Unit T25: Aircraft Hydraulic Systems Design and Performance

Unit code:	T/504/0126
QCF level:	6
Credit value:	15

Aim

The aim of this unit is to give learners an understanding of the principles that underpin hydraulic system design. Learners will apply them to the analysis and assessment of performance of aircraft hydraulic power and associated integrated systems.

Unit abstract

As aircraft have increased their operating speeds and have grown in size and complexity, the need for more power to operate, for example, flight controls and landing gear, has also grown. These very high power requirements can be met in a number of ways by utilising electrical, pneumatic or hydraulic power supply systems. All these power supply mediums have relative advantages and disadvantages and they may be utilised to best effect by adopting a modern integrated systems approach.

This unit first considers the underpinning principles on which the design of hydraulic fluid power circuits depend in order to meet specified service requirements. The case for hydraulic power and associated systems in aircraft is then considered, with an overview given of the aircraft system design and performance parameters needed to ensure safe, reliable and efficient aircraft hydraulic systems operation in both normal and emergency situations. The underpinning fluid theory is then used to analyse typical hydraulic power supply systems for both commercial and military aircraft, with special attention being paid to the design parameters and performance of the components within these systems. Finally, the design and performance of representative aircraft alighting gear and power flying control actuation systems, are assessed.

Learning outcomes

On successful completion of this unit a learner will:

1 be able to design hydraulic fluid power circuits to meet specified service requirements

2 understand the design requirements for the safe operation and performance of aircraft hydraulic systems

3 be able to analyse the design and performance of aircraft hydraulic power supply systems and their components

4 be able to assess the design and performance of aircraft landing gear and power flying control actuation systems.

Unit content

1 Be able to design hydraulic fluid power circuits to meet specified service requirements

Fluid power principles: fluid properties of mineral- and ester-based hydraulic oils, eg fluid pressure, fluid compressibility effects, viscous force and flow, viscosity variation and temperature, laminar flow, turbulent flow; fluid system work, energy and power parameters, eg system loads, service requirements, continuity and energy equations; pressure loss estimates in straight pipes and fittings, eg use of Darcy formula, friction factor, Moody diagrams

Pump and motor circuit design: pump design characteristics, eg fixed/variable displacement, capacities, operating pressures, volumetric efficiency, mechanical efficiency, flow control, pressure control, pressure and power matching; motor design characteristics, eg rotary motor power requirements, sizing, motor system performance, reversal control, speed control, torque control; design and performance evaluation of pump and motor circuits, use of computer software

Linear actuator circuit design: actuator design characteristics (types, sizing, piston buckling, dynamic braking, effects of load change); fluid storage, eg reservoirs, accumulators, sizing, emergency provision; actuator control circuitry, eg flow control (such as directional control valves, restrictor valves, bypass valves), pressure control (such as relief valves, reducing valves, counterbalance valves); design and performance evaluation of linear actuator circuits, use of computer software

2 Understand the design requirements for the safe operation and performance of aircraft hydraulic systems

Hydraulic system safety requirements: standards, eg JAR/FAR/CS 23, 25, 27, 29, MOD standards, MIL-HDBK-217, design codes; system design implications, eg failure mode considerations, failure criticality, redundancy provision (multiple centralised power systems, differing types of power source, system segregation, multiple control channels)

Power source design provision: mechanical, eg engine driven pumps (EDP), power transfer units (PTU); electrical, eg AC and DC motor pumps, electrically driven power packs; pneumatic (bleed air turbine driven pump, ram air turbine driven pump, accumulators)

Hydraulic systems design requirements: design requirements, eg for landing gear (such as extension/retraction, steering, braking), for primary flight controls (such as ailerons, rudder, elevators, canards), for secondary controls (such as flaps, slats, spoilers, airbrakes), for utilities (such as cargo doors, ramps, passenger stairs, bomb bay doors, canopy actuation)

3 **Be able to analyse the design and performance of aircraft hydraulic power supply systems and their components**

Aircraft hydraulic power supply systems: initial design parameters (pressure, flow rate, criticality (vital, essential, ancillary services, loading, duty cycle)); required system provision (for emergencies, oil conditioning, storage, heat dissipation, loading, power); power supply component selection and system design architecture to meet provision requirements, eg pump(s), power pack(s), linear actuators, rotary actuators, motors, reservoir(s), heat exchanger(s), accumulator(s), filters

Aircraft hydraulic power system components: required component design parameters for eg pump/power pack, reservoirs, filtration equipment, pressure, temperature and flow control components; pressure control component performance (orifice theory, restrictor theory, relief valve orifice characteristics, flow and force considerations); flow and directional control component performance (pressure-compensated flow control, modulating and electro-hydraulic flow control valves, directional control valves)

4 **Be able to assess the design and performance of aircraft landing gear and power flying control actuation systems**

Landing gear actuation system design: assessment of undercarriage and door hydraulic retraction systems, eg pressure, flow and directional control, sequencing (mechanical, hydraulic, electronic), normal and emergency operation provision; assessment of steering and braking systems, eg nosewheel steering, wheel alignment, single bogy and multiple bogy (motion control, differential braking, automatic braking, anti-skid control)

Power flying control system design: assessment of conventional actuation systems, eg modulating and electro-hydraulic flow control, mechanical and hydraulic servo-valve actuators, mechanical signalling, electrical signalling, integrated actuator power packs, multiple redundancy electro-hydraulic emergency provision; assessment and performance of fly-by-wire integrated systems, eg computer controlled electronically signalled hydraulic actuation, electro-hydrostatic actuators, electro-mechanical actuators, fly-by-wire flight control systems integration

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 Be able to design hydraulic fluid power circuits to meet specified service requirements	1.1 Assess and compare the fluid properties of mineral- and ester-based hydraulic oils used in hydraulic power circuits 1.2 Determine fluid system work, energy and power parameters for specified service loads 1.3 Determine fluid pressure loss estimates through hydraulic system pipes and fittings 1.4 Determine pump and motor design characteristics to meet specified service loads 1.5 Evaluate design and performance parameters of fluid pump and motor circuits against specified service requirements 1.6 Evaluate, linear actuator, control circuitry and fluid storage design and performance parameters against specified service requirements
LO2 Understand the design requirements for the safe operation and performance of aircraft hydraulic systems	2.1 Investigate the safety standards and codes of practice for aircraft hydraulic systems safety and performance, assessing their influence on system design 2.2 Compare and contrast the design provision of combined mechanical, electrical and pneumatic power sources, between large passenger and military fast jet aircraft 2.3 Determine the system operating conditions under which power transfer units and ram air turbine driven hydraulic pumps are required for hydraulic system operation 2.4 Compare and contrast the design requirements for landing gear, elevator flight control and cargo door hydraulic systems, during normal and emergency situations

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO3 Be able to analyse the design and performance of aircraft hydraulic power supply systems and their components	3.1 Analyse an aircraft hydraulic power supply system, determining design parameters for specified system loading and duty cycle demands 3.2 Select suitable components to meet required aircraft hydraulic power supply system provision 3.3 Analyse system architectures, selecting the most efficient layout to meet specified system provision 3.4 Analyse aircraft hydraulic power supply; reservoirs, pumps and filtration equipment performance, determining design parameters to meet specified system provision 3.5 Analyse pressure, flow and directional control component performance, determining design parameters to meet specified system provision
LO4 Be able to assess the design and performance of aircraft landing gear and power flying control actuation systems	4.1 Compare the performance of two different landing gear retraction system flow control, sequencing and emergency provision, designs 4.2 Assess the differences between, motion control, steering, braking and anti-skid systems for military single bogy and civil multiple bogy aircraft landing gear configurations 4.3 Compare and contrast the differences in the design provision of conventional mechanically signalled and electrically signalled and hydraulically actuated power flying control systems 4.4 Compare the performance of modern computer controlled fly-by-wire integrated flight control actuation systems with their conventional system counterparts

PD031360 – Edexcel BTEC Level 6 Diploma specification in Engineering –
Issue 1 – May 2012

Guidance

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

The learning outcomes in this unit are linked closely with:

Level 4	Level 5	Level 6
Unit 87: Construction and Operation of Aircraft Fluid Systems	*Unit 88: Principles and Applications of Aircraft Fluid Systems*	*Unit T7: Modelling and Simulation*

The content of this unit has been designed and mapped against the Engineering Council's current learning outcomes for IEng accreditation. The completion of the learning outcomes for this unit will contribute knowledge, understanding and skills towards the evidence requirements for IEng registration.

See *Annexe B* for mapping of the Edexcel Level 6 units to IEng programmes.

Essential requirements

Learners will need access to hydraulic simulation software to meet the unit outcomes. Suitable simulation and modelling packages include (but are not restricted to) Mathworks, 'MATLAB/Simulink SimHydraulics toolbox', 'Flowmaster V7 Hydraulics' and/or 'LMS Imagine Lab AMESim with hydraulic components library'.

Delivery

The learning outcomes are best delivered in the numerical order they appear in the unit, using a variety of teaching techniques, including the use of computer simulation and modelling software. Formal input from the tutor is likely to be through lectures, tutorials and structured visits. Organisations where the design, modelling, manufacture and testing of aircraft hydraulic systems and components take place will be useful to enhance learning.

Assessment

The unit may be best assessed through a combination of investigative assignments (such as computer simulation exercises) and formal written assessments. They will need to be sufficient to meet the unit outcomes, external examiner requirements and centre quality standards.

Resources

Textbooks

Chapple P J – *Principles of Hydraulic Design* (Coxmoor Publishing Co, 2008) ISBN 978-1901892154

Gotz W – *Hydraulics, Theory and Applicati*ons (Bosch Automation, 1998) ISBN 978-3980592536

Manring N – *Hydraulic Control Systems* (John Wiley & Sons, 2005) ISBN 978-0471693116

Moir I and Seabridge A – *Aircraft Systems:Mechanical, Electrical and Avionics Subsystems Integration* (Wiley-Blackwell, 2008) ISBN 978-0470059968

Neese W – *Aircraft Hydraulic Systems* (Krieger Publishing Co, 1991) ISBN 978-0894645624

Website

www.bfpa.co.uk	The British Fluid Power Association (BFPA) produces several useful publications on aspects of hydraulic systems design.

