Wake Vortex Encounter Gust Size and Magnitude Flight Data

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Presentation

– Flight data (NRC program)
– Context of gust size/rise/fall-lengths and magnitudes (gust peak speeds)
– Example of flight data
  – Continuous turbulence
  – Rise/fall analysis
  – Discrete (turbulent trailing vortex cores)
CONTEXT – Proceeding to a definition of an acceptable WVE:

- Requires design & certification of structure, aeroservoelasticity, systems, aerodynamics; *in turn*
  
  - Requires definition of WVE gust magnitudes and rise-lengths, for the formulation of design standards: -
    - Discrete gusts, *and*
    - Continuous gust spectra
  
  - Combination (superposition)?
    - Not presently required for aircraft gust-load certification
In which WVE realms:

- Both following realms are desirable:
  - Improvement upon existing landing-approach WT separation standards, and
  - Establishment of enroute WT separation standards
  - both involve $t_{\text{WAKE}} [40:120]$ seconds
    - wake vortex trailing pair probably have turbulent cores, may be in significant individual or/and mutual instability state
    - flight data has both dissipative turbulence scale and intensifying turbulent scales, which are more likely to be core instability modes
EXAMPLE – Trailing pair crossplane-referenced vortex-induced wind perturbations
Trailing pair crossplane
Continuous gust spectra

PSD of longitudinal gustiness, vortex core traverses

- Flight data, 8-15 nm wake length, 53-90 sec age
- FAR 25, App. F with $U_\sigma = 85$ fps with $\sigma = 85/3.5$ fps

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Continuous gust spectra

- FAR 25 for typical weight/dim 50-70,000 lb transport a/c

PSD of lateral gustiness, vortex core traverses

flight data, 8-15 nm wake length, 53-90 sec age
FAR25, App.F with \( U_\sigma = 85 \text{ fps with } \sigma = 85/3.5 \text{ fps} \)
Continuous gust spectra
Rise and fall magnitudes & lengths (peaks and troughs counting) of $w_{CZ}$
Rise and fall magnitudes & lengths of $w_CZ$ normalised
WVE - discrete vortex core traverses:

Modelling of gust-rise/fall shape
– depends upon extent of asymptotic $V_T$ rise
– examine flight data traverses
Vortex core traverses:

\[ \Gamma_{\text{GEN}} \approx 735 \text{ m}^2/\text{s} \]

- Wake age, \( t = 53 \text{ sec} \)
- Wake length 7.5 nm, \( \Gamma = 630 \text{ m}^2/\text{s} \)
- advance/recede tails overlay
- Superposition of mean + turbulent, peak \( V_T > 20 \text{ m/s} \) (66 fps)
Vortex core traverse #2:
- Wake age, t = 58 sec
- Wake length 8 nm
- $\Gamma = O[630]$ m$^2$/s
- Sec features away from core edges
Vortex core traverse #3:
- Wake age, $t = 60$ sec
- Wake length 8.4 nm
- $\Gamma = O[620]$ m$^2$/s
- Lower turbulence, B-H models well
**Vortex core traverse #4:**
- Wake age, \( t \approx 68 \text{ sec} \)
- Wake length 9.5 nm
- \( \Gamma = \mathcal{O}[600] \text{ m}^2/\text{s} \)
- large \( V_T \) near core edge
**Vortex core traverse #5:**
- Wake age, \( t = 74 \) sec
- Wake length 10.4 nm
- \( \Gamma = O[580] \) m²/s
- Secondary vortex, \( V_\Gamma \sim r^{1/5} \) profile

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**Vortex core traverse #6:**
- Wake age, $t = 76$ sec
- Wake length 10.6 nm
- $\Gamma = \mathcal{O}[570] \text{ m}^2/\text{s}$
- Secondary vortex

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**Vortex core traverse No. 7:**
- Wake age, $t = 90$ sec
- Wake length, 12.6 nm
- $\Gamma = O[380]$ m$^2$/s
**Vortex core traverse No.8:**

- Wake age, \( t = 101 \) sec
- Wake length, 14.2 nm

\[ \Gamma = O[360] \text{ m}^2/\text{s} \]
Conclusions:

– WVE, present & future occur with trailing vortices likely turbulent, incl. cores

– Have considered WVE gust size & magnitude 8-20nm wake survey flight data, from the viewpoints of
  – Continuous turbulence spectra loading, for helices around & through vortices
    – \( \Omega(v_Z) \) of the order of magnitude of FAR 25 design limit spectra; and
  – Rise/fall peaks & troughs analysis (typ. For fatigue loading)
    – groupings of gust rise/falls into a number of discrete non-dim rates
      – Possibility of normalising by generator
  – discrete vortex core traverse size/magnitude profiles
    – Examined eight profiles in detail:- for each , mean + turbulent \( (V_T'/V_T) \)
      \([50-100\%]\) flow superposition evident; peak \( V_T > 66 \) fps, FAR limit mag.
      – Line vortex (Rankine) model, &
      – Burnham-Hallock model – generally \((7/8 \text{ times})\) under-estimated \( V_T \) at core edges – for the good ID, core traverse had low turbulence content;
      – Line vortex model captured core edge \( V_T \) augmentation by sec vortices, implying non-dissipative in nature, core-stability driven?

Further examination of existing & future data warranted.
QUESTIONS?