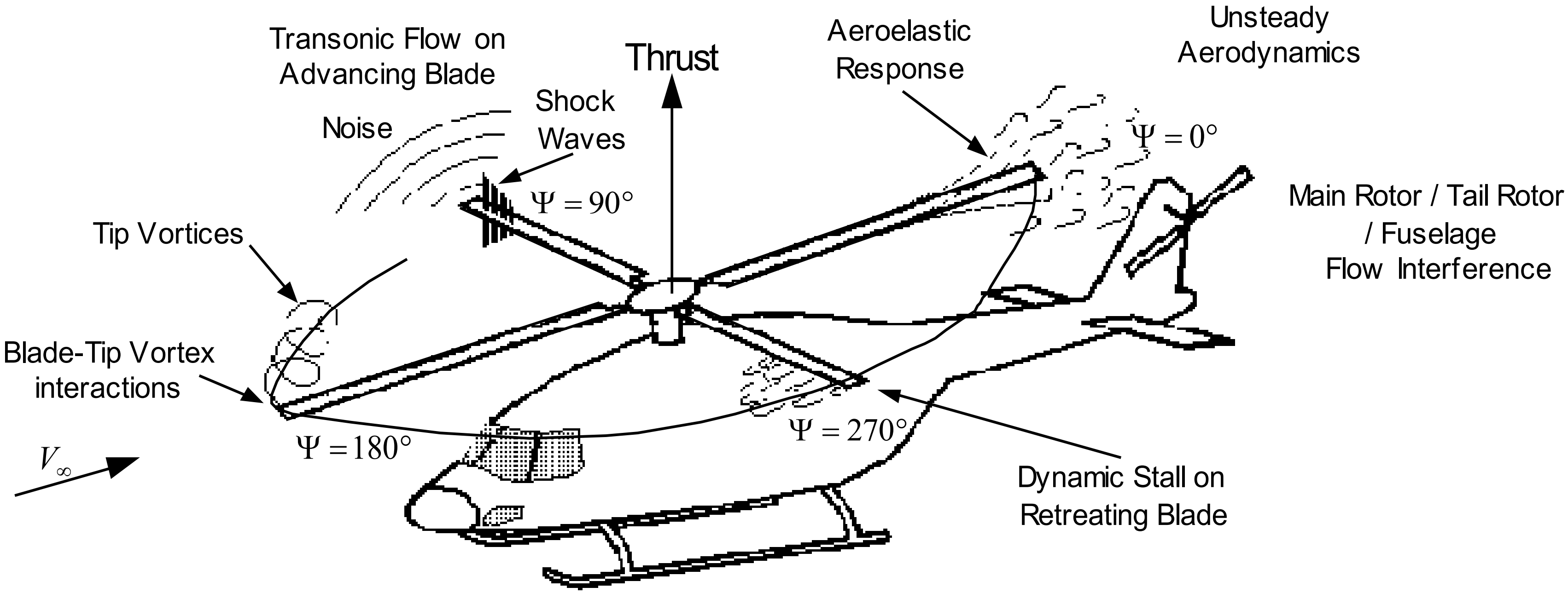
Helicopter Aerodynamics and Performance

Preliminary Remarks

The problems are many..



A systematic Approach is necessary

- A variety of tools are needed to understand, and predict these phenomena.
- Tools needed include
  - Simple back-of-the envelop tools for sizing helicopters, selecting engines, laying out configuration, and predicting performance
  - Spreadsheets and MATLAB scripts for mapping out the blade loads over the entire rotor disk
  - High end CFD tools for modeling
    - Airfoil and rotor aerodynamics and design
    - Rotor-airframe interactions
    - Aeroacoustic analyses
  - Elastic and multi-body dynamics modeling tools
  - Trim analyses, Flight Simulation software
- In this work, we will cover most of the tools that we need, except for elastic analyses, multi-body dynamics analyses, and flight simulation software.
- We will cover both the basics, and the applications.
- We will assume familiarity with classical low speed and high speed aerodynamics, but nothing more.

Plan for the Course

- PowerPoint presentations, interspersed with numerical calculations and spreadsheet applications.
- Part 1: Hover Prediction Methods
- Part 2: Forward Flight Prediction Methods
- Part 3: Helicopter Performance Prediction Methods
- Part 4: Introduction to Comprehensive Codes and CFD tools
- Part 5: Completion of CFD tools, Discussion of Advanced Concepts

References

- Wayne Johnson: Helicopter Theory, Dover Publications,ISBN-0-486-68230-7
- Gordon Leishman: Principles of Helicopter Aerodynamics, Cambridge Aerospace Series, ISBN 0-521-66060-2
- Prouty: Helicopter Performance, Stability, and Control, Prindle, Weber & Schmidt, ISBN 0-534-06360-8
- Gessow and Myers
- Stepniewski & Keys
- https://rotorcraft.arc.nasa.gov/FINAL_Harris%20Vol%20II_Feb%2011%202013.pdf (Free!)

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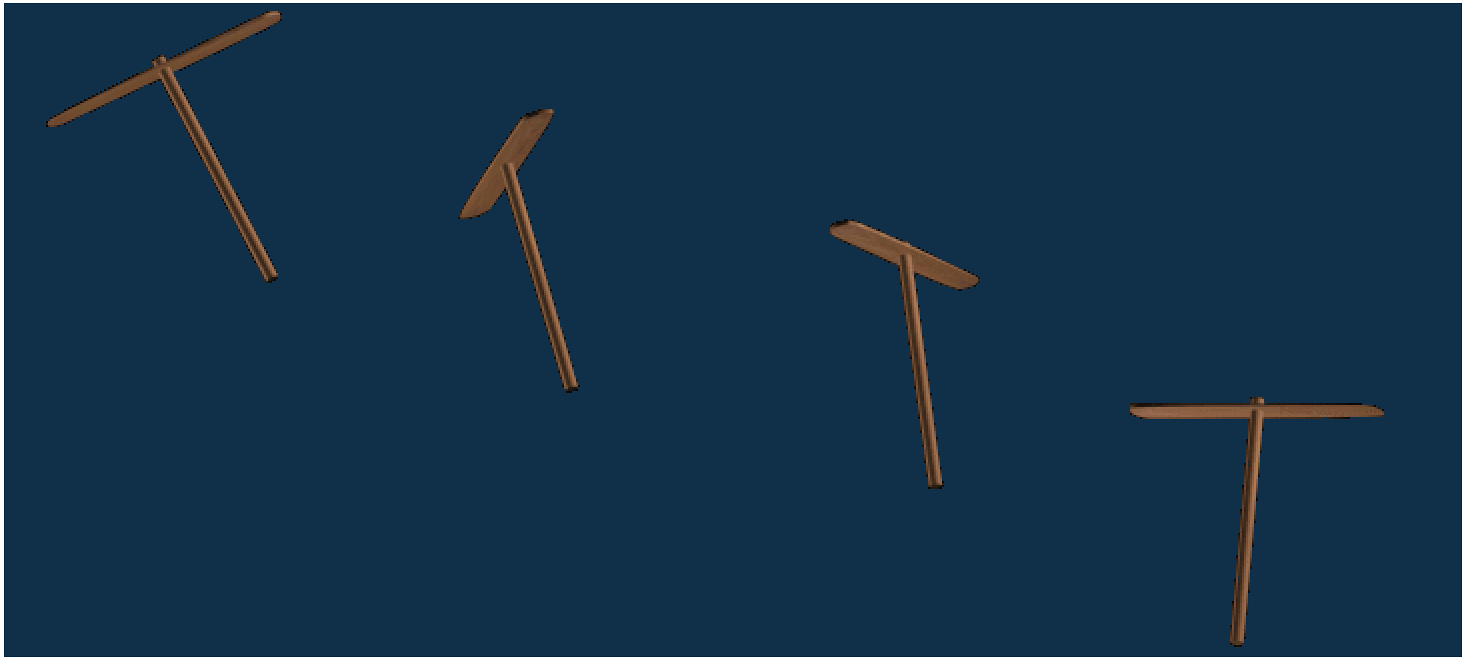
Earliest Helicopter..
Chinese Top



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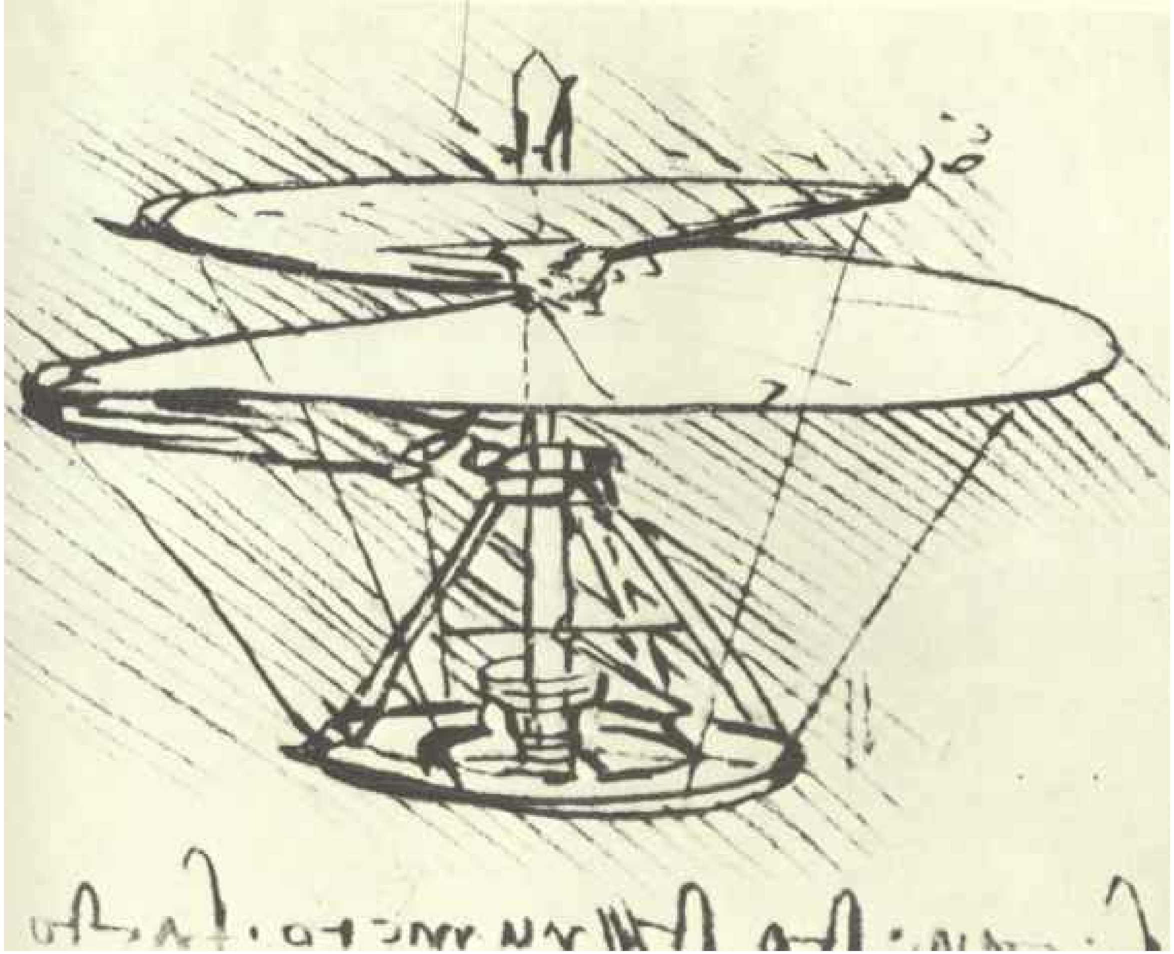
Helicopter Aerodynamics

Leonardo da Vinci (1480? 1493?)



Human Powered Flight?

$\text{Weight} = 160\text{lbf}$

Rotor Radius~ 6ft

Rotor Area = 100 sq.ft

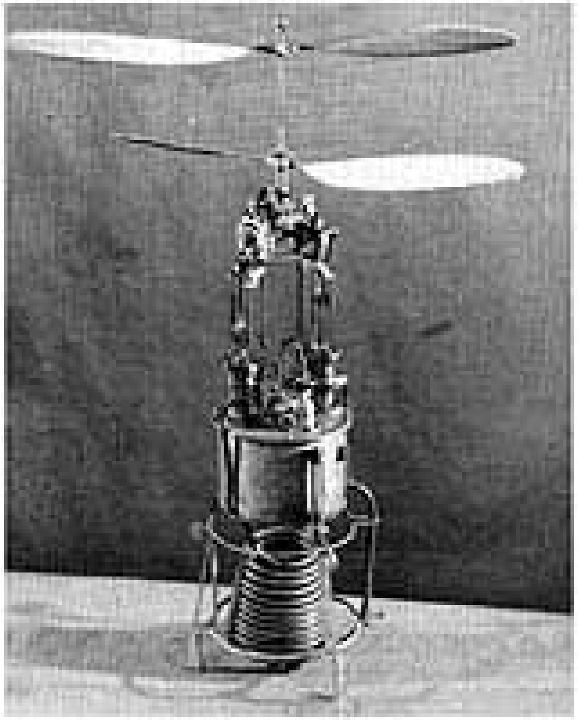
$\text{Density} = 0.00238 \text{ slugs per cubic feet.}$

$$\text{Ideal Power} = \text{W}\sqrt{\frac{\text{W}}{2\rho\text{A}}} = 5.33HP$$

Actual Power = Ideal Power/Figure of Merit

= 5.33/0.8 = 6.7 HP

D’AmeCourt (1863)
Steam-Propelled Helicopter



Paul Cornu (1907) First man to fly in helicopter mode..

https://en.wikipedia.org/wiki/Cornu_helicopter

De La Cierva invented Autogyros (1923)

Cierva introduced hinges at the root that allowed blades to freely flap

Hinges

Only the lifts were transferred to the fuselage, not unwanted moments.

In later models, lead-lag hinges were also used to Alleviate root stresses from Coriolis forces

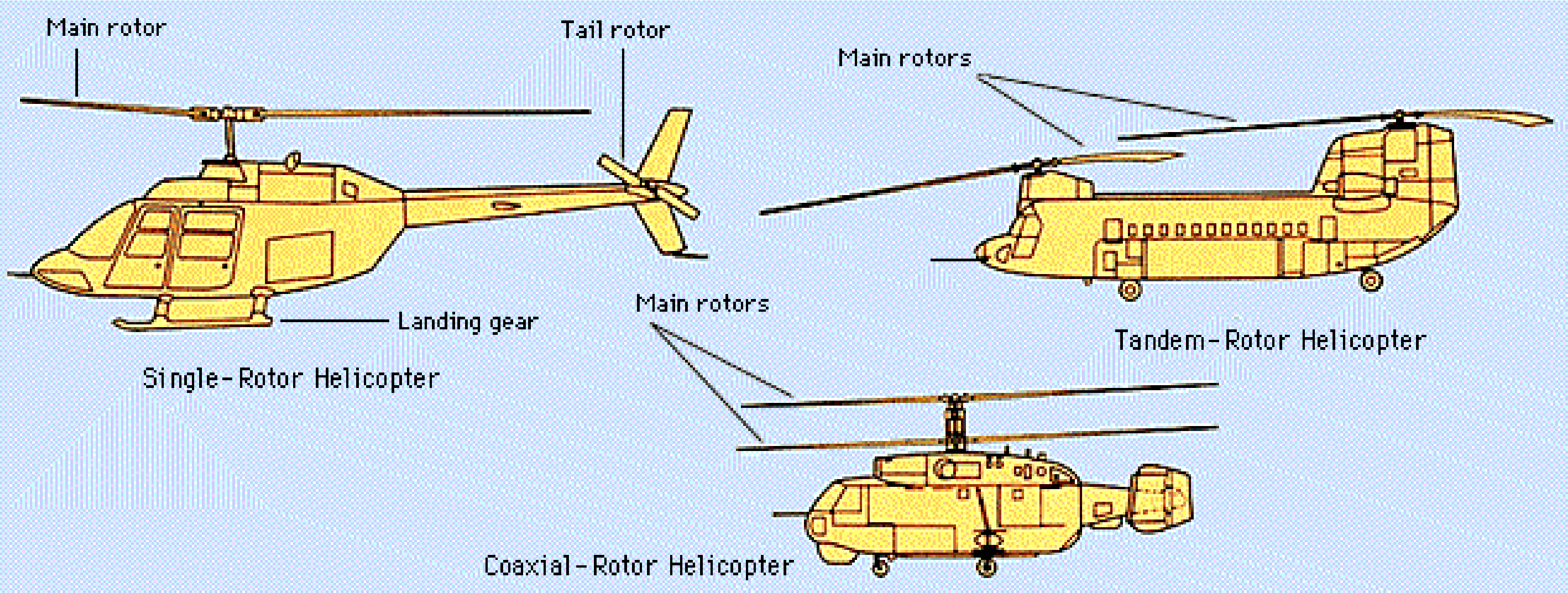
Igor Sikorsky
Started work in 1907, Patent in 1935

Used tail rotor to counter-act the reactive torque exerted by the rotor on the vehicle.

Sikorsky's R-4

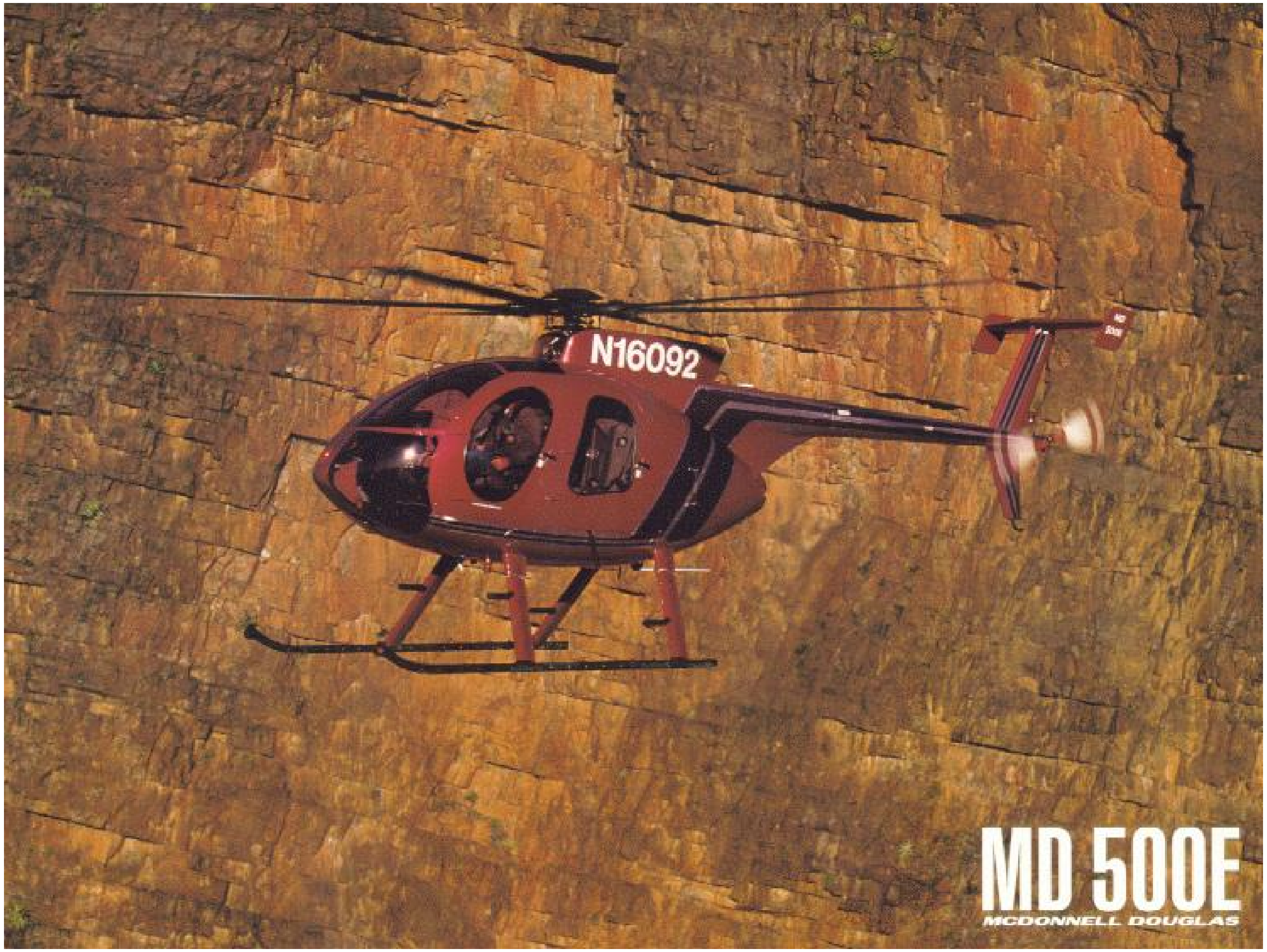
SIKORSKY ' R-4 HELICOPTER While Igor Sikorsky's first helicopter flew in Russia as long ago as 1909, his first practicable helicopter, the two-seat VS-316A, was first tested in January 1942. Two years later, as the R-4, it became the world's first helicopter to enter production, 130 being built. Its 180 hp piston engine enabled it to attain a speed of 82 mph at a weight of 2,530lb. It was adopted by the American Armed Services and also by the RAF. From it was developed the four-seat Sikorsky S-51 which, built under licence by Westland as the Dragonfly, became Britain's first helicopter.

Ways of countering the Reactive Torque



Other possibilities: Tip jets, tip mounted engines

Single Rotor Helicopter

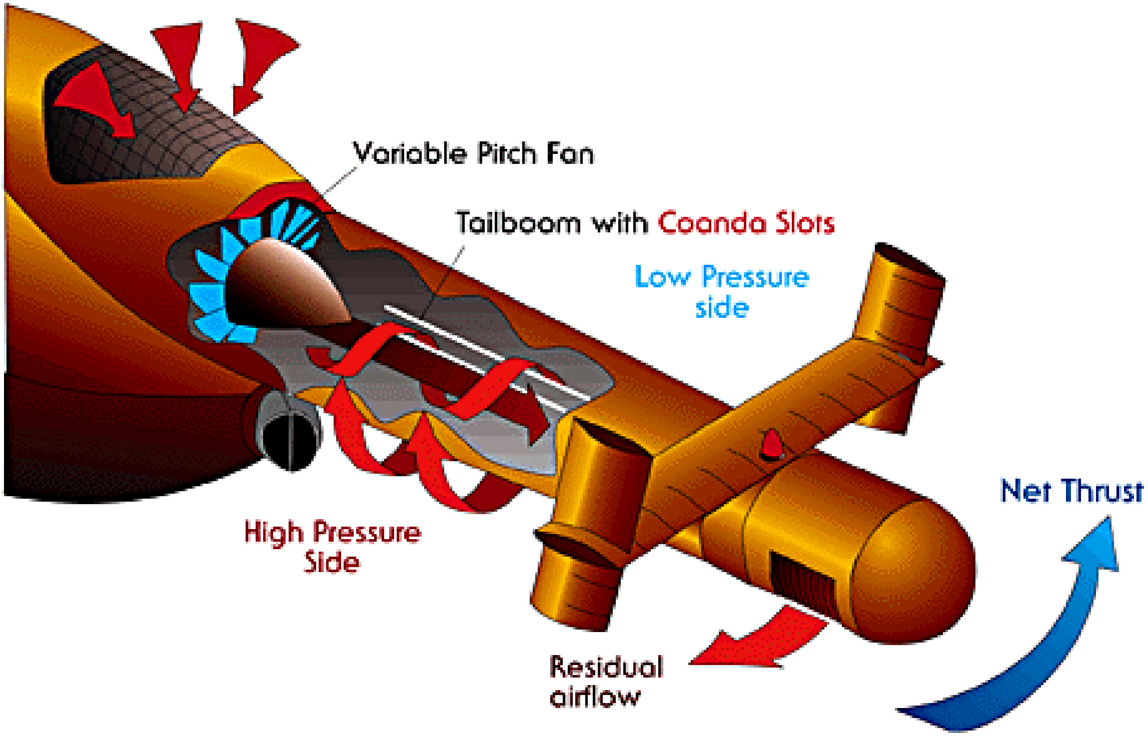


Tandem Rotors (Chinook)

Coaxial rotors
Kamov KA-52

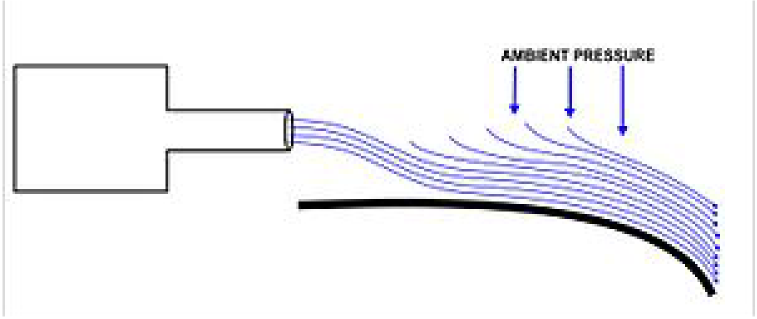
NOTAR Helicopter

NOTAR Concept



Coanda Effect

- When a jet is blown tangentially to a curved surface, it follows the surface contour



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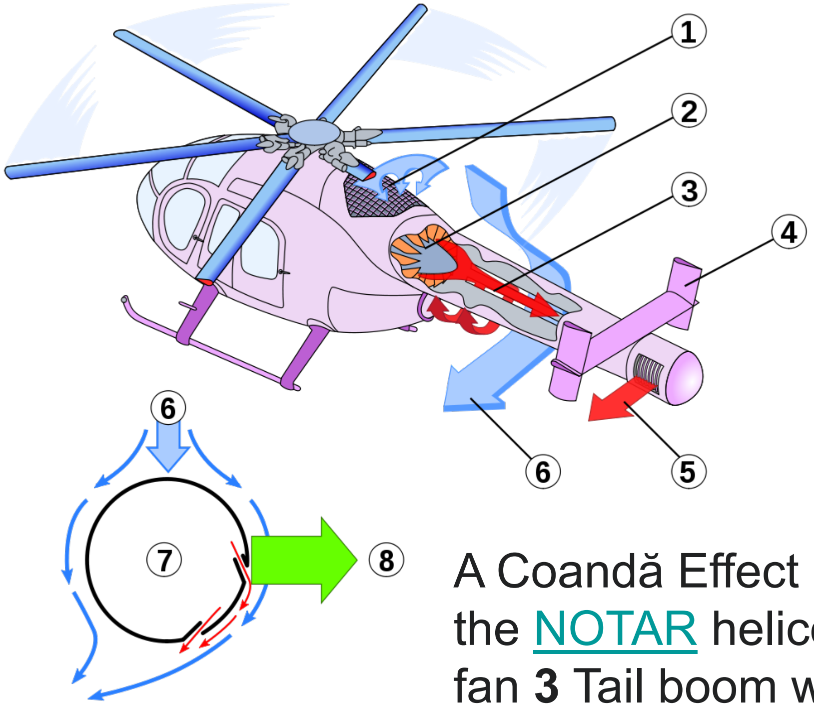

A Coandă Effect (items 3,6–8) replaces the tail rotor in the NOTAR helicopter. **1** Air intake **2** Variable pitch fan **3** Tail boom with Coandă Slots **4** Vertical stabilizers **5** Direct jet thruster **6** Downwash **7** Circulation control tail boom cross-section **8** Anti-torque lift

Tilt Rotor Vehicles

Helicopters tend to grow in size..

	AH-64A	**AH-64D**
Length	58.17 ft (17.73 m)	58.17 ft (17.73 m)
Height	15.24 ft (4.64 m)	13.30 ft (4.05 m)
Wing Span	17.15 ft (5.227 m)	17.15 ft (5.227 m)
Primary Mission Gross Weight	15,075 lb (6838 kg) 11,800 pounds Empty	16,027 lb (7270 kg) Lot 1 Weight

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Primary Mission Gross Weight	15,075 lb (6838 kg) 11,800 pounds Empty	16,027 lb (7270 kg) Lot 1 Weight
Hover In-Ground Effect (MRP)	15,895 ft (4845 m) [Standard Day] 14,845 ft (4525 m) [Hot Day ISA + 15C]	14,650 ft (4465 m) [Standard Day] 13,350 ft (4068 m) [Hot Day ISA + 15 C]
Hover Out-of-Ground Effect (MRP)	12,685 ft (3866 m) [Sea Level Standard Day] 11,215 ft (3418 m) [Hot Day 2000 ft 70 F (21 C)]	10,520 ft (3206 m) [Standard Day] 9,050 ft (2759 m) [Hot Day ISA + 15 C]

	AH-64A	**AH-64D**
Primary Mission Gross Weight	15,075 lb (6838 kg) 11,800 pounds Empty	16,027 lb (7270 kg) Lot 1 Weight
Vertical Rate of Climb (MRP)	2,175 fpm (663 mpm) [Sea Level Standard Day] 2,050 fpm (625 mpm) [Hot Day 2000 ft 70 F (21 C)]	1,775 fpm (541 mpm) [Sea Level Standard Day] 1,595 fpm (486 mpm) [Hot Day 2000 ft 70 F (21 C)]
Maximum Rate of Climb (IRP)	2,915 fpm (889 mpm) [Sea Level Standard Day] 2,890 fpm (881 mpm) [Hot Day 2000 ft 70 F (21 C)]	2,635 fpm (803 mpm) [Sea Level Standard Day] 2,600 fpm (793 mpm) [Hot Day 2000 ft 70 F (21 C)]
Maximum Level Flight Speed	150 kt (279 kph) [Sea Level Standard Day] 153 kt (284 kph) [Hot Day 2000 ft 70 F (21 C)]	147 kt (273 kph) [Sea Level Standard Day] 149 kt (276 kph) [Hot Day 2000 ft 70 F (21 C)]
Cruise Speed (MCP)	150 kt (279 kph) [Sea Level Standard Day] 153 kt (284 kph) [Hot Day 2000 ft 70 F (21 C)]	147 kt (273 kph) [Sea Level Standard Day] 149 kt (276 kph) [Hot Day 2000 ft 70 F (21 C)]

Power Plant Limitations

- Helicopters use turbo shaft engines.
- Power available is the principal factor.
- An adequate power plant is important for carrying out the missions.
- We will look at ways of estimating power requirements for a variety of operating conditions.

High Speed Forward Flight Limitations

- As the forward speed increases, advancing side experiences shock effects, retreating side stalls. This limits thrust available.
- Vibrations go up, because of the increased dynamic pressure, and increased harmonic content.
- Shock Noise goes up.
- Fuselage drag increases, and parasite power consumption goes up as V^3.
- We need to understand and accurately predict the air loads in high speed forward flight.

Concluding Remarks

- Helicopter aerodynamics is an interesting area.
- There are a lot of problems, but there are also opportunities for innovation.
- This course is intended to be a starting point for engineers and researchers to explore efficient (low power), safer, comfortable (low vibration), environmentally friendly (low noise) helicopters.