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DEVICES FOR EXTERNAL CONICAL SURFACES MEASUREMENTS

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***Abstract*—**The problem of machining and measuring conical surfaces with great accuracy is a challenging current subject in engineering. Cutting edge methods which measure the conicity and form errors of manufactured conical parts are accurate but involve high-costs equipments. New, accurate, practical and economical measuring instruments should be developed and to this end, the paper proposes some simple yet precise measuring devices. The paper presents the geometrical elements concerning a conical fitting that may be useful in designing and manufacturing diverse external taper measurements devices. The basic principles to be considered are determined and the minimum essential notions in designing the devices are presented. The calibrated rings method is considered and mechanical or digital callipers will be used in developing the devices.

Keywords — conical surfaces, taper, measurement, calliper, device

I. INTRODUCTION

THE problem of machining conical surfaces with great accuracy is a challenging current subject in engineering [1]. Modern techniques from various domains also require employment of adequate technologies in manufacturing precise conical mechanical parts [2], [3]. Up to date methods which measure the form errors of manufactured conical parts are accurate but involve high-costs equipments [4]-[6]. To be mentioned that in practical situation, not only very expensive methods and equipments, but techniques which use classical instruments can also provide reliable results with respect to the taper cone evaluation and measurement [7], [8]. A method based on a simple but realistic principle is proposed and the devices used for applying it are presented.

II. GENERAL ASPECTS UPON CONICAL FITTINGS PRECISION

Due to many advantages - precise centering, sealing opportunity, gap adjustment, the conical fittings are often used in machine building.

The main elements of a conical fitting are presented in Fig. 1, [9].

1) $\mathbf{d_M}, \mathbf{d_m}$ *- the large and small diameters, respectively, of the conical shaft*
2) $\alpha/2$ *- angle between the generator and the axis;*
3) α *- cone angle, in axial section;*
4) $\mathbf{l_{23}}$ *- distance between two cross-sections of diameters* $\mathbf{d_2}$ *and* $\mathbf{d_3}$ *respectively;*
5) $\mathbf{l}$ *- distance between the reference surface for dimensioning and the nominal cross-section of diameter* $\mathbf{d_1}$ *- one of the frontal surfaces of the part or any other surface of functional significance can be chosen as reference surface;*
6) $\mathbf{L_B}$ *- basic distance of conical fitting, representing the distance, on axial direction, between two surfaces of the assembly,* $\mathbf{L'_B}$*, or directly connected to the assembly,* $\mathbf{L''_B}$*;*
7) $\mathbf{l_{d,D}}$ *- length of external/internal cone;*
8) $\mathbf{H}$ *- contact length between the two conical surfaces.*

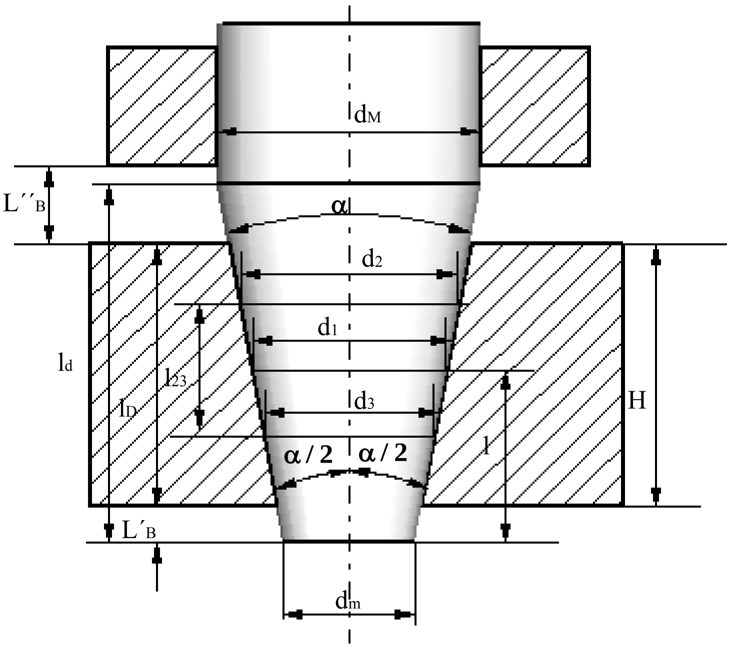


Fig. 1. Conical fitting

Using the above presented elements, the following parameters are defined for conical surfaces:

1) inclination:

$$\mathbf{I = tg\frac{\alpha}{2} = \frac{d_2 - d_3}{2l_{23}}} \qquad (1)$$

2) conicity:

$$\mathbf{C = 2I = 2tg\frac{\alpha}{2} = \frac{d_2 - d_3}{l_{23}}} \qquad (2)$$

There are two methods applied for prescribing the conical fitting precision: nominal conicity method and tolerated conicity method, respectively, with the known cases from literature.

CALIBRATED RINGS METHOD

Fig. 2, [10], presents the principle of calibrated rings method. According to relations (2), the angle can be found. The following notations are used:

3) **d** *- small ring diameter;*

4) **D** *- large ring diameter;*

5) **l** *- distance between the inferior surfaces of calibrated rings.*

The devices are manufactured on dimension ranges, according to the minimum and maximum diameters of the measured cones.

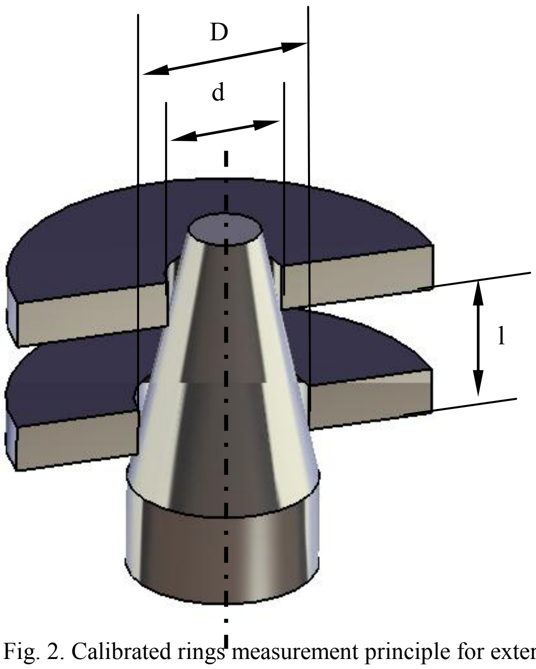


Fig. 2. Calibrated rings measurement principle for external conicity

The device developed in accordance with the principle presented in Fig. 2 has the following disadvantages:

1) requires supplementary operations for rings' positioning and measurements of **l** *distance;*

2) low measurements productivity;

3) small precision of measurements.

From the above mentioned considerations, the design and manufacturing of devices for measuring external conicity using vernier callipers – with vernier scale or digital display, is required, [11].

III. VERNIER DEVICE FOR EXTERNAL CONICITY MEASUREMENTS.

The vernier device proposed for external conicity measurements, presented in Fig. 3, has the following main components:

1) base for fix calibrated ring;

2) holder for mobile calibrated ring;

3) fastening screws;

4) universal mechanical calliper;

5) base plate.

The measuring domain is large due to both the length of the ruler and to the possibility of using rings of different diameters; the resolution to which the **l** length is measured is **0.05 mm**.

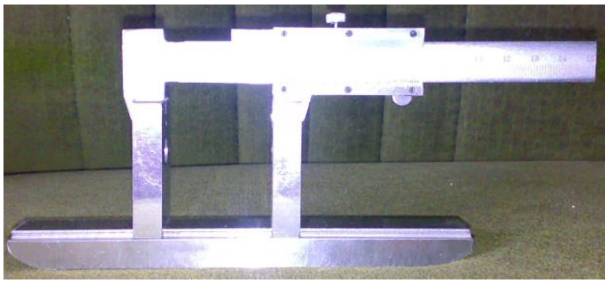


Fig. 3. Vernier device for external conicity measurements

The operating mode for the presented device is shown in Fig. 4.

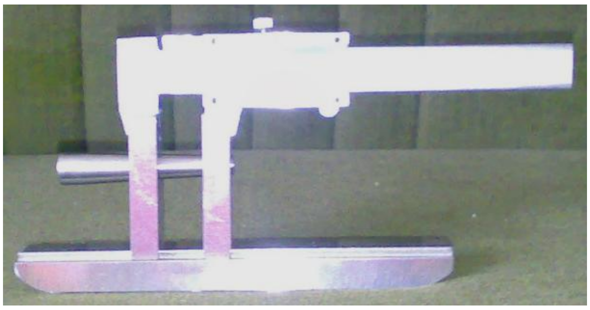


Fig. 4. Vernier device working method

The diameters of the calibrated rings are precisely measured and the distance between them is found using the vernier calliper.

IV. DIGITAL DEVICE FOR EXTERNAL CONICITY MEASUREMENTS

The digital device proposed for external conicity measurements is presented in Fig. 5, consists from the same main components as the previous tool, but uses a digital calliper for measuring the distance between the two cross-sections.

The device includes additionally a hand wheel for attaining the **l** dimension and a screw for fastening the part to be measured.

The operating method using this device is similar to the previous one, as seen in Fig. 6.

Fig. 5. Digital device for external conicity measurements (upper view)

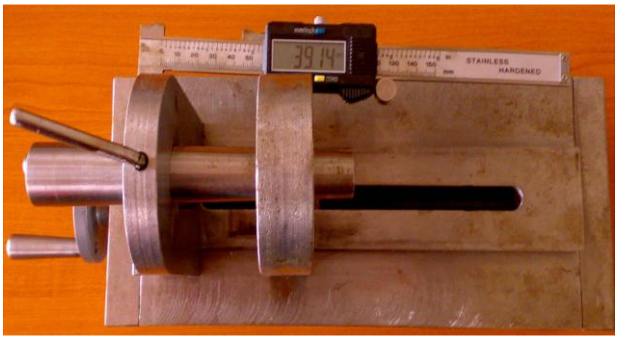


Fig. 6. Operating method using the digital device (upper view)

The measuring domain is large both due to the ruler length and to the possibility of employing rings of different diameters, and the measurement resolution for the **l** dimension is **0.01mm** .

V. CONCLUSIONS

Considering the importance of conical fittings, setting their precision and measuring with accuracy the corresponding parts is most important, [12]. Therefore, new, more precise, handy and economical measuring instruments should be developed.

In the present work, an indirect technique was applied, namely the calibrated rings method.

The measuring domain is expected to be as large as possible, and to this end, a series of pairs of rings, with internal diameters corresponding to the measured parts, can be designed.

A higher precision is intended and thus, precision callipers were used, either mechanical or digital.

If the calibrated rings are executed and measured with accuracy and considering their measurement error, as well as the callipers error when measuring the "**l**" distance between the two cross-sections, the precision of the designed and manufactured devices is according to Table I.

The diameters of the discs were measured with a digital calliper, having a resolution of **0.01** mm/division and a maximum error of **0.02 mm,** [13]. The distance **l** is found using the mechanical calliper (maximum error **0.05** *mm***,** [13]) and digital calliper, respectively, (maximum error **0.02** *mm*).

TABLE I.
MEASUREMENT ERROR

No.	Measuring device	Error
1.	Vernier device	±5′
2.	Digital device	±4′

The values of estimated measurement errors from Table I are the values obtained for a value of 10 mm of the race (distance between the two cross-sections). For smaller values of the measured angles, that is for greater values of the distance between the cross-sections, the error decreases significantly.

The measuring domain (half-angle) for the designed and manufactured devices is presented in Table II.

TABLE II.
MEASUREMENT DOMAIN

No.	Measuring device	Measurement domain
1.	Vernier device	5°30′-30°
2.	Digital device	5°30′-30°

In order to make a comparison and to validate once more the method, as well as the developed devices, measurements were made with a workshop optical microscope connected to computer, Fig. 7, which uses the measurement scheme presented in Fig. 8.

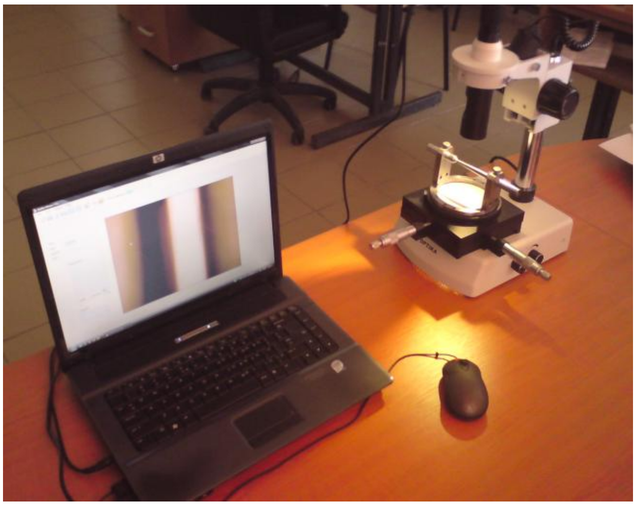
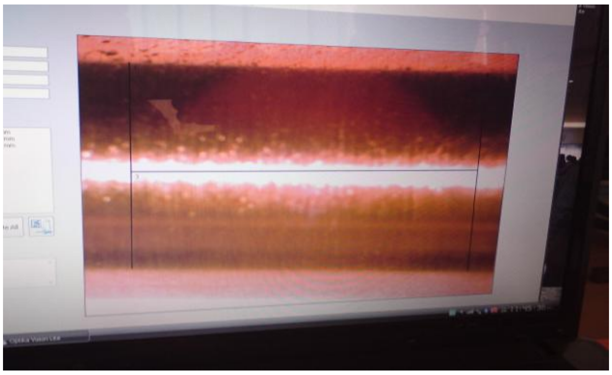


Fig. 7. Optical microscope connected to computer

The results obtained using the two designed devices were compared to the results obtained with the workshop microscope and are presented in Fig. 9.

The comparison (Fig. 9) between the results obtained using the digital device (series 2) and the results obtained with the optical microscope connected to computer (series 1) show a good agreement. In the same Fig. 9, the measurements obtained with the vernier device (series 3) indicate values with a few minutes smaller than the other series.

The results presented for validation in Fig. 9 proved a good agreement, all together with increased precision, higher measurement productivity and economically competitive cost.



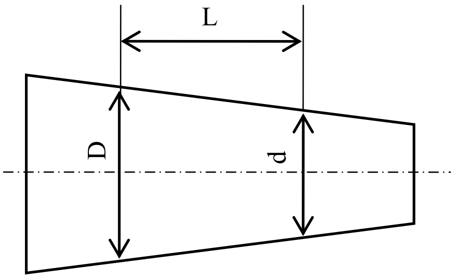


Fig. 8. Principle of measurement using the optical microscope connected to computer

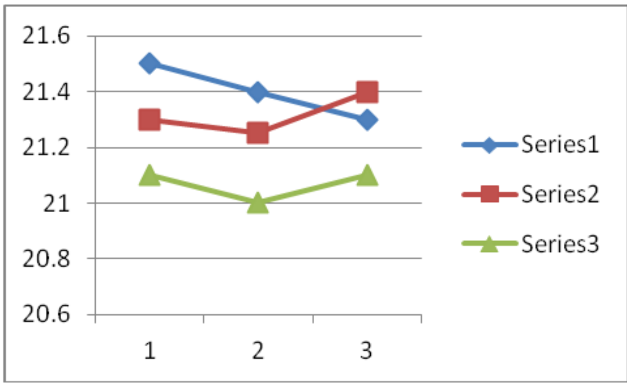


Fig. 9. Comparison of experimental results

Experimental data were obtained by measurements made with each of the three instruments presented above and the average values were considered, as presented in Table III:

TABLE III.
EXPERIMENTAL DATA

	Measurement No.			
	1	2	3	Average value
Series 1	21.54	21.41	21.31	21.42
Series 2	21.32	21.25	21.39	21.32
Series 3	21.12	21.01	21.14	21.09

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