

AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

HELICOPTER AERODYNAMICS STRUCTURES AND SYSTEMS

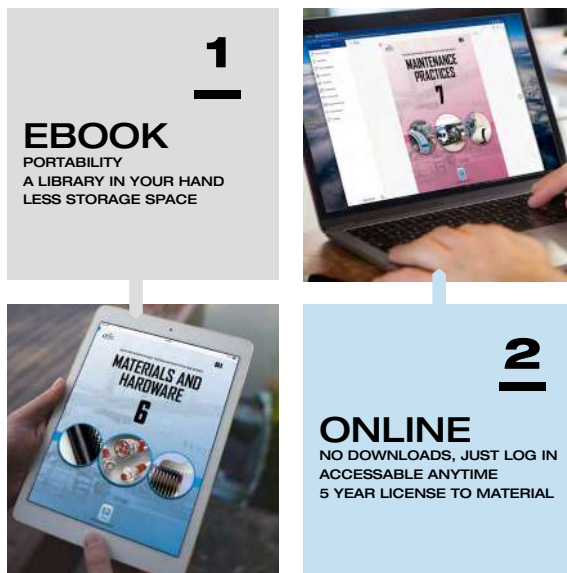
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Special thanks to our instructors, contributors, and authors

Authors - Laurence Peyrebrune and Dominique Couture

Contributor - Peter A. Vosbury

Layout and Design by Michael Amrine

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VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2016.01	Module creation and release.
002	2025.04	Regulatory update for EASA 2023-989 compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 002 are:

- 12.7.2 *Test Equipment For Avionics* - Added topic.
- 12.10 *Portable Fire Extinguishers* - Added topic.
- 12.12 *Servicing Hydraulic Systems* - Added topic.
- 12.16 *Pneumatic/Vacuum Systems* - Submodule deleted per EASA 2023-989.
- 12.18 *Printing, Structural Monitoring* - Content deleted per EASA 2023-989.

HELICOPTER AERODYNAMICS STRUCTURES AND SYSTEMS

Revision Log	iii
Measurement Standards	iv
Basic Knowledge Requirements	v
Part 66 Basic Knowledge Requirements	vi
Table of Contents	ix

12.1 THEORY OF FLIGHT — ROTARY WING AERODYNAMICS..... 1.1

Historical Perspective	1.1
Introduction To Theory of Flight	1.3
Terminology	1.4
Effects of Gyroscopic Precession	1.6
Torque Reaction and Directional Control	1.6
Torque Reaction	1.6
Directional Control	1.7
Dissymmetry Of Lift, Blade Tip Stall	1.7
Vertical Flight	1.7
Forward Flight	1.8
Translational Lift	1.8
Dissymmetry Of Lift	1.8
Translating Tendency and Correction	1.9
Coriolis Effect And Compensation	1.9
Coning	1.9
Coriolis Effect	1.9
Vortex Ring State, Power Settling, Overpitching	1.10
Vortex Ring State/Power Settling	1.10
Overpitching	1.10
Autorotation	1.10
Hovering Autorotation	1.11
Ground Effect	1.11
Submodule 1 Practice Questions	1.13
Submodule 1 Practice Answers	1.14

12.2 FLIGHT CONTROL SYSTEMS (ATA 67)2.1

Introduction	2.1
Cyclic Control	2.1
Collective Control	2.2
Throttle Control	2.2
Correlator	2.3
Governor	2.3
Swashplate	2.3
The Cyclic Movement And The Swashplate	2.3
The Collective Movement And The Swashplate	2.3
Yaw Control: Anti-Torque Control, Tail Rotor, Bleed Air	2.4
Anti-Torque Control, Tail Rotor	2.4
The Tail Collective Hinge	2.4
The Tail Flapping Hinge	2.5
The Tail and Pedal Connection	2.5
Different Solutions	2.5
The Fenestron Solution	2.6
The Bleed Air NOTAR System	2.7
Main Rotor Head: Design And Operation Features	2.7
Fully Articulated Rotor Systems	2.7
Semi-Rigid Rotor Systems	2.9
Rigid Rotor Systems	2.9

Bearingless Rotor Systems	2.10
Blade Dampers: Function And Construction	2.10
Hydraulic Damper	2.10
Multiple Disk Damper	2.11
Elastomeric Damper	2.11
Rotor Blades: Main And Tail Rotor Blade Construction And Attachment	2.11
Main And Tail Rotor Blade Construction And Attachment	2.11
Wooden Rotor Blades	2.11
Metal Rotor Blades	2.11
Composite Rotor Blades	2.12
Blade Attachment	2.12
Tail Rotor Blade Construction And Attachment	2.13
Blade Construction	2.13
Blade Attachment	2.13
Fenestron Tail Rotors	2.14
Fenestron Blade Construction	2.15
Fenestron Blade Attachment	2.15
NOTAR Type Anti-Torque Rotor	2.15
NOTAR Blade Construction	2.15
NOTAR Blade Attachment	2.16
Trim Control, Fixed And Adjustable Stabilizers	2.16
Vertical And Horizontal Stabilizers	2.16
System Operation: Manual, Hydraulic, Electrical And Fly-By-Wire	2.17
Manual Operation	2.17
Hydraulic Operation	2.17
Electrical Fly-By-Wire Operation	2.17
Stability Augmentation System (SAS)	2.17
SAS Components	2.17
SAS Operations	2.18
Artificial Feel	2.18
Friction	2.18
Elastic Rod	2.18
Hydraulic Damper	2.19
Balancing And Rigging	2.19
Rods	2.19
Transmission Unit	2.19
Relay	2.20
Balancing	2.20
Bellcrank	2.20
Rigging	2.20
Submodule 2 Practice Questions	2.25
Submodule 2 Practice Answers	2.26

12.3 BLADE TRACKING AND VIBRATION ANALYSIS (ATA 18)3.1

Introduction	3.1
Vibration Types	3.1
Imbalance	3.2
Track	3.2
Ground Resonance	3.2
Vibration Reduction Methods	3.2
Amplitude Reduction	3.2
Vibration Opposition	3.2
Static And Dynamic Balancing	3.3
Static Balancing	3.3

TABLE OF CONTENTS

Dynamic Balancing	3.3	Drains	5.6
Rotor Alignment	3.4	Ventilation	5.6
Main Rotor And Tail Rotor Tracking	3.4	System Installation Provisions	5.6
Submodule 3 Practice Questions	3.7	Lightning Strike Protection Provisions	5.7
Submodule 3 Practice Answers	3.8	Bonding Procedures and Precautions	5.7
12.4 TRANSMISSION	4.1	Section B	5.7
Introduction: Power Transmission	4.1	Construction Methods of: Stressed Skin Fuselage, Formers, Stringers, Longerons, Bulkheads, Frames, Doublers, Struts, Ties, Beams, Floor Structures, Reinforcement, Methods of Skinning and Anti-Corrosive Protection	5.7
Gear Boxes, Main and Tail Rotors	4.1	Truss Type	5.7
Gear Boxes	4.1	Monocoque Type	5.8
Main and Tail Rotors	4.1	Bonded and Composite Construction	5.9
Clutches, Free wheel Units and Rotor Brakes	4.4	Formers, Stringers, Longerons, Bulkheads, Frames	5.9
Clutches	4.4	Doublers	5.9
Free Wheel Units	4.4	Struts and Ties	5.9
Rotor Brakes	4.4	Beams, Floor Structures, and Reinforcements	5.9
Tail Rotor Drive Shafts, Flexible Couplings, Bearings, Vibration Dampeners and Bearing Hangers	4.5	Skinning	5.9
Tail Rotor Drive Shafts	4.5	Anti-Corrosive Protection	5.9
Flexible Couplings	4.5	Pylon, Stabilizer, and Undercarriage Attachments	5.10
Bearings	4.5	Fuselage and Tail Structure	5.10
Bearings for Transmissions	4.5	Pylon	5.10
Maintenance of Bearings	4.5	Stabilizer	5.10
Vibration Dampers	4.6	Undercarriage Attachments	5.10
Hydraulic Damper	4.6	Seat Installation	5.11
Computer Controlled Dampers	4.6	Doors: Construction, Mechanisms, Operation, and Safety Devices	5.11
Bearing Hangers	4.6	Windows and Windscreen Construction	5.11
Submodule 4 Practice Questions	4.7	Fuel Storage	5.12
Submodule 4 Practice Answers	4.8	Firewalls	5.12
12.5 AIRFRAME STRUCTURES	5.1	Engine Mounts	5.12
Airworthiness Requirements for Structural Strength	5.1	Structure Assembly Techniques: Riveting, Bolting, Bonding ..	5.12
Certification Specification (CS) 27	5.1	Riveting, Bolting	5.12
Certification Specification (CS) 29	5.1	Bonding	5.12
Structural Classification, Primary, Secondary, Tertiary	5.2	Methods of Surface Protection: Chromating, Anodizing, Painting, And Cladding	5.12
Primary Structure	5.2	Anodizing	5.13
Secondary Structure	5.2	Chromating	5.13
Tertiary Structure	5.2	Painting	5.13
Fail Safe, Safe Life, Damage Tolerance Concepts	5.2	Cladding	5.13
Fail-Safe Concept	5.2	Surface Cleaning	5.13
Examples of Fail Safe Design Techniques	5.3	Exterior Aircraft Cleaning	5.13
Safe Life Concept	5.3	Snow and Ice	5.14
Damage Tolerance Concept	5.3	Salt Air Operating Environment	5.14
Zonal and Station Identification Systems	5.3	Acrylic Windows	5.14
Zonal System	5.3	Airframe Symmetry: Methods of Alignment and Symmetry Checks	5.14
Station Identification System	5.3	Lateral Control of the Tail Position	5.14
Stress, Strain, Bending, Compression, Shear, Torsion, Tension, Hoop Stress, and Fatigue	5.4	Horizontal Control of the Tail Position	5.14
Stress and Strain	5.5	Submodule 5 Practice Questions	5.15
Tension	5.5	Submodule 5 Practice Answers	5.16
Compression	5.5	12.6 AIR CONDITIONING (ATA 21)	6.1
Torsion	5.5	12.6.1 - Air Supply	6.1
Shear	5.5	Sources of Air Supply Including Engine Bleed and Ground Cart 6.1	
Bending	5.5	Ram Air	6.1
Hoop Stress	5.6		
Metal Fatigue	5.6		
Drains and Ventilation Provisions	5.6		

TABLE OF CONTENTS

Bleed Air	6.1	Horizontal Situation Indicator, Turn And Slip Indicator, Turn Coordinator.	7.9
Bleed Air From an Engine.	6.1	Gyroscopic Principles	7.9
Bleed Air From an APU	6.1	Ring Laser Gyro	7.10
Ground Cart	6.1	Micro Electro Mechanical System (MEMS)	7.10
Heated Air Sources	6.2	Artificial Horizon	7.11
Heaters	6.2	Attitude Director	7.12
Heat Exchangers	6.2	Direction Indicator	7.12
Combustion Heaters	6.2	Horizontal Situation Indicator	7.13
12.6.2 - Air Conditioning	6.2	Turn And Slip Indicator	7.13
Air Conditioning Systems	6.2	Turn Coordinators	7.14
Vapor Cycle Air Conditioning	6.2	Compasses	7.14
Basic Vapor Cycle	6.2	Direct Reading, Remote Reading	7.14
Vapor Cycle Air Conditioning System Components	6.3	Direct Reading	7.14
Refrigerant	6.3	Magnetic Deviation	7.15
Receiver Dryer	6.4	Magnetic Variation	7.16
Thermal Expansion Valve	6.4	Dip Error	7.16
Evaporator	6.4	Vertical Magnetic Compasses	7.16
Compressor	6.5	Remote Reading	7.16
Condenser	6.5	Vibration Indicating Systems (HUMS)	7.17
Service Valves	6.5	Glass Cockpit	7.18
Air-Cycle Air Conditioning	6.6	Other Aircraft System Indications	7.19
System Operation	6.6	Remote Sensing And Indications	7.19
Pneumatic System Supply	6.7	Synchro Type Remote Indicating Instruments	7.19
Component Operation	6.7	DC Selsyn Systems	7.19
Pack Valves	6.7	AC Synchro Systems	7.19
Bleed Air Bypass	6.7	Fuel And Oil Pressure Gauges	7.19
Primary Heat Exchanger	6.7	Mechanical Movement Indicators	7.20
Refrigeration Turbine Unit and Secondary Heat Exchanger	6.8	Tachometers	7.20
Refrigeration Bypass Valve	6.8	Electric Tachometers	7.20
Distribution System	6.8	Collective Pitch Transmitter	7.20
Air Ducts	6.9	Temperature Measuring Instruments	7.20
Flow and Temperature Control Systems	6.9	Non-Electric Temperature Indicators	7.21
Flow Control System	6.9	Electric Temperature Indicators	7.22
Temperature Control System	6.10	Thermocouple Temperature Indicators	7.22
Air Conditioner Control Panel	6.10	Turbine Gas Temperature Indicating Systems	7.23
Temperature	6.10	Pressure Measuring Instruments	7.24
Fan Speed	6.10	Engine Oil Pressure Instruments	7.26
Mode Selection	6.10	Manifold Pressure Instruments	7.26
Protection and Warning Devices	6.10	Fuel Pressure Instruments	7.27
Submodule 6 Practice Questions	6.11	Hydraulic Pressure Instruments	7.27
Submodule 6 Practice Answers	6.12	Vacuum Pressure Instruments	7.28
12.7 INSTRUMENTS/AVIONICS SYSTEMS.....	7.1	Pressure Switches	7.28
Introduction	7.1	12.7.2 - Avionics Systems	
Classification By Type	7.3	(ATA 22, 23, 34)	7.29
Flight Instruments	7.3	Autoflight (ATA 22)	7.29
Engine Instruments	7.3	Stability Augmentation System	7.29
Navigation Instruments	7.4	Basic Autopilots (3-Axes)	7.29
Pitot-Static Instruments	7.4	Superior Modes Of 3-Axes Autopilots	7.29
Altimeter, Air Speed Indicator, Vertical Speed Indicator.	7.4	Superior Modes Of 4-Axes Autopilots	7.30
Pitot Tubes And Static Vents Principle	7.4	Automatic Transition To The Hover	7.30
Altimeters	7.5	Communications (ATA 23)	7.30
Airspeed Indicators	7.7	Very High Frequency (VHF) Radios	7.30
Vertical Speed Indicator	7.8	High Frequency (HF) Radios	7.31
Gyroscopic Instruments	7.9	Satellite Communication Systems	7.31
Artificial Horizon, Attitude Director, Direction Indicator,		Service Interphone System	7.31

TABLE OF CONTENTS

Navigation Systems (ATA 34).....	7.31	Alternator Drive	8.5
VOR Navigation System	7.31	AC Alternator Control Systems	8.5
Automatic Direction Finder (ADF)	7.33	Emergency Power Generation	8.5
Radio Magnetic Indicator (RMI)	7.35	Voltage Regulation And Circuit Protection	8.6
Instrument Landing Systems (ILS).....	7.35	Voltage Regulation	8.7
Localizer	7.35	Parallel Generator Operations.....	8.7
Glideslope	7.36	Differential Voltage	8.7
Compass Locators	7.37	Generator Controls For High Output Generators	8.7
Marker Beacons	7.37	Other Voltage Regulation	8.7
Microwave Landing System (MLS)	7.37	Carbon Pile Regulators	8.8
MLS Expansion Capabilities	7.38	Three Unit Regulators	8.8
Flight Director Systems; Distance Measuring		Circuit Protection	8.8
Equipment (DME)	7.38	Reverse Current Sensing	8.8
Area Navigation Systems (RNAV)	7.40	Over Voltage Protection	8.8
Flight Management System.....	7.40	Over Excitation Protection	8.8
Satellite Navigation Systems	7.41	Current Limiting Devices	8.8
Inertial Navigation System (INS)	7.41	Fuses.....	8.8
Air Traffic Control Transponder, Secondary		Circuit Breakers	8.8
Surveillance Radar.....	7.42	Power Distribution.....	8.9
Secondary Surveillance Radar.....	7.42	Inverters, Transformers, And Rectifiers	8.9
Transponder Tests And Inspections	7.44	Inverters	8.9
Altitude Encoders	7.44	Rotary Inverters	8.9
Traffic Alert And Collision Avoidance System (TCAS)	7.44	Permanent Magnet Rotary Inverters.....	8.9
Weather Avoidance Radar.....	7.45	Inductor Type Rotary Inverters.....	8.10
Radio Altimeter (RA)	7.45	Static Inverters.....	8.11
Avionics General Test Equipment.....	7.46	Transformers	8.11
Built in Test Equipment	7.46	Voltage Transformers.....	8.12
Avionics Test Equipment.....	7.46	Power Transformers.....	8.12
Multimeters	7.46	Audio Transformers.....	8.12
Oscilloscope.....	7.46	RF Transformers	8.12
Pitot-Static Test Equipment	7.47	Autotransformers	8.12
Specialized Test Equipment	7.47	Current Transformers	8.12
Data Bus Analyzers	7.47	Power In Transformers	8.13
Test Equipment Calibration	7.48	Rectifiers	8.13
Submodule 7 Practice Questions.....	7.49	Transformer Rectifiers.....	8.13
Submodule 7 Practice Answers	7.50	External/Ground Power.....	8.13
		Submodule 8 Practice Questions.....	8.15
		Submodule 8 Practice Answers	8.16
12.8 ELECTRIC POWER (ATA 24).....	8.1	12.9 EQUIPMENT AND FURNISHINGS (ATA 25).....	9.1
Batteries: Installation And Operation	8.1	Section A	9.1
Lead-Acid Batteries.....	8.1	Emergency Equipment Requirements	9.1
Valve Regulated (Sealed) Lead-Acid Batteries (VRLA)	8.1	Fire Extinguishers.....	9.1
Nickel Cadmium Batteries (NiCd)	8.1	First-Aid Kits.....	9.2
Lithium-Ion Batteries	8.2	Maintenance of First-Aid Kits	9.2
Battery Installation	8.2	Crew Survival Kits.....	9.2
Battery Charging.....	8.3	Life Jackets.....	9.2
Constant Voltage Charging.....	8.3	Life Rafts	9.3
Constant Current Charging	8.3	Emergency Locator Transmitter (ELT)	9.3
Battery Maintenance	8.3	Types of ELTs	9.3
Battery Overheating.....	8.4	Emergency Lighting and Marking	9.4
Battery Freezing.....	8.4	Supplemental Oxygen	9.4
Electrolyte Spillage	8.4	Determination of Oxygen	9.4
Storage of Batteries	8.4	Seats, Harnesses, And Belts	9.4
Battery Ventilation Systems	8.4	Seats	9.4
DC Power Generation; AC Power Generation	8.4	Emergency Exit Marking	9.4
DC Power Generation	8.4		
AC Power Generation	8.4		

TABLE OF CONTENTS

Escape Slides	9.5	Discharge Valves	10.6
Seat Belts and Harnesses	9.5	Pressure Indication	10.6
CS-29.561 Requirements	9.5	Two Way Check Valve	10.6
Passenger Seats	9.6	Discharge Indicators	10.7
Crew Seats	9.6	Thermal Discharge Indicator (Red Disk)	10.7
Lifting Systems	9.6	Normal Discharge Indicator (Yellow Disk)	10.7
Rescue Hoists	9.6	Fire Switch	10.7
Electric Hoists	9.6	Fire Extinguisher System Maintenance	10.7
Electric Hoist Operation	9.7	Container Pressure Check	10.7
Hover Trim Control	9.7	Discharge Cartridges	10.8
Electric Hoist Safety Systems	9.8	Agent Containers	10.8
Hydraulic Hoists	9.8	System Tests	10.8
Cargo Hooks	9.8	Continuous Loop Fire Detection System	10.8
Four Point Sling Assembly	9.9	Dual Loop Systems Automatic Self Interrogation	10.8
Load Cell	9.9	Fire Detection Control Unit (Fire Detection Card)	10.8
Frangible Link	9.9	Section B	10.9
Section B	9.9	Portable Fire Extinguishers	10.9
Emergency Floatation Systems	9.9	Portable Extinguisher Types	10.9
Cabin Layout and Cargo Retention	9.10	Halon Fire Extinguishers	10.9
Cargo Retention	9.10	Pressurized Water Extinguishers	10.9
Equipment Layout	9.10	Non-Suitable Extinguishers	10.9
Cabin Furnishing Installation	9.11	Maintenance and Inspection	10.9
Submodule 9 Practice Questions	9.13	Submodule 10 Practice Questions	10.11
Submodule 9 Practice Answers	9.14	Submodule 10 Practice Answers	10.12
12.10 FIRE PROTECTION (ATA 26)	10.1	12.11 FUEL SYSTEMS (ATA 28)	11.1
Fire Protection	10.1	Fuel System Layout	11.1
Fire Zones	10.1	Gravity Feed Systems	11.1
Fire Prevention	10.1	Pressure Feed Fuel System	11.1
Fire and Smoke Detection and Warning Systems	10.1	Complex Fuel Systems	11.1
Requirements For Overheat and Fire Detection Systems	10.1	Fuel Tanks	11.1
Thermal Switch Systems	10.2	Fuel Tank Construction	11.2
Thermocouple Systems	10.2	Integral Fuel Cells	11.2
Continuous Loop Systems	10.2	Bladder Fuel Tanks	11.3
Fenwal System	10.2	Fuel Tank Repair	11.3
Kidde System	10.3	Integral Tanks	11.3
Sensing Element Fault Indication	10.3	Bladder Tanks	11.3
Combination Fire and Overheat Warning	10.3	Supply Systems	11.3
Support Tube Mounted Sensing Elements	10.3	Fuel Feed	11.4
Dual Loop Systems	10.3	Non-Pressurized Fuel Systems	11.4
Fire Detection System Maintenance	10.4	Pressurized Fuel Systems	11.4
Flame Detectors	10.4	Fuel System Components	11.4
Smoke Detection Systems	10.4	Lines And Fittings	11.4
Light Refraction Type	10.5	Fuel Valves	11.5
Ionization Type	10.5	Manual Valves	11.5
Carbon Monoxide Detectors	10.5	Motor Operated Valves	11.6
Carbon Monoxide Chemical Detectors	10.5	Solenoid Operated Valves	11.6
Carbon Monoxide Monitors (Sensors)	10.5	Fire Shut Off Valves	11.6
Fire Extinguishing Systems	10.5	Fuel Pumps	11.7
Fire Extinguisher Agents	10.5	Centrifugal Boost Pumps	11.7
Water - Class A	10.5	Ejector Pumps	11.7
Carbon Dioxide (CO ₂) - Class B or C	10.5	Fuel Filters	11.7
Dry Powder Chemicals	10.5	Gaskets, Seals and Packings	11.8
Halogenated Hydrocarbons - Class A, B, or C	10.5	Dumping, Venting And Draining	11.8
Fixed Container Fire Extinguishing Systems	10.5	Dumping	11.8
Containers	10.6	Fuel Vent Systems	11.8

TABLE OF CONTENTS

Fuel System Drains	11.9	Maintenance of Accumulators	12.7
Cross Feed And Transfer	11.10	Heat Exchangers	12.7
Cross Feed And Transfer	11.10	Pressure Generation: Electric, Mechanical, and Pneumatic	12.7
Indications And Warnings	11.10	Mechanical, Electrical, And Pneumatic Driven Pumps	12.7
Fuel Quantity Indicating Systems	11.11	Hand Pumps	12.7
Ratiometer Type	11.11	Single Action Hand Pumps	12.7
Capacitance Type	11.11	Double Action Hand Pumps	12.8
Mechanical Type	11.12	Rotary Action Hand Pumps	12.8
Fuel Flow Meters	11.12	Classification Of Pumps	12.8
Fuel Heating	11.12	Constant Displacement Pumps	12.8
Fuel Pressure Gauges	11.12	Gear Type Power Pump	12.8
Pressure Warning Signal	11.13	Gerotor Pump	12.9
Fueling And Defueling	11.13	Piston Pumps	12.9
Fueling	11.13	Vane Pump	12.9
Refueling By Gravity	11.13	Variable Displacement Pumps	12.9
Pressure Refueling	11.13	Hydraulic Seals	12.10
Defueling	11.14	Packings	12.10
Fire Hazards When Fueling Or Defueling	11.14	V-Rings	12.10
Fuel Contamination	11.15	U-Ring	12.10
Water	11.15	O-Rings	12.11
Solid Particle Contaminants	11.16	Gaskets	12.11
Surfactants	11.16	Wipers	12.11
Microorganisms	11.16	Emergency Pressure Generation	12.11
Improper Fuel	11.16	Hydraulic Motors	12.12
Submodule 11 Practice Questions	11.19	Power Transfer Units (PTUs)	12.13
Submodule 11 Practice Answers	11.20	Hydraulic Motor Driven Generators (HMDG)	12.13
12.12 HYDRAULIC POWER (ATA 29)	12.1	System Contamination And Filters	12.14
System Layout	12.1	Hydraulic Fluid Contamination	12.14
Open Center Hydraulic Systems	12.1	Contamination Check	12.14
Closed Center Hydraulic Systems	12.1	Hydraulic Sampling Schedule	12.14
Evolution Of Hydraulic Systems	12.2	Contamination Control	12.14
Hydraulic Power Pack System	12.2	Hydraulic System Flushing	12.15
Modern High Performance Systems	12.2	Filters	12.15
Hydraulic Fluids	12.2	Micron Filters	12.15
Hydraulic Fluid Properties	12.3	Maintenance Of Filters	12.16
Viscosity	12.3	Filter Differential Pressure Indicators	12.16
Chemical Stability	12.3	Pressure Control	12.16
Flash Point	12.3	Pressure Relief Valves	12.16
Fire Point	12.3	Pressure Regulators	12.17
Types Of Hydraulic Fluids	12.3	Pressure Reducers	12.17
Mineral Base Fluids	12.3	Power Distribution	12.17
Polyalphaolefin Base Fluids	12.3	Shutoff Valves	12.17
Phosphate Ester Base Fluids	12.3	Selector Valves	12.17
Intermixing of Fluids	12.3	Check Valves	12.18
Compatibility With Aircraft Materials	12.4	Orifice Type Check Valve	12.18
Hydraulic Reservoirs And Accumulators	12.4	Sequence Valves	12.18
Reservoirs	12.4	Pressure Controlled Sequence Valve	12.18
Non Pressurized Reservoirs	12.4	Mechanically Operated Sequence Valve	12.19
Pressurized Reservoirs	12.4	Priority Valves	12.19
Air Pressurized Reservoirs	12.4	Shuttle Valves	12.20
Fluid Pressurized Reservoirs	12.5	Quick Disconnect Valves	12.20
Accumulators	12.5	Hydraulic Fuses	12.20
Types of Accumulators	12.6	Hydraulic Actuators	12.21
Spherical	12.6	Linear Actuators	12.21
Cylindrical	12.6	Rotary Actuators	12.21
		Indication And Warning Systems	12.21

TABLE OF CONTENTS

Interface With Other Systems	12.23	Quadricycle Type	14.2
Servicing	12.23	Classification of Landing Gear	14.2
Hydraulic Fluid Contamination	12.23	Non-Articulated or Telescopic Type	14.2
Contamination Prevention	12.23	Articulated or Levered Suspension Type	14.2
Fluid Monitoring	12.23	Four-Bar Linkage Mechanism	14.2
Fluid Compatibility	12.23	Wheelbase	14.3
Hydraulic System Maintenance and Troubleshooting		Wheel Track	14.3
Checklist	12.23	Semi-Articulated or Semi-Levered Suspension Type	14.3
Submodule 12 Practice Questions	12.25	Fixed and Retractable Landing Gear	14.4
Submodule 12 Practice Answers	12.26	Landing Gear Attachment	14.4
12.13 ICE AND RAIN PROTECTION (ATA 30).....	13.1	Landing Gear Elements	14.4
Ice Formation, Classification and Detection	13.1	Main Landing Gear Elements	14.5
Types of Aircraft Ice	13.1	Shock Strut Assembly	14.5
Clear Ice	13.1	Nose/Tail Landing Gear Elements	14.5
Rime Ice	13.1	Shock Strut Assembly	14.5
Gleam Ice	13.1	Trailing Arm Assembly	14.5
Icing Effects	13.2	Fork and Axle Assembly	14.5
Ice Detection	13.2	Centering Cams (Locating Cams)	14.5
Pressure Ice Detectors	13.2	Landing Gear Material	14.5
Vibrating Ice Detectors	13.2	Corrosion Protection	14.6
Hot Rod Ice Detector	13.3	Shock Absorbing	14.6
Serrated Rotor Ice Detector Head	13.3	Shock Struts	14.6
Anti-Icing and De-Icing Systems: Electrical, Hot Air and		Shock Strut Construction	14.6
Chemical	13.3	Metering Pins	14.7
Thermal Anti-Ice Systems	13.3	Damping Or Snubbing Devices	14.7
Thermal Engine Anti-Ice (EAI)	13.4	Axles	14.7
Electrical Anti-Ice Systems	13.4	Valve Fitting Assembly	14.7
Mechanical De-Icing Systems	13.5	Torque Links	14.8
Chemical Anti-Ice Systems	13.5	Nose Gear Shock Struts	14.8
Ground Chemical De-Icing	13.5	Tail Bumper Assembly	14.9
De-Icing Procedures	13.5	Jacking Points And Towing Lugs	14.9
Windshield Anti-Icing	13.6	Shock Strut Instruction Plate	14.9
Windshield Hot Air De-Ice/De-Fog	13.6	Shock Strut Operation	14.9
Rain Repellent and Removal	13.6	Servicing Shock Struts	14.10
Chemical Rain Repellent	13.6	Bleeding Shock Struts	14.10
Hydrophobic Coatings	13.7	Extension/Retraction Systems: Normal And Emergency	14.11
Pneumatic Rain Removal Systems	13.7	Hydraulic Extension And Retraction Systems	14.12
Probe and Drain Heating	13.7	Selector Valves	14.12
Thermal Electric Anti-Icing	13.7	Safety Locks	14.12
Probe Anti-Ice	13.7	Downlock And Uplock Mechanisms	14.12
Drain Anti-Ice	13.8	Ground Locks	14.13
Wiper Systems	13.8	Sequence Valves	14.13
Mechanical Wiper Systems	13.8	Actuators	14.13
Wash/Wipe Systems	13.8	Electric Extension And Retraction Systems	14.13
Submodule 13 Practice Questions	13.11	Electric/Hydraulic Extension And Retraction Systems	14.13
Submodule 13 Practice Answers	13.12	Pneumatic Extension And Retraction Systems	14.14
12.14 LANDING GEAR (ATA 32).....	14.1	Normal Extension	14.14
Section A	14.1	Emergency Extension Systems	14.14
System Description And Operation	14.1	Mechanical Emergency Extension Systems	14.14
Landing Gear Types And Construction	14.1	Hydraulic Emergency Extension Systems	14.16
Skid Gears	14.1	Landing Gear Retraction Test	14.16
Wheels	14.1	Wheels, Tyres, Brakes	14.17
Tail Wheel Type	14.2	Wheels	14.17
Tricycle Nose Wheel Type	14.2	Wheel Construction	14.17
		Inboard Wheel Half	14.18
		Outboard Wheel Half	14.19

TABLE OF CONTENTS

On Aircraft Wheel Inspection	14.19	Automatic Adjuster Pins	14.37
Proper Installation	14.19	Torque Tube	14.37
Axle Nut Torque	14.19	Brake Housing And Piston Condition	14.37
Off Aircraft Wheel Inspection	14.19	Seal Condition	14.37
Disassembly Of The Wheel	14.19	Brake Malfunctions And Damage	14.37
Inspection Of The Wheel Halves	14.20	Overheating	14.38
Tie Bolt Inspection	14.20	Dragging	14.38
Key And Key Screw Inspection	14.20	Chattering Or Squealing	14.38
Fusible Plugs	14.20	Steering	14.38
Balance Weights	14.20	Nose Wheel Steering	14.38
Wheel Bearings	14.21	Shimmy Dampers	14.38
Inspection Of Wheel Bearings	14.21	Piston Type	14.38
Lubrication of Bearings	14.21	Vane Type	14.39
Tyres And Tubes	14.21	Non-Hydraulic Shimmy Damper	14.39
Tyre Classification	14.21	Skids And Floats	14.39
Ply Rating	14.21	Skids	14.39
Tube Type Or Tubeless	14.21	Skids And Shock Absorbers	14.39
Bias Ply Or Radial	14.21	Skid Dampeners	14.40
Tyre Terminology	14.22	Skid and Wheels	14.41
Bead	14.22	Floats	14.41
Carcass Plies	14.22	Fixed Utility Floats	14.41
Tread	14.22	Emergency Pop-Out Floats	14.41
Sidewall	14.23	Section B	14.42
Helicopters Tyre Types	14.23	Sensors	14.42
Tyre Inspection	14.23	Indications And Warning	14.42
Inflation	14.23	Safety Switches	14.43
Tread Condition	14.23	Squat Switches, Proximity Sensors	14.43
Tread Damage	14.24	Air-Ground Sensing	14.43
Sidewall Condition	14.26	Submodule 14 Practice Questions	14.45
Tubes	14.26	Submodule 14 Practice Answers	14.46
Tube Construction And Selection	14.26		
Tube Storage And Inspection	14.26		
Tyre Mounting	14.27		
Tube Type Tyres	14.28		
Tyre Balancing	14.28		
Brakes	14.29		
Types And Construction Of Helicopter Brakes	14.29		
Floating Disc Brakes	14.29		
Fixed Disc Brakes	14.30		
Dual Disc Brakes	14.31		
Multiple Disc Brakes	14.31		
Electric Brakes	14.31		
Brake Actuating Systems	14.32		
Independent Master Cylinders	14.32		
Boosted Brakes	14.33		
Parking Brakes	14.33		
Emergency Brakes	14.33		
On Aircraft Servicing	14.33		
Lining Wear	14.34		
Air In The System	14.35		
Fluid Type	14.36		
Inspection For Leaks	14.36		
Proper Bolt Torque	14.36		
Off Aircraft Brake Servicing and Maintenance	14.37		
Bolt And Threaded Connections	14.37		
Discs	14.37		
		12.15 LIGHTS (ATA 33)	15.1
		External: Navigation, Landing, Taxiing, Ice	15.1
		Navigation/Position Lights	15.1
		Anti-Collision Lights	15.2
		Rotating Beacons	15.2
		Strobe Lighting	15.3
		Landing Lights	15.3
		Taxi Lights	15.3
		Ice Inspection Lights	15.3
		Internal: Cabin, Cockpit, Cargo	15.3
		Fluorescent Lights	15.4
		Fluorescent Lamp Operating Circuit	15.4
		Flight Deck Lighting	15.4
		Integral Instrument Lighting	15.4
		Cabin Lighting	15.5
		Cargo and Baggage Compartments Lights	15.5
		Emergency Lighting	15.5
		Electroluminescence	15.6
		Self Illuminating Signs	15.6
		Floor Mounted Escape Path Lighting	15.6
		Emergency Exit Lighting Activation	15.6
		Submodule 15 Practice Questions	15.7
		Submodule 15 Practice Answers	15.8

TABLE OF CONTENTS

12.16 (RESERVED).....	16.1
This submodule is reserved by EASA for future use.	16.1
 12.17 INTEGRATED MODULAR AVIONICS (IMA) (ATA 42).....	17.1
Integration Of Avionics	17.1
Digital Data Bus Use Reduces Wiring	17.2
Core Systems	17.3
Core Processor Input/Output Module (CPIOM).....	17.3
Network Components	17.3
Submodule 17 Practice Questions.....	17.5
Submodule 17 Practice Answers	17.6
 12.18 ONBOARD MAINTENANCE SYSTEMS (ATA 45)	18.1
Central Maintenance Computers.....	18.1
Built-In Test Equipment (BITE)	18.2
Data Loading Systems	18.3
Electronic Library System	18.4
Submodule 18 Practice Questions.....	18.5
Submodule 18 Practice Answers	18.6
 12.19 INFORMATION SYSTEMS (ATA 46).....	19.1
Adoption by the Helicopter Operators.....	19.1
Aircraft General Information Systems	19.1
The Airbus System	19.1
Network Server System	19.2
Secure Communication Interface	19.2
Central Data Acquisition Module.....	19.2
Flight Deck Information System	19.2
Maintenance Information System	19.2
Electronic Logbooks	19.2
Passenger Cabin Information System.....	19.3
Cabin Wireless Connectivity.....	19.3
Leaky Line Antennas	19.3
Miscellaneous Information Systems.....	19.3
Submodule 19 Practice Questions.....	19.5
Submodule 19 Practice Answers	19.6
 Acronym Definitions.....	19.7

Flight Control Systems (ATA 67)

Submodule

2



12.2 Flight Control Systems (ATA 67)

SUBMODULE KNOWLEDGE DESCRIPTIONS

LEVEL

A3/A4

12.2	Flight Control Systems (ATA 67) Cyclic control; Collective control; Swashplate; Yaw control: antitorque control, tail rotor, bleed air; Main-rotor head: design and operation features; Blade dampers: function and construction; Rotor blades: main and tail-rotor blade construction and attachment; Trim control, fixed and adjustable stabilisers; System operation: manual, hydraulic, electrical, fly-by-wire; Artificial feel; Balancing and rigging.
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2

12.2 FLIGHT CONTROL SYSTEMS (ATA 67)

INTRODUCTION

There are three major controls in a helicopter used by the pilot during flight: the collective pitch control, the cyclic pitch control, and the anti-torque pedals or tail rotor control. Sometimes in addition to these major controls, the pilot must also use the throttle control, which is usually mounted directly to the collective pitch control for controlling engine power. [Figure 2-1]

The control systems described in this chapter are not limited to the single main rotor type helicopter but are used in one form or another in most helicopter configurations. All examples refer to a counterclockwise main rotor blade rotation, such as viewed from above. If flying a helicopter with a clockwise rotation, left and right references must be reversed, particularly in the areas of rotor blade pitch change, anti-torque pedal movement, and tail rotor thrust.

CYCLIC CONTROL

The cyclic pitch control is usually projected upward from the cockpit floor, between the pilot's legs or in some models between the two pilot's seats. [Figure 2-2]

The purpose of the cyclic-pitch control is to cause the tip-path plane of the main rotor to tilt as required to provide for movement of the helicopter in a desired direction: forward, rearward, left, and right.

As discussed in *Submodule 1*, the total lift force is always perpendicular to the tip-path plane of the main rotor. The main rotor tilts in the direction called for by the control, and the helicopter moves as directed. When the control stick is in neutral, the helicopter remains stationary in the air (hover). If wind is

present, the helicopter drifts in the direction of wind unless sufficient cyclic movement (rotor thrust) is applied to cancel the effect of the wind.

The rotor disk is also subject to the effect of gyroscopic precession as described in *Submodule 1*. To counteract this effect, the mechanical linkages for the cyclic control rods are rigged in such a way that they decrease the pitch angle of each rotor blade at approximately 90° in the point of the rotor's rotation as it reaches the direction of cyclic displacement and increases the pitch angle of the rotor blade at approximately 90° after it passes the direction of displacement. An increase in pitch angle increases the angle of attack; a decrease in pitch angle decreases the angle of attack. When the cyclic is moved forward, the angle of attack decreases as the rotor blade passes the right side of the helicopter and increases on the left side (on the retreating blade). This results in a maximum downward deflection of the rotor blade in front



Figure 2-1. Helicopter controls on the flight deck.

of the helicopter and a maximum upward deflection behind it, causing the rotor disk to tilt forward.

COLLECTIVE CONTROL

The collective pitch control (or simply "collective" or "thrust lever") is located on the left side of the pilot's seat and is operated with the left hand. The collective is used to make changes to the pitch angle of the main rotor blades and acts simultaneously, or "collectively". Through a series of mechanical linkages, as the collective lever is raised, there is a simultaneous and equal increase in pitch angle of all main rotor blades. As it is lowered, there is an equal decrease in pitch angle. The amount of movement in the collective lever determines the



Figure 2-2. Location of cyclic pitch control.

amount of blade pitch change. [Figure 2-3] An adjustable friction control helps prevent inadvertent collective lever movement.

With a change in pitch angle comes a change in the load on each blade, which affects the speed or Revolutions Per Minute (RPM) of the main rotor. As the pitch angle increases, the blade takes a bigger bite of air that increases the load on the blade, and so the rotor RPM decreases. Decreasing pitch angle decreases the load on the blade, and RPM increases. To maintain a constant rotor RPM, which is essential in helicopter operations, a proportionate change in power is required to compensate for the change in load on the blades. This is accomplished with the throttle control or governor, which automatically adjusts engine power according to the position of the collective.

In Figure 2-3A the collective pitch control is lowered, which causes the blade angle and the amount of lift created to decrease along with applying a proportional decrease in engine power. [Figure 2-3B]. In Figure 2-3C the collective is raised to increase the lift created by the blades Figure 2-3D, and the governor or throttle increases the engine power to maintain the rotor RPM.

THROTTLE CONTROL

The function of the throttle and the governor is to regulate engine RPM by increasing or decreasing fuel flow towards the engine when the collective is raised or lowered. If the governor is an automatic system, to maintain RPM the throttle must be moved manually with the twist grip. The throttle control is much like a motorcycle throttle and works the same way. Twisting the throttle to the left increases RPM. Twisting to the right decreases RPM. As with any aircraft control, large adjustments of either collective pitch or throttle should be avoided. All corrections should be made using smooth pressure.

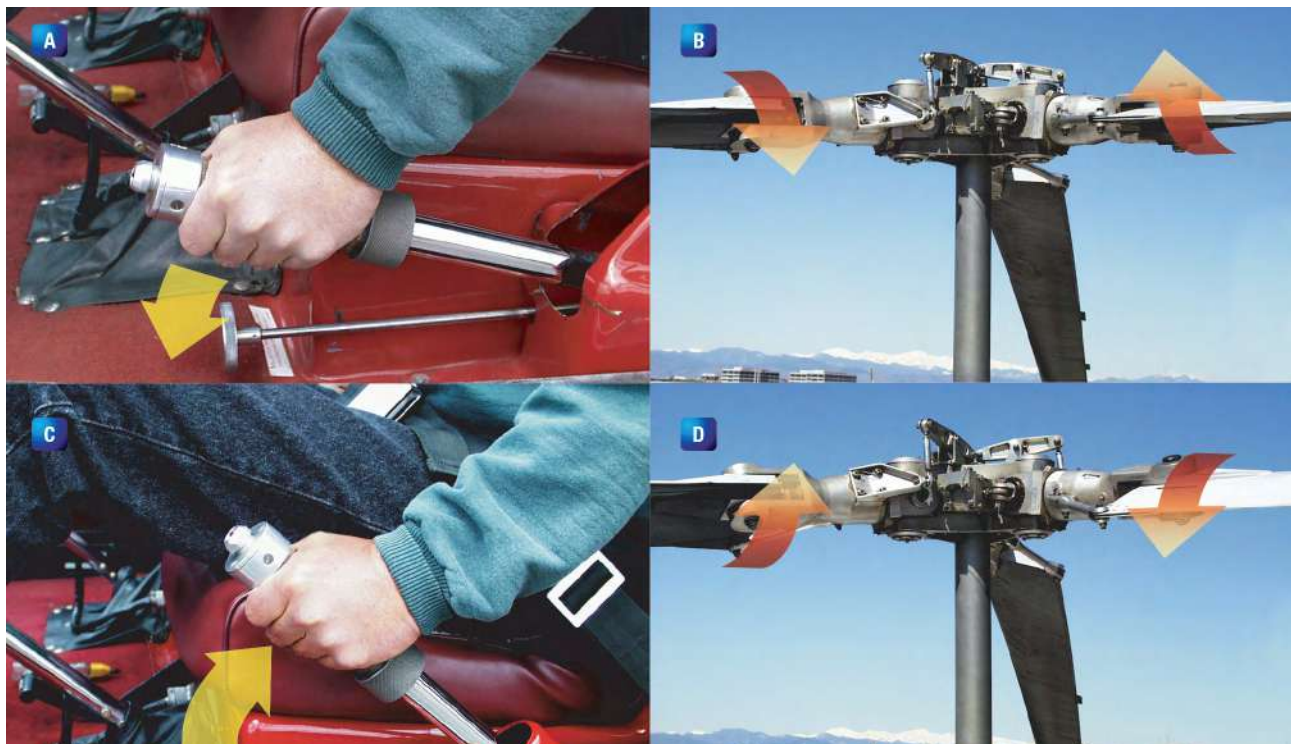


Figure 2-3. Movement of collective pitch control-throttle and effect on rotor blades.

CORRELATOR

A correlator is an automated mechanical connection between the collective lever and the engine throttle. When the collective lever is raised, power is automatically increased; when lowered, power is decreased. This system maintains RPM close to the desired value, but still requires adjustment of the throttle for fine tuning.

GOVERNOR

A governor is a sensing device that monitors rotor and engine RPM and makes the necessary adjustments to keep rotor RPM constant. In normal operations, once the rotor RPM is set, the governor keeps it constant and there is no need to make any throttle adjustments. Governors are common on all turbine powered helicopters as they are a function of the fuel control system and are used on some piston engine helicopters.

SWASHPLATE

When a pilot moves the collective or cyclic controls on the flight deck, a signal is sent to the main rotor blades to cause them to change their angles. From the flight deck, the signal can originate as the movement of cables and pulleys, push/pull tubes, or even an electronic signal. The command for a change in blade or rotor angle must start from the non rotating fuselage and find its way to the main rotor blades which are rotating. The device which permits these changes is called a swashplate. [Figure 2-4]

The swashplate is made of two circular plates, one on the bottom that is attached to the frame of the helicopter and does not rotate, and one on the top that is attached to the rotating blade assembly. The plates are separated by a set of bearings allowing the top plate to rotate over the bottom plate while physically being in contact with it, so forces can be transferred. Figure 2-5 shows a simplified swash plate as part of a main rotor system.

A swashplate assembly consists of the parts shown in Figure 2-6. The lower swashplate is locked in rotation by the fixed scissor. This scissor is connected between the top of the main gearbox and the lower swashplate. This plate is actuated by the control rods of the cyclic and collective linkages and has two possibilities of movement.

As each blade rotates through the tip path plane, the variation of the blade pitch is accomplished through the tilting of a fixed swashplate and its mechanical linkages (pitch angle rods).

THE CYCLIC MOVEMENT AND THE SWASHPLATE

When the pilot moves the cyclic pitch control, this command sends the lower swashplate around a ball joint and tilts the upper swashplate which remains in parallel with the rotor due to its two bearings. The rotary swashplate now spins in an inclined circle. This means that the pitch change rods are constantly undergoing up and down movements. As they are attached to the rotor they will constantly change the blade pitches between high to low values with each revolution, thus creating high lift at one point on the rotating disc and low at 180° from that point. [Figure 2-7]

In other words, the swashplate will tilt the main rotor in the requested direction and therefore the helicopter will also move in this desired direction. To define the plane represented by the



Figure 2-4. Light helicopter swashplate.

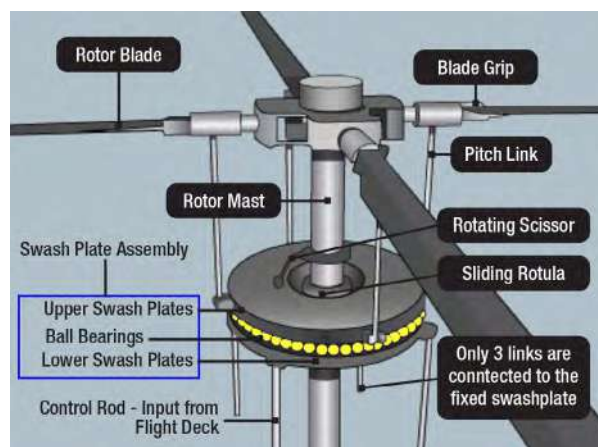


Figure 2-5. Simplified figure of a helicopter swashplate.

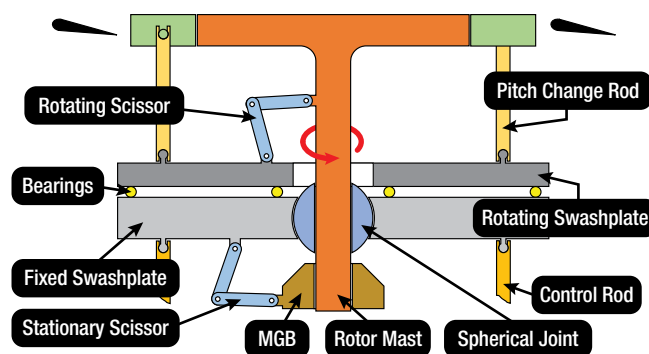


Figure 2-6. Swashplate component.

swashplate, it is necessary to connect three points which define the different tilting axis. [Figure 2-8]

THE COLLECTIVE MOVEMENT AND THE SWASHPLATE

The lower swashplate is connected to a ball joint that slides up and down along the rotor mast. When the pilot pulls the collective control, a command is sent to the lower swashplate by three connecting rods as shown in Figure 2-5 as "input from flight deck".

These three rods push the lower swash plate in parallel upwards, which also pushes the upper swashplate and ball joint as one unit. The upper swash plate, through these links, applies force to the rotor blades and so changing the angle of attack of all the blades in the same direction regardless of the inclination of the swashplate. [Figure 2-9]

It is possible to operate the cyclic stick and the collective stick simultaneously. In that case all the bellcranks move, transmitting a specific movement to the swashplate which acts to control the angle of attack of each blade as the pilot wishes.

YAW CONTROL: ANTI-TORQUE CONTROL, TAIL ROTOR, BLEED AIR

ANTI-TORQUE CONTROL, TAIL ROTOR

Yaw for an aircraft (helicopter or airplane) is a movement that takes place around the vertical axis. The three axes of rotation for a helicopter are shown in Figure 2-10. For a helicopter with a single main rotor yaw control is accomplished by the tail rotor (anti-torque rotor).

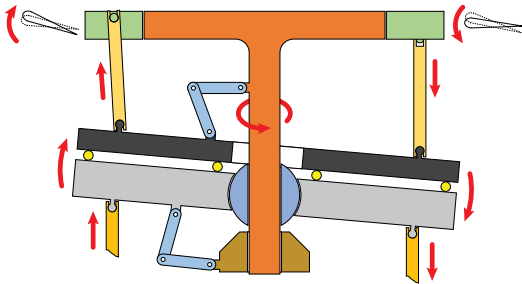


Figure 2-7. Cyclic movement.

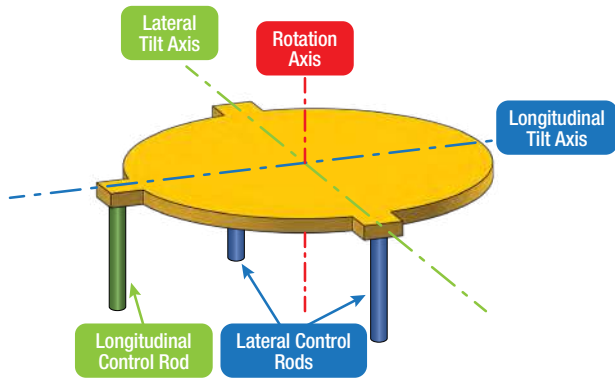


Figure 2-8. Light helicopter axis description.

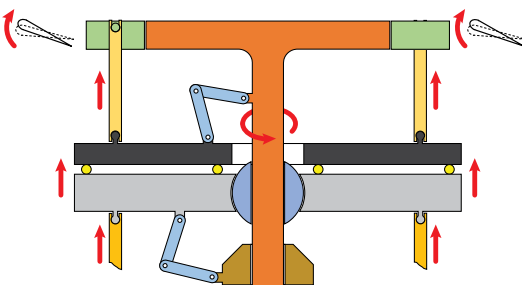


Figure 2-9. Collective movement.

One method to counteract torque is to place a small propeller at the end of the tail boom. Its purpose is to create thrust that acts in the opposite direction of the helicopter's tendency to rotate. The tail rotor force, in newtons, multiplied by the distance from the tail rotor to the main rotor, in meters, creates a torque in newton meters that counteracts the main rotor torque. The main difference is that there is no cyclic control as it is not necessary to modify the direction of the lift but simply to increase or decrease thrust as a collective command. [Figure 2-11]

THE TAIL COLLECTIVE HINGE

The tail collective hinge system is the same, regardless of the number of blades on the tail. To modify the thrust of the tail rotor, it is necessary to be able to change the angle of attack of all the blades at the same time. To create the collective movement

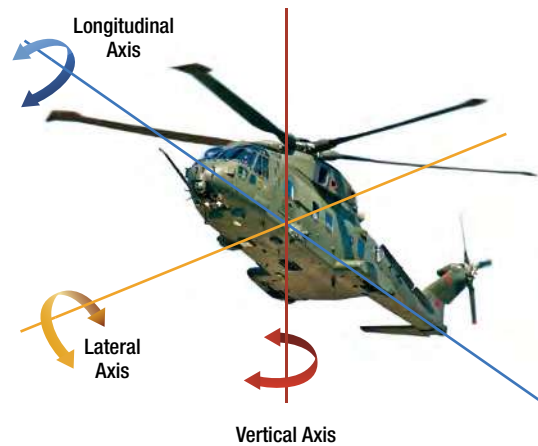


Figure 2-10. Three axes of rotation for a helicopter.



Figure 2-11. Tail rotor description.

on the tail blades, a servo control acts on a platter called a spider. When the spider is in motion, the pitch change rods connected between it and the blades force the latter to move around its feathering hinge.

When the main rotor is turning counterclockwise (viewed from the top), its torque will try to rotate the fuselage clockwise. This makes the nose of the helicopter yaw to the right. When the anti-torque rotor is producing the correct amount of thrust to exactly counteract the torque of the main rotor, the nose of the helicopter will remain steady in the same direction. Making the helicopter yaw to the right is accomplished by pushing on the right anti-torque pedal. [Figure 2-12] This action reduces the thrust of the tail rotor (by reducing the blade angle) to less than what is needed to counteract the torque and the helicopter yaws to the right. When the pilot pushes the left anti-torque pedal, increases the blade angle of the tail rotor, the nose of the helicopter will yaw to the left. It is important to understand that the tail rotor does not control the direction in which the helicopter is flying. It only controls the direction in which the fuselage is heading. The direction of flight is controlled by the cyclic pitch system, as previously described.

THE TAIL FLAPPING HINGE

When a helicopter is in motion, the translation speed is added or subtracted from the rotation speed of the blades depending on whether it is an advancing or a retreating blade. This problem is the same on the tail rotor. To solve it, a flapping hinge is added. On the tail rotor, the blades are lighter than the main rotor and the movement is easy to control. When the blade rotates in the advancing zone, the pitch is automatically changed by the change rod which reduces the angle of attack. With this reduction in lift, the reaction of the blade is to return to the average flying plan. [Figure 2-13]

When the blade retreats, it tends to move closer to the tail structure. To avoid contact, the pitch change rod increases the pitch. The reaction of the blade with the increased pitch is to move away from the structure. [Figure 2-14]



Figure 2-12. Movement of right pedal.

THE TAIL AND PEDAL CONNECTION

Because the tail rotor is too far from the pedals to connect with connecting rods, the usual solution is to route cables through the tail structure. [Figure 2-15] At the end of the tail beam, the movement of the cables controls the servo-control of the tail. When the servo-control extends or retracts, it changes the position of the spider and so changes the blade's angle of attack thus adjusting thrust.

DIFFERENT SOLUTIONS

During translational flight, the tail rotor uses 20% of the power supplied by the motor. The remaining 80% is given to the main rotor. Different solutions are used to reduce the power consumption of the tail and restore maximum torque to the main rotor.



Figure 2-13. Advancing zone flapping movement.



Figure 2-14. Retreating zone flapping movement.