EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Basics of transport and handling technology KKS/ZDMT

Presentation 6

HELICOPTERS

Overview, techniques, aerodynamics and mechanics of flight

Jiří Barták, Petr Barták

Version 2011

This presentation is part of project CZ.1.07/2.2.00/15.0383
Innovations of Study specialisation Transport Vehicles and Handling Machinery with respect to market needs

This project is co-financed by
European Social Fund and the state budget of the Czech Republic

Contents

- Presentation 1/3 (introduction)
  - Basic aerodynamics
  - Basic mechanics of flying
  - Air traffic
- Presentation 2/3 (aeroplanes)
  - Basic terms
  - Aeroplane classification
  - Design of individual parts
- Presentation 3/3 (helicopters)
  - Basic terms
  - Basic aerodynamics and mechanics of helicopters
  - Helicopter technology

Characteristics of helicopters

A helicopter is a heavier-than-air, powered aircraft driven by rotating aerofoils.

CLASSIFICATION OF HELICOPTERS

Aircraft with rotating aerofoils	Unpowered	Glider
	Powered	Combined with fixed wing (tiltrotor)
		Autogyro
		Helicopter
		Gyrodyne

CLASSIFICATION OF HELICOPTERS– autogyro

- Autogyro used in WW2 by the German submarine fleet

CLASSIFICATION OF HELICOPTERS– tiltrotor

- Bell Boeing V-22 Osprey- military role in Afghanistan and Iraq

CLASSIFICATION OF HELICOPTERS– autogyro

CLASSIFICATION OF HELICOPTERS– gyrodyne

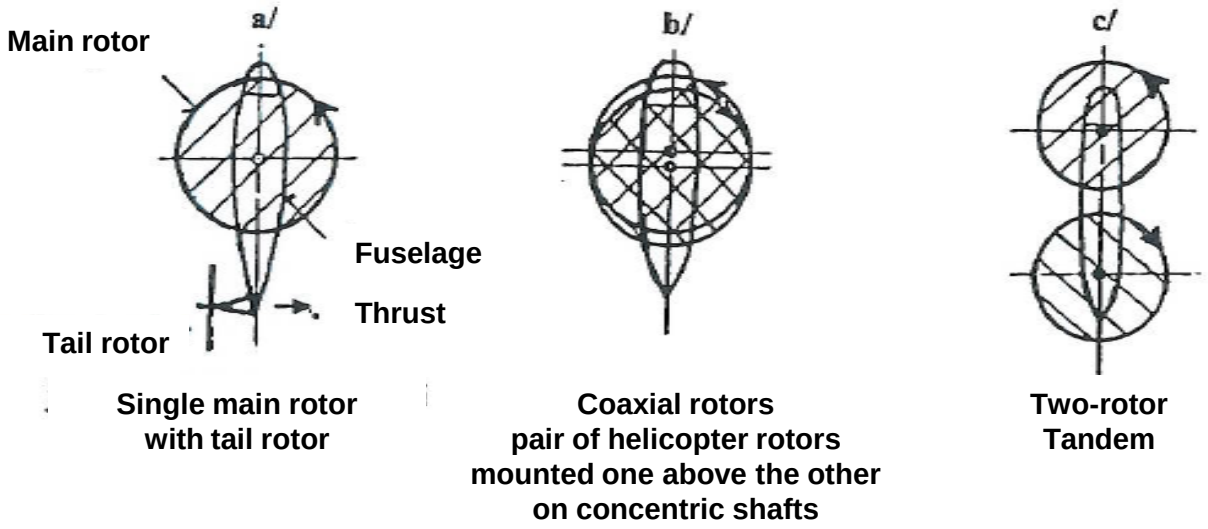
CLASSIFICATION OF HELICOPTERS

Classification of helicopters

- **Helicopter**
  - **Weight category**
    - **Ultralight (to 600kg)**
    - **Light (to 2500 kg)**
    - **Medium (to 8000kg)**
    - **Heavy (over 8000 kg)**
  - **Number of rotors**
    - **Single motor**
    - **Multi-motor (expanded: two rotors in line)**
  - **Power source of drive rotor**
    - **Mechanical**
    - **Reactive (at end of rotor blades)**
  - **Means of balancing reaction moment**
    - **Reaction moment does not occur**
    - **Reaction moment occurs**
      - **Tail rotor**
      - **Multiple drive rotors**
      - **Gas jets from turbines at end of fuselage**
  - **Means of control**
    - **Direct**
    - **Indirect (for single motors – tail rotor)**
  - **Means of landing**
    - **On land (multi-wheel landing gear)**
    - **On water (floats)**
    - **On land and water (combined)**

CLASSIFICATION OF HELICOPTERS

CLASSIFICATION OF HELICOPTERS



Single main rotor with tail rotor

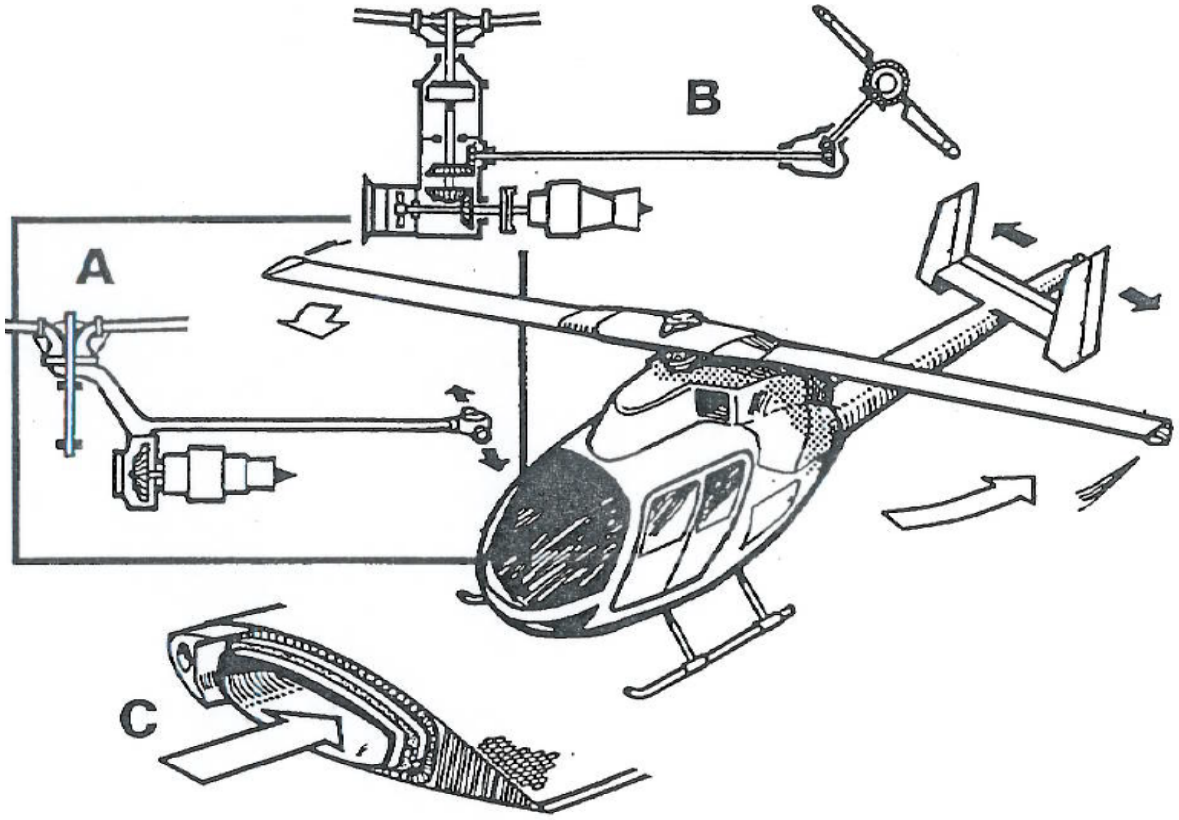
Coaxial rotors pair of helicopter rotors mounted one above the other on concentric shafts

Two-rotor Tandem

Some possible arrangements for rotors.

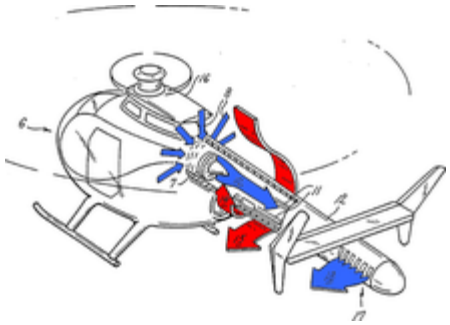
CLASSIFICATION OF HELICOPTERS

Diagram of helicopter powered by compressed air
A-rotors driven by compressed air
B- rotor shaft driven mechanically by jet engine
C – cavity in rotor blade
Compressed air from compressor (0.3 to 0.5 MPa, temp. 200 to 300℃). Compressed air travels from the separator in the rotor head along the blade cavities to the tip jets.



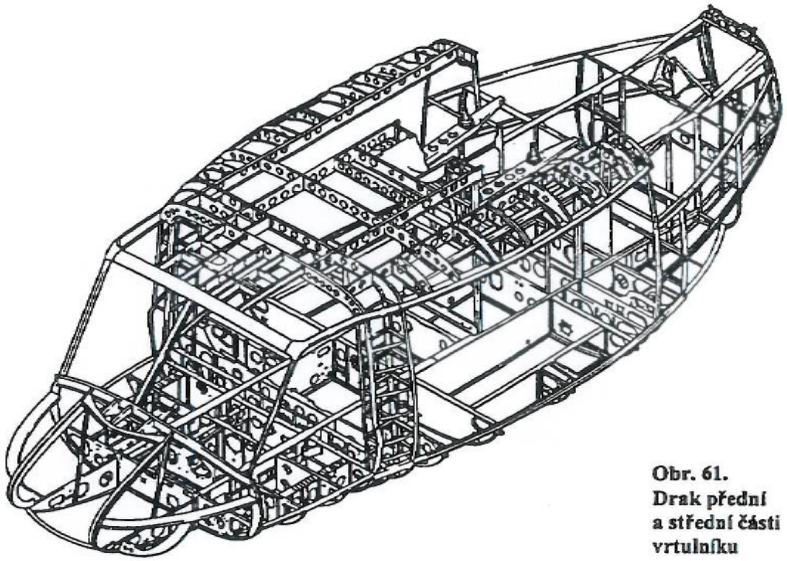
Basic information about helicopters

- A helicopter is a powered, heavier-than-air, aircraft driven by horizontally rotating aerofoils.
- Tilting along the horizontal axis changes the angle of attack of the rotor blades: cyclical control.
- Climbing is controlled by collective changing the angle of attack and engine power: collective control
- Torque originating from the main rotor drive must be balanced: tail rotor, NOTAR, Fenestron, multiple rotors, etc.
- Engines: may be single engine, two engine, driven in ‘twins’, and multiple engines.



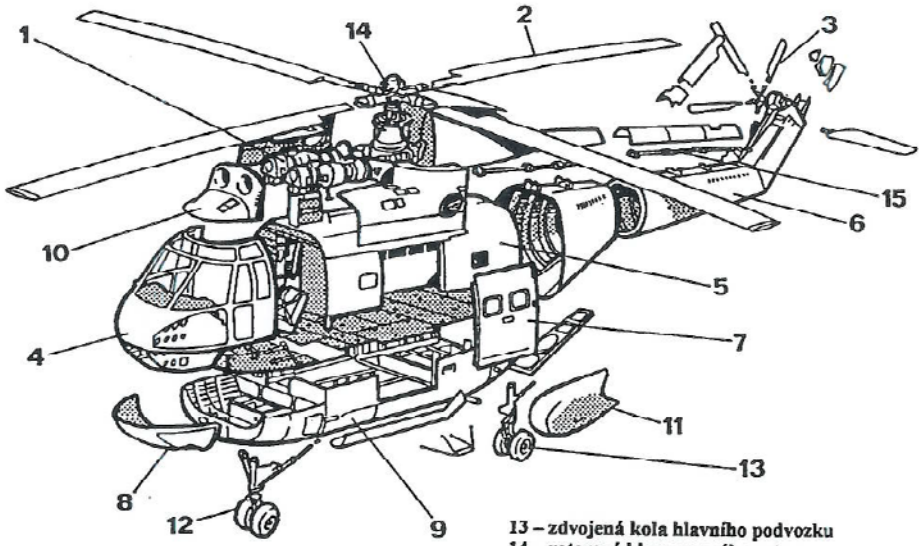
Helicopter and its structure

Helicopter structure
Construction
- Airframe
  - Front section
  - Centre section
  - Rear section
- Drive system
  - Piston engine
  - Jet engine
  - Transmission (including rotor head and reducer)
- Accessories and equipment



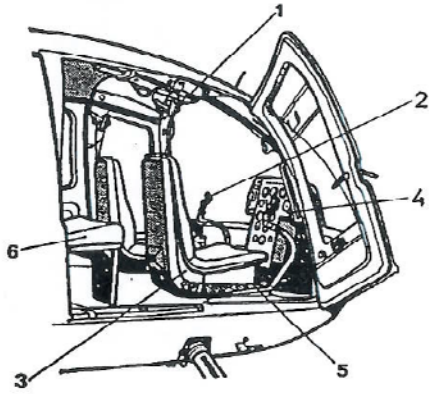
Obr. 61.
Drak přední a střední části vrtulníku

Fig. 55 Basic construction of helicopter
1) Engine (jet), 2) Main rotor 3) Tail rotor, 4) Cabin 5) Cargo bay 6) Tail boom 7) Cargo bay door 8) Lower cover of cabin 9)Lower section of airframe 10) Front engine cowling 11) Main landing gear cowling 12) Nose landing gear wheel pair 13) Main landing gear wheel pair 14) Main rotor head 15) Tail rotor drive shaft (transmission)



5 – prostor pro náklad
6 – zadní část draku
7 – dveře nákladního prostoru
8 – spodní kryt pilotní kabinu
9 – spodní část draku
10 – přední kryt motorů
11 – kryt hlavního podvozku
12 – přední zdvojená kola podvozku
13 – zdvojená kola hlavního podvozku
14 – rotorová hlava nosného rotoru
15 – hřídel vyrovnávacího rotoru (transmise)

Cabin of light helicopter
1)Radio headphones, 2) Cyclic stick 3) Pilot seat 4) Dashboard 5) Seat belts 6)Passenger seat

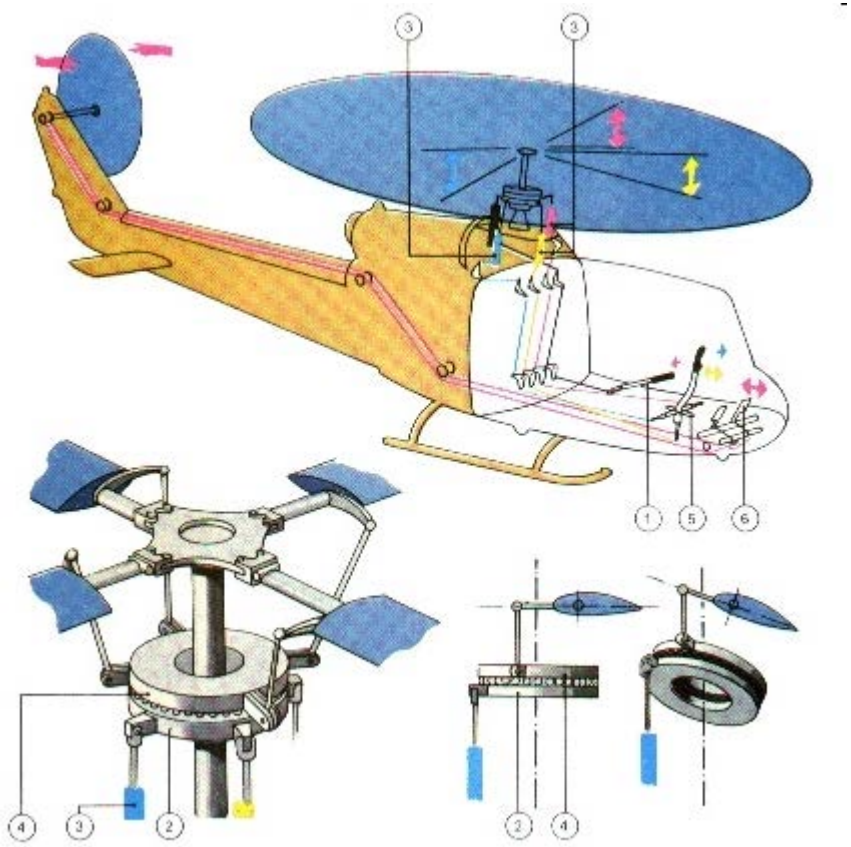


Helicopter and its structure

Function

- **Rotor**
  - **-Rigid**
  - **- Semi-rigid**
  - **- Articulated**
    - **Articulated blades (around all 3 axes)**
      - **Rotor head**
      - **Blade arm**
      - **Rotor blades (flapping, tilting, rotating)**
      - **Damper**
    - **Articulated blades**
    - **Constant velocity (homokinetic) rotor head**
  - **- Drive system (engine and transmission incl. main and aux. reducers)**
  - **- Fuselage**
  - **- Control system**
    - **Cyclic– cyclic stick**
      - **swash plate (oldest and most common)**
    - **Collective– lever changes pitch of all blades equally**
    - **Fuel– rotating handle releases fuel to engine (on lever)**
    - **Tail rotor– foot pedals (changes pitch of tail rotor and its drag)**
- **- Tail surface**
- **- Equipment**
- **- Landing equipment**

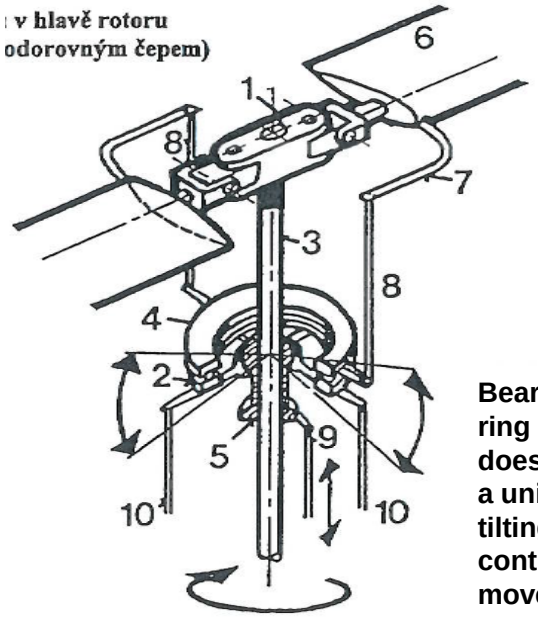
Basic diagram of a helicopter



Helicopter – swash plate

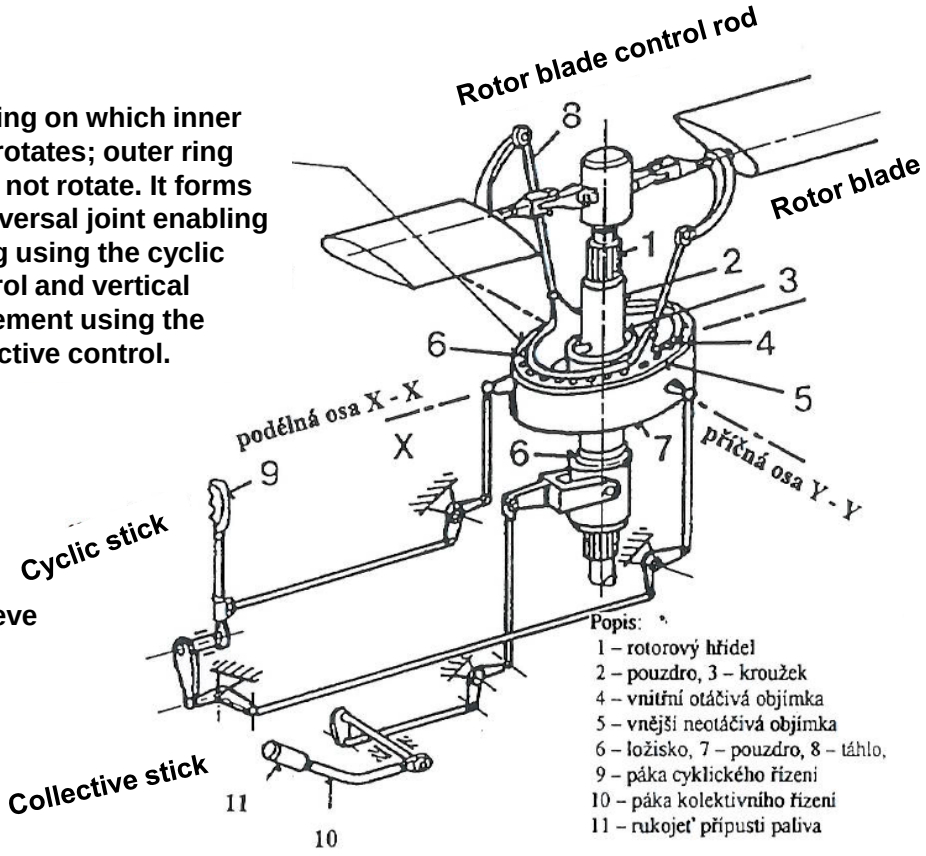
Main rotor assembly (vertical and horizontal pins)
Top: diagram showing pitch adjustment by swash plate

1 **Rotor head**
2 **Non-rotating part of swash plate**
3 **Main rotor shaft**
4 **Upper rotating part of swash plate**
5 **Vertical mobile guide for swash plate with universal joint**
6 **Rotor blade**
7 **Rotor blade control lever**
8 **Vertical push rod for rotor blade**
9 **Push rod connected to collective control (vertical movement of swash plate)**
10 **Push rod connected to cyclic control (tilt of swash plate, movement of helicopter forwards or sideways)**



Bearing on which inner ring rotates; outer ring does not rotate. It forms a universal joint enabling tilting using the cyclic control and vertical movement using the collective control.

1 **Mast**
2 **Casing**
3 **Ring**
4 **Internal rotating sleeve**
5 **External non-rotating sleeve**
6 **Bearing**
7 **Casing**
8 **control rod**
9 **Cyclic control stick**
10 **Collective control stick**
11 **Fuel control handle**

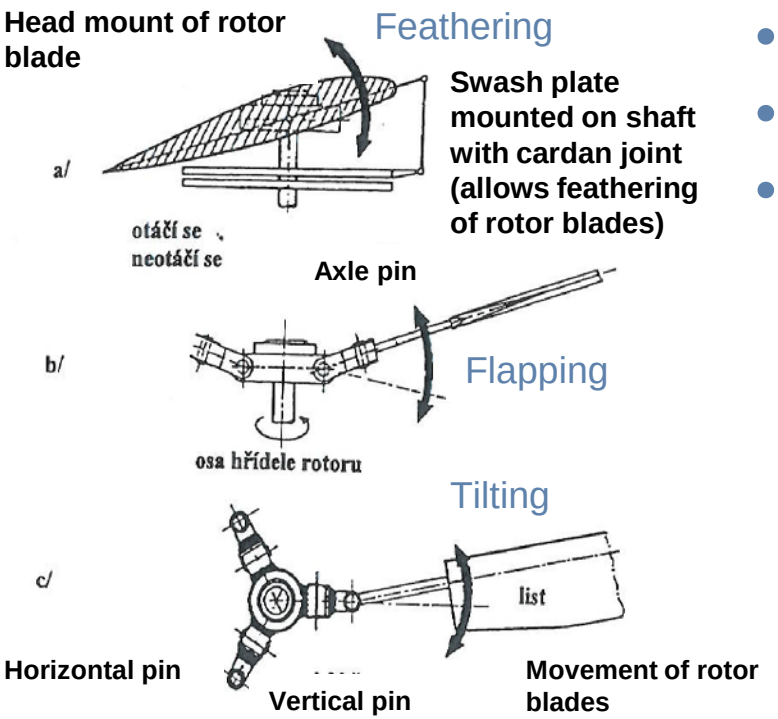


Helicopter – main rotor

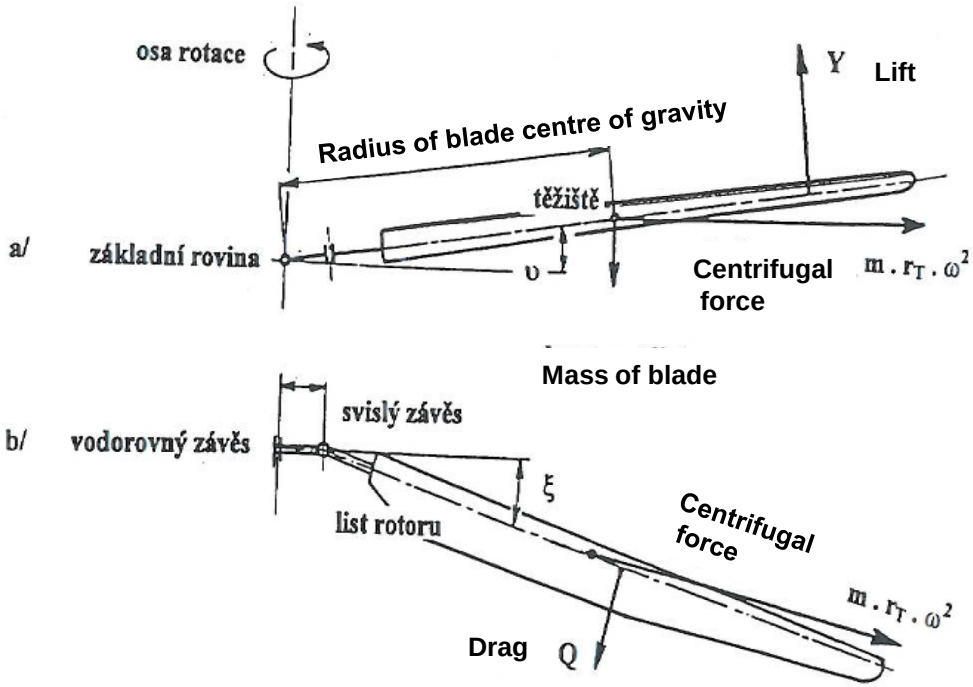
A helicopter main rotor has 3 functions:
- Creates lift to overcome the weight of the helicopter
- Translates drag into forward movement
-Contributes to the stability and controllability of the whole helicopter

The rotor blades of large transport helicopters are usually fixed to the rotor head using three reinforcing mounts:
- Horizontal mount- enables blade to flap in the plane of the blade axis and the rotor shaft
Various designs exist : rigid, semi-rigid and articulated, where vertical and horizontal mounts are replaced by a completely flexible mount in the rotor head (viz appendix Bell407)
- Axial mount– allows rotation about its own axis
- Vertical mount – sometimes called 'drag' mount, allows blades to tilt in the plane of their rotation

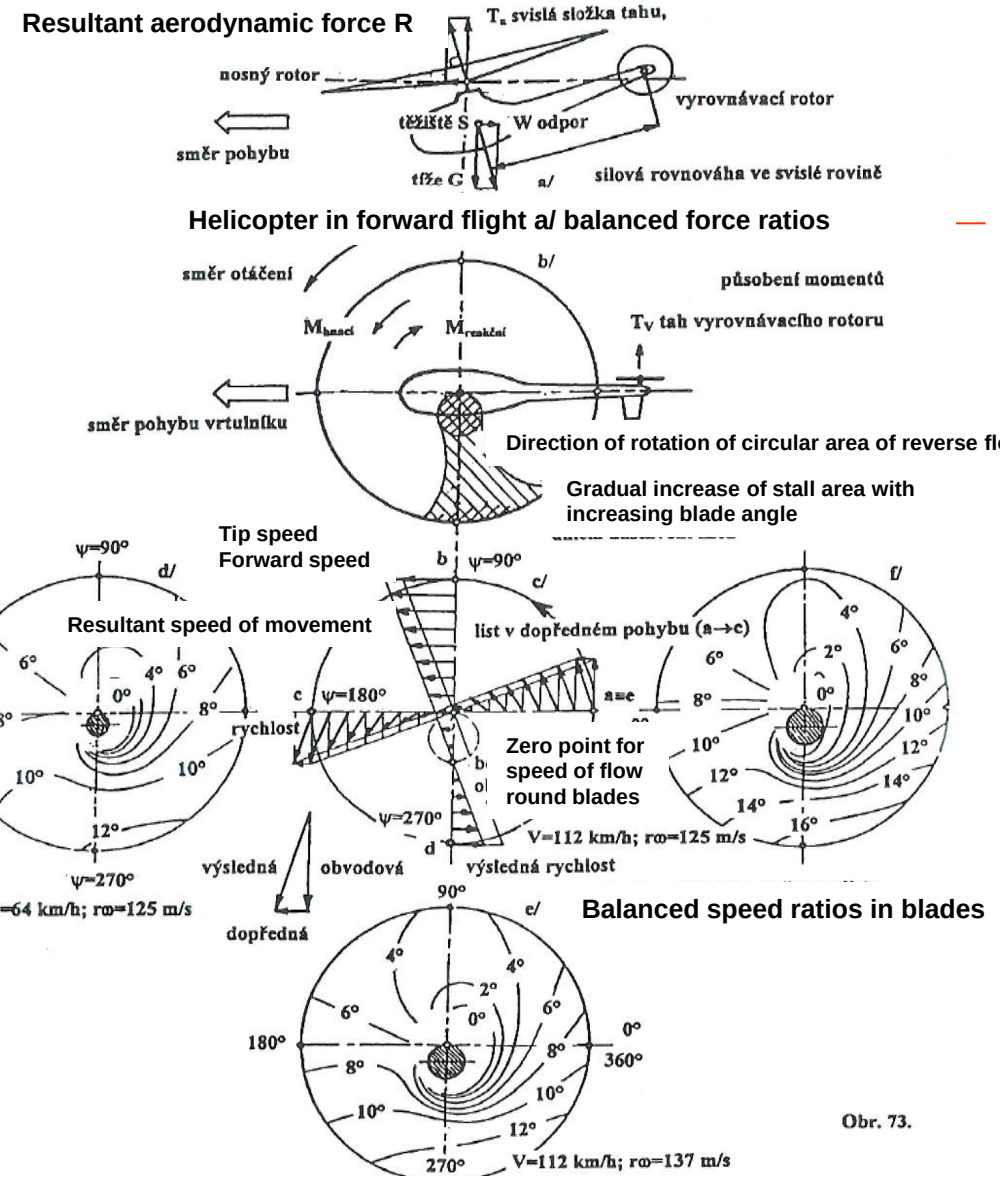
Helicopter – movement of rotor blades



- Feathering
- Flapping
- Tilting

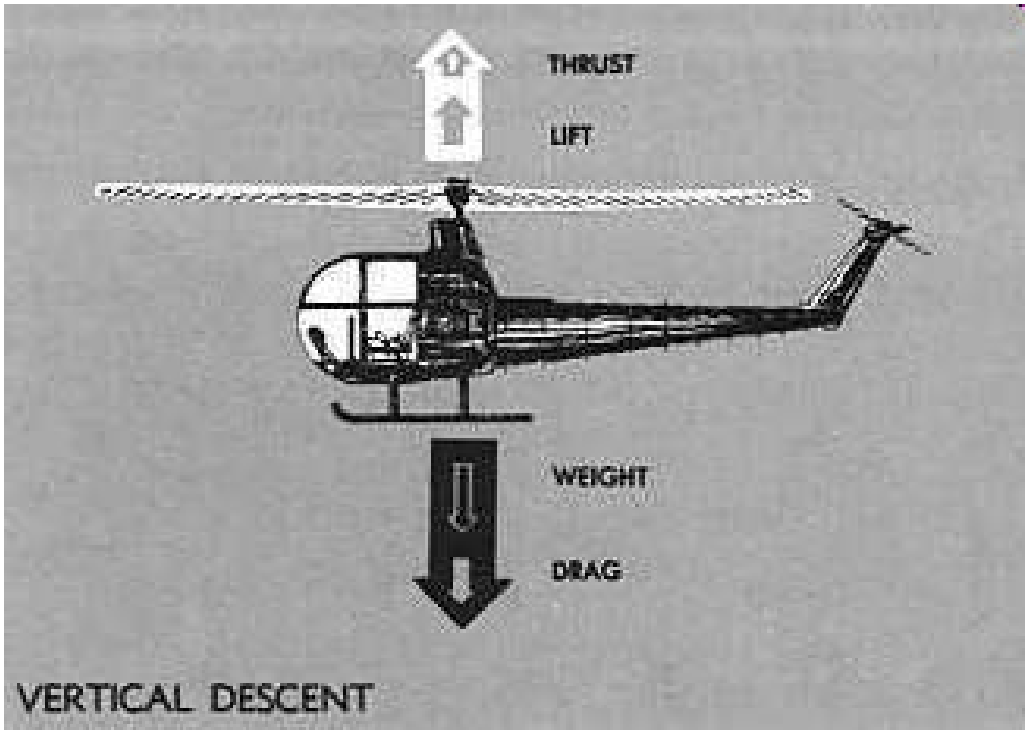


Helicopter – main rotor

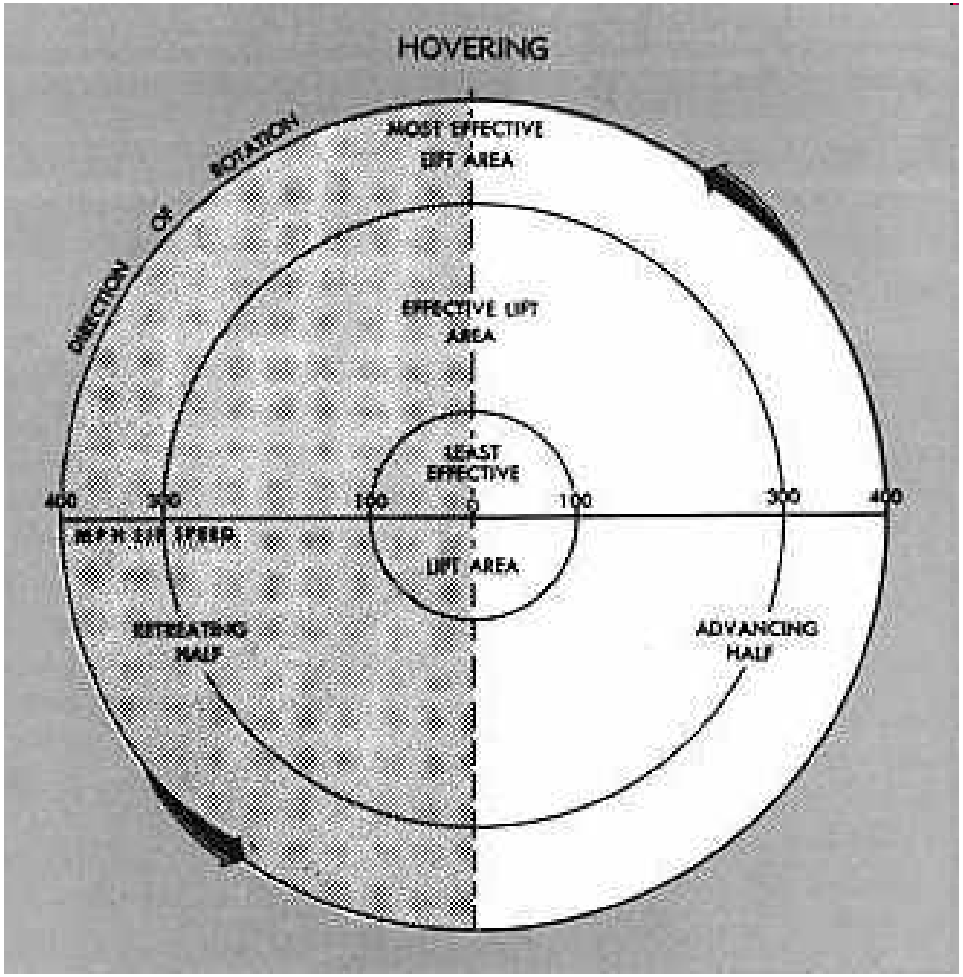


b/ applied moment and first stall area with increased angle of attack
c/ speed ratios for flows round blades (balanced ratios)
d/e/f/ distribution of local angles of attack on rotor blades (for given helicopter and its operational parameters). The point of zero speed is not identical to the axis of rotation, giving rise to aerodynamic asymmetry of rotor air flow. At constant speeds it can be seen that aerodynamic ratios are very complex, as they change along the blade (with radius of rotation r) and for any rotation angle(azimuth angle). In reality the ratios are even more complex as they are spatial, air flow comes from upper side of rotor cone, changes with speed of flight and cyclic with blade angle. Critical values for stalling on blade profiles are reached on retreating blade (in relation to forward flight).

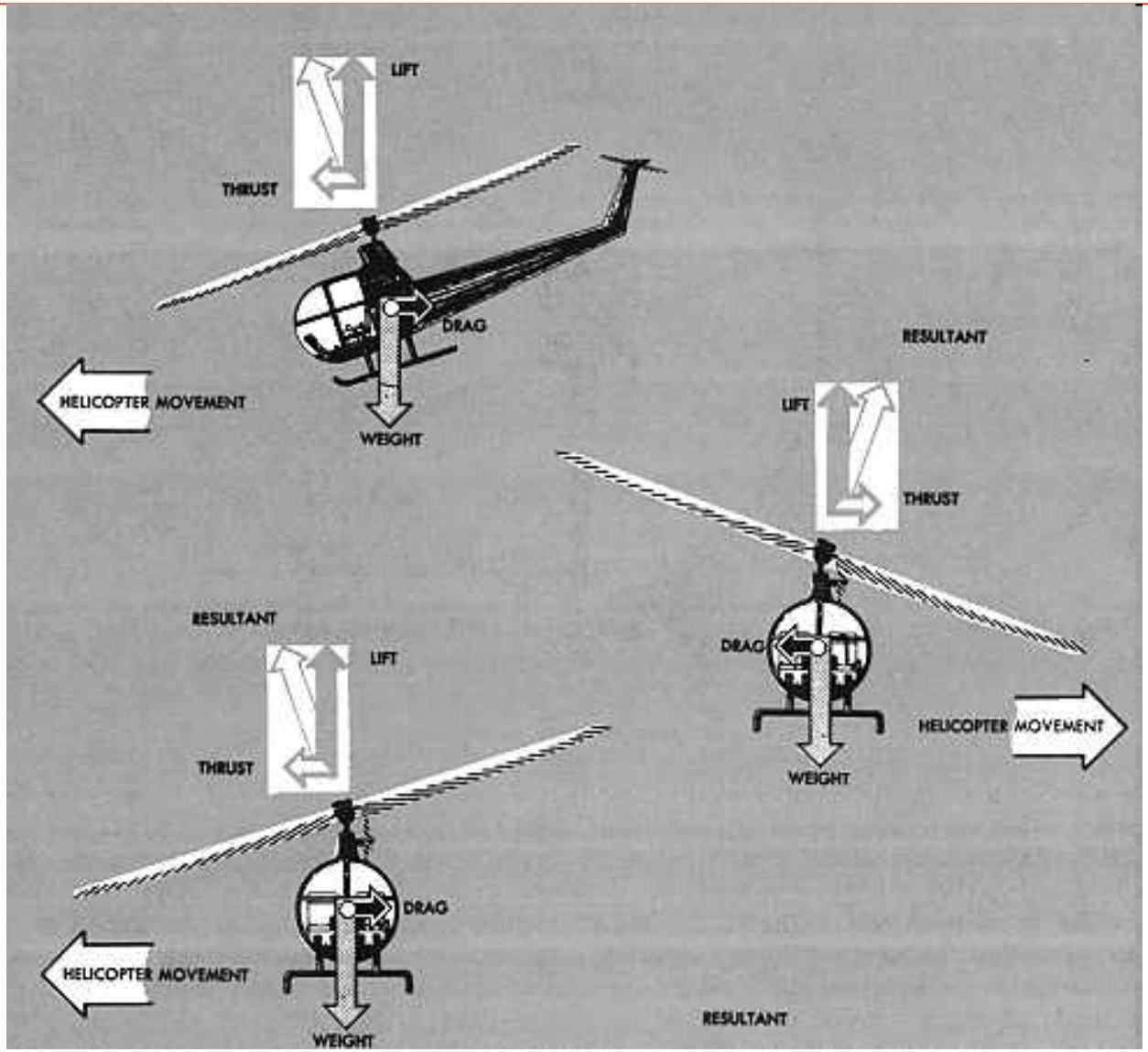
BASICS OF HELICOPTER FLIGHT



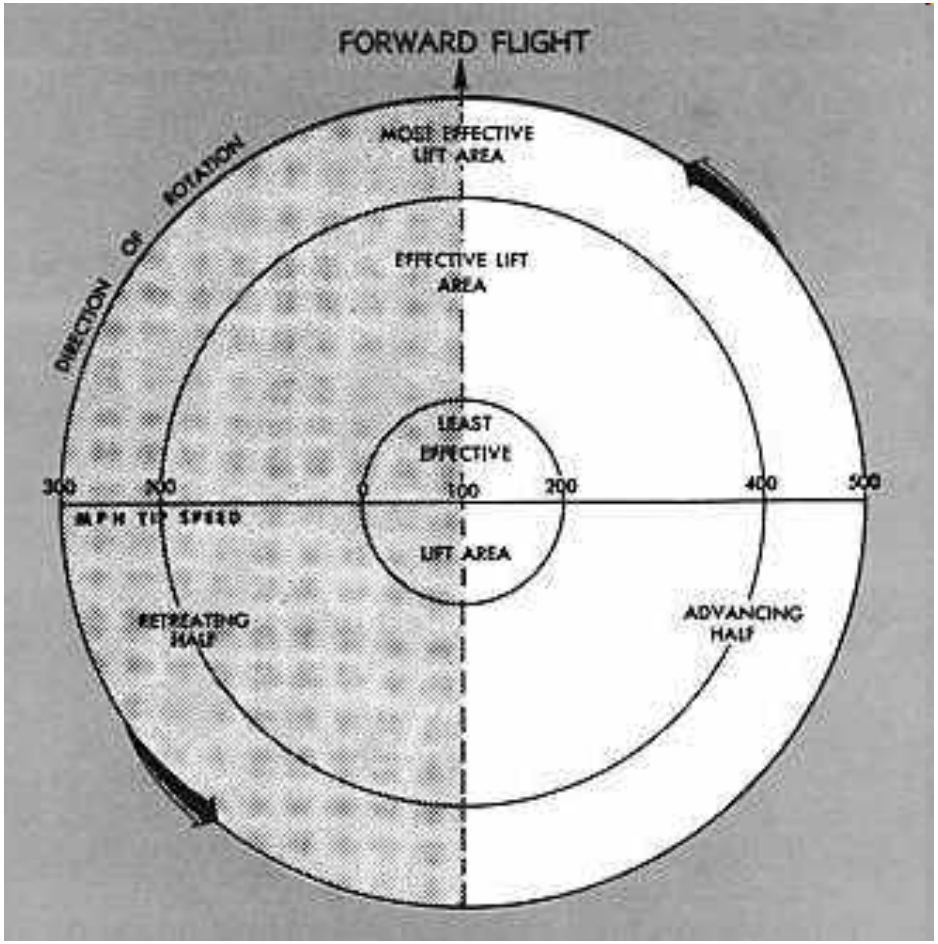
BASICS OF HELICOPTER FLIGHT- HOVERING



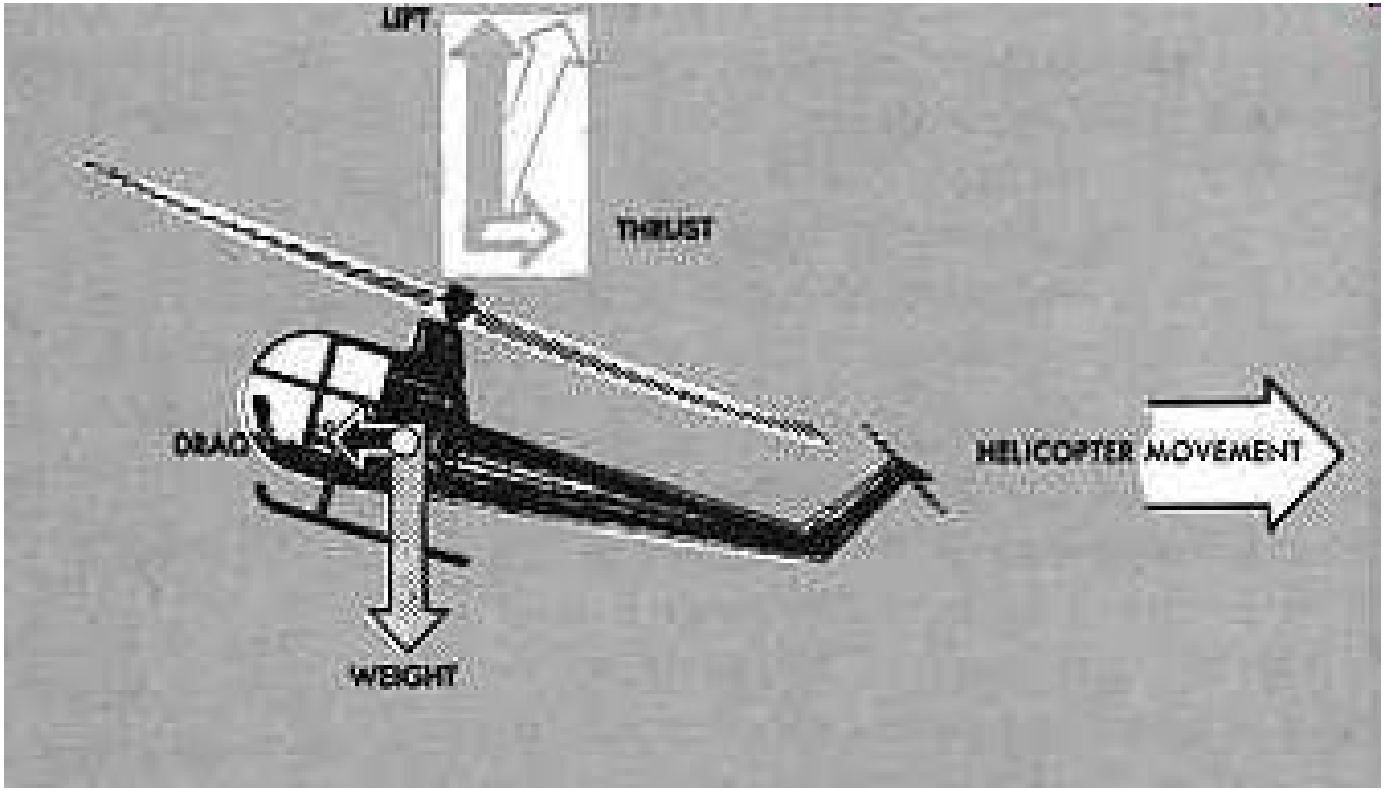
BASICS OF HELICOPTER FLIGHT



BASICS OF HELICOPTER FLIGHT– FORWARD FLIGHT

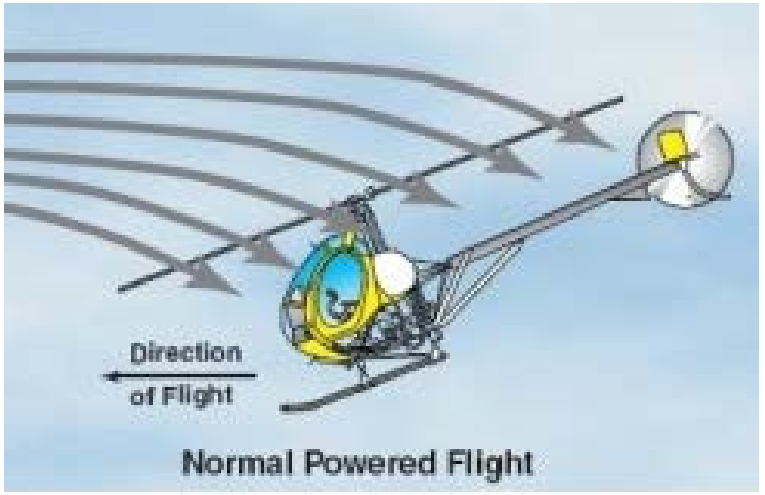


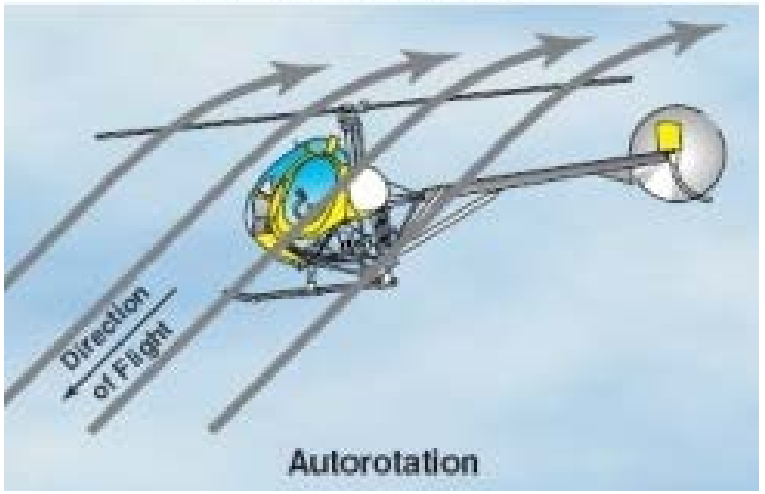
BASICS OF HELICOPTER FLIGHT



Autorotation

- Autorotation happens when the main rotor is turned by the approaching air flow
- It occurs when the engine cuts out
- In certain situations it enables safe landing even after engine cut-out
- Requires suitable conditions: enough height and/or enough forward speed
- Autogiros function in autorotation mode throughout their flight





INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Acknowledgements

This project is co-financed by
European Social Fund and the state budget of the Czech Republic

Project CZ.1.07/2.2.00/15.0383
Innovations of Study specialisation Transport Vehicles and Handling Machinery with respect to market needs