Unit 19: Mechanical Measurement and Inspection Techniques

Unit code: J/600/0269

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will give learners a broad understanding of the mechanical measurement and inspection techniques used to ensure components meet the required dimensional and accuracy standards.

Unit introduction

In order to produce components that meet the design criteria, manufacturing companies have to know whether the components they make are to the required dimensional and accuracy standards. Companies carrying out maintenance activities also need to know that the components they are working with, repairing or servicing are to the required size and accuracy.

Measurement and inspection play an important role in establishing these needs and support other areas of assuring quality in the products produced. The process of finding out whether a product is accurate and to dimensional standards also needs to be done in an efficient and effective way.

The aim of this unit is to provide a broad understanding of mechanical measurement and inspection techniques that apply to a range of engineering activities within different companies. The unit will give learners an understanding of a range of techniques and equipment commonly used in mechanical measurement and inspection.

Learners will be introduced to principles of measurement and the use of comparators and gauges, along with sampling and statistical process control (SPC). Learners will develop the skills needed to select and use standards, measuring equipment, comparators and gauges. They will be able to appreciate the fundamental requirements of measurement and inspection techniques and be able to apply standards to these.

Learners will have an opportunity to carry out practical measurements using linear measuring equipment and techniques and comparators and gauges. They will also be able to prepare a process control chart for a given process.

Learning outcomes

On completion of this unit a learner should:

1 Understand principles and applications of mechanical measurement

2 Be able to use measurement equipment and techniques

3 Be able to use comparators and design a gauging system for inspection

4 Be able to apply sampling and statistical process control (SPC) during inspection.

Unit content

1 Understand principles and applications of mechanical measurement

Limits and fits: eg concepts of limits and fits, definitions of the types of fits (clearance, transition, interference)

Tolerances: principles eg standard symbols and interpretation, maximum material condition, maximum variation of form, grades of tolerance; hole tolerances, shaft tolerances

Principles of measurement: units; standards eg BS969, BS1134, BS2634, BS4500; calibration eg national standards, traceability; errors and instruments; kinematics of equipment

2 Be able to use measurement equipment and techniques

Linear measurement equipment: range (verniers, callipers, micrometers); principles involved; scales; types; use in dimensional measurement; specific calibration issues

Further measurement techniques: determining surface texture eg significance to component function, surface texture symbols, roughness average, waviness, finish, amplitude parameters, spacing parameters, instrumentation used for surface texture measurement; determining alignment eg principles of straight edges, measurement of straightness, squareness, flatness and parallelism; determining angular measurements eg concepts of geometry, divided circles, principles of angular measurement, angular scales, methods for angular measurement, taper measurement

3 Be able to use comparators and design a gauging system for inspection

Comparators: types of comparator, magnification, cosine errors, use of angle dekkor, specific calibration issues

Gauge design: principles of gauge design (gauge types, gauge materials, Taylor's principle, principle of go/no-go gauging); slip gauges as references for length standards (classification of slip gauges, multiple slip gauge use, ancillary equipment, care and maintenance required, wringing); slip gauges for instrument calibration (use with dial gauges in dimensional measurement, specific calibration issues)

Simple application: measuring a component containing round (external or internal), linear and angled features, following the use of a high precision manufacturing method such as grinding eg the jaw of a toolmaker's clamp

4 Be able to apply sampling and statistical process control (SPC) during inspection

Sampling: acceptance sampling, 100% inspection

Statistical process control: charts (mean, range) eg process capability, conformance, cost, process variability; process eg grinding machine, high-volume lathe

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the different types of fits	**M1** evaluate the use and accuracy of linear measuring equipment when used on given products	**D1** analyse the use of the concept of limits and fits
P2 use tolerancing principles to calculate hole and shaft tolerances for a range of required component fits [IE4]	**M2** compare different uses of comparators when used to measure dimensional accuracy	**D2** analyse the calibration requirements of comparators and measurement equipment.
P3 explain the principles of measurement	**M3** explain process capability in relationship to statistical process control (SPC) for a given process.	
P4 use linear measurement equipment to carry out practical measurements for given products [SM3]		
P5 use further measurement techniques on given products to establish surface texture, alignment and angular measurements [SM3]		
P6 use comparators to measure dimensions and angles for a simple given product [SM3]		
P7 design a gauging system for a simple given application [CT1]		
P8 explain the technique of acceptance sampling and state when 100% inspection is applicable		

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P9 produce control charts for a given process.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

Most of this unit will involve a practical delivery approach, although certain areas rely on a good understanding of different underlying principles. Some areas require the development of skills, whereas others, such as sampling and statistical process control, only need an overview. More detailed study will, however, be required on process capability.

Learners need to be given a broad overview of the different measurement and inspection techniques and the use of equipment and comparators. A good understanding of the techniques engineers use in deciding which measurement or inspection technique to apply is also required. Learners need access to standards etc to ensure that they have opportunities to design an appropriate gauging system that should cover internal and external features. Simple go/no-go gauge design would be suitable.

The unit provides opportunities for practical learning activities which can relate to a variety of products, possibly drawn from the learners' background. Often learners will be from a background where such measurement and inspection techniques are used and can be more motivated if they are able to study techniques they are familiar with. Learners will need a range of products to measure or design a gauging system for while developing their practical measurement and gauge designing skills.

Industrial visits, if available, will help underpin the breadth of application needed, otherwise practical demonstrations will be useful. Although learners may come across coordinate measuring machines (CMM) in industry, this unit concentrates on the aspects of simple practical measurement techniques and gauging principles that can be used across engineering disciplines.

The learning outcomes can be delivered in any order, although learning outcomes 2, 3 and 4 do to some degree rely on an understanding of learning outcome 1.

The teaching and learning strategies used to deliver the unit need to take into account that evidence needs to be available for portfolio assessment.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit content, scheme of work and assessments • explain the concepts and definitions of limits and fits • explain tolerancing principles and their application • explain units of measurement, standards and calibration • discuss the kinematics of equipment. *Practical learner activity*: • calculating hole and shaft tolerances for a range of different component fits.
Preparation for and completion of **Assignment 1: Tolerances and Fits** (P1, P2, P3 and D1).
Whole-class teaching: • explain the principles of linear measurement • explain and demonstrate the use of a range of linear measurement equipment • explain equipment calibration. *Practical learner activity*: • practise use of verniers, callipers and micrometers.
Whole-class teaching: • explain and demonstrate the measurement of surface texture • explain and demonstrate how to determine alignment • explain and demonstrate how to determine angular measurements. *Practical learner activities*: • practise use of further measurement techniques on a range of products. *Industrial visit*: • view the industrial use of linear equipment and measuring techniques in a local engineering company.
Preparation for and completion of **Assignment 2: Using Measurement Equipment and Techniques** (P4, P5 and M1).
Whole-class teaching: • explain and demonstrate the use of comparators • explain the principles of gauge design • explain and demonstrate the use of slip gauges. *Practical learner activities*: • use slip gauges as references for length and for instrument calibration • measuring a range of components containing round, linear and angled features.
Preparation for and completion of **Assignment 3: Comparators and Gauges** (P6, P7, M2 and D2).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the application of sampling and 100% inspection • explain statistical process control and the use of control charts. *Individual learner activity*: • producing control charts for both mean and range.
Preparation for and completion of **Assignment 4: Sampling and Statistical Process Control** (P8, P9 and M3).
Feedback, unit evaluation and close.

Assessment

It is important that the assessment strategies used should be designed to suit the needs of learners and the local environment. Good assessment strategies are likely to be supported by proper presentation of appropriate evidence. Portfolios should not contain course notes, research etc unless it is to become part of the required evidence and assessment.

It is likely that a range of products will need to be measured and inspected to ensure learners have opportunities to cover the techniques, equipment and systems listed and meet the requirements of the grading criteria. The following guidance will help tutors to interpret the grading criteria and indicate possible assessment strategies.

To achieve a pass grade learners need to demonstrate the use and knowledge of the different measurement and inspection techniques listed in the content. They will also need to describe the different types of fits, know how to calculate tolerance requirements and understand the underlying principles of measurements.

Learners should carry out successful practical measurements using a range of measuring equipment and comparators. It is important that they measure the attributes listed in the content and criteria (surface texture, alignment and angular measurement). Help could be given for this level of performance. Using a given product they should be able to design simple go and no-go gauges for internal and external features of the product. Learners also need to describe acceptance sampling in basic terms and state when 100 per cent inspection might be suitably employed.

To achieve a merit grade learners should be able to evaluate the accuracy of equipment used and compare and contrast the use of comparators. They should show a more detailed understanding of statistical process control by explaining its relationship with process capability.

To achieve a distinction grade learners are expected to demonstrate a high level of understanding of the concept of limits and fits. At this level learners should show skills in analysing the calibration requirements associated with traceability of working standards. Greater detail will be evident, although grading should be restricted to the analysis skills used.

It may be appropriate to develop four assignments for the assessment of this unit, three of which would be of a practical nature.

The first assignment could be a time-constrained assignment addressing criteria P1, P2, P3 and D1. A range of data for all three types of fit should be given allowing learners to apply their knowledge of tolerancing to develop suitable tolerances for each fit. Tasks need to be included that ensure the range of unit content – such as maximum material condition and tolerance grades – are covered (P2). Written tasks should be given for the other criteria targeted in this assignment. This type of assessment instrument ensures authenticity of individual responses.

For the second assignment, addressing criteria P4, P5 and M1, a range of products need to be made available so that each learner is able to use a vernier, a calliper and a micrometer. It would be useful if the products had both internal and external features to be measured. Obviously the products need to be machined to allow the accuracy that demands the use of this equipment. The instructions should ensure that surface texture, alignment and angular measurements are taken.

Particular care needs to be taken with the choice of product to ensure it is large enough to allow alignment measurements to be taken as ranged in the content. At least two products are required to ensure the range of features and accuracy can be measured and the use of the equipment evaluated. A written task needs to follow the practical activity to address M1. A witness statement/observation record would support the evidence for the use of this equipment, along with a table of measurements taken.

The third assignment, addressing criteria P6, P7, M2 and D2, could also be based around a practical exercise. The choice of product for the use of comparators (P6) needs to ensure that there are both dimensions and angles to be measured. No more than two angles are required otherwise the product will be too complex.

Care will need to be taken when planning an assessment activity for the designing of a gauging system (P7). Data or a particular specification should be made available that ensures the principles of gauge design are applied and slip gauges are used. The unit content suggests as an example the jaw of a toolmaker's clamp, so in this case as long as there are external and internal features, linear and angled features the product is suitable. An overly complex product would not be suitable. A written task should be given to provide opportunities for criteria M2 and D2, and could be an extension of the practical work. Again, a witness statement/observation record would support evidence of the use of comparators, along with a table of measurements taken.

The last and fourth assignment would address criteria P8 and P9 and could be extended to cover M3. Data needs to be given for a process that allows learners to present control charts for both mean and range (P8). A further written task needs to be set for M3.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3 and D1	Tolerances and Fits	A time-constrained assignment requiring learners to demonstrate their knowledge of tolerances and fits.	A practical assignment requiring learners to calculate tolerances for component fits supported by written tasks.
P4, P5 and M1	Using Measurement Equipment and Techniques	An assignment requiring learners to use linear measuring equipment and further measuring techniques.	A practical task in which learners use verniers, callipers and micrometers and determine surface texture, alignment and angular measurements on at least two products. A further written task can be used to give learners an opportunity to evaluate the use of linear measuring equipment.
P6, P7, M2 and D2	Comparators and Gauges	A practical assignment requiring learners to use comparators and design a gauging system.	Two practical tasks in which learners first measure dimensions and angles using comparators. Learners then need to design a gauging system. A further written task could build on the practical work so that learners can carry out a comparison and analysis for M2 and D2.
P8, P9 and M3	Sampling and Statistical Process Control	An assignment requiring learners to investigate sampling and inspection techniques.	A series of three written tasks in which learner provide an explanation of sampling and inspection techniques. Learners will then need to produce control charts from given data.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with the following unit titles in the Engineering suite:

Level 1	Level 2	Level 3
	Engineering Marking Out	
	Application of Quality Control and Measurement in Engineering	

The unit also links to the Level 3 NVQ in Engineering Technical Support, particularly:

- Unit 11: Inspecting Mechanical Products
- Unit 17: Checking and Calibrating Mechanical Inspection Equipment.

Essential resources

A range of measuring and inspection equipment as defined by the content is necessary, plus a range of products for learners to measure. Centres will need to provide access to engineering data handbooks, manufacturers' specifications and suitable current British Standards (eg BS969: Limits and Tolerances on Plain Limit Gauges, BS1134: Method for the Assessment of Surface Texture).

Employer engagement and vocational contexts

The use of vocational contexts is essential in the delivery and assessment of this unit. Much of the work can be set within the context learners' work placements or based upon case studies that relate to local industries.

There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Drake P – *Dimensioning and Tolerancing Handbook* (McGraw-Hill, 1999) ISBN 0070181314

Griffith G – *Geometric Dimensioning and Tolerancing: Applications and Inspection* (Prentice Hall, 2001) ISBN 9780130604637

Timings R L – *Fundamentals of Engineering* (Newnes, 2002) ISBN 0750656093

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	analysing and evaluating material condition, variation of form and grades of tolerance when calculating hole and shaft tolerances
Creative thinkers	designing a gauging system for a simple given application
Self-managers	organising time and resources when using measurement equipment and techniques.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	setting goals with success criteria for their development and work when using linear equipment and further measuring techniques
Team workers	collaborating with others when carrying out group work when using mechanical measurement and inspection techniques and equipment.

Functional Skills – Level 2

Skill	When learners are ...
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	calculating tolerances for a range of required component fits
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the principles of measurement
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the principles of measurement and the technique of acceptance sampling.