; 4- rotating plate; 5- centering device; 6- micrometric screw of the longitudinal sleigh; 7- fixing piece accessory; 8- fixing collar; 9- lower lamp; 10- locking console screw; 11- console; 12- wheel to move the console; 13- column; 14- ocular head; 15- central eyepiece; 16- peripheral eyepiece; 17- optical system; 18- upper lamp; 19- piece to be controlled; 20- circular scalr of degrees; 21- circular vernier.

Example of reading the rotation angle of the lined plate plăcii liniate (see the detail): 76°12’.

2.5.1. Measuring the outer diameter to a screw on the measurement microscope.

The necessary equipment's and accessories: workshop measurement microscope with centering device.

The measurement scheme: in order to measure the outer diameter d, of a screw on the measuring microscope, the measurement scheme is presented in figure no. 7.

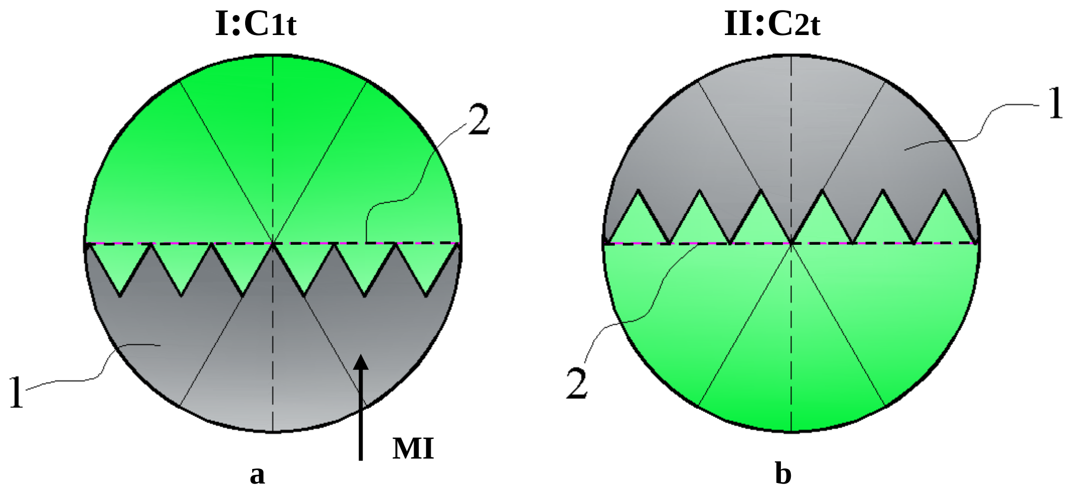


Fig. no. 7
Measuring the outer diameter to a screw on the measurement microscope

The measurement technique: the screw to be controlled will be positioned in the centering device which is mounted on the transversal sleigh. The transparent lined plate will be rotated until the horizontal reticle 2, will be parallel to the screw axis; then the transversal sleigh will be moved such that the reticle 2 will be tangent to the outside of the tread (position I). In this position (figure no. 7.a), the first value C_1t, will be noted (this value will be read at the micrometric screw of the transversal sleigh).

The transversal sleigh will be moved (movement MI) until the same reticle 2, will be tangent to the outside of the tread in the diametrically opposite position (position II); in this position (figure no. 7.b), the second value C_2t, will be noted (this value will be read at the micrometric screw of the transversal sleigh also).

Obtaining the effective value of the outer diameter: the effective value of the measured outer diameter will be calculated with the math formula:

$$d=\left|C_{1t}-C_{2t}\right|. \quad (4)$$

2.5.2. Measuring the inner diameter to a screw on the measurement microscope.

The necessary equipment's and accessories: workshop measurement microscope with centering device.

The measurement scheme: in order to measure the inner diameter d_1, of the screw on the measuring microscope, the measurement scheme is presented in figure no. 8.

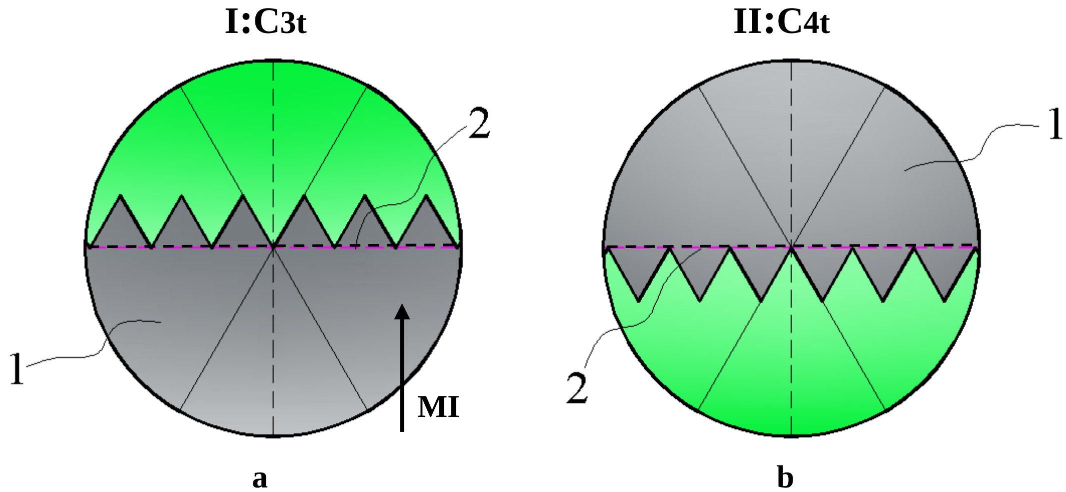


Fig. no. 8
Measuring the inner diameter to a screw on the measurement microscope

The measurement technique: the screw to be controlled will be positioned in the centering device which is mounted on the transversal sleigh. The transparent lined plate will be rotated until the horizontal reticle 2, will be parallel to the screw axis; then the transversal sleigh will be moved such that the reticle 2 will be tangent to the tread bottoms (position I). In this position (figure no. 8.a), the value C_3t, will be noted (this value will be read at the micrometric screw of the transversal sleigh).

The transversal sleigh will be moved (movement MI) until the same reticle 2, will be tangent to the tread bottoms in the diametrically opposite position (position II); in this position (figure no. 8.b), the value C_4t, will be noted (this value will be read at the micrometric screw of the transversal sleigh also).

Obtaining the effective value of the inner diameter: the effective value of the measured inner diameter d_1, will be calculated with the math formula:

$$d_1=\left|C_{3t}-C_{4t}\right|. \qquad (5)$$

2.5.3. Measuring the pitch diameter to a screw on the measurement microscope.

The necessary equipment's and accessories: workshop measurement microscope with centering device.

The measurement scheme: in order to measure the pitch diameter d_2, of a screw on the measuring microscope, the measurement scheme is presented in figure no. 9.

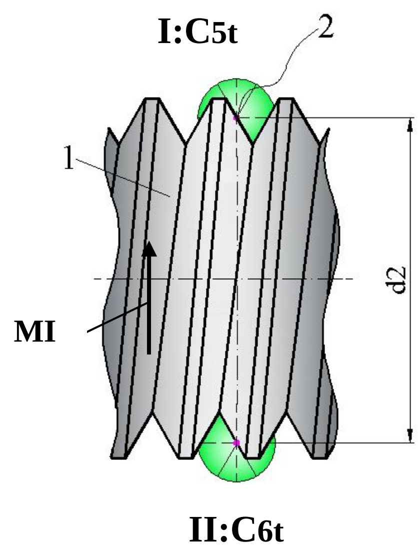


Fig. no. 9
Measuring the pitch diameter to a screw on the measurement microscope

The measurement technique: the screw to be controlled will be positioned in the centering device which is mounted on the transversal sleigh. By moving the transversal and the longitudinal sleighs, the intersection point 2 of the reticles of the transparent lined plate, will be overlapped to a flank of the thread (in the middle of the thread height, approximately: position I); in this position (figure no. 9), the value C_5t, will be noted (this value will be read at the micrometric screw of the transversal sleigh).

The transversal sleigh will be moved (movement MI) until the same intersection point 2, will be overlapped to a flank of the thread in the diametrically opposite position (position II); in this position (figure no. 9), the value C_6t, will be noted (this value will be read at the micrometric screw of the transversal sleigh also).

Obtaining the effective value of the pitch diameter: the effective value of the measured pitch diameter d_2, will be calculated with the math formula:

$$d_2 = \left| C_{5t} - C_{6t} \right|. \qquad (6)$$

Note: in order to reduce the measurement error due to the angle of the thread, two measurements will be made; the second measurement will be made on the opposite flank of the thread. The final value of the measured pitch diameter will be the average value.

2.5.4. Measuring the pitch to a screw on the measurement microscope.

The necessary equipment's and accessories: workshop measurement microscope with centering device.

The measurement scheme: in order to measure the pitch p, of a screw on the measuring microscope, the measurement scheme is presented in figure no. 10.

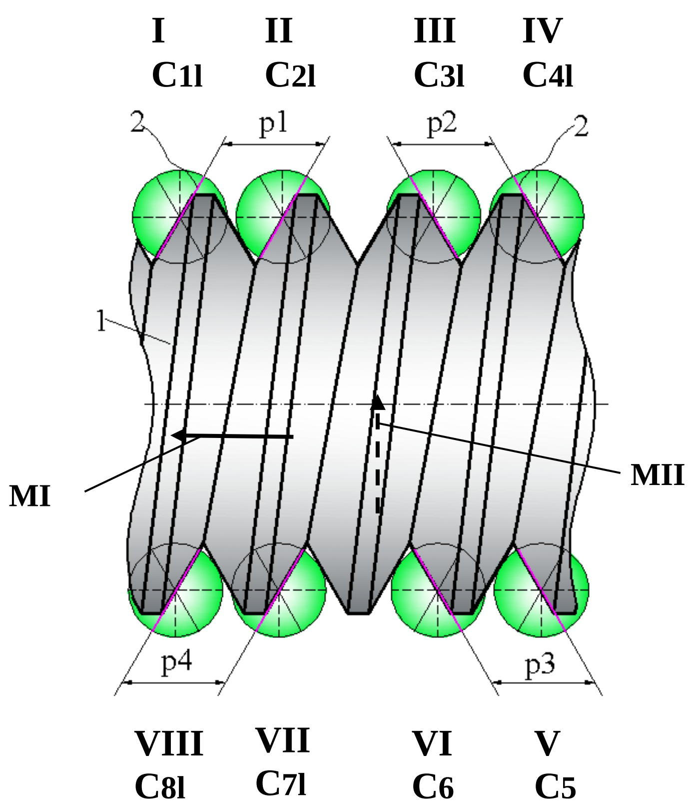


Fig. no. 10
Measuring the pitch to a screw on the measurement microscope

The measurement technique: the screw to be controlled will be positioned in the centering device which is mounted on the transversal sleigh. By moving the transversal and the longitudinal sleighs, the inclined reticle 2, of the transparent lined plate, will be overlapped to a flank of the thread (position I); in this position (figure no. 10), the first value C_1l, will be noted (this value will be read at the micrometric screw of the longitudinal sleigh).

The longitudinal sleigh will be moved (movement MI) until the same inclined reticle2, will be overlapped to the next flank of the thread (position II); in this position (figure no. 10), the second value C_2l, will be noted (this value will be read at the micrometric screw of the longitudinal sleigh also).

The first value p_1, of the pitch, will be calculated with the math formula:

$$p_1 = \left| C_{1l} - C_{2l} \right|. \tag{7}$$

In the same way, will be measured the pitch p_2, on the opposite flanks in the same side of the thread (positions III and IV); the values C_3l and C_4l will be noted.

The second value p_2 of the pitch, will be calculated with the math formula:

$$p_2 = \left| C_{3l} - C_{4l} \right|. \tag{8}$$

Then, two measurement will be made in the diametrically opposite position of the thread (positions V, VI, VII and VIII); the corresponding values C_5l, C_6l, C_7l and C_8l will be noted. In this way, another two values p_3 and p_4, of the pitch will be calculated:

$$p_3 = \left| C_{5l} - C_{6l} \right|. \tag{9}$$

$$p_4 = \left| C_{7l} - C_{8l} \right|. \tag{10}$$

Obtaining the effective value of the pitch diameter: the effective value of the measured pitch p, will be the average value of the four measured pitches:

$$p = \frac{p_1 + p_2 + p_3 + p_4}{4}. \tag{11}$$

Note: in order to reduce the measurement error due to the angle of the thread, the four measurements were made.

2.5.5. Measuring the angle of the flanks to a screw on the measurement microscope.

The necessary equipment's and accessories: workshop measurement microscope with centering device.

The measurement scheme: in order to measure the angle of the flanks α, of a screw on the measuring microscope, the measurement scheme is presented in figure no. 11.

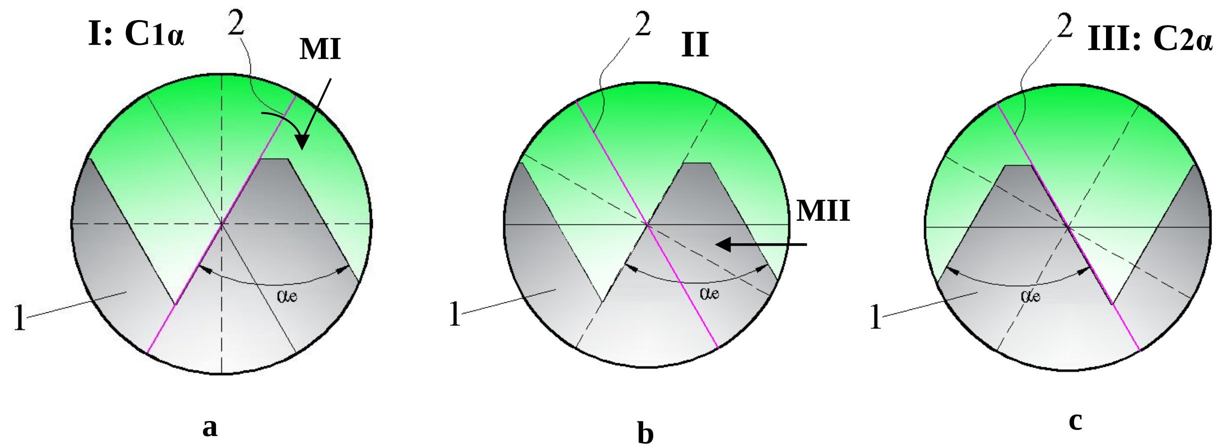


Fig. no. 10
Measuring the angle of the flanks to a screw on the measurement microscope

The measurement technique: the screw to be controlled will be positioned in the centering device which is mounted on the transversal sleigh. By moving the transversal and the longitudinal sleighs, the inclined reticle 2, of the transparent lined plate, will be overlapped to a flank of the thread (position I); in this position (figure no. 11.a), the first value $C_1\alpha$, will be noted (this value will be read at the peripheral eyepiece of the ocular head).

The transparent lined plate will be rotated (move MI) until the same reticula 2, will be in parallel position to the opposite flank of the thread (position II, figure 11.b); then, the longitudinal sleigh will be moved (move MII) until the reticula 2, will be overlapped to the opposite flank (position III). In this position (figure no. 11.c), the second value $C_2\alpha$, will be noted (this value will be read at the peripheral eyepiece of the ocular head, also).

The longitudinal sleigh will be moved (movement MI) until the same inclined reticle2, will be overlapped to the next flank of the thread (position II); in this position (figure no. 10), the second value C_2l, will be noted (this value will be read at the micrometric screw of the longitudinal sleigh also).

Obtaining the effective value of the angle of flanks: the effective value of the measured angle of the flanks α_e, will be calculated with the math formula:

$$\alpha_e = \left| C_{1\alpha} - C_{2\alpha} \right|. \tag{12}$$

Note: in order to reduce the measurement error due to the angle of the thread, two measurements will be made; the second measurement will be made in the diametrically opposite position of the thread. The final value of the measured angle of the thread will be the average value.

3. How to perform the laboratory work

To carry out the laboratory work the following steps shall be completed:

Step no. 1: the execution drawing of the piece to be controlled, will be drawn; on the execution drawing, the tolerance of the dimension to be measured will be noted.

Step no. 2: the specified dimension will be measured by applying the specified measuring method.

Step no. 3: the effective value of the measured dimension will be calculated.

Step no. 4: the effective value of the measured dimension will be compared with the prescribed tolerance (when the tolerance is known).

Step no. 5: the decision concerning the controlled piece will be made:

- if $Ae \leq IT$, the controlled piece is accepted to be used;
- if $Ae > IT$, the controlled piece is rejected from use.