Unit 31: Computer Aided Manufacturing

Unit code: A/600/0284

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners an understanding of the use of computers in modern manufacturing and how they are applied to product design and manufacture.

Unit introduction

An understanding of how computer aided manufacturing (CAM) systems operate within an engineering business is important for anyone thinking of a career in the design and manufacture of products.

This unit aims to develop an appreciation of the use of computer systems in a world-class manufacturing environment and how they are applied to product design and manufacture. Emphasis is placed on the need for a total approach to product development, in particular the interface between the various functions of the design and make process and the use of simultaneous engineering.

Learners will start by investigating how CAM systems are used to increase the profitability of a business by reducing manufacturing costs, improving quality and being more responsive to customer needs. This is followed by a look at how simultaneous engineering is used to bring together the many functions of a manufacturing business so that there is a team-based, multi-disciplinary approach to problem solving. Learners then investigate how simultaneous engineering can be used to meet the demands of a customer-driven economy where people expect an off-the-shelf service for customised products.

The unit also covers how newly designed components are modelled using three-dimensional CAD software so that their functionality can be assessed and any errors corrected before the machining process is simulated using CAM software. Cutting metal is expensive and getting it right first time is a crucial aspect of economic manufacture.

Learners will investigate how manufacturing processes can be automated by using industrial robots to move materials and components between the machine tools and the workstations that make up a flexible manufacturing system (FMS). Finally, learners will be given the specification for a component, use CAD software to design it and use CAM software to produce a set of instructions for downloading to a machine tool which could be used to make it.

Learning outcomes

On completion of this unit a learner should:

1 Understand the benefits of CAM and the significance of simultaneous engineering

2 Understand how the CAD/CAM interface operates and modelling is used to simulate the manufacturing process

3 Understand the use of industrial robots and flexible manufacturing systems in engineering

4 Be able to design a simple component and generate a programme for a CNC machine using a CAD/CAM software package.

Unit content

1 Understand the benefits of CAM and the significance of simultaneous engineering

Benefits of CAM: increased profitability eg reduced machine set-up times, greater flexibility in terms of batch sizes, reduction in lead times, reduction of labour costs, lower unit costs, optimised use of cutting tools, production of complex shapes; improvements in quality eg elimination of human error, consistent accuracy; greater responsiveness to the requirements of the customer; competing in the world market place

Simultaneous engineering: parallel operation of tasks; multi-discipline team-based working eg marketing, design, modelling, rapid prototyping, manufacturing, development; time-based management eg integration of activities, lean manufacturing, total quality management (TQM), shorter development times, faster time to market, right first time, improved communication

2 Understand how the CAD/CAM interface operates and modelling is used to simulate the manufacturing process

CAD/CAM interface: CAD eg product design using industry-standard CAD software, modification of design ideas, production of working drawings; CAM eg generation of part programmes, scheduling of raw materials; specialised linking software eg edgeCAM, Autodesk Inventor/Esprit, SolidWorks; universal formats eg extensions (such as DXF, IGS, AI, EPS, PLT, NC), propriety formats (such as DWG, CDR, CDL, GE3, NC1, BMP, MSP, PCX, TIF)

Modelling and simulation: use of CAD/CAM software eg 3D modelling of the product, simulation of tool changing and toolpaths in the machining process, simulation of sequential manufacturing processes, rapid prototyping; benefits eg elimination of machining errors, reduction in scrap rates

3 Understand the use of industrial robots and flexible manufacturing systems in engineering

Robots: applications eg pick and place systems, product handling, product assembly, machine loading, safe operation, codes of practice (Health and Safety Executive HSG43, Provision and Use of Work Equipment Regulations); advantages eg consistency of performance, 24/7 continuous working, reduced cycle times; limitations eg high standard of maintenance required, precise programming needed, computer systems failure will cause breakdown, new products require complete reprogramming, certain processes still need a skilled operator, complex and expensive equipment

Flexible manufacturing systems: benefits eg production of different parts without major re-tooling, efficient production of customised products, ease of responding to changes in product mix and production schedules, lean manufacture; processing machines eg CNC machine tool, machining centre, flexible cell, welding station, assembly; loading and unloading systems eg material handling, pick and place, fixed position robot, conveyors; coordination of the working schedule eg process monitoring by computer, optical recognition, inspection, total quality management (TQM)

4 Be able to design a simple component and generate a programme for a CNC machine using a CAD/CAM software package

Using CAD/CAM software: hardware eg CAD workstation, data storage, hard-copy equipment, network system to download data to machine tools; software eg 2D/3D CAD, databases, single-component CAD files, part programming, macros, cutter path simulation; post-processing eg transfer of post-processed files/data between systems, download to machine tools, inspection and quality management

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 explain how the use of a CAM system can benefit the operation of a manufacturing business [IE3, IE4]	**M1** describe the criteria used to assess the viability of introducing CAM and simultaneous engineering systems into a business	**D1** analyse a current low-technology manual manufacturing system for suitability to move to a CAM environment.
P2 describe the strategies used in simultaneous engineering	**M2** explain the cost benefits of moving from low-technology manual manufacturing to high-technology automated manufacturing	
P3 explain how the interface between design and manufacture can be integrated using suitable CAD/CAM software	**M3** explain the use and operation of robots to move parts between workstations in a flexible machining system.	
P4 explain the reasons for carrying out modelling of a component and simulation before actually cutting metal		
P5 describe the applications, advantages and limitations of industrial robots [IE4]		
P6 explain why a flexible manufacturing system will produce productivity gains for a business deploying a range of processing machines, loading and unloading systems and coordinated work schedules [IE4]		

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:**
P7 use appropriate software to design a simple component and produce a part program which could be post-processed and used to manufacture it on a CNC machine. [IE4, CT1, CT5]		

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

The four learning outcomes are strongly linked and the delivery strategy used should ensure that these links are emphasised.

There are close links between this and several other units within the qualification; this needs to be taken into account when designing schemes of work, learning activities and assignments. The unit is best placed in the second year of a course as it does require a reasonable level of computer proficiency and knowledge of manufacturing processes.

Learners need to gain a coherent view of the manufacturing process within an engineering context. They need to understand that for a business to remain profitable it is crucial that an effective manufacturing system is in place. It should be impressed on learners that success in the marketplace can be achieved only if manufactured products are fit for purpose, marketable and meet customer requirements.

To establish the context of CAM, tutors could begin with a general overview of how computers can be used to plan, manage and control the operation of businesses involved in the manufacture of engineered products. This then leads into learning outcome 1. In order to deliver the unit content effectively, learners would benefit from the use of case studies based on companies which successfully use CAM and simultaneous engineering.

To effectively cover learning outcome 2, learners would benefit from visits to the design department of an engineering company to find out about the systems in place and the links between design and manufacture. If learners are employed, it may be useful to base their research on their own company, if appropriate.

To achieve learning outcome 3 learners must investigate the use of industrial robots and flexible manufacturing systems in engineering. The intention here is not to get bogged down in looking at the detailed operating principles of this type of equipment as this is done in other units. Emphasis should be placed on the safe operation of robot devices and the selection of a particular type of robot to carry out a specific task. Learners need to be guided both here and when designing the assignment that covers P5 – specific situations which require the use of a robot. P5 is written as a plural and a sensible number of applications would be three. These need to be carefully chosen so that a range is considered (eg a pick-and-place system for assembling components onto a circuit board, loading of raw material into a machine tool, moving components between stations in a machining cell). Some of the evidence for learning outcome 3 may be best found by carrying out a case study based on a visit to local industry.

When delivering learning outcome 4 it should be remembered that some learners will have limited CAD experience. It is not the intention of this unit to make them experts in the use of CAD or CAM software. Additionally, they may have limited or no knowledge of CNC machining. To meet the learning outcome they should only be required to look at a very simple component suitable for manufacture on a three-axis machine. A rectangular block with radiused corners and a simple profile which is end milled into its top surface would be perfectly acceptable. A key fob with the initials of the learner machined into its surface will provide enough scope to achieve grading criterion P7. It should be noted that there is no requirement for the component to be manufactured, but where a centre does have the necessary equipment it will add interest for learners if they are able to see their design being machined.

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 and scheme of work • overview of how computers can be used to help plan, manage and control the manufacture of products • explain the benefits of using CAM in terms of profit, quality and ability to respond to customer and market needs • explain the use of simultaneous engineering and how it is used to reduce lead times. *Small-group study:* • use of case studies to research the use of CAM and simultaneous engineering.
Preparation for and carrying out **Assignment 1: Using CAM and Smart Systems in an Engineering Business** (P1, P2, M1)
Whole-class teaching: • explain the use of CAD in terms of its industrial use modifying and producing designs and working drawings. Explain the use of CAM for generating part programmes and scheduling materials • explain the use of linking software and universal and propriety formats • describe and demonstrate the use of CAD/CAM software and explain the benefits. *Industrial visit:* • visit to design department of local engineering company to view the links between CAD and CAM through the design and manufacturing process.
Preparation for and carrying out **Assignment 2: CAD/CAM Interfacing** (P3, P4, M2)
Whole-class teaching: • explain the use and applications of robots in the modern manufacturing industry • discuss the benefits and limitations of using robots • explain the benefits of using flexible manufacturing systems • describe the use of processing machines, loading and unloading systems and the coordination of the working schedule.
Preparation for and carrying out **Assignment 3: Industrial Robots and Flexible Manufacturing Systems** (P5, P6 and M3)
Whole-class teaching: • explain and demonstrate the use of CAD hardware and software for producing simple component designs and programs for their manufacture. *Learner practical activities:* • practise using CAD/CAM software to design components and part programs for CNC machines.
Preparation for and carrying out **Assignment 4: Using CAD/CAM Software** (P7)
Preparation for and carrying out **Assignment 5: Evaluating the Suitability of a CAM Environment** (D1)
Feedback on assessments, unit review and evaluation.

Assessment

Assessment of this unit could be through five assignments.

It is suggested that the first assignment covers P1 and P2, with learners being asked to support their thoughts with evidence taken from published case studies relating to well known companies (eg Toyota and Airbus Industries). It is important that learners demonstrate a good understanding of the reasons why, in a customer-driven, global market environment, a manufacturing company can survive only if it uses smart systems in the operation of its business. There is scope to expand this first assignment to include M1. A visit to an engineering company which has moved to using world class manufacturing systems would be a good way of gathering research information.

Grading criteria P3 and P4 complement each other and can be assessed through a second assignment. Learners should not be expected to demonstrate proficiency in the use of CAD/CAM software. A visit to a company to look in detail at the way a component is designed and manufactured would be a useful way to gather evidence. This could involve talking to a CAD designer and being shown the processes of design, modelling and manufacturing. There is scope to include M2 in this assignment.

A third assignment could cover grading criteria P5 and P6. Thought needs to be given to structuring the tasks so that learners restrict themselves to just the applications of robots and do not get sidetracked into explaining in great detail their operating principles. As recommended earlier, restricting learners to three applications will be enough to produce valid evidence to meet P5. As criterion M3 builds on P5 and P6 it can be a part of the third assignment.

The fourth assignment could be a practical activity covering P7. The component to be designed should be kept very simple as learners are not required to prove competence in using high-level design skills. As suggested earlier, a simple embossed key fob design which uses the line, arc, diameter and text commands in its design will produce a profile sufficiently complex for a part program and its post-processing. Screen prints could be used as evidence of tool path simulation, supported by witness statement or observation records of learner performance.

M1 builds on P1 and P2. To achieve it there should be evidence of thought having been given to the pressure on design and manufacturing engineers to optimise resources and use business improvement techniques.

M2 links into P3 and P4 but also draws on knowledge from P1 and P2. Explanations should be supported by examples taken from real companies which have successfully moved from low-technology to high-technology manufacturing systems and might include figures for the amounts of cost savings achieved.

M3 requires a greater understanding of how a robot operates and will build on knowledge gained when achieving P5 and P6. Evidence presented should be at a systems (black box) level and the assignment tasks should not be asking for detailed knowledge about, for example, the internal workings of a specific drive or sensor unit within the robot. Tasks based on a scenario which relates to a specific machining system could be used to generate evidence. Learners are not expected to explain how the actual machining functions operate because the criterion relates only to the handling and moving of parts.

Grading criterion D1 builds on content covered in learning outcomes 1, 2 and 3 and could be a very detailed piece of writing based around a scenario. For this reason it might be best covered by a fifth assignment. Learners could assume the role of a manufacturing engineer who has been tasked with presenting proposals to senior management on the implications and suitability of moving from low-technology manufacturing to a CAM environment. There are a lot of well documented examples of how this has been achieved successfully by well-known companies and care must be taken to ensure that what learners present as evidence is authentic. Where appropriate, employed learners should be given the option of analysing their own company.

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 and M1	Using CAM and Smart Systems in an Engineering Business	Learners have been asked by their employer to produce a report on the benefits of using CAM and the strategies used in simultaneous engineering.	A written assignment for which learners produce a report detailing the benefits of CAM to a modern manufacturing business and the use of simultaneous engineering.
P3, P4 and M2	CAD/CAM Interfacing	Learners need to provide an explanation of how CAD/CAM software is integrated and the reasons for simulation for a local manufacturer considering moving over to CAM systems.	A written assignment for which learners produce a report into the interface between design and manufacture and the purpose of simulation. A further task would require learners to explain the cost benefits of modern manufacturing systems.
P5, P6 and M3	Industrial Robots and Flexible Manufacturing Systems	Learners have been asked by their employer to produce a report on the benefits and limitations of using industrial robots and the use of flexible manufacturing systems.	A written assignment consisting of tasks requiring learners to discuss the applications of industrial robots and explain why a flexible manufacturing system can produce gains for a business.
P7	Using CAD/CAM Software	Learners need to design a component for a client and produce a part program for its manufacture.	A practical assignment for which learners will need to design a component and produce the part program necessary for its manufacture. Evidence is likely to be supported by screen prints and tutor observation records.
D1	Evaluating the Suitability of a CAM Environment	Learners have been asked by senior management to investigate the implications and suitability of moving from low-technology manufacturing to a CAM environment.	A written assignment for which learners produce a report detailing the suitability of moving to a CAM system for a low-technology manual system.

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
	Part Programming CNC Machines	Engineering Design
		Computer Aided Drafting
		Computer Numerical Control of Machine Tools
		Manufacturing Planning

Essential resources

- Centres will need to give learners access to 2D/3D commercial CAD software and CAM software which integrates with the CAD package used for designing.
- Extracts from appropriate standards and legislation and access to industry-standard CNC machining centres and flexible manufacturing systems are also needed.

Employer engagement and vocational contexts

The use of real engineering information, documentation and materials should underpin the delivery and assessment of this unit. Much of the work could be set in the context of learners' work placements or be based on the relevant activities of local employers. Site and company visits could provide opportunities to relate the theoretical and documentation aspects of electrical installations.

Further information on employer engagement is available from the organisations listed below:

- 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

Amiriouche F M – *Principles of Computer Aided Design and Manufacturing* (Prentice Hall, 2004)
ISBN 0130646318

Colestock H – *Industrial Robotics: Selection, Design and Maintenance* (TAB Books Inc, 2004)
ISBN 0071440526

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	exploring the use of CAM systems from different perspectives to identify benefits analysing and evaluating information relating to CAM, industrial robots and flexible manufacturing systems, judging its relevance and value
Creative thinkers	generating ideas and exploring possibilities when using software to design a simple component and produce a part program for its manufacture trying out alternatives or new solutions and following ideas through when using software to design a simple component and produce a part program for its manufacture.

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 reviewing progress and acting on the outcomes
Team workers	collaborating with others when working in small groups on formative practical activities
Self-managers	organising time and resources and prioritising actions.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	generating a programme for a CNC machine using CAD/CAM software
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the use of CAD/CAM systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining the use and benefits of CAM systems in manufacturing.