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METHOD AND DEVICE FOR ANGLE CONTROL OF CONICAL SHAFTS

BY

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Abstract. The paper presents some methods and devices required in conical shafts control. These notions are necessary in designing and manufacturing devices for measuring external conical surfaces. Indirect methods of measuring the cone angle were analyzed, due to the advantages of these methods regarding the accuracy of the measurement and is proposed a solution for the analyzed problem. Following the analysis of the indirect methods analyzed, the aim of the paper is to develop a new constructive solution for the measurement of conical surfaces, an alternative to the existing ones and that offers advantages through maneuverability, precision and ease in measuring the characteristic aspects of interest. The way in which the cone angle is determined, using the trigonometric method for the device presented as a possible solution.

Keywords: conical shaft, control device, cons angle, measurement.

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1. Introduction

Conical fittings are commonly used in machine manufacturing because they provide precise centering, effective sealing, and the ability to adjust gaps.

Conical assemblies are joints where components connect through conical surfaces, with one part featuring an inner cone and the other having an outer cone. They are characterized by their constructive and technological simplicity, as well as the ease of assembly and disassembly of component elements. Conical assemblies aim is to fix the relative position of two parts, both in the radial and axial directions, creating the tightness or clearance necessary for assembly (Popa, 2006; Lăzărescu and Ștețiu, 1984).

Current standards regulate the tolerance of conical surfaces by several tolerance methods, depending on the functional role of smooth conical joints.

The tolerance methods of inner or outer conical surfaces are established by the standards SR ISO 5166: 1992 and ISO 3040:2016, how specifies graphical indication applicable to a cone (right-angle circular cones) to define its dimensioning or to specify its tolerancing (ISO Standard, 2016).

The following tolerance methods of conical surfaces are established:

• the nominal taper method, or, the nominal taper angle;

• the tolerated taper method, or, the tolerated taper angle;

• the method of tolerancing linear dimensions (diameters and length of the conical surface) (Potorac, 2013; Cioată and Munteanu, 2020; Cioată *et al.*, 2020).

Standards are not limiting, and it is also possible to apply other methods of tolerancing conical surfaces, such as the method of tolerancing the shape of the conical surface, etc.

Both mentioned methods are established in such a way as to ensure the functional requirements of the part.

When determining the tolerancing method and tolerance type for conical surfaces, several key criteria must be considered, including:

- The functional role of the surface within the conical assembly (whether for fixed, movable, or sealing joints),
- Requirements for contact between the conjugate conical surfaces,
- Constraints on the relative axial positioning of the conical components within the joint,
- The necessity for high precision in linear/angular dimensions or the defined shape of the conical surface (Cioată and Munteanu, 2020; Joshi, 2020).

Tolerancing methods are closely linked to the control techniques used to assess the specific characteristics of conical surfaces, particularly outer surfaces in the paper context.

As previously mentioned, the accuracy of conical assemblies and the interchangeability of component parts depend on the precision of the diameters and angle of the cone. A study aimed to analysed the indirect methods for the cone angle measurement is realised in the paper case.

2. Methods and principles of measurement of cons angle

As mentioned earlier, conical surfaces are currently widely used. Based on the review of specialized literature, various methods for controlling external conical surfaces have been identified and classified, as shown in Fig. 1.

The indirect method for measuring the cone angle is approached from a trigonometric perspective, by calculating the angle based on the cone diameters (Potorac *et al*., 2013), but in the case of inner surface.

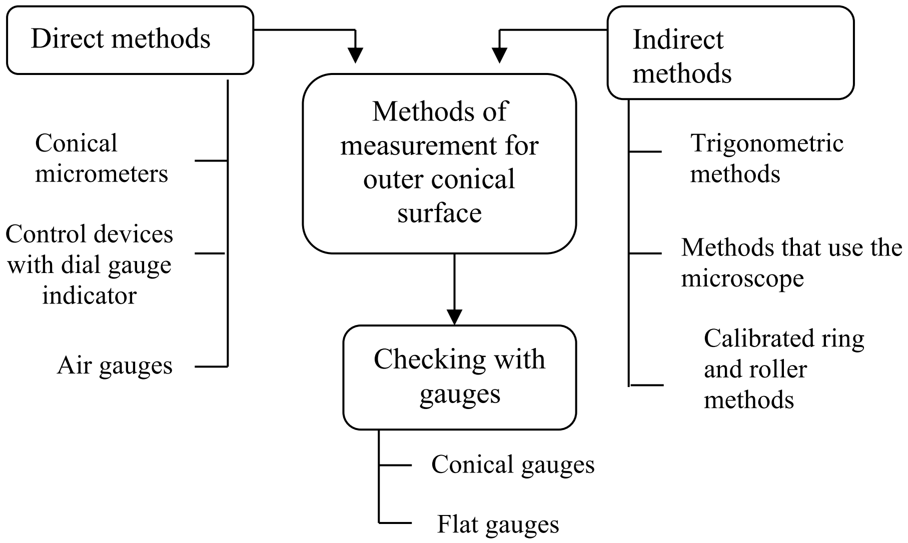


Fig. 1 – Clasification methods of cones control.

For outer surfaces two indirect methods were considered in the paper:

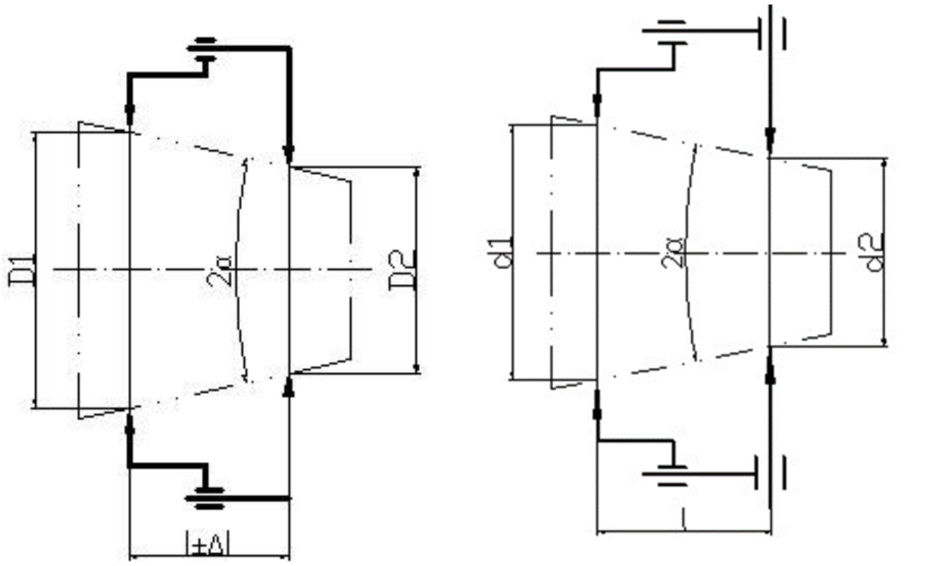
- M1, an indirect method with two calibrated rings;
- M2, an indirect method with a portable device (Popa *et al*., 2006).

Method M1 consists of measuring the variation δl of the distance l between sections with diameters d_1 and d_2 ($d_1 < d_2$) after which contact is made between the active surfaces of the measuring device and the external conical surface (Fig. 2a).

The angle deviation can be determined using the Eq. (1):

$$\delta\alpha = k\Delta l \tag{1}$$

were $k = f(d_1, d_2, l)$ represent a constant of the measuring equipment.



a) b)

Fig. 2 – Schematic diagram of methods.

The contact between the probes and the conical surface to be controlled is achieved by two adjacent rollers with diameters d_1 and d_2 materialized by two ring gauges with precisely determined diameters D_1 and D_2, respectively.

The M2 method consists of measuring the three characteristic dimensions: d_1, d_2, l with appropriate measuring instruments (Fig. 2b); the diameters d_1 and d_2 of the sections after which the contact between the probes and the outer conical surface is made are measured with a length measuring device, and the distance l between the sections is materialized with the help of gauges blocks.

The effective value of the angle of the controlled conical surface is determined by the relation (2):

$$2\alpha = 2tg\frac{d_2 - d_1}{2l} \tag{2}$$

The contact between the probes and the conical surface to be controlled is achieved by means of calibrated cylindrical rollers with the same diameter that are brought into contact with the generators of the outer conical surface in diametrically opposite positions.

The two methods considered were analysed, highlighting their advantages and disadvantages and a new measurement method can be established that combines the advantages of the two methods and eliminates some of their disadvantages. Thus, the propose method is an indirect method characterized by the following aspects:

- the contact between the active surfaces of the spherical probes and the outer conical surface is made at points, in two sections perpendicular to the axis of the conical surface, having different diameters d_1 and d_2;
- the measured quantity is the variation of the diameter d_2 of the large section;
- the constant quantities: diameter d_1 of the small section and the distance l between the two sections;
- the dimension after which the zero adjustment is made is the diameter d_2 of the large section of the conical surface.

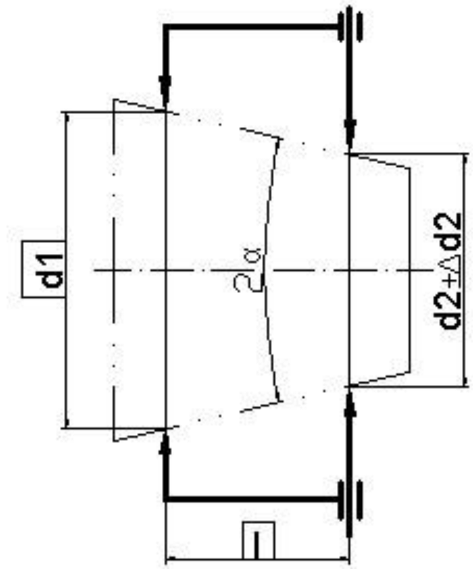


Fig. 3 – The proposed method of measurement.

The established measurement method consists of measuring the variation δd_2 of the diameter d_2 of the large section of the cone formed by the sections after which the contact between the active surfaces of the control device and the controlled outer conical surface is made.

The angle deviation can be determined with the relation, Eq. (3):

$$\delta\alpha = k\,\delta d_2 \tag{3}$$

In this relation k and represent a constant of the measuring equipment, that depends of the characteristics of the conical surfaces, $k = f\,(d_1,\ d_2,\ l)$ (Henzold, 2006).

The contact between the active surfaces of the control device and the outer conical surface is achieved at four points evenly distributed on the two circumferences, materializing adjacent circles with diameters d_1 and d_2.

The choice of a specific method (Fig. 4) depends on its advantages while considering the inherent disadvantages. Additionally, the availability of control equipment and the feasibility of acquiring or designing an appropriate variant play a crucial role in the decision-making process.

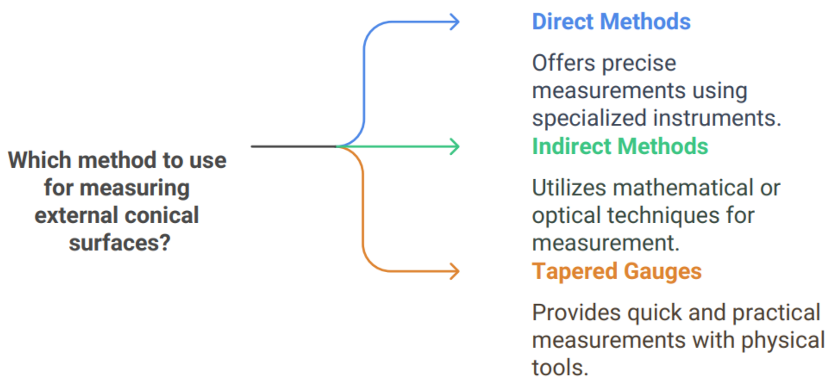


Fig. 4 – Methods diagram.

3. Devices for cones angle measurement

Any control device, for the particular case of angle measurement, must satisfy the following certain requirements, including:

- measurement accuracy;

- high manoeuvrability, so as to ensure rapid measurement of the angle of the conical surface;

- quick and easy zero adjustment, without requiring additional expensive accessories (cylindrical gauges, conical gauges, parallel plane gauges, angular gauges, etc.);

- large measurement range that allows measuring the angle of the external conical surface with a wide range of diameters and lengths, respectively with a corresponding range of measured angle values;

- the control device can be portable or stationary.

The use of portable control devices is essential and widely adopted, as they allow for real-time measurement of processed parts before they are removed from the clamping devices on machine tools. This enables necessary adjustments to ensure compliance with prescribed dimensional limits. In contrast, removing heavy parts for measurement on stationary equipment results in excessive time consumption, increased processing costs, and, in many cases, difficulties in repositioning and securing parts for corrective actions on potentially remediable rejects.

Based on the proposed measurement method, a schematic diagram of the control device is presented, which solved the following issues:

- rapid control of the outer conical surface;
- measurement of the variation of the large diameter, d_2, of the measured section (Fig. 5);
- zero adjustment of the control device;

• ensuring a measurement range for the three measured characteristics:

- diameter d_1 of the small section;
- diameter d_2 of the large section;
- distance l between the measured sections.

• ensuring the correct orientation of the control device in the measurement position;

• establishing the constant of the control device.

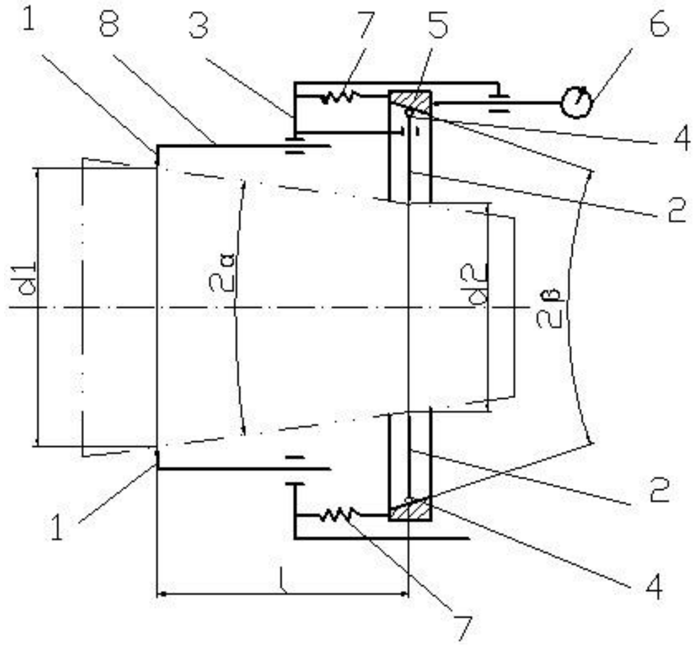


Fig. 5 – Device measurement principle.

According to the principle diagram (Fig. 5), the control device is provided with fixed probes, during the measurement which come into contact with the outer conical surface on the circumference with diameter d_1 and probes 2, mobile during the measurement, in contact with the outer conical surface with diameter d_2; the mobile probes 2 move in the body 3 of the control device and come into contact with the inner cone 5 by means of their active spherical surface 4, determining the displacement of the measuring cone 5.

The displacement of the outer cone 5 is transmitted to the dial comparator 6 whose measuring tip is brought into contact with the front surface of the cone. The measuring force is achieved by the tension of helical spring.

The zero adjustment of the control device is carried out on a conical ring gauge with the taper angle equal to the nominal value of the angle to be controlled; after adjustment, the control device is placed on the part to be controlled and after making contact between the probes 1 and 2 with the outer conical surface, the indication i of the indicator instrument 6 is noted.

The value $\delta\alpha$ of the measured angle is obtained with the relation, Eq. (4):

$$\delta\alpha = k \cdot l \tag{4}$$

where $k = f(d_1, d_2, l, \beta)$, is a characteristic of the control device expressed in units of angle relative to a division of the indicator instrument (Table 1).

Table 1
Value of the constant k

l [mm]	50	55	60	65	70	75
k	41.5``	37.5``	34.5``	32``	29.5``	27.5``

The modification of the distance l, between the sections with diameters d_1 and d_2 corresponding to the fixed probes 1 and mobile 2, is achieved by moving the support 8 of the fixed probes 1 in the body 3 of the control device and fixing it in the established position.

4. Conclusions

When applying methods for measuring the angle of external conical surfaces, universal and special measuring instruments can be used, as well as control devices that can be stationary or portable; portable control devices have the advantage of allowing parts to be controlled right at the processing site, when they are clamped in locating and clamping devices.

Taking these aspects into account, the paper proposes the design of a constructive variant of a portable technological device for measuring the angle of external conical surfaces of shaft-type parts, in the execution process, which would be equipped with a universal means of measuring linear dimensions (indicator instrument/ dial gauge indicator).

The choice of control technologies that use high-performance measuring instruments can have negative effects on the economic efficiency of the production of parts. Therefore, it is necessary to use control methods and devices with precision corresponding to the established tolerances, at least in some phases of the processing of parts. This would reduce the control time and its cost by the fact that the technological control devices can be made during the manufacturing preparation of the units that produce the considered parts.

Considering the conclusions drawn, the aim was to present a measurement method and a possible device that would eliminate these disadvantages and accumulate the advantages of some of the analysed methods.

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DISPOZITIV ȘI METODE DE CONTROL A UNGHIULUI SUPRAFEȚELOR CONICE EXTERIOARE

(Rezumat)

Lucrarea prezintă câteva metode și dispozitive necesare în controlul arborilor conici. Aceste noțiuni sunt necesare în proiectarea şi fabricarea dispozitivelor de măsurare a suprafețelor conice exterioare. Au fost analizate metode indirecte de măsurare a unghiului conului, datorită avantajelor acestor metode în ceea ce privește acuratețea măsurării și se propune o soluție pentru problema analizată. În urma analizei metodelor indirecte analizate, scopul lucrării este să propună o nouă soluție de măsurare a suprafețelor conice, ce reprezintă o alternativă la cele existente și care oferă avantaje prin manevrabilitate, precizie și ușurință în măsurarea aspectelor caracteristice de interes. Este prezentat și modul în care se determină unghiul conului, folosind metoda trigonometrică pentru dispozitivul prezentat ca soluție.