Introduction to Aerospace Engineering

Lecture slides
Intro to Aerospace Engineering
AE112-9-10  Cockpit & Systems

Prof.dr.ir. Jacco Hoekstra
Boeing 727 cockpit
Airbus A320

Airbus was first to introduce glass cockpit together with fly-by-wire on A320
A380 cockpit

Check out:  http://www.gillesvidal.com/blogpano/cockpit1.htm
Classic GA cockpit: Cessna 172 Skyhawk
Glass in GA aircraft: Diamond DA-42 Twin Star
Modern fighter cockpits: HOTAS, MFDs & HMD

F-16 Fighting Falcon

J SF F-35 Lightning I I

HMD
1. **Instrumentation**
'This instrument has a 10 feet accuracy'
What’s our speed? Which speed?

Primary Flight Display (PFD)
Units for speed, altitude & vertical speed

- Circumference earth is 40000 km

- 1 nm = 1 minute = 40000 /360 /60 = 1852 m

- 1 kts = 1 nm/hr = 1852 m/ 3600 s = 0.51444... m/s

- \( M = \frac{V}{a} \) with speed of sound \( a = \sqrt{\gamma R T} \)

- 1 ft = 0.3048

- 1 ft/min = 0.3048 m / 60 s =0.00508

E.g. 400 kts = 400*0.514444 = 206 m/s; = 400*1.852 = 741 km/hr

Note:
1 nm = 1852 m
1 mile = 1609 m
1 kts ≠ 1 mph
1 kts = 1.15 mph

For air: \( \gamma = 1.40 \)
How do we measure speed?

Primary Flight Display (PFD)
First of all: forget the wind!
Airspeed: Pitot Tube
Air data computer ADC
Airspeed, VS and altitude
Equivalent airspeed: no ISA required

- Equivalent airspeed is quickest way to get dynamic pressure

\[ \frac{1}{2} \rho_0 V_{EAS}^2 = \frac{1}{2} \rho V_{TAS}^2 \]

So:

\[ C_L \frac{1}{2} \rho_0 V_{EAS}^2 S = C_L \frac{1}{2} \rho V_{TAS}^2 S \]

- If we assume no instrument errors and no compressibility effect (low Mach number), then EAS = CAS = IAS
Static pressure, dynamic pressure, total pressure

- Speed from difference static & total pressure

- Altitude from difference between static pressure and reference as set by pilot (QNH setting) based on definition in standard atmosphere

- V/S as change in $p_{st}$

Use:  

$$p_{tot} = p_{st} + p_{dyn} = p_{st} + \frac{1}{2} \rho V^2$$

And ISA with QNH setting
What’s our speed? Which speed?

- Ground speed: true airspeed + drift due to wind

IAS = Indicated Airspeed

CAS = Callibrated airspeed

EAS = Equivalent airspeed

TAS = True airspeed

GS = Ground speed

M = Mach number = $V_{TAS}/a$

$EAS = TAS \times \sqrt{\frac{\text{actual air density}}{\text{standard air density}}}$

$\frac{1}{2} \rho_0 V_{EAS}^2 = \frac{1}{2} \rho V_{TAS}^2$

EAS is often used in specifications because it specifies a certain dynamic pressure!
Homework assignment

- Complete the following tables (Hint: use Excel or other program):

<table>
<thead>
<tr>
<th>Altitude</th>
<th>TAS</th>
<th>EAS</th>
<th>Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (SL)</td>
<td>250 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000 ft</td>
<td>250 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL100 / 10000 ft</td>
<td>250 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL200 / 20000 ft</td>
<td>250 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL300 / 30000 ft</td>
<td>250 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL400 / 40000 ft</td>
<td>250 kts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Altitude</th>
<th>TAS</th>
<th>EAS</th>
<th>Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (SL)</td>
<td>365 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000 ft</td>
<td>365 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL100 / 10000 ft</td>
<td>365 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL200 / 20000 ft</td>
<td>365 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL300 / 30000 ft</td>
<td>365 kts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FL400 / 40000 ft</td>
<td>365 kts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Altitude</th>
<th>TAS</th>
<th>EAS</th>
<th>Mach</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (SL)</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>3000 ft</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>FL100 / 10000 ft</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>FL200 / 20000 ft</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>FL300 / 30000 ft</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
<tr>
<td>FL400 / 40000 ft</td>
<td></td>
<td></td>
<td>0.92</td>
</tr>
</tbody>
</table>

- Airbus gives the following maximum operating speeds (Vmo/Mmo):
  A330: 360kias/M0.86
  A340: 330kias/M0.86

What would this mean?
At low altitude the IAS is limiting at high altitude the Mach number. As a result, the speed margin between minimum and maximum speeds will become less.
Altitude

- Pressure altitude is not real altitude
- Adjust for pressure at sea level: QNH
- Above transition altitude: 4500 ft -> FL045
  *Assume at sea level: 1013,25 mbar (=29,92 inch Hg)*

- Flight levels are used above a so-called ‘transition altitude’
- Flight levels use a 100 ft unit
- FL085 means 8500 ft above the 1013.25 hPa pressure
Altitude

- Pressure altitude is not real altitude
- Adjust for pressure at sea level: QNH
- Above transition altitude: 4500 ft -> FL045 (relative to $p_0 = 1013.25 \text{ hPa} = 1 \text{ atm}$)

QNH
Altitude

- Pressure altitude is not real altitude
- Adjust for pressure at sea level: QNH
- Above transition altitude: 4500 ft -> FL045 (relative to $p_0 = 1013.25$ hPa = 1 atm)
Altitude

- Pressure altitude is not real altitude
- Adjust for pressure at sea level: QNH
- Above transition altitude: 4500 ft -> FL045 (relative to p<sub>0</sub> = 1013.25 hPa = 1 atm)

### Table for determining transition level

<table>
<thead>
<tr>
<th>QNH (in millibars)</th>
<th>Transition altitude (in feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1032-1050</td>
<td>FL25 FL35 FL45 FL55 FL175</td>
</tr>
<tr>
<td>1014-1032</td>
<td>FL30 FL40 FL50 FL60 FL180</td>
</tr>
<tr>
<td>996-1013</td>
<td>FL35 FL45 FL55 FL65 FL185</td>
</tr>
<tr>
<td>978-995</td>
<td>FL40 FL50 FL60 FL70 FL190</td>
</tr>
<tr>
<td>960-977</td>
<td>FL45 FL55 FL65 FL75 FL195</td>
</tr>
<tr>
<td>943-959</td>
<td>FL50 FL60 FL70 FL80 FL200</td>
</tr>
</tbody>
</table>