

Unit 27: Welding Principles

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

The majority of processes used in industry to produce welded joints rely on the application of heat. The amount of heat used varies according to the process, but one common factor is that the metallurgical structure of the metal will be changed to some extent by the welding operation. An understanding of the effects that these changes may have on the application of the completed fabrication is essential for welders and those responsible for the specification of the welding process and any post-weld heat treatments.

Determining the weldability of a metal can be complex; for example, simply judging a steel by its low carbon content could be an expensive mistake. If all the alloying elements in the steel are taken into account, it can be calculated that the steel will have characteristics similar to a medium to high carbon steel. In terms of its weldability, the steel may require different treatment before, during and after welding.

This unit will develop learners' knowledge of the structure of pure metals and the effects of adding alloying elements. Using both practical and investigative techniques, learners will develop an understanding of the operation of a range of welding processes, enabling them to make an informed choice for given applications.

Identification of defects is vital in ensuring the quality of the finished product. Welding can be carried out using manual, semi-automatic and fully automated systems. But, irrespective of the method used, defects can and do occur. Learners will need to demonstrate their knowledge of the techniques employed in defect detection and the quality standards used in industry.

Learning outcomes

On completion of this unit a learner should:

- 1 Understand the physical features of welding processes
- 2 Describe the effects of welding and select post-weld heat treatments
- 3 Know about the factors affecting the weldability of metals
- 4 Know about weld testing and quality standards.

Unit content

1 Understand the physical features of welding processes

Welding processes: main processes eg manual metal arc (MMA), metal-arc gas shielded (MAGS), tungsten-arc gas shielded (TAGS), oxy-acetylene; additional processes eg resistance (such as spot, seam), friction, flash butt, laser, electron beam, explosive, exothermic (thermit), capacitor discharge stud welding, friction stir welding

Electric arc: alternating current (AC); direct current (DC); heat distribution at the anode and cathode; effect of magnetic fields; applications of AC and DC

Shielding gases: functions eg atmospheric protection, arc initiation; shielding gases eg inert, argon, helium; active gases used in mixtures eg carbon dioxide (CO₂), nitrogen, oxygen; applications eg MAGS, TAGS, plasma-arc

Electrode coverings and fluxes: functions of coverings and fluxes eg atmospheric protection, slag, removal of impurities, alloying, arc initiation; composition eg basic, rutile, cellulosic, iron powder; fluxes eg fused, agglomerated; applications of coverings and fluxes eg MMA welding, submerged arc welding, braze welding

Oxy-acetylene combustion: chemical composition of the inner and outer envelope; heat distribution; applications of flame types, eg neutral, oxidising, carburising

2 Describe the effects of welding and select post-weld heat treatments

Effects of welding heat input: distortion control eg pre-setting, pre- and post-heating, total heat input, weld deposition (skip and back step) techniques; effects eg distortion (expansion and contraction), expansivity, residual stress; effects of cooling rate eg hardening, grain growth, cracking; structure of the welded joint eg heat-affected zone (HAZ), crystal structure (such as equi-axed, columnar), grain growth; heat distribution during welding eg thermal gradients, heat flow, joint configuration (butt, tee, cruciform)

Post-weld heat treatments: for ferrous metals eg annealing (full, process), normalising; for heat treatable aluminium alloys eg solution treatment, precipitation hardening

3 Know about the factors affecting the weldability of metals

Weldability: factors eg melting temperature, carbon equivalent, rate of heating/cooling (thermal shock), thermal conductivity, residual stress, degree of restraint (the rigidity of the construction), dilution, hardenability, dissolved hydrogen, pre- and post-heat temperature; impurities eg phosphorous (cold shortness), sulphur (hot shortness); mechanical properties eg tensile strength, impact strength

4 Know about weld testing and quality standards

Weld test techniques: non-destructive eg visual (weld gauges, dimensional), radiographic (such as x-ray, gamma ray), ultrasonic, dye penetrant, magnetic particle; destructive eg fracture, bend test, macro/microscopic examination, tensile, fatigue, hardness

Weld defects: visual eg undercut, overlap, excess weld metal, concavity, cracking (such as cold cracking, hot cracking, crater, transverse, longitudinal, centre-line, HAZ), blowholes, oxidation, restarts; internal eg porosity, inclusions (such as slag, metallic, gaseous), lack of inter-run fusion, cavities

Quality standards: in relation to relevant standards eg British Standard/European Standard (BS EN) 15614, BS EN 278, BS EN 288, American Society of Mechanical Engineers (ASME) IX

Grading grid

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

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 select one welding process for each of four given applications and give reasons for their selection	M1 explain the process and operation of two different welding processes	D1 compare and contrast two welding processes for one given application and describe the reasons why one is better than the other
P2 describe the physical features of the electric arc	M2 explain how two post-weld heat treatment processes affect the grain structure and properties of welded joints in two given metals	D2 justify the selection of one weld testing technique for the detection of given weld defects and describe the reasons the selection meets the criteria to a relevant quality standard.
P3 describe the function of two given shielding gases/mixtures and three given electrode coverings/fluxes	M3 explain how one non-destructive and one destructive weld testing technique detect given visual and internal weld defects.	
P4 describe oxy-acetylene combustion		
P5 describe three methods of controlling the effects of distortion caused by welding heat input		
P6 describe the effects of heat input and the effects of the rate of cooling and heat distribution during welding on the grain structure of two given welded joints		

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:
<p>P7 select a post-weld heat treatment process for a given ferrous metal and a given aluminium alloy welded joint</p> <p>P8 describe four factors and two impurities and state how they affect weldability and mechanical properties</p> <p>P9 describe a non-destructive and a destructive weld test procedure</p> <p>P10 select weld testing techniques to detect four different visual and two different internal weld defects to a relevant quality standard.</p>		

Essential guidance for tutors

Delivery

Delivery of this unit should use a combination of practical demonstrations and investigative assignments.

Ideally, learners will be given the opportunity to watch a range of welding processes. This could be through observation of a tutor-led demonstration which would preferably lead to hands-on experience of at least one process. Alternatively, industrial visits or videos/DVDs could be used to ensure that learners are exposed to a range of processes.

Observation in a practical setting will ensure that they are aware of the heat input required to fuse metals together. The effects of distortion could also be best illustrated in practical workshop sessions. Inspection of welds completed in the welding workshop will also have the advantage of providing specimens for use in the detection of weld defects.

Tutors should ensure that learners are aware of the hazards and safe working practices associated with the use of welding equipment and common hand tools before supervising such activities.

The use of appropriate visual aids will enable centres to deliver parts of the unit content that they may not have access to in a practical context. Commercially produced weld specimens containing known defects can be used to help ensure uniformity in the recognition of defects.

Where learners are employed in an engineering environment, assignments could be designed to link to welding activities in their workplace. The use of industrial visits can enhance learners' knowledge of processes carried out by local companies.

Centres should have access to the necessary facilities and equipment to allow learners to observe at least one destructive and one non-destructive weld test. Mechanical properties such as hardness, ductility and tensile strength can be compared using simple equipment. Learners will require instruction in the safe operation of such equipment.

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.

Assessment

To achieve a pass grade, all the pass criteria must be met. The pass criteria P1, P2, P3 and P4 could be achieved by asking learners to select and describe functions and features of industrial applications of welding processes. Learners' responses could include both written and oral questioning. The requirement of four given applications should include both a main and an additional process as ranged by the unit content.

Achievement of P5 could be achieved by means of a written assignment. To enable learners to understand the effects of distortion it may be appropriate for them to participate in an associated practical task. This could involve measuring the angle between two plates (eg before and after the deposition of a tee fillet weld).

To achieve P6 a written assignment could be set in which learners are asked to consider two joints that are subjected to extremes of heat input due to the process parameters. One joint could be in thin metal, welded by a process with a high deposition rate (eg MAGS or laser), compared with a thicker metal welded using a slower deposition process (eg MMA or oxy-acetylene welding).

P7 could be met using a written assignment requiring learners to investigate treatments appropriate to one ferrous and one non-ferrous metal.

For P8, a written assignment could be used based on a range of factors and impurities known to affect the weldability and properties of metals.

A written task asking learners to describe any of the non-destructive and destructive tests as ranged in the content could be set for P9. There is an opportunity to set different procedures for different learners or to concentrate on areas familiar to those learners that are employed.

Criterion P10 could be achieved using a combination of practical assessments and research. Learners could either use welds produced in the welding workshop or commercially produced weld specimens with known defects, to correctly select appropriate weld testing techniques relevant to a given quality standard.

To achieve M1 learners would be expected to produce a written response based on the activities carried out to achieve P1, P2, P3 and P4. Tutors could design an assignment to ensure that learners cover the range of processes using both gas-shielded and flux-covered processes.

Assessment of M2 could be in the form of a written assignment, set as an extension to the activities used to meet criteria P6 and P7.

M3 could be assessed using a combination of written and oral questions based on the activities used to meet P9 and P10. Oral responses would be acceptable as long as they were properly recorded for verification purposes and also if they are not the sole source of evidence.

To achieve distinction criterion D1 learners need to compare and contrast two welding processes based on the work they did to meet P1, P2, P3, P4 and M1. They will need to give their reasons why one process is better than the other for the given application.

Assessment of D2 could be in the form of a written task relating to the responses given when achieving P9, P10 and M3. Learners would be expected to demonstrate their knowledge of not only the applications and operation of the weld testing technique, but also that of a given quality standard.

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

This unit can be linked to *Unit 22: Fabrication Processes and Technology* and *Unit 23: Applications of Welding Technology*.

Although the unit does not have any direct links with the Level 3 National Occupational Standards, it may contribute to the knowledge requirements for some aspects of the Level 3 NVQ in Fabrication and Welding.

Essential resources

Centres will require access to welding equipment to allow learners to observe at least one process, and weld testing facilities for at least one destructive and one non-destructive test.

Indicative reading for learners

Textbooks

Davies A C – *Science and Practice of Welding, Volume 1* (Cambridge University Press, 1993) ISBN 052143565X

Davies A C – *Science and Practice of Welding, Volume 2* (Cambridge University Press, 1993) ISBN 0521435668

Smith B – *Welding Practice* (Butterworth-Heinemann, 1995) ISBN 0340614064

Timings R – *Fabrication and Welding Engineering* (Newnes, 2006) ISBN 0750666919

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Staff should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Communication Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> researching welding processes and weld test procedures and describing methods of controlling the effects of distortion. 	<p>C3.2 Read and synthesise information from at least two documents about the same subject. Each document must be a minimum of 1000 words long.</p> <p>C3.3 Write two different types of documents, each one giving different information about complex subjects. One document must be at least 1000 words long.</p>
Problem solving Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> describing methods of controlling the effects of distortion. 	<p>PS3.1 Explore a problem and identify different ways of tackling it.</p>