VTOL Design Loads and Interaction of Systems and Structures

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An Agency of the European Union
Design Loads VTOL MoC

→ General

→ Design Load Requirements:
  → VTOL.2200 Structural Design Envelope
  → VTOL.2215 Flight loads conditions
  → VTOL.2205 Interaction of systems and structures
  → VTOL.2220 Ground and water loads

→ Summary
General
Complexity of VTOL aircraft

Different safety objectives:

Flight control system interaction with flight envelope:
VTOL.2200 Structural Design Envelope

- Proposed MOC published 25 May 2020
- 15 comments reviewed and MOC under revision
VTOL.2200 Design Airspeeds

**VTOL MODE (CS-27)**

- $V_{rearward}$
- $V_{sideward}$
- $V_{HVTOL}$
- $V_{N EVTOL}$
- $V_{DVTOL}$

Constraints:

1. $V_{N EVTOL} \leq 0.9 V_{DVTOL}$
2. $V_{HVTOL} <= V_{N EVTOL}$

**AEROPLANE MODE (CS-23)**

- $V_{VA}$ need not be $> V_{C}$
- $V_{VC}$
- $V_{VNO}$
- $V_{NO} < 0.89 V_{N E}$
- $V_{VNE}$
- $V_{VNE} \leq 0.9 V_{D}$
- $V_{VHB}$ need not be $> V_{C}$
- $V_{VC}$ need not be $> 0.9 V_{H}$
- $V_{VH} <= V_{N EV}$
- $V_{VH} <= V_{N EV}$

Constraints:

1. $V_{NO} < 0.89 V_{NE}$
2. $V_{VNO} < 0.89 V_{NE}$
3. $1.25 V_{C} \leq V_{D}$
4. $V_{VH} <= V_{N EV}$
5. $V_{VNE} \leq 0.9 V_{D}$
VTOL.2200 Design Airspeeds

All configurations and modes should be considered for design airspeed(s) definition: more than one airspeed definition set may be necessary.
VTOL.2215(a) Flight Load Conditions

- Proposed MOC published 25 May 2020
- 19 comments reviewed and MOC under revision

1g Symmetric Flight
- Symmetrical pull-up and recovery
  - Max positive load factor
  - Max associated pitch accelerations
- Symmetrical pushover and recovery
  - Max negative load factor
  - Max associated pitch accelerations

Rolling Flight Conditions
- 2/3 max positive load factor
  - Max associated pitch and roll accelerations

Gusts
- Vertical and horizontal

Yawing Conditions
- Max associated yaw acceleration
  - Max transient sideslip angles

Vertical TO
- Max slope

Unsymmetrical loads due to lift/thrust unit failure
  (failure case)

NEW!
Design Airspeeds / Flight Loads

ALL CONFIGURATIONS / MODES

ENHANCED ONLY

VB
User Defined

66 ft/sec gust
Max flight speed in turbulence (rough air)

VNO

VNO ≤ VNE
VNO ≤ VH

VD

VNE

VNE ≤ 0.9VD

VH

VH <= VNE

VH <= VH

VH <= VH

Level Flight
Symmetric Pullup
Symmetric Pushover
Rolling Pullup
30ft/sec gust
LTU failure

Yaw Manoeuvre
(VH or VNE whichever less)
50 ft/sec gust

Yaw Manoeuvre
(VH or VNE whichever less)

All critical speeds and configurations should be considered for each flight manoeuvre, up to the aircraft maximum defined: VD(s), VH(s) or VNE(s)
VTOL.2205 Interaction of systems and structures

System failures:

- Flight control systems (FBW)
- Autopilots
- Stability augmentation systems
- Load alleviation
- Flutter control
- Fuel / energy management
VTOL.2205 Interaction of systems and structures

→ MOC based on CS 25 Appendix K

**CS 25 Appendix K**
structure whose failure could prevent continued safe flight and landing

**MOC VTOL.2205**
any structure the loading of which may be changed by failure(s) of the system

→ Scenarios to consider:

<table>
<thead>
<tr>
<th>System fully operable</th>
<th>System in failure condition</th>
<th>Failure indication</th>
<th>Dispatch with known failure conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal condition</td>
<td>At time of occurrence</td>
<td>Detectability</td>
<td>Limitations may be established</td>
</tr>
<tr>
<td></td>
<td>Static Strength(^{(1)})</td>
<td></td>
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<tr>
<td></td>
<td>Residual Strength</td>
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<td></td>
<td>Vibrations</td>
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<td></td>
<td>Flutter (if failure causes</td>
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<td></td>
<td>velocity increase)</td>
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<tr>
<td></td>
<td>Continuation of the flight</td>
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<tr>
<td></td>
<td>Static Strength(^{(1)})</td>
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<tr>
<td></td>
<td>Flutter(^{(1)})</td>
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<tr>
<td></td>
<td>Fatigue &amp; Damage Tolerance</td>
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</table>

\(^{(1)}\) For determination of **Safety Factor** and **Flutter Speed**, the probability will be consistent with the safety objective defined in SC VTOL for Category Enhanced and Category Basic (no. passengers)
Reference: MOC VTOL.2510 Equipment, systems, and installations

Table 1: Safety Objectives

<table>
<thead>
<tr>
<th>Category Enhanced</th>
<th>FS</th>
<th>Reference</th>
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<tbody>
<tr>
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<td>[Note C and D]</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Category Basic</th>
<th>Failure Condition Classifications</th>
<th>Allowable Qualitative Probability</th>
<th>Allowable Quantitative Probability (Note C and D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 to 9 passengers (Basic 3)</td>
<td>Minor</td>
<td>Probable</td>
<td>$\leq 10^{-3}$ FDAL D (see Note B)</td>
</tr>
<tr>
<td>2 to 6 passengers (Basic 2)</td>
<td>Major</td>
<td>Remote</td>
<td>$\leq 10^{-5}$ FDAL C</td>
</tr>
<tr>
<td>0 to 1 passenger (Basic 1)</td>
<td>Hazardous</td>
<td>Extremely Remote</td>
<td>$\leq 10^{-7}$ FDAL B</td>
</tr>
</tbody>
</table>

Factor of safety at the time of occurrence

$$FS \geq 10^{-X}$$

Factor of safety for continuation of flight

$$FS \geq 10^{-X}$$

$P_j$ – Probability of occurrence of failure mode $j$ (per hour)

$Q_j$ – Probability of being in failure condition $j$
**VTOL.2220 Ground and Water Loads**

- **Ground conditions:**
  - Proposed MOC published 25 May 2020
  - 3 comments reviewed and MoC under revision

- **Water conditions:**
  - Seaplane and amphibian water landing loads to be addressed in Phase 3 MOC
Summary

→ **Complexity** in VTOL design load definition: different safety objectives, configurations and modes, and complex flight control systems

→ **Interaction of systems and structures** needs comprehensive analysis to consider all failures that could influence loading and flutter

→ Many valuable comments received during Phase 1 consultation will lead to **improvement and simplification** of the proposed design load MoCs

→ **Further design load MoCs** will be released for public consultation in Phases 2 and 3
Thank you for your attention

Feel free to submit your questions on our live event platform.....