Unit 90: Helicopter Gas Turbine Engines, Transmissions, Rotors and Structures

Unit code: M/600/7345
QCF Level 3: BTEC Nationals
Credit value: 10
Guided learning hours: 60

Aim and purpose

This unit will develop learners' knowledge and understanding of helicopter turbo-shaft engines, transmissions, rotors and structures.

Unit introduction

This unit will broaden learners' knowledge and understanding of helicopter engines and transmission systems and how single rotor and twin rotor systems interact for control and stability during flight. Learners will look at the construction of a turbo-shaft engine and the systems used to monitor its performance. They will analyse the component parts and arrangement of a helicopter power train, before looking at methods used to assemble and align helicopter structures. This unit will not only be of benefit to learners studying at BTEC National level, but also those following a modern apprenticeship in helicopter manufacture or maintenance, as well as those undergoing aircraft training with the armed forces.

Learning outcomes

On completion of this unit a learner should:

1 Know the principles and construction of a helicopter turbo-shaft engine

2 Understand the principles and construction of helicopter main and tail rotor transmission systems

3 Know about helicopter structures and their assembly methods and alignment techniques

4 Know about the function and construction of helicopter flight control systems.

Unit content

1 Know the principles and construction of a helicopter turbo-shaft engine

Arrangement and operation: constructional arrangement and operation of the turbo-shaft engine, mechanical engine control, electronic engine control and fuel metering systems (FADEC)

Engine monitoring systems: eg exhaust gas temperature (EGT), turbine temperature, engine speeds (N1, N2, Ng, Nf), oil pressure, oil temperature, fuel pressure (temperature and flow), engine oil system, engine fuel system

Principles: eg potential energy, kinetic energy, Newton's law of motion, Brayton cycle; compare relationships eg force, work, power, energy, velocity, acceleration

Modules of a turbo-shaft engine: inlet eg compressor inlet ducts, effects of various inlet configurations, ice protection; compressors eg axial, centrifugal and mixed, constructional features, operating principles, applications, fan balancing; causes and effects of compressor stall and surge; methods of air flow control eg bleed valves/bands, variable inlet guide vanes, variable stator blades; combustion section eg constructional features, principle of operation; turbine section eg operation and characteristics of different turbine blade types, disc attachment, nozzle guide vanes, causes and effects of turbine blade stress and creep; exhausts eg constructional features and principles of operation; free power turbine and main engine output shaft and gearbox arrangement and principle of operation

2 Understand the principles and construction of helicopter main and tail rotor transmission systems

Rotor operation: types of main rotor head (rigid, semi-rigid, fully articulated); gearboxes; main rotor; intermediate/angle; tail rotor; transmission systems; clutches; free wheel units (such as ramp and roller and spragg); rotor brake drive shafts (such as main engine output, intermediate and tail rotor drive)

Components: used to obtain main and tail rotor drive eg ancillary equipment (tail rotor hub, gimbal ring/ carden ring, flexible couplings), systems for fold and spread of main rotor, systems for tail pylon fold, ACSRs, bearings (radial, axial), seals (static, dynamic), lubrication types and applications

3 Know about helicopter structures and their assembly methods and alignment techniques

Helicopter structures: structures eg monocoque, semi-monocoque, truss; constructional features eg ties, struts, stringers, longerons, frames, formers, bulkheads, sub division of airframe; classification of structure eg primary, secondary, tertiary

Assembly: assembly methods eg types of fasteners, jigs and fixtures, airframe rigging, symmetry checks; alignment techniques

4 Know about the function and construction of helicopter flight control system

Function of flight control systems: cyclic control eg rigging, operation, swashplate; collective control eg rigging, operation; yaw control eg anti-torque, tail rotor, NOTAR technology, bleed air, main rotor heads achieving control eg features (such as design, operational), blade dampers (such as function, construction), rotor blades (such as construction, attachment), tail rotor blades (such as construction, attachment), trim control (such as fixed stabilisers, adjustable stabilisers), system operation (such as manual, hydraulic, electrical, fly by wire)

Construction of flight control systems: components eg cables and pulleys, turnbuckles, brackets, levers, linkages, pivots, valves, micro-switches, locks, connecting rods, stops, jacks, dampers, yaw pedals, cyclic pitch lever, collective pitch lever, auto pilot systems, AFCS, series and parallel actuators, mixer units; types of controls and respective axes about which they provide control; collective, cyclic, yaw pedals, flying control components eg push pull tubes, torque tubes, bell cranks, gradient unit, control boosts

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 constructional arrangement and operation of a turbo-shaft engine	**M1** explain the working cycle of a turbo-shaft engine and identify the various modules, including the axial and centrifugal compressor and the reason for including a free power turbine	**D1** analyse two different helicopter transmission systems used to drive both the main and tail rotors and determine how speed, torque and power train alignment is achieved
P2 describe the function of engine control and fuel metering systems	**M2** explain the operation of a turbo-shaft engine lubrication and fuel system	**D2** carry out a real or simulated rigging operation on a helicopter main or tail rotor flying control system using the appropriate tools and manuals.
P3 identify four engine monitoring systems and describe the information each one is indicating	**M3** remove, examine, refit and align main and tail rotor transmission components in a real or simulated environment	
P4 state the principles of a turbo-shaft engine and compare relationships in the gas flow through the engine [IE1]	**M4** explain how airframe alignment is maintained during manufacture or repair and how a symmetry check is carried out.	
P5 describe the construction of the main components of a turbo-shaft engine		
P6 identify the three types of main rotor heads and describe the operation of a fully articulated head		
P7 describe the components used to obtain main and tail rotor drive and their arrangement on a typical helicopter		

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:**
P8 describe helicopter structures, their constructional features and classification		
P9 identify the assembly methods and alignment techniques used in helicopter structures		
P10 identify the three helicopter controls used during flight and describe how they achieve control about the three axes		
P11 identify the main components and types of controls and components used in the construction of flight control systems on a typical helicopter		

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

Delivery of this unit should be designed to give learners a thorough understanding of rotary wing aircraft engines, controls and airframes.

When delivering the unit content associated with aircraft engines tutors should concentrate on the turbo-shaft engine, as this is the most common engine in use on helicopters. The operation and control of the engine should be covered in sufficient detail that learners are aware of how power is taken from the engine along with the methods used to control and monitor the operation of the engine. Learners will need to be given access to gas turbine engines so that the construction of components and sections can be examined and explored. Single and double or even triple engine layouts should be considered when looking at the control and monitoring of engines.

The main rotor controls for a single main rotor helicopter have many common components. The general layout of the controls and the subtle differences between the spider arms, swashplates and non rotating components should be examined so that learners will feel confident when faced by either type or system. There should be sufficient access to main and tail rotor controls on a helicopter to allow real or simulated rigging procedures to be undertaken on them. These should also be used to demonstrate how lift is generated and manipulated to give directional flight and the interaction required from all three controls to gain controlled flight.

The layout of the transmission system from the engine(s) to the main and tail rotor gearboxes and to the blades should be investigated by comparing two different helicopters with sufficiently differing layouts. For this reason it may be preferable to use a single engine and a twin engine helicopter where possible. One of the examples used should be available for real or simulated work so that fitting work on the systems may be carried out. This should also ensure that one type of main rotor head will be available for examination so that learners can determine how the final run of the control system is connected to the blades, how lift and thrust forces produced are carried back through to the airframe and how undesirable forces are resolved. All aspects of the transmission system (power train) should be explored so that the student will develop a thorough understanding of the requirements of the systems.

The construction of the airframe as a support for the transmission and flight control systems along with its purpose of carrying a payload should be considered holistically to integrate all the system requirements. Emphasis should be placed on the load carrying ability of the various airframe constructions and the need to fit transmission components and flying control components in positions that ensure the integrity of the systems. The interaction of the airframe, control systems and transmission systems should be stressed to reinforce the necessity of design with learners. The layout and construction of the main rotor gearbox due to the interaction of the control system used or vice-versa and the necessity of flexibility within the transmission system (power train) and rigidity within the control system should be explored. This will enable the students to understand the complexity of the helicopter as a fully integrated collection of independent systems.

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 assessment strategy • in an aircraft environment, explain and familiarise learners with helicopters, engines, transmissions (power trains), flying controls and structures • in an aircraft maintenance environment demonstrate the constructional arrangements of engines and differing engine controls (FADEC) • explain construction of engine monitoring systems, EGT, N1, N2, EGT, Ng, Nf and engine oil and fuel systems • explain Newton's law, Brayton cycle, force, work, power, energy and velocity of gas flows • compare compressor designs, ice protection, stalling and surging and airflow control, variable inlet guide vanes, bleed bands etc • compare combustion designs, principles and turbine designs, stress and creep. Examine gearbox arrangements. *Individual activity:* • investigate (using manuals and related documents) engine layout and construction comparing different engines where available.
Prepare and carry out **Assignment 1: Helicopter Turbo-shaft Engines** (P1, P2, P3, P4, P5, M1, M2)
Whole-class teaching: • identify and compare different rotor head designs and features. Examine and compare gearboxes and powertrains, speeds of shafts and rotors • a real or simulated drivetrain component removal, fit and installation. *Group activity:* • view a helicopter to examine powertrains and various components within transmissions and gearboxes.
Prepare for and carry out **Assignment 2: Helicopter Rotor Transmission Systems** (P6, P7, M3, D1)
Whole-class teaching: • identify helicopter structures, constructional features and explain classification of structures • explain the assembly methods and alignment techniques used for the construction of helicopter structures *Industrial visit:* • view helicopter structure assembly methods.
Prepare for and carry out **Assignment 3: Helicopter Structures** (P8, P9, M4)

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • demonstrate the three flying controls and functionally move all controls to reflect the actions on the rotors • explain use of inverted airfoils (elevators) to aid reduction of airframe drag and re-positioning of tail rotor gearbox angle to improved C of G range and overall lift component, eg Blackhawk • detail and identify control components within flying controls and how they interact with other controls. *Individual activity:* • in a real or simulated environment carry out rigging operations on main or tail rotor controls using appropriate tools and manuals.
Prepare for and carry out **Assignment 4: Helicopter Flight Control Systems** (P10, P11, D2)
Feedback on assessment and unit review.

Assessment

This unit could be assessed through the use of four assignments incorporating a practical exercise or simulation.

The criteria covering learning outcome 1 (P1, P2, P3, P4, P5, M1 and M2) are probably best assessed using a formal written assignment. This assignment would require learners to describe a turbo-shaft engine in terms of its layout and operation and the function and operation of the engine control and fuel metering systems (P1 and P2). They should then develop this to explain the full working cycle of the engine with reference to the engine modules and the free turbine (M1). They should include the gas flow relationships at all stages through the engine (P4), whilst considering lubrication systems (M2) and the monitoring systems employed on the engine (P3).

P5 is concerned with the physical layout of the engine in relation to its attachment to the first part of the transmission system and the free turbine take off position. Learners' descriptions will need to include inlet, compressor, combustion section, turbine section and exhaust components and free turbine and main engine output gearbox arrangements.

This can link to learning outcome 2 (P6, P7, M3 and D1) which is concerned with the transmission of the power from the engine to the main and tail rotor hubs and how the transmission is installed and aligned on the helicopter. Evidence for this outcome is likely to come through a written assignment. Learners will need to be shown the three types of main rotor head but should concentrate on the fully articulated head (P6) as this is the more complex and requires a greater amount of servicing. The description given for P7 should include any relevant ancillary systems, systems for rotor spread and fold, bearings, seals and lubrication.

An examination of more than one helicopter type will be necessary for learners to compare transmission (powertrain) layouts and power transmission (D1). Practical work or simulated work on at least one helicopter type will allow learners to display their ability to fit and align various transmission components as necessary (M3).

The main rotor head construction will provide a link to the control systems at learning outcome 4 and the fitting of most of the transmission components will provide a link to learning outcome 3.

Learning outcome 3 (P8, P9 and M4) should be integrated with the other outcomes to enable learners to understand the structural requirements and classification of the airframe (P8), especially at the mounting points for the engine, transmission components and flying control components. Learners need to understand alignment requirements and methods used (P9) to achieve the correct orientation of aerodynamic surfaces and transmission components and be able to explain how this is achieved and checked (M4) during manufacture or repair.

Learning outcome 4 is intended to cover the construction, layout and operation of the main flying controls rather than the aerodynamics of flight, apart from the basic directional control about the flight axes (P10). Learners will be able to cover the main components and types of control (P11) by means of a formal assignment that investigates the layout of the control system on one aircraft type. A sufficiently complete control system must be available to allow learners to carry out practical or simulated rigging activities (D2). This does not have to be a full rig of the flying controls but should reflect the amount of rigging that is required after various maintenance procedures.

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, P4, P5, M1, M2	Helicopter Turbo-shaft Engines	A written explanation of the principles of the turbo-shaft engine.	Written response to set tasks.
P6, P7, M3, D1	Helicopter Rotor Transmission Systems	A formal written assignment and a practical/simulated task.	Written response to set tasks with a practical task for M3. Witness statements will be required for practical task.
P8, P9, M4	Helicopter Structures	A formal written assignment where access to a helicopter will be most beneficial.	Written response to set tasks.
P10, P11, D2	Helicopter Flight Control Systems	A formal written (assignment) and practical/simulated tasks where access to a helicopter or part control system is required.	Written response to set tasks with a practical task for D2. Witness statements will be required for practical work.

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:

Level 1	Level 2	Level 3
		Principles of Helicopter Flight and Aerodynamics

Essential resources

Access to the following resources is considered essential to meet the learning outcomes:

- a range of helicopter components, particularly power plants, transmission (powertrain) components, main rotor heads and tail rotors
- relevant data books and manufacturers' specifications, aircraft publications and manuals and quality control procedures
- real or training centre helicopter, in a real or training helicopter maintenance environment.

Employer engagement and vocational contexts

Liaison with employers would prove to be of immense benefit to centres, especially if they are able to offer help with the provision of resources that may not be available at the centre. Visits to military or civil aircraft maintenance, overhaul or repair facilities, to view maintenance activities on live aircraft would also be of great benefit to learners.

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. 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

Kroes M, Watkins W and Delp F – *Aircraft Maintenance and Repair* (McGraw Hill, 2007) ISBN 0077231546

Wagtendonk W J – *Principles of Helicopter Flight* (Aviation Supplies, 2007) ISBN 1560276495

Other publications

Air Publications – 101 Series of manuals and aircraft engineering publications (Military)

ATA 100 Series, specialist publications sanctioned by EASA (European Aviation Safety Agency)

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	identifying questions to answer and problems to resolve when comparing the relationships of pressure, temperature and velocity.

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.

Functional skills – Level 2

Skill	When learners are ...
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating helicopter engines, transmissions, rotors and structures
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing the function and operation of helicopter engines, transmissions, rotors and structures.