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Wake turbulence risk analysis for parallel runways

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Analysis of wake turbulence occurrences at Sydney Airport 2012–2016
ATSB report

• [Wake separation] standards are not applicable to parallel runways which are separated by more than 760 m.

• [...] ATSB identified a potential safety issue regarding the high proportion of wake turbulence occurrences at Sydney Airport.

• [...] the likelihood of encountering wake turbulence increased substantially, with Runway 34 Right

• [...] increased likelihood of wake turbulence [...] during parallel runway operations, when operating on Runway 34 Right with wind coming from the west or north-west, and/or following an Airbus A380.
Overview

• This is preliminary work to
  • consider key model and assumption
  • gain feedback from industry before further development
  • gain an insight into basic features and initial outcomes.
Example tracks: Sydney 34L 34R

- A380 on 34L: 291 flights
- M (<80000 kg) on 34R: 921 flights
Example vortex motion
Example vortex motion: ground effect
Possible high risk \(\sim 70\) degrees (\(\sim\)Westerly)

NOTE: angle definition
Worst risk  ~ 70 degrees, 25 knots (~Westerly wind)
Effects

- Complex interaction of
  - Initial vortex strength (aircraft size, mass, speed)
  - Altitude
  - Descent and lateral motion of vortex
  - Wind-induced motion of vortex
  - Position of adjacent track (height, lateral distance)
Vortex height just wrong
Vortex too high
Vortex strength with aircraft size, speed

Vortex circulation for sample flights at \( \sim 10000 \) m from threshold

- A380
- B747
- B772
- B773
- B787
- A330
- A320

Circulation \([\text{m}^2/\text{s}]\)

Mean Landing Mass \([1000 \text{ kg}]\)
Risk contours with angle and speed – see 70 degrees (~Westerly)
On-going work

• Model vortex decay break-up with wind speed
• Allow for errors in wind
• Relative timing between 34R and 34L
  • What ‘stagger’ between operations is necessary?
• Known wake turbulence occurrences
  • How do they match with theory?
• Wake interaction force
  • Rattle a few tray tables? or,
  • Serious aircraft rotation?
• Formal risk assessment
  • Risk of minor/major occurrence each year?
Conclusions

- Wake turbulence for offset parallel runways not considered internationally
- For Sydney the risk may be only important at ~70 degrees from axis (~westerly)
- Continue work and discuss at ICAO Separation and Safety Panel
- Method and computer code able to be applied for any set of approaches:
  - For following aircraft on same runway
  - For Melbourne LAHSO and Brisbane CROPS double-go-around risk
  - For departures
  - New parallel runway operations.
Thank you

- Rubai Amin, Dr Amelia Gontar and Dr Daniel Schauries assisted with the data collection

Discussion and Questions?

What are your thoughts on wake risk?
Have you hear of RECAT?
   - Categorising L, M, H, J into 5-6 new categories
   - FAA, Europe (RECAT-EU) and soon China
   - Reduce wake-separation distances for some pairs of aircraft (such as: large-Medium from Heavy).
Method

- Circulation decays
- Ground effect
- Wind effects
Method

• Initial circulation: $\Gamma_0 = \frac{m_l g}{\rho V_l s b_l}$
• Initial spacing: $b_0 = s b_l$
• Initial downward speed: $w_0 = \frac{\Gamma_0}{2\pi b_0} = \frac{m_l g}{2\pi \rho V_l b_0^2}$
• Circulation decays: $\frac{\Gamma(t)}{\Gamma_0} = 1 - \frac{t^*}{\alpha}, \alpha \approx 6$
• Non dimensional time: $t_0 = \frac{b_0}{w_0} = \frac{2\pi b_0^2}{\Gamma_0}$
• Vortex spread: $\Delta y = f_e V_l t$
• Rolling moment coefficient: $RMC_0 = \frac{\Gamma_v}{V_f b_f}$
Method

• Variation in height:
  • aircraft 34L initial height (10 m) (\(\text{altitude [m]} / 200\))
  • aircraft 34R initial height (20 m) (\(\text{altitude [m]} / 100\))
  • vortex height (20 m) (\(\text{cross time [s]} / 10\))

• Overlap probability based on 10m aircraft and vortex.
• Integrate this with Circulation strength and height difference over whole track
Method

- Altitude difference when vortex crosses path on 34R
- Circulation strength at crossing
- Product $\sim$ risk
Method

- Vortex decay (Cheng 2016)

\[ \frac{\Gamma(t)}{\Gamma_0} = 1 - \frac{t^*}{\alpha}, \]
Method

- Vortex spread (Schroeder 2012)
- $\Delta y = f_e V_l t$
Method

• Vortex height (Swol 2009)

• $\Delta y = f_e V_l t$
Sydney
34. USA dept Transport, 2014, Aircraft Wake Turbulence Advisory Circular, 2/10/14, AC no: 90- 23G.