APPROACH TO THE CALIBRATION OF CALLIPERS - ISO13385:2011 vs DIN862:1988 STANDARDS

Isabel Perfeito(*)
CATIM - Technological Center for Metal Industry, Porto, Portugal
(*)Email: isabel.perfeito@catim.pt

ABSTRACT

In the context of dimensional metrology, the caliper, apparently one of the simplest measuring instruments is one of the most used in industry, in any of its sectors. Since a large number of these callipers are calibrated in accredited laboratories, these devices are part of the calibration work routine of dimensional metrology laboratories. Recently, due to the replacement of the calibration standard DIN862: 1988 for the ISO 13385: 2011, the calibration laboratories were forced to update their Accreditation Annex. The aim of this paper is to describe the main changes in callipers calibration based on the current standard (ISO 13385: 2011), in comparison with the discontinued standard (DIN 862: 1988), in order to assist the understanding of concepts, certificate validation and internal calibrations.

Keywords: dimensional metrology, callipers, calibration, DIN862 standard, ISO13385 standard.

INTRODUCTION

Measuring instruments, as good as they are, always have an associated error because they cannot be manufactured absolutely free from errors. Best accuracy of the measuring instrument usually means more difficulty of manufacture and consequently greater the associated costs to the manufacturing process. In this perspective, measuring instruments must be selected according to the required accuracy of measurement.

The management and monitoring of measurement equipment which is part of the calibration process becomes vital.

In Metrology when discussing issues related to equipment calibration, it is important define concepts such as "traceability" and "calibration". Metrological traceability is defined as "property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty." (2.41, VIM - 3rd edition).

To ensure traceability of measurements, all measuring equipments must be calibrated to traceable standards, national or international standards, according to the recommendations of International Bureau of Weights and Measures (BIPM), so our measurements can be related to the International System of Units (SI).

According to the definition of metrological traceability, the calibration is an essential requirement for monitoring and measuring and control equipment for organizations which are certified by ISO 9001 and/or accredited by ISO/IEC 17025 standards.
Again we can find in the Internacional Vocabulary of Metrology, VIM, the definition of calibration "operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.” (2.39, VIM - 3rd edition).

It is through calibration that we can evaluate the metrological characteristics of the instruments and we can validate the results of the measurements, because they depend on these characteristics. The lack of this knowledge can lead to an incorrect assessment of the conformity of a product, when based on a measurement parameter.

The calibration procedures for measuring instruments they shall be based on national or internationals standards.

A standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose.

There are several International Standards to apply to the calibration of callipers however these current standards are referenced in the standard ISO13385:2011 published by International Organization for Standardization (ISO). To this approach were selected for comparison current Standard ISO13385: 2011 and redraw Standard DIN 862:1988.

The field of application of DIN 862: 1988-Requirements and testing, applies to universal callipers and callipers for depth measurements. This standard makes no distinction in the calibration method of these two types of callipers.

The ISO 13385: 2011 consists of two parts as follow:


In the current Standard for callipers calibration (ISO 13385: 2011), we can find a set of measuring tests that evaluate their metrological characteristics with special attention to the interior measuring jaws, compared with the previous standard (DIN 862: 1988 ). The selection of standards gauges required for calibration also suffers an adjustment due to change / increase of tests to perform. Unlike the previous standard the indication of the maximum permissible errors are not included in ISO 13385: 2011.

It is expected that the calibration certificate of a universal calliper which could previously be calibrated according to DIN 862: 1988 and at this moment can be calibrated by ISO 13385-1, requires a new approach because there is an increase of measuring tests which will be described in this work.

**GENERAL CHARACTERISTICS AND NOMENCLATURE OF CALLIPER**

The calliper is a measuring instrument that can make several types of measurements such as external, internal or depth measurements. Its operation is based on the movement of a slider which moves along the calliper beam. We can find callipers with measuring ranges variables. In general we can classify as small callipers those whose measurement range reaches 300 mm and as large callipers those whose range exceed 300 mm and can reach to 2000 mm.
Regarding types of indication devices we can find callipers with analog indication, vernier scale or circular scale or digital display.

On callipers with analogue indication, vernier and circular callipers, we can find scale interval of 0.02 mm and 0.05mm and in digital callipers indications of 0.01 mm.

Currently there are numerous types of callipers for many different applications.

Typically, it is possible to distinguish three types of callipers by the design of their jaws:

- Independent jaws for external and internal measurements
- One only jaws with two measuring faces for external and internal measurements
- Jaws to depth measurements

To a better understanding follow images and nomenclature above.

![Fig. 1](image1.png)  
**Fig. 1** - Example for a design for a calliper for external, internal and depth measurement

![Fig. 2](image2.png)  
**Fig. 2** - Example for a design for a calliper for external, internal measurement with a fine adjustment device
Inherent to the construction of the calliper as a measuring instrument, there are errors that we must consider when we make measurements with this instrument.

Although detailed evaluation of these errors it is not the aim of this work, their appointment and knowledge of its existence is important to minimize measurement errors that may occur when used in everyday life and during the calibration process. It also helps to understand the measurement methods used in calibration.

We can name the principle of Abbe (Abbe’s principle) which states that maximum accuracy may be obtained only when the standard is in line with the axis of the object being measured. Calliper, except calliper depth gauge, does not comply with Abbe’s principle. In order to minimize such errors, measurements shall be made with the standard gauge or workpiece held as close as possible to the beam. It should also be ensured that there is no excessive clearance between the main scale and the slider in order to ensure that the measuring faces of the external measuring jaws are parallel. Note that in case of callipers depth gauges they are not affected by this error (Flack, 2014).

In analogue callipers (vernier and circular scale) another type of construction errors to considerer is the parallax error. Usually the graduated face of the main scale and the vernier callipers are not in the same plane and therefore the apparent alignment of these two graduations will vary slightly depending on the viewing angle. The best way to avoid it is take the measurements viewing the scale directly above the graduation (Flack, 2014).
Another factor that may influence the measurements is the measurement force that the operator carries out the measurement. There is one type of calliper named by constant force dial calliper, especially to make measurements on materials that deform easily but in general the other types of callipers have no force control device. The force measurement can vary at each measurement, especially if performed by different operators. The speed at which the slider moves on the beam when excessive, can introduce measurement errors. We can minimize the errors if we gently move the slider on the beam and do not apply excessive force measurement. Wherever possible, measurements should be at the nearest position of the main scale (Flack, 2014).

Due to type of jaws, we can point out the errors caused by crossed knife-edges. These errors can be significant when small diameters are measured (<5 mm) and therefore the measurements must be made in the center line of the diameter that we want to measure.

**CALIBRATION**

The aim of the calliper calibration is evaluate the metrological characteristics of the measuring instrument. Errors are determined by calibration and are presented in a calibration certificate.

In order to be able to do comparison between the International Standards ISO13325: 2011 and DIN862: 1988 this document will be referred to general and some aspects relevant to understanding of the calibration process, however will be more relevant the differences between the two Standards. The terminology adopted and the design features are similar in both Standards as have been described in the previous section of this paper, the focus of this approach will be directed to the metrological characteristics.

**Scope / Field of application**

The DIN 862 applies to a maximum measuring range of 2000 mm to analogue callipers and circular vernier scale resolutions of 0.1 mm, 0.05mm and 0.02mm. For digital callipers applies to 1000 mm maximum range, resolution of 0.01 mm.

The ISO 13385 standard is more inclusive in the field of application, is indicated for analogue callipers (vernier scale and circular) and callipers digital display. This standard has no limitations with regard to the resolution of the calliper to calibrate.

**Metrological characteristics**

**General conditions**

As a good practice is essential to keep the measurement equipment in good condition and keep it clean so it can fulfill their function correctly. Callipers are not exception. Over time it is possible that the calliper starts to show some flaws in its operation such as clearance between the slider and the beam, problems at the lock devices, lack of flatness and / or parallelism of the measuring faces and many others that can interfere with your performance. The clearance between the slider and the beam should allow the slider to move smoothly in the beam along its entire length.

When the slide calliper is clamped, with the locking screw or locking device, the indication obtained cannot be changed. In the digital calliper shall not change more than one digital step.
In both DIN 862 and ISO 13385, the results are directly influenced by deviations from flatness and parallelism of the measuring faces. Therefore the requirements for straightness, flatness and parallelism of the measuring faces are specified separately.

**Zero setting**

The zero setting is made with the jaws for external measurements closed. The digital callipers should be able to setting zero at any point in its range. The vernier callipers have a fixed zero point. The analogue callipers with adjustable circular scale should be able to setting zero at any point in its range. Due to the different design features of the measuring face of the calliper depth gauge, the zero must be carried out with the aid of a measuring plane.

**Measurement of errors**

**DIN 862:1988**

With regard to the measurement of errors, DIN 862 considers that the measurements for determining the measurement error must be in random points along the length of the measuring jaw in different positions of the measuring range. The measuring force applied should be the same in both directions of travel. Consider the positive direction the same direction that is used to set zero. The measuring standards used must be gauge blocks according to DIN 861-1 and gauge rings in accordance with DIN 2250-2.

**ISO 13385:2011**

About the determination of the errors, standard ISO 13385 determine that the test methods recommended should evaluate the performance of the calliper throughout its measuring range. The errors of indication apply to any type of indication of callipers when the setting zero is performed with the jaws of external measurements closed. The errors of indication do not depend on the callipers range.

The methods described are not the only valid test methods but their use is recommended by ISO 13385.

The error of indication shall be determined with appropriate standards or with appropriate measurement uncertainty. For example, gauge blocks according to standard ISO 3650.

To better understand which are the main differences in methodology between DIN 862 and ISO 13385 a step by step approach will be carried out.
ISO 13385:2011 - Part 1: Callipers; Design and metrological characteristics

Partial surface contact error, \( E \)

This is the error of indication when the measuring faces of the calliper are partially used. It is determined by the difference between the indicated reading and the calibrated value from the measurement standard.

To determine this error, measurements can be made in measurement standards with small faces, for example gauge blocks at different positions along the jaws and in any position of its measuring range.

![Fig. 8 - Example of test method to determine partial surface contact error, \( E \)](image)

Repeatability of partial surface contact error, \( R \)

The repeatability of partial surface contact error can be determined by measuring, for example, a gauge block at any position of the measuring faces for external measurements and at any point within the measuring range of the calliper.

![Fig. 9 - Example of test method to determine repeatability of partial surface contact error, \( R \)](image)

Line contact error, \( L \)

This error can be tested by measuring a cylindrical measurement standard, for instance a cylindrical pin, of a small diameter at different positions along the jaws, perpendicular to plane of jaws. It is not need to test this error in more than one position in the measuring range.

This error it is determined by the variation over two or more readings.

The importance of this test method relies on the fact that it is possible to detect worn measuring faces of used callipers.
Fig. 10 - Example of test method to determine repeatability of partial surface contact error, $R$

**Full surface contact error, $J$**

Full surface contact error can be tested by measuring a measurement standard, for example gauge block, which covers the whole measuring surface of the jaws and is determined by the variation over two or more readings.

Once again it is not need to test this error in more than one position in the measuring range.

Fig. 11 - Example of test method to determine full surface contact error, $J$

**Error due to crossed knife-edge distance, $K$**

Dedicated exclusively to the type of knife-like jaws, this error must be determined by measuring a setting ring gauge with a nominal value not exceeding 5 mm. This error it depends on the clearance between the measuring faces and the thickness of the knife-edges faces. This error it is determined by the difference between the indicated reading and the calibrated value from the measurement standard.

Fig. 12 - Example of test method to determine error due to crossed knife-edge distance, $K$
Scale shift error, $S$

This is the error of indication when using measuring faces other than measuring faces for external measurement. Full contact of the measuring faces must be provided. Scale shift error includes error of form of the measuring faces for depth measurements and change of the direction of measuring force. It is not necessary to test this error in more than one position within the measuring range.

Test method may be to measuring a gauge block (full contact measurement) with the faces for external measurements, and then measuring a setting ring gauge with the same nominal value with the measuring faces for internal measurement. This error it is determined by the variation over two or more readings. It is very important to use the gauge block and the setting ring gauge of the same size.

Note that for callipers with crosses knife edges, scale shift error must be performed using a setting ring gauge with diameter not being less than 5 mm.

This same method can be used to test the scale shift error between measuring faces for external measurements and the depth measuring rod.

ISO 13385:2011 - Part 2: Calliper depth gauges; Design and metrological characteristics.

Partial surface contact error, $E$

This error may be tested using a pair of measuring standards with small faces, for instance gauge blocks, when in contact with the surface plate according to ISO 8512-2:1990, grade 1, at different positions along the base, at any point within the measuring range.

It is determined by the difference between the indicated reading and the calibrated value from the measurement standard.

Form deviation of the measuring surface of the base is including.
**Repeatability of parcial surface contact error, R**

The repeatability of parcial surface contact error can be determined by measuring, for example, a gauge block at any position of the measuring face of the measuring base and at any point within the measuring range of the calliper depth gauge.

![Example of test method to determine repeatability of parcial surface contact error, R](image)

**Maximum permissible error**

After calibration it is necessary to perform the analysis of the calibration certificate and proving conformity or nonconformity with specifications of the measuring instrument and in this case specifications are usually given as maximum permissible errors.

The DIN 862 provides limits of error, $G$, function of the measured length, $l$, and are to be determine on the basis of two equations. These equations determined $G$, apply for conditions where the direction of the force applied during measurement does not change. Where it does change and for measurements with the depth rod the values obtained for the limits of error are to be increase by 20 $\mu$m.

Unlike DIN 862, ISO 13385 does not quantify the maximum permissible errors. To prove conformance and non-conformance with specifications applies ISO 14253-1.

Uncertainty of measurement shall be conformed according to ISO 14253-2 and ISO/IEC Guide 98-3.

The manufacturer shall specify maximum permissible errors information for the calliper metrological characteristics permitted by specifications.

**RESULTS**

To better understand the concepts of this approach follows a practical example application indicating which the tests are carried out for calibration according to DIN and calibration according to ISO.

The standard gauges used in both calibration are similar but due to some recommendations in ISO 13385-1 should be used a few more standard equipment including ring gauges with specific nominal values and pin gauges.
CONCLUSIONS

The callipers calibration according to the ISO 13385: 2011 compared with DIN 862: 1988, allows, in general, a more detailed assessment of its metrological characteristics.
Although the number of tests have increased, they are easy to perform. Considering that ISO 13385: 2011 does not indicate what the maximum permissible errors for determining the acceptance criteria.

From a practical point of view it is intended that this approach assist the transition to the current calibration standard essentially on the analysis of the calibration certificate development of acceptance criteria for calipers that can be determined based on the process where the calliper is used.

REFERENCES


