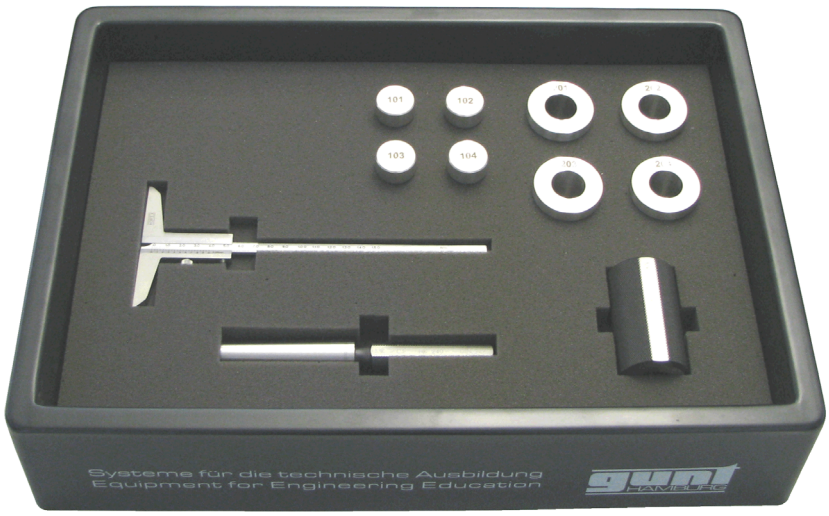
Teaching Material

PT 202 Dimensional Metrology II:
Training Kit 2



Teaching Material

Dipl.-Geogr. Uta Linke

This manual must be kept by the unit.

Before operating the unit:
- Read this manual.
- All participants must be instructed on handling of the unit and, where appropriate, on the necessary safety precautions.

Table of Contents

1 Introduction

1.1 Subject, target group and learning objectives

The **PT 202** training kit is part of the G.U.N.T. learning concept for dimensional metrology. The training kit includes various items of test equipment and test objects. An internal taper and an external taper are used as examples to perform, document and evaluate measuring exercises.

The main application of the training kit is in the training of specialist technicians.

The learning content includes:

- Testing an external taper with a taper gauge
- Testing an internal taper with a taper plug gauge
- Keeping a measurement log
- Estimating measurement variations
- Identifying typical errors

1.2 Didactic information for the tutor

This teaching material is designed to assist you in preparing your lessons. You can put together sections of the material as information for your students and use them in their lessons.

The teaching material also includes prepared worksheets for the students, along with the corresponding solutions.

To support your teaching, we also provide this material in PDF format on a CD. We grant you unrestricted rights to reproduce the teaching material for the purposes of your teaching work.

1.3 Structure of teaching material

Chapter 2 – Safety

This chapter contains safety information, which must be taken into account when using the **PT 202** training kit.

Chapter 3 – Principles of metrology

Explains the difference between testing, measuring and gauging, and between calibration, adjustment and official calibration. Systematic and random measuring variations and actions to avoid these are also dealt with in this chapter.

Chapter 4 – Dimension check with the PT 202 training kit

The components of the **PT 202** training kit are outlined here. It outlines the structure of the test equipment and how to read off measured values. Dimension drawings illustrate the dimensions that can be measured on the test objects. There is an explanation of how the dimensions are recorded on the test objects using test equipment.

Chapter 5 – Tasks

This chapter contains worksheets for the students. These include questions on metrology and exercises in measuring and using the test equipment and objects in the **PT 202** training kit.

Chapter 6 – Solutions

This chapter contains the solutions to the exercises for the teacher.

2 Safety

2.1 Intended use

The unit is to be used only for teaching purposes.

2.2 Structure of the safety instructions

The signal words DANGER, WARNING or CAUTION indicate the probability and potential severity of injury.

An additional symbol indicates the nature of the hazard or a required action.

Signal word	Explanation
⚠ DANGER	Indicates a situation which, if not avoided, **will** result in **death or serious injury**.
⚠ WARNING	Indicates a situation which, if not avoided, **may** result in **death or serious injury**.
⚠ CAUTION	Indicates a situation which, if not avoided, may result in **minor or moderately serious injury**.
NOTICE	Indicates a situation which may result in **damage to equipment**, or provides instructions on **operation of the equipment**.

Symbol	Explanation
	Notice

2.3 Safety instructions

NOTICE

Test equipment and test objects are sensitive.

- Handle all components of the **PT 202** training kit with great care.

3 Principles of metrology

3.1 Testing – measuring – gauging

In general, testing means comparing an actual value with a set or specified value. We can differentiate between testing, measuring and gauging.

Testing

Testing involves using **test equipment** to establish whether a **test object** meets the specified requirements.

Measuring

Measuring involves using a measuring instrument with a scale, on which the measured variable can be **read off**.

The **measuring instrument** has a scale. It can be fixed (solid measure, e.g. ruler) or adjustable (indicating measuring instrument, e.g. calliper gauge).

The result is a **measured value**, consisting of a numerical value and a unit.

Examples:

- Calliper gauge
- Micrometer
- Dial gauge

Gauging

Gauging involves **comparing** a dimension or shape with a gauge that has the specified dimension or shape.

The **gauge** represents the negative shape, i.e. it is the counterpart to the test object. It is fixed, has no scale and, in general, no moving parts. There are dimension gauges, form gauges and limit gauges.

The result is a **conclusion** as to whether the test object lies within specified limits.

Examples:

- Radius gauge
- Taper gauge

3.2 Calibration – adjustment – official calibration

Operational or legal regulations may stipulate that test equipment has to be compared with a reference. We differentiate between calibration, adjustment and official calibration depending on the test equipment and the activity.

Calibration

Comparison of the values measured using an item of test equipment (measuring instrument or gauge) with a reference.

This identifies the level of variation between two values (measuring instrument) or whether the variation between two values lies within certain limits (gauge).

This variation is noted.

Calibration does not involve any modification of the test equipment.

Adjustment

Changing the display on a measuring instrument due to a variation identified during calibration.

Gauges cannot be adjusted.

Official calibration

Calibration and adjustment of a measuring instrument by a **statutory body**, for example the state calibration authority.

Examples:

- A calliper gauge is calibrated by measuring and noting the difference from a reference.
- An example of adjustment would be changing the zero indicator on a pressure gauge so that it corresponds to the zero indicator on a reference pressure gauge.
- Equipment such as scales used in food shops are officially calibrated. The statutory body thus confirms that adjustment has been carried out in accordance with the regulations.

In general, all objects that have a greater accuracy than the test equipment can be used as a reference.

3.3 Measuring variations

3.3.1 Systematic measuring variations

Systematic measuring variations can be identified by calibration. The measured value is then corrected by the amount of the variation to give the measuring result.

Measuring result = Measured value ± Variation

The sign is crucial here.

Significant systematic measuring variations include:

- Reference temperature

  The reference temperature for test equipment and test objects is 20 °C, i.e. test equipment and test objects should have this temperature.

  If the temperatures differ from this, the measured length must be corrected using the temperature and material-specific coefficient of linear expansion.

- Abbe's comparator principle for measuring instruments

  This principle was established in 1893 by Ernst Abbe, the former owner of the Carl Zeiss company (optical industry). It states that the length to be measured and the scale of the measuring instrument must be positioned flush to one another.

The micrometer conforms to this principle.

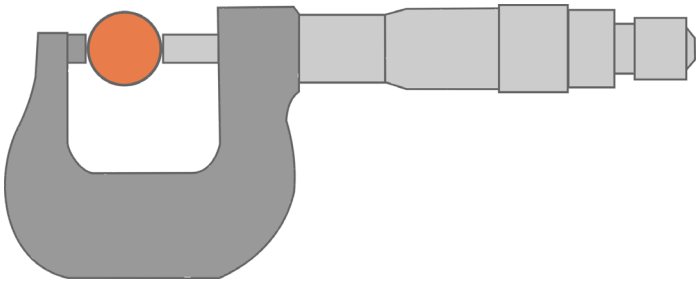


Fig. 3.1 Measuring instrument in line with Abbe's comparator principle

The calliper gauge does not conform to Abbe's comparator principle – as the scale and the measuring object do not lie on an axis. Therefore, measuring errors can occur by tilting the gauge (see Fig. 3.2).

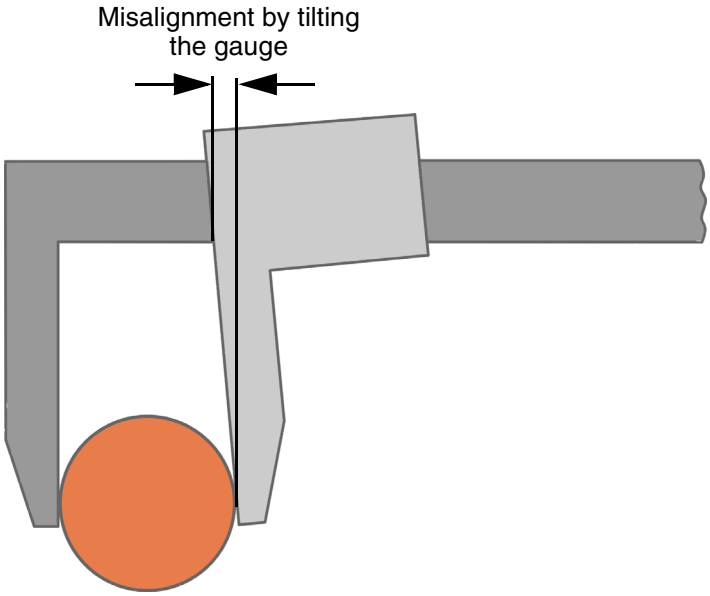


Fig. 3.2 Measuring error by tilting the gauge

3.3.2 Random measuring variations

Random measuring variations are different for each measurement. They cannot be identified by calibration and thus cannot be corrected.

Examples of random measuring variations include:

- Contamination

  Test equipment must always be stored separately from test objects. In the laboratory or workshop, test equipment is stored in particular locations where they will be protected from contamination, severe temperature fluctuations and moisture.

- Reading error due to parallax

  Look at the scale from a right angle when reading the measured value. An inclined view can falsify the reading.

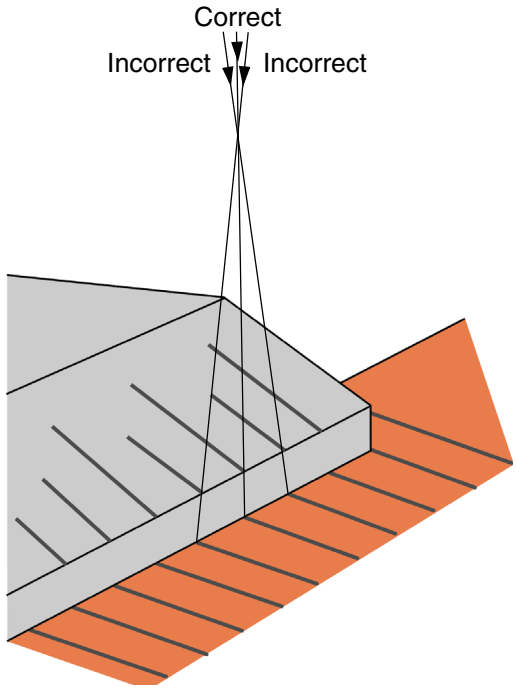


Fig. 3.3 Reading error due to parallax

Random measuring variations are reduced by:

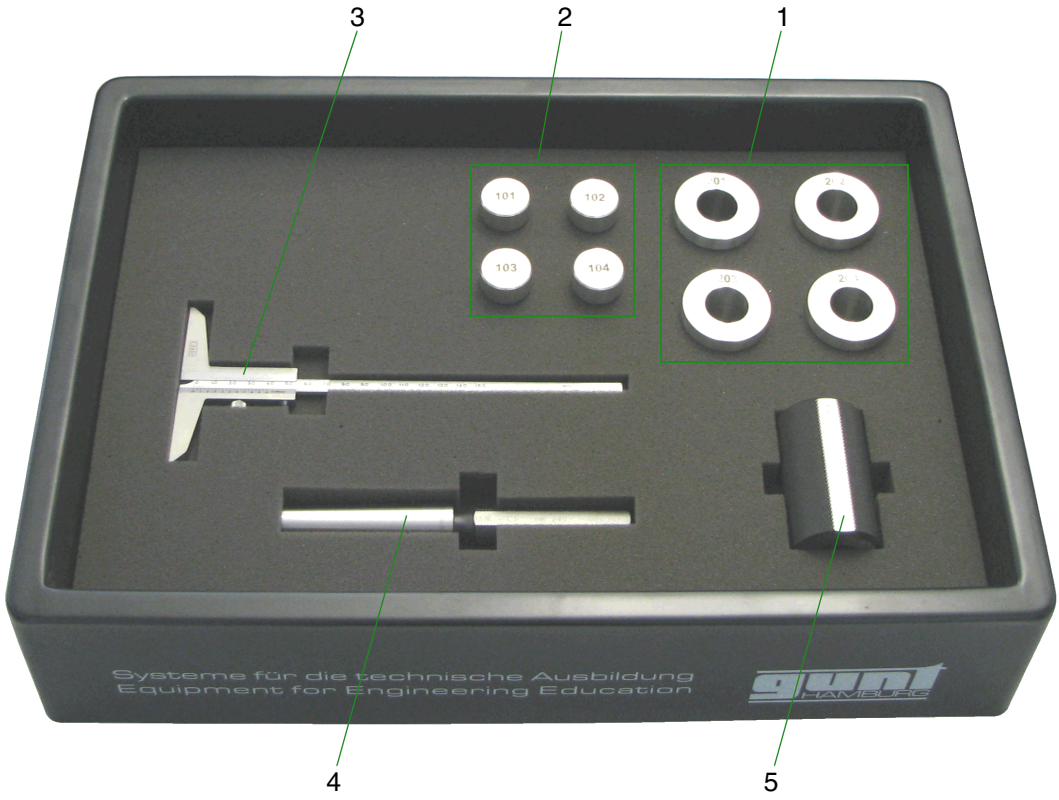
- Careful and calm working
- Multiple measurements

  Measure each dimension several times, if possible with the measuring object at different positions. For example, measure round measuring objects three times, turning the object by 120° each time.

  Then calculate the mean value of your measurements.

4 Dimension check with the PT 202 training kit

4.1 Components



Item	Designation	Measuring range	Additional specifications
1	Internal tapers 201 to 204		See Chapter 4.3, Page 20
2	External tapers 101 to 104		See Chapter 4.3, Page 20
3	Depth calliper gauge	0...150mm	Reading accuracy: 0,05mm
4	Taper plug gauge		MT 3
5	Taper gauge		MT 3

Fig. 4.1 PT 202 training kit

4.2 Test equipment

4.2.1 Taper gauge and taper plug gauge

Taper gauges are used to test external tapers while taper plug gauges are used to test internal tapers. Both are gauges, i.e. the angle and shape of a test taper is compared with the angle and shape of the gauge taper. The result is an indication of whether the test object is within specified limits ("Good") or outside specified limits ("Reject").

The **PT 202** training kit contains a taper gauge and a taper plug gauge.

Fig. 4.2 Taper gauge

Fig. 4.3 Taper plug gauge

The information on the taper gauges has the following meaning:

MT	Morse taper, named after the American Stephen A. Morse (lived in 19th Century)
A or C	Shape of taper A: Sleeve with draw-in thread for fixing C: Pin with draw-in thread for fixing
3	Taper size The sizes MT 0 (smallest diameter) to MT 6 (largest diameter) are included
DIN 229	Standard for Morse tapers

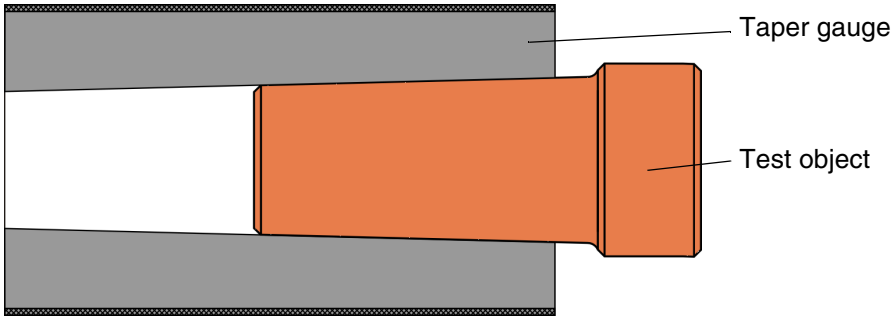


Fig. 4.4 External taper and taper gauge

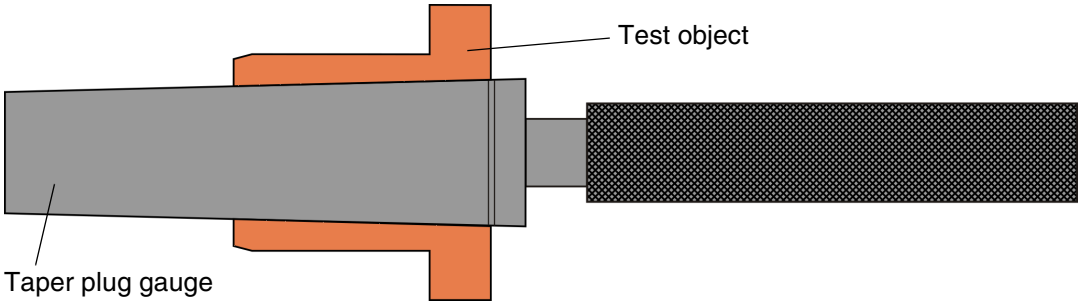


Fig. 4.5 Internal taper and taper plug gauge

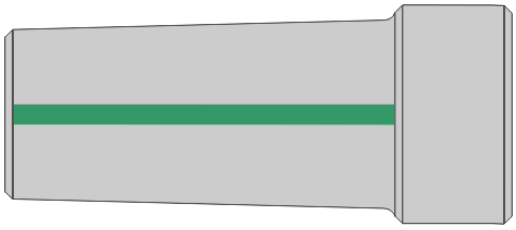


Fig. 4.6 Applying the marking

The procedure for testing the **taper angle** and **taper shape** of an external or internal taper is as follows:

- Draw three markings at equal intervals along the length of the taper with chalk or surface paste.

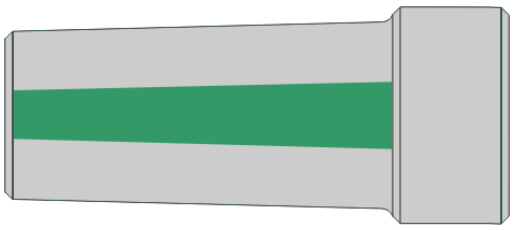
  The taper can be the test object (external taper) or the taper plug gauge.
- Slide the test object carefully into the sleeve and turn it slightly back and forth.

  The sleeve can be the test object (internal taper) or the taper gauge.
- Remove the taper from the sleeve.
- The distribution of the chalk or surface paste represents the contact pattern.

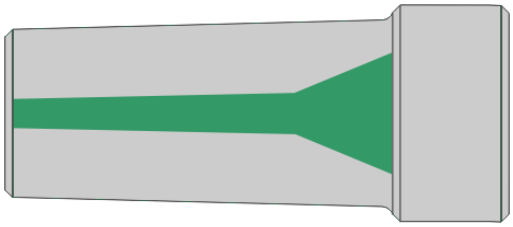
  Where there is contact with the taper, the chalk or paste is rubbed in evenly.

  Where there is no contact with the taper, the marking is unchanged.

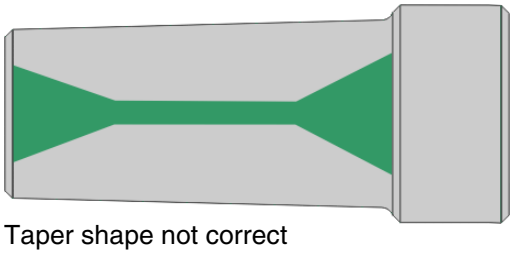
  Fig. 4.7 shows some examples.



Taper angle and taper shape correct



Taper angle not correct



Taper shape not correct

Fig. 4.7 Contact patterns

Taper diameter

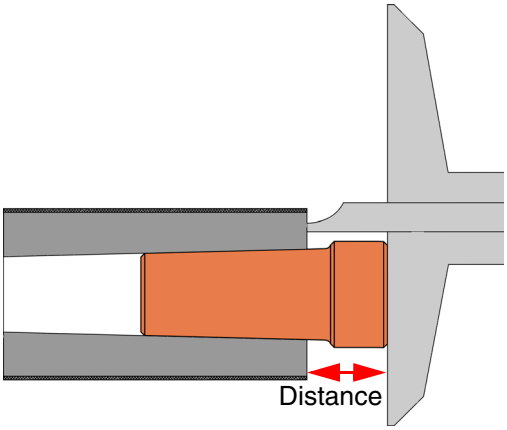


Fig. 4.8 Testing the diameter of an external taper

Testing the taper diameter of an external taper:

- Slide the test object carefully into the taper gauge.

  The nominal diameter is the larger diameter on the front of the taper gauge.

- Use a depth calliper gauge to measure the distance between the front of the test object and the position of the nominal diameter.

  If the measured value lies within the tolerance specified in the external taper drawing, the diameter is "Good".

  If the measured value lies outside the tolerance specified in the external taper drawing, the diameter is a "Reject".

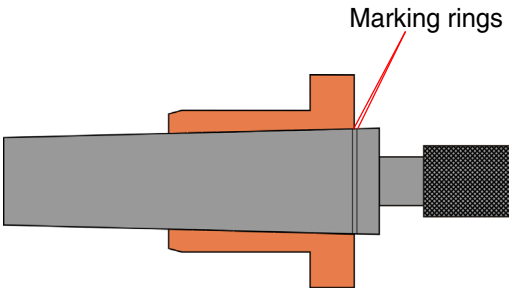


Fig. 4.9 Testing the diameter of an internal taper

Testing the taper diameter of an internal taper:

- Slide the test object carefully over the taper plug gauge.
- On the taper plug gauge are two marking rings (tolerance markings).

  If the front surface of the test object is between the two marking rings, the diameter is within the tolerance and is "good".

  If the front surface of the test object is outside the two marking rings, the diameter is outside the tolerance and is thus a "reject".

4.2.2 Depth calliper gauge

Because of its versatility for different measuring tasks, ease of use and handling, the calliper gauge is the most important length measuring instrument in metalworking. The **PT 202** training kit includes a depth calliper gauge for depth measurements.

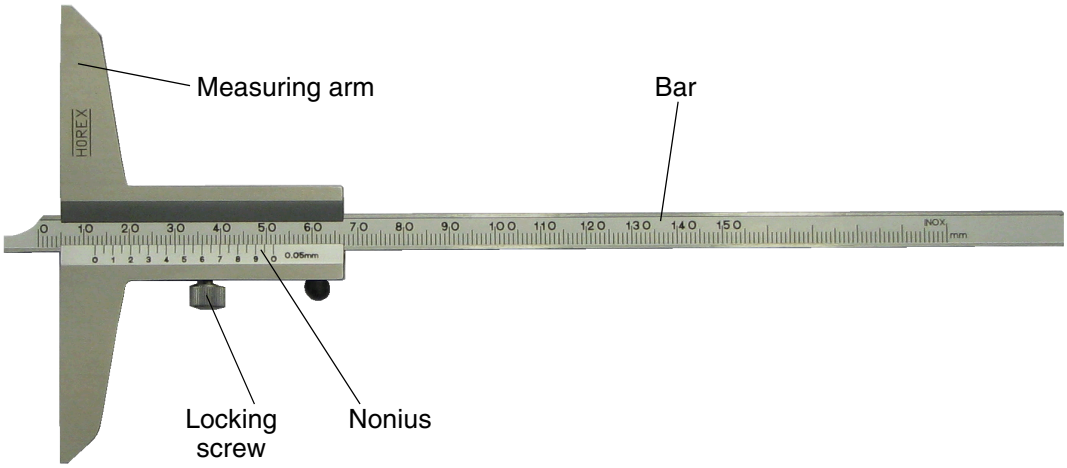


Fig. 4.10 Depth calliper gauge

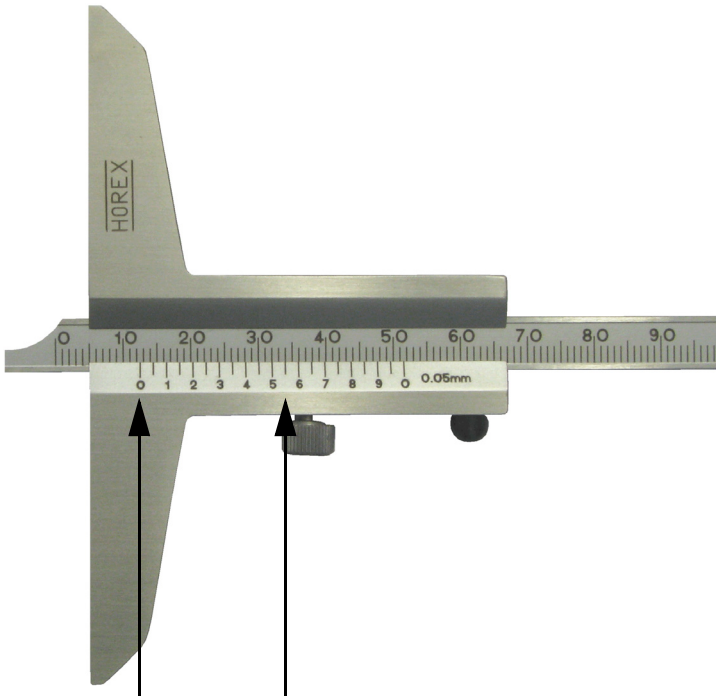
The depth calliper gauge consists of a bar with millimetre graduations and a measuring arm, which makes a right angle with the bar. The measuring arm has a scale, known as the nonius.

The depth calliper gauge is used to measure depths.

The locking screw allows the depth calliper gauge to be used as an adjustable gauge.

The depth calliper gauge is read as follows:

- View the zero line of the nonius as the decimal point. Read off the full millimetres at the zero line of the nonius.
- Then look to the right of the zero line for the graduation on the nonius that coincides with a graduation on the scale. Read off the tenths of millimetres there.



Reading at the zero line of the nonius

Value: 12

Reading at the graduation on the nonius that coincides with a graduation on the scale

Value: 0,55

Value read: 12,55 mm

Fig. 4.11 Reading the depth calliper gauge

4.3 Test objects

In the **PT 202** training kit, four external tapers and four internal tapers are used as test objects. The dimension drawings with the requirements for the tapers (setpoint dimensions) are shown in Fig. 4.12.

For training purposes however, the manufacturing dimensions of the tapers differ from the specifications in the dimension drawings. This enables the students to check whether the tapers meet the requirements ("Good") or not ("Reject"), see Tab. 4.1.

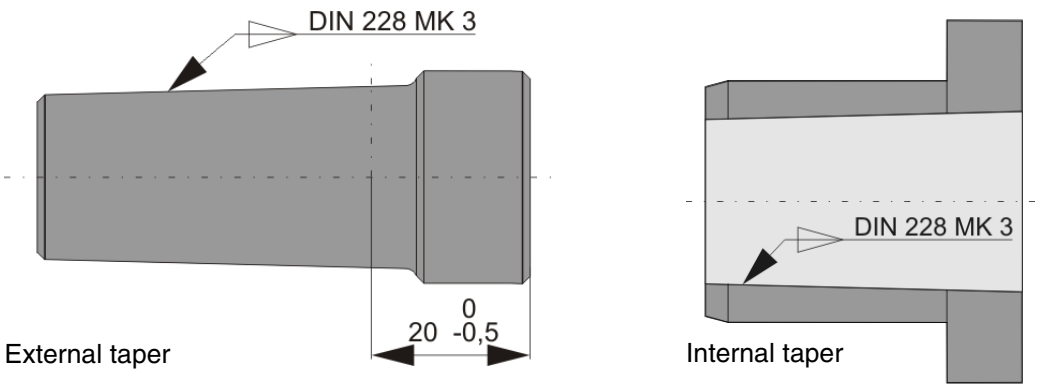


Fig. 4.12 Drawing of external taper and internal taper, scale 1 : 1 (setpoint dimensions)

	External taper				Internal taper			
	101	**102**	**103**	**104**	**201**	**202**	**203**	**204**
Quality of taper angle	Good	Good	Good	Reject	Good	Good	Reject	Reject
Quality of taper shape	Good	Good	Reject	Good	Good	Good	Good	Good
Quality of taper diameter	Good	Reject	Good	Good	Reject	Good	Good	Good

Tab. 4.1 Quality of external taper and internal taper

4.4 Examples for testing the test objects

The **PT 202** training kit contains a selection of test equipment for testing the taper dimensions specified in Tab. 4.1, Page 20.

Fig. 4.13 to Fig. 4.15 show examples of tests on an external taper and an internal taper.

Fig. 4.13 Testing the angle and shape of an external taper

Fig. 4.14 Testing the diameter of an external taper

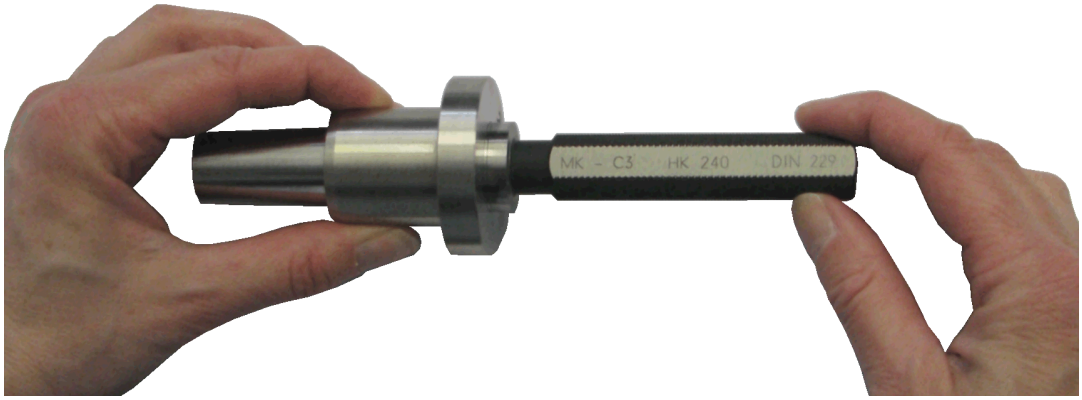


Fig. 4.15 Testing the angle, shape and diameter of an internal taper

5 Tasks

5.1 Worksheet A – Metrology

Page 1

1. Are the following items of test equipment classed as measuring instruments or gauges?

	Measuring instrument	Gauge
Taper gauge		
Taper plug gauge		
Depth calliper gauge		

2. What can you test with gauges?

☐ The dimensions of a test object.

☐ The shape of a test object.

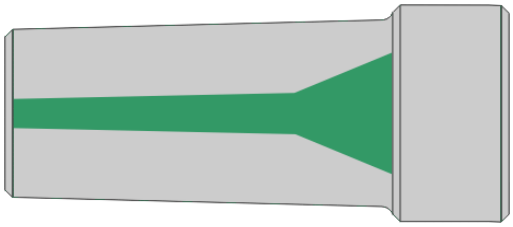
3. Can you use a gauge as a reference for calibration?

4. Can you adjust a gauge?

5.2 Worksheet B – Taper gauge and taper plug gauge

Page 1

1. A test object with external taper is tested using the taper gauge and shows the following contact pattern:



Evaluate the contact pattern.

Taper angle	☐ Good ☐ Reject
Taper shape	☐ Good ☐ Reject

2. What are the two marking rings on the taper plug gauge used for?

5.3 Worksheet C – Performing measurements on an external taper

Page 1

1. Test the angle, shape and diameter of the external taper.

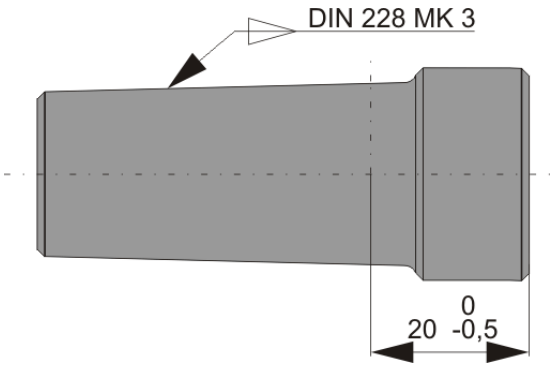
   Compare your results with the drawing.

   In the test report, record whether the external taper dimensions are "good" or "reject".

   Working medium:

   - Taper gauge
   - Depth calliper gauge
   - External taper

   Drawing scale 1 : 1 (setpoint dimensions)



Worksheet C – Performing measurements on an external taper

Page 2

Test report	
Test object:	External taper no. ____
Date:	_____

Dimension	Quality
Taper angle	☐ Good ☐ Reject
Taper shape	☐ Good ☐ Reject
Taper diameter	☐ Good ☐ Reject

5.4 Worksheet D – Performing measurements on an internal taper

Page 1

1. Test the angle, shape and diameter of the internal taper.

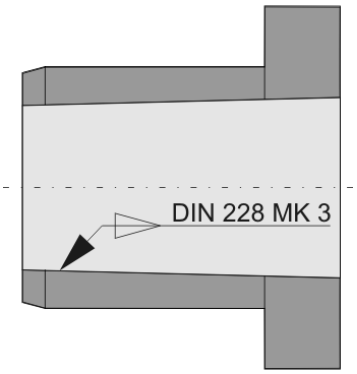
   Compare your results with the drawing.

   In the test report, record whether the external taper dimensions are "good" or "reject".

   Working medium:

   - Taper plug gauge
   - Internal taper

   Drawing scale 1 : 1 (setpoint dimensions)



Worksheet D – Performing measurements on an internal taper

Page 2

Test report	
Test object:	Internal taper no. ____
Date:	_____

Dimension	Quality
Taper angle	☐ Good ☐ Reject
Taper shape	☐ Good ☐ Reject
Taper diameter	☐ Good ☐ Reject

6 Solutions

6.1 Worksheet A – Metrology

Page 1

1. Are the following items of test equipment classed as measuring instruments or gauges?

	Measuring instrument	Gauge
Taper gauge		X
Taper plug gauge		X
Depth calliper gauge	X	

2. What can you test with gauges?

☒ The dimensions of a test object.

☒ The shape of a test object.

3. Can you use a gauge as a reference for calibration?

Yes, if the gauge has greater accuracy than the test object.

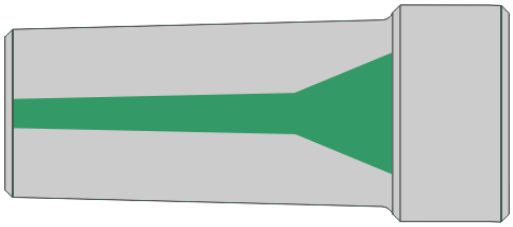
4. Can you adjust a gauge?

No. Adjustment changes the display on test equipment, which is not possible on a gauge.

6.2 Worksheet B – Taper gauge and taper plug gauge

Page 1

1. A test object with external taper is tested using the taper gauge and shows the following contact pattern:



Evaluate the contact pattern.

Taper angle	☐ Good ☒ Reject
Taper shape	☒ Good ☐ Reject

2. What are the two marking rings on the taper plug gauge used for?

The marking rings are used to test the nominal diameter.
If the front surface of the test object lies between the two marking rings, the diameter is within the tolerance and is "good".
If the front surface of the test object lies outside the two marking rings, the diameter is outside the tolerance and therefore a "reject".

6.3 Worksheet C – Performing measurements on an external taper

Page 1

1. Test the angle, shape and diameter of the external taper.

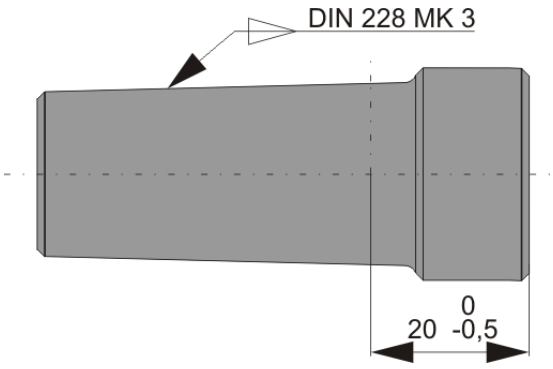
   Compare your results with the drawing.

   In the test report, record whether the external taper dimensions are "good" or "reject".

   Working medium:

   - Taper gauge
   - Depth calliper gauge
   - External taper

   Drawing scale 1 : 1 (setpoint dimensions)



Worksheet C – Performing measurements on an external taper

Page 2

Test report	
Test object:	External taper no. ____
Date:	_____

Dimension	Quality
Taper angle	☐ Good * ☐ Reject *
Taper shape	☐ Good * ☐ Reject *
Taper diameter	☐ Good * ☐ Reject *

* Information for the teacher: The values depend on the taper and are therefore not specified here. For comparison, the qualities of all tapers are specified in a table on the next page.

Worksheet C – Performing measurements on an external taper

Page 3

For the teacher only

	External taper			
	101	**102**	**103**	**104**
Quality of taper angle	Good	Good	Good	Reject
Quality of taper shape	Good	Good	Reject	Good
Quality of taper diameter	Good	Reject	Good	Good

6.4 Worksheet D – Performing measurements on an internal taper

Page 1

1. Test the angle, shape and diameter of the internal taper.

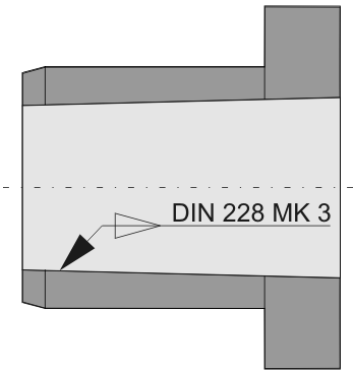
   Compare your results with the drawing.

   In the test report, record whether the external taper dimensions are "good" or "reject".

   Working medium:

   - Taper plug gauge
   - Internal taper

   Drawing scale 1 : 1 (setpoint dimensions)



Worksheet D – Performing measurements on an internal taper

Page 2

Test report	
Test object:	Internal taper no. ____
Date:	_____

Dimension	Quality
Taper angle	☐ Good * ☐ Reject *
Taper shape	☐ Good * ☐ Reject *
Taper diameter	☐ Good * ☐ Reject *

* Information for the teacher: The values depend on the taper and are therefore not specified here. For comparison, the qualities of all tapers are specified in a table on the next page.

Worksheet D – Performing measurements on an internal taper

Page 3

For the teacher only

	Internal taper			
	201	**202**	**203**	**204**
Quality of taper angle	Good	Good	Reject	Reject
Quality of taper shape	Good	Good	Good	Good
Quality of taper diameter	Reject	Good	Good	Good