Skip to content

Chat history

You said:

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I need your help on writing a Continuous vibration (due to unbalance) analysis report for certification (as per CS-E requirements) for a turboshaft engine. I am first going to give you the index I had in mind and we will build the initial plan and talk about the modifications that you may recommend. I supplied the contents headers of the report I initially thought (see images)

ChatGPT said:

51 saniye düşündüm

Below is an “initial-plan” outline that merges the headings you sketched with the structure normally expected in EASA engine certification reports (CS-E Book 1 §810 Continuous Vibration and the supporting AMC/GMs). I’ve kept your wording wherever possible, but added a few sections (⚙️ suggested) or reordered items where auditors typically look for them.

0. Front Matter

Title Page (document number, revision, issue date, NDA statement)

Record of Revisions / Document History

Sign-off Sheet (Chief Engineer, Compliance Verification Engineer, Independent Checker)

Executive Summary ⚙️ – 1-page plain-language digest of objective, methods, results, and statement of compliance.

1. Glossary and Abbreviations

2. Objective

§ Heading Purpose Key tips

2.1 Objective of Document Why this analysis report exists (to demonstrate compliance with CS-E 810 for the HP Compressor Casing (HPCC) of XYZ turboshaft).

2.2 Objective of Project Link to overall engine programme milestones (e.g. EASA type-certificate issuance, rig test schedule).

3. Scope

| | Make crystal-clear what is and is not covered (HPCC only? whole compressor module? rest of engine by similarity?). |

4. Referenced Documents

Contracts, standards (e.g. ISO 1940-1 balance grades; MIL-STD-810 vibe exposure), internal procedures, previous blade-off reports, etc.

Table 1 – Reference Documents (Ref-No, Title, Current Rev).

5. System Description and Architecture

5.1 Engine Description

5.2 Engine Operation

5.2.1 Two-Stage Centrifugal Compressor (overview)

5.2.2 High-Pressure Centrifugal Compressor Casing (HPCC) – hardware under study

5.2.3 Rotor system layout, bearing supports, squeeze-film dampers ⚙️

5.2.4 Instrumentation and vibration monitoring (proximity probes, accelerometers) ⚙️

6. Compliance & Certification Basis

6.1 Applicable CS-E Paragraphs

CS-E 810(a)/(b) Continuous Vibration

CS-E 800 (Rotor Integrity) – cross-reference for CBO run-on/run-down blade-loss forcing

CS-E 520(c)(2) (forces transmitted to aircraft structure)

EASA

6.2 AMC & GM References

AMC E 810 (analysis vs. test guidance)

AMC E 520(c)(2) (engine model validation)

EASA

6.3 Means of Compliance Matrix ⚙️

Table 2 – for every CS-E item list: “Requirement text”, “Method (Analysis/Test/Similarity)”, “Section Ref”.

7. Analysis

Table 3 – Blade-Out & Unbalance Analyses Performed for HPCC

7.1 Analysis Tools

ANSYS Mechanical (ver./build, element types), CFX aero damping inputs, XL Rotor-Dynamics workbook, etc.

7.2 Analysis Specifications

§ Heading Content highlights

7.2.1 Purpose & Scope Tie back to §2.

7.2.2 Analysis Method Coupled FE rotor-blade-casing model, Campbell diagram screening, transient unbalance simulation (direct integration).

7.2.3 Assumptions Linear material damping, isotropic supports, single-blade loss equates to ½ Δm Ω² forcing, etc.

7.2.4 Limitations Discuss model truncation, exclusion of torsional modes, etc.

7.2.5 Conditions Detailed below.

7.2.5.1 CBO Run-On Condition Post-blade-release spool-up to surge limit.

7.2.5.2 CBO Run-Down Condition Auto-shutdown coast-down until 0 rpm.

7.2.5.3 Limit Out-of-Balance Condition Maximum manufacturing residual unbalance per ISO1940-1 G 2.5 (or rig-measured 3 g-mm).

7.2.6 Analysis Scenarios Matrix of speed, temperature, damping cases.

7.2.7 Material Data Elastic-plastic casing curves, temperature dependency table.

7.3 Validation

7.3.1 Validation of Analysis Tools – correlation against rig spin-pit data, modal tests.

7.3.2 Validation of Analysis Method – sensitivity study, mesh convergence, benchmark vs. AMCA example.

7.4 Results (Sonuçlar) – for each scenario provide:

Peak dynamic stress plots (von Mises map)

Sine-swept displacement vs. speed curves

Interface load time histories (for CS-E 520(c)(2) obligations)

Cumulative damage for HCF assessment (Goodman/Miner)

7.5 Sub-section on HCF Assessment (was 6.4.4 in your notes)

Rainflow counting of HPCC hot-gas side nodes; margin vs. Goodman diagram.

8. Conclusions & Summary

Bullet-form compliance statements (“The HPCC casing satisfies CS-E 810(a)/(b) with a minimum factor of safety of X against ultimate strain during worst-case CBO run-down”).

Recommendations (balance grade, monitoring thresholds).

9. Appendices

A. Detailed FE mesh stats, coordinate systems

B. Damping test reports

C. Input tables (material curves, unbalance weights)

D. CS-E compliance matrix copies for traceability

Key Modifications / Recommendations at a glance

# Change Reason

1 Insert Executive Summary before glossary Many EASA panel reviewers skim this first.

2 Bring Compliance Basis forward (your Section 5) and include a formal Means of Compliance Matrix Aligns with CS-E style and makes audit tracing easier.

3 Put Validation immediately after Analysis Specs & before Results Shows credibility of model before you present numbers.

4 Separate HCF Assessment subsection under Results Keeps transient dynamic results and fatigue life evaluation distinct.

5 Add Risk & Hazard Statement ⚙️ (can be a short paragraph in §8) citing CS-E 510 hazard classifications.

6 Use consistent section numbering (avoid 6.2.7 then 6.3 etc.; auditors notice mismatches).

Next steps

Confirm scope – Are we limiting to the HP Compressor Casing, or all compressor casings?

Agree on analysis toolchain versions and data sources for Validation (§7.3).

Decide on balance grade & residual-unbalance limits for the “Limit OOB” case (ISO G-grade vs. flight test data).

Let me know your thoughts or additional requirements, and we’ll start fleshing out individual sections (e.g. template text, tables, figures, MATLAB/Python scripts for result post-processing).

You said:

Revise your response since you are now using GPT-5

Next steps:

1) We are limited to HP Compressor Casing, as my responsibility is only for static parts of compressor module such as this casing.

2) I am planning to use some ground engine tests and shaker tests on a rig

3) Well, I might need your help on that.

ChatGPT said:

Thought for 1m 22s

Perfect—thanks for the scope/validation notes. Here’s a revised plan tuned to HP Compressor Casing (HPCC) only, using ground engine tests + shaker rig tests, and with a concrete proposal for the Limit Out-of-Balance value you’ll need in the report.

1) Compliance framing (what you must show)

Primary rule: CS-E 810 (blade failure → containment + no hazardous effects, and acceptable out-of-balance running). Your report will reference the engine-level 810 demonstration, but for the HPCC you’ll show structural integrity and margins during CBO run-on, run-down, and Limit OOB cases.

EASA

Vibration characterization: use CS-E 650 (Vibration Surveys) concepts—either tests alone or tests with a validated analysis—to establish vibration characteristics. This is the clean hook for your ground engine test plan.

Forces to the airframe / loads for integrators: AMC E 520(c)(2) expects you to provide validated data (analysis/test) so aircraft constructors can assess forces from out-of-balance running and continued rotation. Your engine-test-derived order-tracked loads + validated FE model meet this.

EASA

2) Validation approach you proposed (refined)

A. Ground engine tests (vibration survey style)

Objective: establish 1× (synchronous) vibration versus speed and phase for the HPCC; obtain strain and interface load data to anchor the model.

Minimum set

Sensors: tri-axial accelerometers on HPCC (flange, mid-span, mount bosses), 1–2 strain gauges at historical hot spots, keyphasor, bearing housing accel(s).

Runs: steady run-up / run-down with order tracking; dwell ~5–10 s near peaks; capture above max rated +2% if safe (mirrors CS-E 650 intent on extending beyond max to catch peaks).

Outputs for model correlation: Campbell diagram (1× tracks), Bode (amp/phase) at HPCC points, time histories at select dwells.

Use in report: “Validated analysis” per AMC E 650 definition (tests + model) and “validated data” per AMC E 520(c)(2).

EASA

B. Shaker rig tests (component/rig)

Objective: tune HPCC FE (modal frequencies, mode shapes, damping/FRFs) without engine noise.

Setup: boundary fixtures that emulate engine supports; broadband excitation (random or stepped sine) up to at least 1.2× the highest 1× crossing from the engine survey.

Correlate: first 6–10 casing modes, MAC > 0.85 where possible; match modal damping (ζ) used in the unbalance response model.

Use in report: documents tool/method validation prior to applying out-of-balance loads; strengthens the “Validated Analysis” claim in AMC E 650.

3) Picking the Limit Out-of-Balance (manufacturing) number

Use ISO 21940-11 (ex-ISO 1940-1) balance quality grades. For high-speed turbomachinery, G 2.5 is widely used; published examples for gas turbine rotors reference G 2.5 with a specific tolerance of 2.37 g·mm/kg (example in ISO 21940-12 Annex shows a gas-turbine rotor at G 2.5).

energiforskmedia.blob.core.windows.net

Formulas you’ll cite in the report (ISO)

Residual unbalance tolerance (total), using service speed

n

n [rpm], rotor mass

M

M [kg], and grade

G

G [mm/s]:

U

per

=

9549

G

M

n

[

g

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mm

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9549GM

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9549G

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syic.com

messmatic.com

Numerical example (to anchor the spec):

Say the HP compressor rotor that drives your casing has

M

=

10

M=10 kg and max service

n

=

40,000

n=40,000 rpm.

With G 2.5:

U

per

≈

9549

×

2.5

×

10

/

40000

≈

6.0

g

\cdotp

mm

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≈9549×2.5×10/40000≈6.0 g\cdotpmm.

That’s the Limit OOB moment you’d impose in the model at the appropriate radius/planes. (If program experience or survey margins are tight, G 1.0 is a conservative alternative; same formula.)

cimat-balancing.com

Webb-Elec Dynamic Balancing

How it applies in FEA: convert

U

U to a rotating centrifugal force at speed

ω

ω using

F

=

U

ω

2

F=Uω

2

(synchronous 1×). Apply as rotating nodal load or equivalent enforced motion on the rotor-to-casing path in your MSUP/transient model.

Wikipedia

dyrobes.com

4) CBO run-on / run-down loads (blade loss)

For the engine-level CBO case, the unbalance is

Δ

m

r

Δmr at the blade radius. Your HPCC report will:

take the validated rotor-dynamic model’s out-of-balance forces vs speed/time (from the blade-loss scenario used for CS-E 810 compliance),

apply them to the validated HPCC FE, and

demonstrate stress & strain margins + HCF margins during run-on (post-release transient) and run-down (shutdown transient). AMC E 810 describes the running-after-failure demonstration and allows combination with containment where applicable.

EASA

5) Report structure (final tweak of your index)

Executive Summary (1 page: objective, methods, pass/fail statement vs CS-E 810).

Compliance Basis & MoC Matrix (CS-E 810; use CS-E 650/AMC for survey; AMC E 520(c)(2) for force datasets).

EASA

+1

System Description (HPCC only; interfaces, supports, monitoring).

Analysis Tools & Validation (modal test correlation from shaker; engine survey Bode/Campbell → “validated analysis” per AMC E 650).

Specifications & Scenarios

Assumptions, limitations, material data.

Conditions: CBO run-on, CBO run-down, Limit OOB (show grade and calculation).

Results

Peak stress/strain maps; interface loads (for AMC E 520(c)(2) hand-over).

HCF assessment (use your chosen Goodman/strain-life method and margins).

EASA

Conclusions & Statement of Compliance

Appendices (sensor layouts, FE mesh stats, ISO 21940 calc sheet, raw Bode/Campbell plots).

6) What I recommend you decide now (and I can help with)

Set the baseline grade to G 2.5 for the Limit OOB case unless your organization mandates stricter (G 1.0). I’ll produce a one-page ISO 21940 calculator sheet (inputs:

M

M,

n

n; outputs:

e

per

,

U

per

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per

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,U

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​

).

energiforskmedia.blob.core.windows.net

messmatic.com

Define test points & acceptance for the ground survey (which accelerometer/strain channels and what constitutes “sufficient correlation”—e.g., ±10% on 1× amplitudes, ±10° phase at key dwells). This ties neatly to “validated analysis” in AMC E 650.

Confirm the engine-program’s 810 blade-loss load set you’ll reuse for HPCC (speeds, decay law, shutdown schedule) so your run-on/run-down traces mirror the CS-E 810 analysis/test basis.

EASA

If you want, I’ll draft:

a MoC matrix page pre-filled with CS-E references,

an ISO-21940 calc appendix (with your rotor data), and

a test plan checklist for the ground survey and shaker rig.

You said:

I will consider your recommendations, however, I also think that the below example plan also looks nice for my application, what do you think (you may replace front bearing structure with my own part):

Table of Contents

1. INTRODUCTION

1.1 COMPONENT DESCRIPTION

1.1.1 Front Bearing Structure

1.1.2 Low Pressure Turbine Casing

1.1.3 Turbine Exit Case

2. ASSUMPTIONS

3. CONCLUSIONS

4. LIMITATIONS AND MAINTENANCE ACTIONS

4.1 LIMITATIONS

4.2 MAINTENANCE ACTIONS

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6.3.1.3 Turbine Exit Case

6.3.2 CBO Rundown load

6.3.2.1 Front Bearing Structure

6.3.2.2 Low Pressure Turbine Casing

6.3.2.3 Turbine Exit Case

6.3.3 CBO Run-on load

6.3.3.1 Front Bearing Structure

6.3.3.2 Low Pressure Turbine Casing

6.3.3.3 Turbine Exit Case

6.3.4 Windmill After CBO

6.3.4.1 Front Bearing Structure

6.3.4.2 Low Pressure Turbine Casing

6.3.4.3 Turbine Exit Case

6.3.5 Propeller Aero Dynamic Excitation & Propeller/Engine Spools Alert Level Imbalance

6.3.5.1 Front Bearing Structure

6.3.5.2 Low Pressure Turbine Casing

6.3.5.3 Turbine Exit Case

6.3.6 Propeller Blade Nickel Sheath Loss Imbalance

6.4 MATERIAL PROPERTIES AND ALLOWABLES

7. RESULTS

7.1 INTEGRITY RESULTS FOR THE CBO RUNDOWN LOAD EVENT

7.1.1 Front Bearing Structure

7.1.2 Low Pressure Turbine Casing

7.1.3 Turbine Exit Case

7.2 FATIGUE RESULTS FOR THE CBO RUN-ON LOAD EVENT

7.2.1 Front Bearing Structure

7.2.2 Low Pressure Turbine Casing

7.2.3 Turbine Exit Case

7.2.4 CBO Run-On Results Summary

7.3 FATIGUE RESULTS FOR PROPELLER AERO DYNAMIC EXCITATION & PROPELLER/ENGINE SPOOLS ALERT LEVEL IMBALANCE

7.3.1 Front Bearing Structure

7.3.2 Low Pressure Turbine Casing

7.3.3 Turbine Exit Case

7.4 FATIGUE RESULTS FOR THE WINDMILL AFTER CBO

7.4.1 Front Bearing Structure

7.4.2 Low Pressure Turbine Casing

7.4.3 Turbine Exit Case

7.5 PROPELLER BLADE NICKEL SHEATH LOSS IMBALANCE

8. REFERENCES

FIGURES LIST

Figure 1 Front Bearing Structure

Figure 2 FBS Vanes Distribution view looking rearward

Figure 3 LPT casing cross section view

Figure 4 TEC Nomenclature View looking forward

TABLE LIST

Table 1 Listing of the Front Bearing Structure components

Table 2 CBO Run-on results summary

By the way, CBO means core blade-out event here

ChatGPT said:

Thought for 59s

Short answer: it’s a solid skeleton—but it’s clearly written for a turboprop (propeller aero-excitation, nickel-sheath loss, etc.). For your turboshaft HP Compressor Casing (HPCC), I’d keep the backbone and swap the propeller pieces for CS-E 650 vibration survey + CS-E 810 blade-loss/continued rotation items, and make “Accepted Method of Compliance” read Means of Compliance (EASA wording).

EASA

Here’s how I’d reshape your exact outline with minimal surgery.

What to change (minimum edits)

Replace all component triplets with your single part (HPCC).

Delete propeller sections (6.3.5, 6.3.6; 7.3, 7.5). They’re turboprop-specific.

Add Ground Engine Vibration Survey under MoC (ties directly to CS-E 650) and reference the blade-loss model validation per AMC E 520(c)(2).

EASA

+1

Keep “Thermal load” as a pre-stress/base state, then superimpose unbalance/CBO loads.

Move “Conclusions” to the end (or keep a one-page Executive Summary up front).

Define a Limit Out-of-Balance (manufacturing) case via ISO 21940 (formula

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=9549GM/n).

rotorlab.tamu.edu

cimat-balancing.com

Your outline, rewritten for HPCC (turboshaft)

INTRODUCTION

1.1 COMPONENT DESCRIPTION

1.1.1 High-Pressure Compressor Casing (HPCC)

(figures: layout, supports, measurement points)

ASSUMPTIONS

– Linear material in vibration range, support stiffness/damping, thermal state used for base stress, etc.

REQUIREMENTS

– CS-E 650 Vibration Surveys (characterise engine vibration + margins).

– CS-E 810 Blade Failure (use of blade-loss loads, containment at engine level; no hazardous effects).

– CS-E 520(c)(2) Validated data to provide forces during out-of-balance running and continued rotation after shutdown.

EASA

+2

EASA

+2

LIMITATIONS AND MAINTENANCE ACTIONS

4.1 Limitations (speed ranges if any peak > margins, from §7 results; aligns with CS-E 650(f),(g)).

4.2 Maintenance Actions (alert thresholds, inspection if alert exceeded).

EASA

MEANS OF COMPLIANCE (rename this section)

5.1 Analysis Toolchain (FEA versioning, rotor-dynamic coupling, post-processing)

5.2 Validation Approach

5.2.1 Ground Engine Vibration Survey (order-tracked Bode/Campbell, strains/loads for correlation).

EASA

5.2.2 Shaker/rig Modal Tests (FRFs, ζ, mode shapes to tune HPCC model).

5.2.3 Blade-loss model validation per AMC E 520(c)(2) (correlate transient loads from release through rundown).

EASA

ANALYSES & LOAD CASES

6.1 Material Properties & Allowables

6.2 Thermal Load (steady pre-stress state used in all cases)

6.3 CBO Run-down Load (engine shutdown transient after blade loss; cross criticals).

EASA

6.4 CBO Run-on/Continued Rotation (post-release, transient before shutdown and any windmilling if applicable to the core).

EASA

6.5 Limit Out-of-Balance (Manufacturing/Service) (ISO 21940 grade—e.g., G2.5—to set

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; convert to synchronous 1× force

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2

F=Uω

2

).

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cimat-balancing.com

6.6 Alert-Level Imbalance / Vibration Thresholds (program-defined; used for §4 actions).

6.7 Analysis Method (transient or MSUP; damping assumptions; mesh & convergence; interfaces delivered for CS-E 520(c)(2)).

EASA

RESULTS

7.1 Integrity under CBO Run-down (peak stress/strain maps, margins, interface loads)

7.2 HCF under CBO Run-on / continued rotation (rainflow/Goodman; margins)

7.3 HCF under Limit OOB (speed sweep; worst 1× crossings; margins vs endurance limit per CS-E 650(f))

EASA

7.4 If applicable: Windmilling after shutdown (only if the core continues to rotate under aircraft- or gas-path-driven windmilling; otherwise mark N/A).

EASA

7.5 Summary Tables & Figures (Bode/Campbell correlation, stress hotspots, MoS dashboard)

CONCLUSIONS (statement of compliance with CS-E 650/810 + any limitations introduced)

REFERENCES (CS-E/AMC extracts, ISO calc sheet, test plans & reports)

FIGURES & TABLES LIST

Why this version fits regulators (and your test plan)

CS-E 650 lets you combine engine tests with validated analysis to establish acceptable vibration characteristics and margins; your ground survey goes straight here.

EASA

CS-E 810 + AMC E 520(c)(2) expect you to use a validated engine model to generate the transient out-of-balance loads from blade loss (release → rundown), and to provide the resulting interface forces to the aircraft/installer; §5.2.3 and §6.3/6.4 do exactly that.

EASA

+1

The Limit OOB case is set transparently via ISO 21940’s

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=9549GM/n (commonly G2.5 for gas-turbine rotors), which auditors instantly recognise; we then apply a synchronous 1× force

F

=

U

ω

2

F=Uω

2

in the model.

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Want me to draft the sections?

If you approve this mapping, I’ll:

prepare a MoC matrix pre-filled with CS-E 650/810 and AMC E 520(c)(2) references;

give you a one-page ISO-21940 calculator (enter rotor mass

M

M and max service

n

n);

template text for §5.2 (engine survey + shaker validation) and §6 (load-case definitions).

To start, send me the HP compressor rotor mass and max service rpm you want to use for the Limit-OOB calculation.

You said:

There are a few things I would like to clarify before you go on.

Validation of the dynamic forces/moments, accelerations, clearances etc. occurring during an out-of-balance condition is not my responsibility, it will mainly be performed by the studies of our whole engine design/analysis team. So defining the out-of-balance limits etc. are also their responsibility as they are the ones that perform the out-of-balance limits and analysis scenarios and plan the related tests for the whole engine, I am just a compressor module structural analysist and part designer whose responsibility is to make sure that my part(s) survives. If required, I am allowed to design small/moderate rig/component tests for my part or take acceleration, strain gage or thermocuple etc. measurements from the ground engine prototypes or rig tests.

ChatGPT said:

Thought for 35s

Crystal clear—that division of responsibilities actually makes your report cleaner. You’re proving part-level structural integrity of the HP compressor casing (HPCC) given the engine team’s out-of-balance (OOB) inputs. Below is a tightened plan (and boilerplate text you can drop in) that reflects that boundary while still aligning with CS-E 650 and CS-E 810 expectations.

What stays with the engine team (for reference in your report)

Derivation & validation of OOB loads and moments (CBO run-on/run-down, windmill if applicable, manufacturing limit OOB).

Vibration survey ownership and any engine-level acceptance/alert thresholds.

Provision of validated datasets for forces/accelerations used by integrators (AMC E 520(c)(2)).

EASA

Compliance demonstration for CS-E 650/810 at engine level (your report contributes evidence for the HPCC).

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EASA

What sits in your HPCC report

1) Scope & Responsibilities (front matter)

Add a short “Responsibility & Interfaces” paragraph:

This document demonstrates the structural integrity and fatigue durability of the HP Compressor Casing (HPCC) under out-of-balance and thermal conditions as specified by the Engine Dynamics team. The derivation and validation of OOB loads, moments, accelerations and clearances are performed at engine level and are out of scope of this report. Engine-level CS-E 650 vibration surveys and CS-E 810 blade-failure demonstrations are referenced herein.

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EASA

Include a one-page RACI table (you → “Responsible” for HPCC integrity; engine dynamics → “Accountable” for load sets and validation; test org → “Responsible” for acquiring survey data; CVE → “Approver”).

2) Inputs & Dependencies (make this its own section)

List exact artefacts you require from the engine team (version-controlled):

CBO run-down time histories (forces/moments at HPCC interfaces, speed vs. time).

CBO run-on/continued rotation histories (pre-shutdown transient).

Manufacturing/Service limit OOB envelope (residual-unbalance per speed, or equivalent 1× force vs. speed). (They will typically set these using ISO 21940/validated practice; you consume them.)

Thermal field (steady) for base-stress.

Support stiffness/damping at HPCC interfaces, and any valid FRFs/Campbell/Bode curves to be used for correlation.

Test references: engine vibration survey runs and any post-processing the engine team deems validated under CS-E 650 / AMC.

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State that these inputs are “validated data” at engine level per AMC E 520(c)(2), and you use them to demonstrate part integrity and to generate part-level reaction loads back to the engine package if requested.

EASA

3) Methods (only your remit)

FE model description (mesh, contacts, material T-dependence).

Load mapping from the provided interface forces/moments to the casing.

Analyses you run:

Thermal pre-stress (steady).

Transient dynamic (CBO run-on/run-down) using supplied histories.

Synchronous 1× sweep for the Limit OOB envelope supplied by engine team.

Fatigue evaluation (rainflow/Goodman or strain-life), using your allowables.

Model validation you own: rig modal tests / local strain/accel from ground engine tests to tune casing modes/damping (this supports “validated analysis” while leaving engine-level validation to the engine team). CS-E 650 explicitly allows test or test + validated analysis for vibration characterisation; you cite their survey and your local correlations.

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4) Acceptance criteria (part-level)

Make these explicit and measurable:

Ultimate / yield margins for peak transient stresses during CBO run-down (no local exceedance).

HCF margin ≥ 1.0 (damage ≤ 1.0) for CBO run-on / Limit-OOB sweeps at all critical nodes.

Clearances you own (if any local casing/rub features) stay positive using the engine-provided rotor orbits/deflections.

Correlation targets for your component validation: e.g., |Δamp| ≤ 10% and |Δphase| ≤ 10° against measured casing Bode at key speeds; first N mode frequencies within ±5% with MAC ≥ 0.85 from the rig test.

Deliverables to engine team (if requested under AMC E 520(c)(2)): HPCC interface reaction loads and dynamic stiffness for integration—engine team remains the owner of aircraft-facing data packages.

EASA

5) Where to anchor CS-E text in your chapters

Requirements: Quote CS-E 650(a): “established by test or a combination of test and validated analysis” and list your reliance on engine survey + validated inputs.

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CBO scenarios: Reference CS-E 810 for blade containment and running following blade failure; clarify that engine team defines the CBO event and you apply their loads to HPCC.

EASA

+1

Validated data to integrators: cite AMC E 520(c)(2) wording about providing forces to aircraft constructors—owned by engine team; your report feeds part-level reactions as needed.

EASA

6) Your Table of Contents (your turboprop outline, trimmed for turboshaft + role clarity)

INTRODUCTION

1.1 Component Description — HP Compressor Casing (HPCC)

1.2 Responsibility & Interfaces (RACI) ⚑ (new)

ASSUMPTIONS & INPUTS

2.1 Provided by Engine Team (validated datasets)

2.2 HPCC Analysis Assumptions (materials, damping, BCs)

REQUIREMENTS (CS-E 650, CS-E 810, AMC E 520(c)(2) references)

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EASA

+1

MEANS OF COMPLIANCE

4.1 Ground Engine Vibration Survey (reference only) — ownership: engine team; usage: correlation targets.

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4.2 HPCC Rig/Component Tests (modal/FRF for tuning)

4.3 FE Analysis Method (thermal pre-stress; transient for CBO run-down and run-on; 1× sweep for Limit-OOB envelope)

ANALYSIS LOAD CASES (all loads supplied by engine team; you detail mapping into HPCC)

5.1 Thermal Load (base state)

5.2 CBO Run-down (transient)

EASA

5.3 CBO Run-on / continued rotation (transient)

EASA

5.4 Limit Out-of-Balance (manufacturing/service) (envelope from engine team)

5.5 Alert-level imbalance criteria (reference only, owned by engine team)

RESULTS

6.1 Integrity under CBO Run-down

6.2 HCF under CBO Run-on

6.3 HCF under Limit OOB

6.4 Sensitivity & Uncertainty (optional)

6.5 Summary Tables & Plots

LIMITATIONS AND MAINTENANCE ACTIONS

7.1 Limitations arising from HPCC results (speed bands, if any) — tie to CS-E 650(f)/(g).

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7.2 Recommended Maintenance Actions (only if your part-level results require them; otherwise “None”)

CONCLUSIONS (clear pass/fail statement for HPCC)

REFERENCES

APPENDICES (sensor layouts for your tests, FE mesh stats, correlation figures)

Drop-in boilerplate (use as needed)

Out-of-Scope Statement.

The determination of residual unbalance limits, CBO scenarios, and validation of engine-level dynamic forces, moments, accelerations, clearances and vibration characteristics is conducted by the Engine Dynamics team as part of the engine-level CS-E 650/810 compliance programme. This report consumes those validated inputs to demonstrate HPCC structural integrity.

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Use of Validated Data (AMC E 520(c)(2)).

Interface reactions and local response data produced herein may be supplied to the Engine Dynamics team for inclusion in their validated data package provided to aircraft constructors; ownership and approval of that package reside with the engine programme.

EASA

If you’re happy with this split, I can draft:

a one-page RACI,

an Inputs & Dependencies checklist you can send to the engine team, and

a rig/engine-instrumentation mini-plan (minimal sensors/acceptance metrics) tailored to your casing.

You said:

Looks kinda good I guess, but I was also given windmilling load case as well, should I include that in this report as well? If ok, you can modify the content accordingly and continue I guess.

ChatGPT said:

Excellent question! Yes—if windmilling (continued rotation after shutdown) is a specified load case from your engine team, it absolutely belongs in your HPCC report. It's recognized in both CS‑E 525 (“Continued Rotation”) and AMC/CS‑E 810 (“running following blade failure”) and must be treated with equal rigor in part-level structural integrity verification.

Here’s how we integrate it:

Why Include Windmilling?

CS‑E 525 requires that if any engine rotating system can continue turning after shutdown, it must not cause any Hazardous Engine Effects. Your HPCC must therefore demonstrate integrity under those loads.

The EASA Advisory Circular (ACJ E 810) also emphasizes running after blade failure—covering windmilling scenarios—as a critical condition to evaluate and contain.

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EASA

+6

EASA

In FAA AC 25‑24, windmilling-induced imbalance loads are clearly recognized as a sustained loading condition that may last well past shutdown—in some cases for the duration of the flight—and must be analyzed and designed for.

Federal Aviation Administration

Updated Table of Contents (incorporating windmilling)

Below is the refined structure reflecting your role, responsibilities, and now the windmilling case:

INTRODUCTION

1.1 Component Description — HP Compressor Casing (HPCC)

1.2 Responsibility & Interfaces (RACI)

ASSUMPTIONS & INPUTS

2.1 Provided by Engine Team: validated loads (CBO run‑down, CBO run‑on/continued rotation, windmilling), thermal fields, support properties, engine survey data

2.2 Structural Analyses Assumptions

REQUIREMENTS

CS‑E 650 — Vibration Surveys (validated data usage)

CS‑E 810 — Blade Failure & Running After Failure

CS‑E 525 — Continued Rotation (windmilling post-shutdown)

AMC E 520(c)(2) — provision of validated part-level reaction data

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YUMPU

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EASA

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EASA

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+10

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+10

EASA

+2

Federal Aviation Administration

+2

MEANS OF COMPLIANCE

4.1 Ground engine vibration survey (validation data)

4.2 HPCC component rig tests (modal tuning)

4.3 FE Analysis Method — thermal, transient, 1× sweep modeling

ANALYSIS LOAD CASES

5.1 Thermal base load

5.2 CBO run-down

5.3 CBO run-on / continued rotation

5.4 Windmilling after shutdown (continued rotation)

5.5 Limit Out-of-Balance (manufacturing/service)

5.6 Alert-level imbalance reference (engine team)

RESULTS

6.1 Integrity under CBO run-down

6.2 HCF under CBO run-on

6.3 HCF under windmilling load case

6.4 HCF under Limit OOB sweep

6.5 Summary tables/plots

LIMITATIONS & MAINTENANCE ACTIONS

7.1 Limitations (speed bands, duration)

7.2 Recommended Maintenance Actions (if windmilling has longer duration effects, e.g. monitoring intervals)

CONCLUSIONS (structural compliance under all load cases)

REFERENCES

APPENDICES (load histories, FE mesh, test correlations)

Integration Notes

Windmilling often subjects your part to prolonged reduced-speed excitation, which may generate fatigue concerns distinct from rapid transients like CBO. Be sure to run transient or steady-state runs as appropriate.

Validate the duration and amplitude envelopes with your engine team to reflect realistic in-flight windmilling scenarios.

If your analysis shows HPCC integrity within your fatigue margins even under extended windmilling, that strengthens your compliance statement.

Let me know if you'd like me to draft the Windmilling load mapping section or adapt the Results tables to clearly show margin comparisons across CBO and windmilling!

You said:

What do you mean by margin comparisons?

ChatGPT said:

Great question—margin comparisons are a clear way to show how much stronger your part (the HP Compressor Casing) is compared to what it needs to withstand under different load cases.

What Is "Margin" in Structural Terms?

In engineering, Margin of Safety (MoS) is commonly used to express how much capacity remains after accounting for expected loads and safety requirements. It’s typically calculated as:

Margin of Safety

=

Strength

Applied Load

−

1

Margin of Safety=

Applied Load

Strength

​

−1

If MoS > 0, the part passes—there’s extra strength "in the bank."

If MoS = 0, you meet the requirement exactly (typical minimum acceptable).

If MoS < 0, you’re at risk—failures could occur under rated loads.

Eng-Tips

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Another nuance: some practices include design or applied safety factors (like 1.15 dynamic factor), but the basic principle remains the same—what’s the strength margin after everything's considered?

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What Are Margin Comparisons?

In your HPCC report, you're dealing with multiple load scenarios: CBO run-down, windmilling, limit out-of-balance, etc. Margin comparisons are side-by-side MoS values for those scenarios. These comparisons help highlight:

Which condition is the most critical (lowest margin).

Whether all scenarios satisfy your pass criteria (e.g., MoS ≥ 0).

Where design changes might be needed if margins are tight.

You could display them in a simple table like:

Load Case Peak Stress (MPa) Allowable Stress (MPa) MoS

CBO Run-down 180 200 0.11 (11%)

Windmilling (steady) 170 200 0.15 (15%)

Limit OOB (manufacturing) 190 200 0.05 (5%)

Why This Matters

Readability: Auditors and reviewers see immediately which case is pushing the limits.

Decision-making: If one margin is low, you might call for a test, design tweak, or inspection step.

Traceability: Tying results back to requirements (e.g. material allowable, CS-E guidance) strengthens compliance justification.

Would you like me to include a draft margin-comparison table in your report template?

You said:

Ok that would be include in the report I guess. Now, I want you to start creating the template for me for each section, so that I can take that template and use it in my own report with my own results. While crafting the document sections and their template paragraphs, do not hesitate to ask me for additional info whenever needed, so that we can create a concise, easy to understand analysis report for CS-E certification, which can be used for other parts of the engine with minimal changes for similar analyses and tests etc.

Start with the introduction section. Write as much detail as possible, and leaving out any important details you don't know or not sure about for me to fill (or you can ask later for clarification for those). Once you are done, I will take a look at what you came up with, ask questions, fill you on details or suggest modifications, and those are done as well, I am going to ask you to go with the next section.

ChatGPT said:

Thought for 36s

Awesome—let’s lock in a clean, auditor-friendly Section 1: Introduction you can drop straight into your report. I’ve written it as a template with clear placeholders ☐ for you to fill. I also flagged a few [INFO NEEDED] items I’ll need from you to tailor the wording.

Citations are placed only where regulators typically ask, so you can keep them in the final report.

1. Introduction

1.1 Purpose of this document

This report demonstrates that the High-Pressure Compressor Casing (HPCC) of the ☐ [ENGINE NAME / PROJECT CODE] maintains structural integrity and acceptable fatigue life when subjected to the out-of-balance (OOB) and thermal conditions provided by the Engine Dynamics team, including core blade-out (CBO) run-down, CBO run-on/continued rotation, windmilling after shutdown, and limit OOB (manufacturing/service). Compliance evidence is presented against the relevant EASA CS-E requirements—principally CS-E 650 (Vibration Surveys), CS-E 810 (Compressor and Turbine Blade Failure), and CS-E 525 (Continued Rotation)—using analysis supported and anchored by test data where applicable.

EASA

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Scope boundary. This is a part-level demonstration for the HPCC only. Derivation and validation of engine-level dynamic forces/moments, accelerations, clearances, and OOB limits reside with the Engine Dynamics organization. Those inputs are treated herein as validated data per AMC E 520(c)(2) and are referenced by document ID and revision.

EASA

Intended audience. Certification authority reviewers, the program CVE(s), engine module leads, and the Engine Dynamics team.

1.2 Component description (HP Compressor Casing)

Part identification. HPCC ☐ [PART NUMBER]; drawing ☐ [DRW NO / CAD CONFIG]; revision ☐ [REV]; serial range ☐ [SERIES/SN].

Function. Provides structural support and flow containment around the HP compressor; interfaces at ☐ [FLANGE A] and ☐ [FLANGE B]; includes features ☐ [BOSS/PORTS/SEALS].

Material & heat treatment. ☐ [ALLOY / SPEC / HT] with temperature-dependent properties (see §6.1).

Mounting & interfaces. Connected to ☐ [UPSTREAM/DOWNSTREAM CASINGS] via ☐ [BOLTS/LOC PINS]; stiffness and damping at the interfaces are defined by the Engine Dynamics team load package ☐ [LOAD PKG ID].

Instrumentation reference (if used for validation). Provisions for ☐ [ACCEL/STRAIN/THERMOCOUPLES] at locations ☐ [IDS]. Final channel list and calibration certificates are included in Appendix ☐.

[INFO NEEDED]:

• Part number(s), drawing & rev; alloy/spec and heat-treat; coatings.

• Interface names and coordinate systems you use in your FEA (so the template’s labels match your model).

• Any integral features (bosses, vanes, anti-rotation lugs) that are stress-critical and will appear in figures.

1.3 Regulatory basis and compliance strategy (summary)

Applicable CS-E paragraphs.

CS-E 650 (Vibration Surveys): establish vibration characteristics and show combined vibratory + steady stresses acceptable; validated by test or by test with validated analysis.

EASA

CS-E 810 (Blade Failure): engine-level requirement for containment and no hazardous effects; the HPCC report consumes the engine team’s CBO load histories to demonstrate part integrity.

EASA

CS-E 525 (Continued Rotation): if rotation continues after shutdown (windmilling), it must not cause unacceptable effects; HPCC integrity under windmilling is assessed using provided loads.

EASA

AMC E 520(c)(2) (Engine Model Validation): defines validated data to be supplied to aircraft constructors; at part level we treat engine-team forces/moments/FRFs as validated inputs and, if requested, return interface reactions for their package.

EASA

Means of compliance (MoC).

Analysis: Finite element analysis (thermal pre-stress + transient dynamic) using ☐ [SOFTWARE / VER]; fatigue assessment via ☐ [METHOD e.g., strain-life/Goodman].

Validation:

Engine ground vibration survey (order-tracked Bode/Campbell, strain/accel at HPCC) used for correlation targets and to support “validated analysis” under CS-E 650.

EASA

Rig/component shaker tests (modal FRFs, ζ) to tune HPCC modes/damping.

Inputs: Engine-level CBO (run-down, run-on), windmilling, and limit OOB load sets supplied and owned by Engine Dynamics; this report documents mapping of those loads to the HPCC model.

1.4 Load cases covered (received from Engine Dynamics)

CBO run-down (post-failure shutdown transient): time histories of forces/moments and speed vs. time at HPCC interfaces.

EASA

CBO run-on / continued rotation (pre-shutdown transient).

EASA

Windmilling after shutdown (continued rotation): duration and envelope per aircraft/mission assumptions; assessed vs. fatigue criteria for HPCC.

EASA

Limit out-of-balance (manufacturing/service): synchronous 1× envelope vs. speed supplied by Engine Dynamics; typically derived from balance-grade practice (e.g., ISO 21940) but defined externally to this report.

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[INFO NEEDED]:

• The exact load package IDs/revisions for each case (so we can cite them consistently later).

• Whether windmilling is steady-state, transient, or a sequence (e.g., glide + relights), and the duration to analyze.

1.5 Responsibilities & interfaces (RACI summary)

Responsible (this report): HPCC structural integrity and fatigue assessment; FE model fidelity; mapping of provided loads to the HPCC; local validation via rig/engine measurements; documentation and traceability.

Accountable (engine-level OOB & dynamics): derivation and validation of OOB loads/limits; engine vibration survey ownership; provision of validated data per AMC E 520(c)(2); definition of alert/acceptance thresholds.

EASA

Supporting: Test & Instrumentation (rig fixtures, sensor calibration), Materials/Allowables (temperature-dependent properties), Quality (configuration control), CVE(s) (compliance verification).

[INFO NEEDED]: Names/roles or teams to populate a 1-page RACI table (optional Appendix).

1.6 Data sources and configuration control

All external inputs are configuration-controlled:

Engine Dynamics load packages: ☐ [PKG IDs, revs] (CBO run-down, CBO run-on, windmilling, limit OOB).

Thermal fields / operating points: ☐ [FILE IDs].

Support stiffness/damping / interface FRFs: ☐ [FILE IDs].

Validation data: engine ground survey test IDs ☐ [IDs]; rig modal test report IDs ☐ [IDs].

FEA environment: solver ☐ [NAME/VER]; element types; contact models; material database ☐ [SOURCE].

Change control follows ☐ [PROGRAM CM PROC]; superseded inputs are archived in Appendix ☐.

1.7 Pass/Fail criteria (part-level, summarized)

Ultimate/Yield integrity: peak stress/strain from each transient load case ≤ allowable at temperature.

Fatigue: cumulative damage ≤ 1.0 (or MoS ≥ 0) at critical nodes for (i) CBO run-on, (ii) windmilling, (iii) limit OOB sweeps established by Engine Dynamics.

Correlation targets (validation): e.g., |Δamp| ≤ 10% and |Δphase| ≤ 10° at key orders; first N modal frequencies within ±5% with MAC ≥ 0.85 (program-standard unless otherwise specified).

Deliverables to engine team (if requested under AMC E 520(c)(2)): HPCC interface reactions / dynamic stiffness for integration.

EASA

[INFO NEEDED]: Confirm your program-standard limits (amp/phase tolerances, MAC/ζ targets) so I set the exact numbers here.

1.8 Document organization

This report follows the structure below to maintain traceability from requirements to evidence:

§2 Assumptions & Inputs (including explicit list of externally validated data).

§3 Requirements (CS-E clauses and MoC matrix).

§4 Means of Compliance (test and analysis strategy).

§5 Analysis Load Cases (thermal, CBO run-down/run-on, windmilling, limit OOB; mapping details).

§6 Results (with margin comparison tables across load cases).

§7 Limitations & Maintenance Actions (only if warranted by results).

§8 Conclusions, §9 References, §10 Appendices.

1.9 Confidentiality & export notice (optional)

This document may contain proprietary technical data of ☐ [COMPANY]. Distribution is limited per ☐ [EXPORT/DATA CLASS]. Reproduction or disclosure without authorization is prohibited.

Quick questions so I can finalize this section:

Engine program identifiers you want on the title/headers (project code, engine designation).

HPCC part number, drawing/rev, and alloy/HT/coatings.

The load package IDs/revisions for CBO run-down, CBO run-on, windmilling, and limit OOB.

Whether windmilling is to be treated as steady, transient, or sequence, and the duration to analyze.

Your preferred validation targets (amp/phase %, modal freq ±%, MAC, damping extraction method).

Once you give me these, I’ll lock the text and then draft Section 2 – Assumptions & Inputs with ready-to-fill tables and checklists.

You said:

Hold on, your writing format doesn't feel that much ready-to-use-by-copy-pasting for me

ChatGPT said:

Thought for 30s

Got it — here’s a copy-paste-ready template for Section 1 – Introduction. I’ve used bracketed placeholders like [ENGINE\_NAME] and kept wording auditor-friendly. You can paste straight into Word/Docs and fill in the blanks.

1. Introduction

1.1 Purpose

This report demonstrates that the High-Pressure Compressor Casing (HPCC) of [ENGINE\_NAME] (project code: [PROGRAM\_CODE]) maintains structural integrity and acceptable fatigue life when subjected to the out-of-balance (OOB) and thermal conditions defined by the Engine Dynamics team. The assessed load cases are:

Core Blade-Out (CBO) run-down (post-failure shutdown transient),

CBO run-on / continued rotation (pre-shutdown transient),

Windmilling after shutdown (continued rotation in flight), and

Limit OOB (manufacturing/service) (synchronous 1× envelope versus speed).

Compliance is shown against EASA CS-E requirements, primarily CS-E 650 (Vibration Surveys), CS-E 810 (Compressor and Turbine Blade Failure), and CS-E 525 (Continued Rotation). Where applicable, the approach uses test and validated analysis per CS-E/AMC guidance.

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1.2 Scope and responsibilities

In scope (this report): HPCC part-level assessment only—FE modelling, thermal pre-stress, transient dynamic response (using provided time histories/envelopes), and fatigue evaluation.

Out of scope (owned by Engine Dynamics): Derivation and validation of engine-level OOB loads/limits, acceleration/clearance predictions, vibration survey ownership, and engine-level CS-E 650/810 demonstrations. This report consumes those datasets as validated inputs consistent with AMC E 520(c)(2).

EASA

1.3 Component description (HPCC)

Part identification: [PART\_NO], drawing [DRW\_NO], rev. [REV]; serial range [SERIES/SN].

Function: Structural flow containment for the HP compressor; interfaces at [UPSTREAM\_INTERFACE] and [DOWNSTREAM\_INTERFACE]; features include [BOSSES/PORTS/SEALS].

Material & heat treatment: [ALLOY/SPEC/HT]; temperature-dependent properties per §6.1.

Mounting & boundary conditions: Interfaces and support stiffness/damping as supplied in load package [LOAD\_PKG\_ID].

Instrumentation (if used for validation): Provisions for [ACCEL/STRAIN/THERMOCOUPLES] at locations [CHANNEL\_IDS]; calibration per Appendix [APPX\_LETTER].

1.4 Regulatory basis and compliance strategy (summary)

CS-E 650 – Vibration Surveys. Establish vibration characteristics and show acceptability by test or a combination of test and validated analysis. Engine ground vibration survey data and local HPCC measurements (if used) provide correlation targets for the model.

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CS-E 810 – Blade Failure. Engine-level blade-failure demonstration (containment and running after failure). HPCC integrity is assessed using the engine-provided CBO load histories mapped to HPCC interfaces.

EASA

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CS-E 525 – Continued Rotation (Windmilling). If rotation continues after shutdown in flight, it must not cause unacceptable effects; HPCC fatigue/integrity is assessed under the windmilling loads provided by Engine Dynamics.

EASA

AMC E 520(c)(2) – Engine Model Validation / Validated Data. Engine-level validated datasets (forces/moments/FRFs/speeds vs. time) are treated as controlled inputs; HPCC interface reactions may be returned to the engine package if requested.

EASA

1.5 Inputs and dependencies (configuration-controlled)

The following externally provided artefacts are required (IDs/revisions to be listed in §2 and Appendix A):

CBO run-down time histories: forces/moments at HPCC interfaces, speed vs. time, file IDs [CBO\_RD\_IDS].

CBO run-on / continued rotation time histories: [CBO\_RO\_IDS].

Windmilling envelope(s) and duration: [WINDMILL\_IDS].

Limit OOB (manufacturing/service) 1× envelope vs. speed: [LIM\_OOB\_IDS]. (Typically derived by engine team from balance quality practice; used here as-provided.)

Thermal field(s) and operating points: [THERMAL\_IDS].

Support properties / interface FRFs: [INTERFACE\_IDS].

Validation data (if used): engine survey run IDs and rig modal/FRF reports: [TEST\_IDS].

All inputs are under program configuration control; superseded artefacts are archived per [CM\_PROCEDURE].

1.6 Analysis and validation approach (overview)

Finite Element Analysis: Thermal pre-stress + transient dynamic response for each load case; post-processing of stress/strain; generation of interface reactions as needed.

Fatigue assessment: [METHOD—e.g., strain-life or Goodman-based HCF], cumulative damage accounting for duration/sequence where applicable (e.g., windmilling).

Validation:

Engine ground vibration survey → model correlation targets (Bode/Campbell, local strain/accel at HPCC).

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Component/rig shaker tests (optional but recommended) → tuning of HPCC modal frequencies/shapes and damping for analysis credibility.

Use of validated data: Engine-level OOB/clearance/acceleration datasets are accepted as validated per AMC E 520(c)(2); this report documents load mapping into the HPCC model.

EASA

1.7 Acceptance criteria (part-level, summary)

Strength: Peak transient stress/strain ≤ allowable at temperature for each case (CBO run-down, CBO run-on, windmilling, limit OOB).

Fatigue: Damage ≤ 1.0 (or MoS ≥ 0) at critical nodes for (i) CBO run-on, (ii) windmilling, (iii) limit OOB sweep; definition of mission/time at risk per engine inputs.

Correlation targets (if applicable): |Δamplitude| ≤ [AMP\_TOL]% and |Δphase| ≤ [PHASE\_TOL]° at agreed orders; first [N] modes within ±[FREQ\_TOL]% with MAC ≥ [MAC\_MIN].

Deliverables to engine package (if requested): HPCC interface reactions/dynamic stiffness for inclusion in the engine validated-data pack (AMC E 520(c)(2)).

EASA

1.8 Document organization

This document is structured to preserve traceability from requirement to evidence:

§2 Assumptions & Inputs → §3 Requirements → §4 Means of Compliance → §5 Analysis Load Cases (thermal, CBO run-down/run-on, windmilling, limit OOB; mapping) → §6 Results (including margin comparison tables across cases) → §7 Limitations & Maintenance Actions → §8 Conclusions → §9 References → §10 Appendices.

(Regulatory hooks: CS-E 650/810/525; use of validated data per AMC E 520(c)(2).)

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Fill-in items I’ll need from you (so I can lock §1 and build §2 next)

[ENGINE\_NAME], [PROGRAM\_CODE]

[PART\_NO], [DRW\_NO], [REV], [SERIES/SN], [ALLOY/SPEC/HT]

Interface names: [UPSTREAM\_INTERFACE], [DOWNSTREAM\_INTERFACE]

Load package IDs/revs: [CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS]

Your preferred correlation targets: [AMP\_TOL]%, [PHASE\_TOL]°, [N], [FREQ\_TOL]%, [MAC\_MIN]

Configuration control reference: [CM\_PROCEDURE]

If this format works, I’ll proceed with §2 Assumptions & Inputs in the same copy-paste style (tables + checklists).

You said:

Why didnt you use a Means of Complicance matrix etc. for 1.4?

ChatGPT said:

Thought for 39s

Great catch. I kept §1.4 lean earlier, but adding a one-page Means of Compliance (MoC) matrix right there is smart—it gives reviewers instant traceability from each CS-E clause to who owns it (Engine Dynamics vs you), how compliance is shown (Test / Analysis / Similarity), and where the evidence lives. CS-E doesn’t mandate a matrix format, but EASA reviews revolve around “means of compliance” and “validated data,” so a matrix is standard practice in certification plans.

FAA

EASA

Below is a copy-paste-ready §1.4 that includes a compact MoC matrix. (We can still keep a full, detailed matrix later in §3.)

1.4 Regulatory basis & means of compliance (matrix)

Applicable rules (summary).

CS-E 650 – Vibration Surveys (establish characteristics by test or test + validated analysis).

EASA

CS-E 810 – Compressor & Turbine Blade Failure (engine-level blade failure; includes running after failure). Your part consumes the engine team’s CBO load histories.

EASA

CS-E 525 – Continued Rotation (windmilling after shutdown must not cause unacceptable effects).

EASA

AMC E 520(c)(2) – Engine model validation / validated data (forces provided to aircraft constructors; engine team owns validation; this report uses those validated inputs).

EASA

Note on terminology: “Means of compliance” = how you show compliance (test/analysis/similarity). “AMC” = EASA’s published Acceptable Means of Compliance (guidance you may follow). The matrix below is a program artifact for traceability; it’s not a regulatory form but is widely used in EASA/FAA projects.

FAA

1.4.1 MoC matrix (quick reference)

CS-E / AMC item Requirement (short text) Applicability to HPCC MoC (Test / Analysis / Similarity) Owner Evidence reference (section / doc ID) Pass/Fail

CS-E 650 Vibration Surveys Establish vibration characteristics; acceptability by test or test+validated analysis Yes (part-level correlation targets) Engine ground test (survey) + validated analysis for HPCC Engine Dynamics (loads/data) + HPCC (model correlation) §4.1 (survey refs), §4.3, §6; Test IDs: [ENG\_SURVEY\_IDS] [ ]

CS-E 810 Blade Failure No hazardous effects; running after failure; containment at engine level Indirect (HPCC integrity using CBO loads) Analysis of HPCC with engine-provided CBO run-down / run-on histories Engine Dynamics (define/validate loads) ; HPCC (apply & assess) §5.2–§5.3; §6.1–§6.2; Load PKGs: [CBO\_RD\_IDS], [CBO\_RO\_IDS] [ ]

CS-E 525 Continued Rotation Continued rotation after shutdown must be acceptable (windmilling) Yes (fatigue/integrity under windmilling loads) Analysis; optional local measurements for model tuning Engine Dynamics (define/validate scenario) ; HPCC (assess) §5.4; §6.3; Load PKG: [WINDMILL\_IDS] [ ]

AMC E 520(c)(2) Validated data Provide validated forces to aircraft constructors By reference (engine-level package) Use engine validated inputs; return HPCC reactions if requested Engine Dynamics (package owner) ; HPCC (supply reactions) §2.1, §6 (interface reactions), Engine Doc: [VALIDATED\_DATA\_ID] [ ]

CS-E 520 Strength (HCF) (program-specific) Strength incl. HCF margins acceptable for combinations incl. vibration Yes Analysis (fatigue method [METHOD]) + correlation HPCC §6.2–§6.4; Materials §6.1; Allowables Doc: [ALLOW\_DOC] [ ]

How to use this table:

Fill [ENG\_SURVEY\_IDS], [CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [VALIDATED\_DATA\_ID], [ALLOW\_DOC], and your fatigue [METHOD] (e.g., strain-life, Goodman).

Tick Pass/Fail once §6 results and correlations are finalized.

Keep the full, detailed MoC matrix in §3 (with exact rule text quotes, acceptance criteria, and cross-references). The §1.4 matrix stays as an executive snapshot.

If you like this, I’ll generate the expanded §3 MoC matrix (with columns for Requirement excerpt, Acceptance criteria, Input set ID, Assumptions, Uncertainty/Sensitivity, and Figure/Table links), pre-filled for CS-E 650/810/525 and AMC E 520(c)(2).

You said:

For now, let's go with Section 2, then we can go with that Section 3.

ChatGPT said:

Thought for 36s

Perfect—let’s build Section 2 – Assumptions & Inputs as a copy-paste template you can drop into your report. I’ll keep placeholders in [BRACKETS], give you fill-tables, and put regulatory hooks only where they matter.

2. Assumptions & Inputs

2.1 Configuration identification

Purpose. Lock the exact items (hardware, load packages, solvers) this analysis is based on.

2.1.1 Hardware & drawing set

Component: HP Compressor Casing (HPCC)

Part number: [PART\_NO]

Drawing/config: [DRW\_NO / CAD CONFIG], Rev [REV]

Material & heat treatment: [ALLOY / SPEC / HT]

Coatings/surface treatments (if any): [COATING\_SPEC]

Serial/lot applicability: [SERIES / SN RANGE or “All”]

2.1.2 Program & document control

Engine designation / program code: [ENGINE\_NAME] / [PROGRAM\_CODE]

Configuration management procedure: [CM\_PROCEDURE / DOC ID]

This report ID / Rev / Date: [DOC\_ID / REV / DATE]

2.1.3 Analysis environment

FE solver: [SOLVER & VERSION]; element types: [ELEM TYPES]; contact models: [CONTACT MODELS]

Post-processing toolchain: [POST TOOL / VERSION]

Material database source: [MAT\_DB / ISSUE] (temperature-dependent properties: see §6.1)

Random seed(s) / numerical tolerances (if applicable): [SEED / TOLS]

2.2 External inputs (engine-level; validated data)

Ownership. These are provided and validated by the Engine Dynamics team; this report consumes them as controlled inputs consistent with CS-E 520(c)(2) / AMC E 520(c)(2) (validated data for blade-loss and continued-rotation assessments).

EASA

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2.2.1 Load packages and references (fill one row per artefact)

ID Title / Description Rev Source (team) Speed range Duration Coordinate frame(s) Notes

[CBO\_RD\_IDS] CBO run-down time histories: forces/moments at HPCC interfaces; speed vs. time [R] Engine Dynamics [MIN–MAX rpm] [s] [GLOBAL / LOCAL\_IFACE] Required by CS-E 810 running-after-failure workflows.

EASA

+1

[CBO\_RO\_IDS] CBO run-on / continued rotation time histories [R] Engine Dynamics [MIN–MAX rpm] [s] [FRAMES] Pre-shutdown transient; maps to HPCC interfaces.

EASA

[WINDMILL\_IDS] Windmilling envelope(s) and duration [R] Engine Dynamics [MIN–MAX rpm] [min/hr] [FRAMES] Continued rotation in flight per CS-E 525.

EASA

[LIM\_OOB\_IDS] Limit OOB (manufacturing/service) 1× force/envelope vs. speed [R] Engine Dynamics [MIN–MAX rpm] [—] [FRAMES] Typically derived from balance-grade practice (ISO 21940); used as-provided here.

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[THERMAL\_IDS] Thermal field(s) / operating point(s) [R] Performance [OPR set] [—] [MODEL CSYS] Pre-stress/base state for all dynamic cases.

[INTERFACE\_IDS] Interface FRFs / support stiffness & damping [R] Engine Dynamics [Hz] [—] [IFACE FRAMES] For model correlation and boundary conditions.

[SURVEY\_IDS] Engine vibration survey (Bode/Campbell, strains/accels) [R] Test Org [MIN–MAX rpm] [—] [SENSOR CSYS] Supports “test or test + validated analysis” per CS-E 650.

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Notes.

• CS-E 650 allows establishing vibration characteristics by test or by test + validated analysis; your survey data will act as correlation targets.

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• CS-E 525 addresses continued rotation (windmilling) after shutdown—include the provided envelope and duration.

EASA

• CS-E 810 covers blade failure and running after failure; your CBO run-down/run-on histories come from that program.

EASA

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2.3 Internal modelling assumptions (HPCC)

(Populate with your actual values; leave N/A where not used.)

2.3.1 Geometry & simplifications

CAD basis: [CAD CONFIG / REV]

Symmetry used: [NONE / ½ / ⅛]; cyclic sectors: [N]

Omitted features (with justification): [FEATURE LIST + RATIONALE]

Threaded joints modeled as: [PRETENSION / WELDED / SPRING]

2.3.2 Materials & temperature

Base alloy: [ALLOY / SPEC]; heat treatment: [HT]

Temperature-dependent E, σy, σu, α, ν: [SOURCE / TABLE REF]

Allowables basis (HCF/LCF): [HAND-BOOK / TEST / A/B-BASIS]

Oxidation/creep relevance for this section: [YES/NO; if YES, how addressed]

2.3.3 Damping & modal parameters

Structural damping model: [MODAL ζ / RAYLEIGH (α,β) / MATERIAL]

Nominal ζ for casing modes in analysis: [e.g., 0.5–1.0%] (tuned later via rig/engine correlation per §4).

Joint damping representation (flanges/seals): [ASSUMPTION]

2.3.4 Boundary conditions & interfaces

Upstream interface: [NAME], constraint type: [SPRING/BC], K/C matrices: [VALUES or REF]

Downstream interface: [NAME], constraint type: [SPRING/BC], K/C matrices: [VALUES or REF]

Contact definitions: [TIED / FRICTIONAL (µ=…)]; preload(s): [VALUES]

2.3.5 Load mapping & frames

Global coordinate system: [GCS NAME/ORIGIN]; local interface CSYS: [IFACE\_A/B CSYS]

Transform method for forces/moments: [DIRECT MATRIX / RBE2 / RBE3 / MPC / COUPLING]

Load application: [NODAL SETS / SURFACE LOADS] with [TIME STEP] and [INTEGRATOR] settings

Thermal-mechanical coupling: [SEQUENTIAL (T→M) / FULLY COUPLED]

2.3.6 Numerical controls

Mesh density targets at hot spots: [ELEM SIZE / ASPECT / JACOBIAN LIMITS]

Convergence criteria: [FORCE/ENERGY/CONTACT %]

Time integration: [SCHEME], Δt [VALUE], stability check [CFL / EIGENVALUE]

2.4 Validation artefacts (part-level)

(You own these for your model credibility; engine team owns engine-level validation.)

2.4.1 Engine survey correlation (if used)

Channels at HPCC: [ACCEL CH IDs / STRAIN CH IDs]

Tach/keyphasor: [YES/NO]; order tracking method: [RESAMPLER / RPM TRACK]

Target metrics:

Bode (1×) amplitude and phase at [LOCATIONS]

Campbell diagram crossings at [FREQUENCIES / RPM]

Acceptance: |Δamp| ≤ [AMP\_TOL]%, |Δphase| ≤ [PHASE\_TOL]° at key dwells.

(Establishing vibration characteristics by test or test + validated analysis per CS-E 650.)

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2.4.2 Rig/component shaker tests (recommended)

Fixture & BC equivalence to engine: [DESCRIPTION]

Excitation: [STEPPED SINE / RANDOM] up to [FREQ]

Modal targets: first [N] casing modes; acceptance ±[FREQ\_TOL]%, MAC ≥ [MAC\_MIN]; damping extraction [HALF-POWER / MDOF ID].

2.5 Strength & fatigue criteria (local, part-level)

(Summarized here for traceability; detailed evaluation appears in §6.)

Ultimate / yield integrity: peak stress/strain ≤ allowable at temperature for each case (CBO run-down, CBO run-on, windmilling, Limit-OOB).

Fatigue (HCF): method [STRAIN-LIFE / GOODMAN]; damage ≤ 1.0 (MoS ≥ 0) at critical nodes for:

(i) CBO run-on (transient), (ii) windmilling (duration [T]), (iii) Limit-OOB (1× sweep).

Reporting: provide margin comparison tables (lowest MoS highlighted) across all cases.

2.6 Data quality checks (to be completed before analysis)

2.6.1 Completeness & format

Time histories present for all HPCC interfaces and all components (Fx,Fy,Fz,Mx,My,Mz) ✅

Speed vs. time present and synchronized ✅

Units and coordinate frames stated for every file ✅

File integrity (hash/CRC): [VALUE] ✅

2.6.2 Sampling & conditioning

Sample rate ≥ [RATE]; anti-alias filter [YES/NO – [CUTOFF]]; interpolation to Δt [VALUE]

RPM resampling/order tracking [YES/NO]; tach alignment [OK]

Thermal field consistency with operating point [CHECK]

2.6.3 Consistency checks

Equilibrium check on interface loads (net result reasonable vs shaft OOB) [OK]

Speed bands cover all resonance crossings [YES/NO]

Windmilling duration matches mission assumption per CS-E 525 [OK].

EASA

2.7 Uncertainty & sensitivity placeholders

Sensor calibration tolerances: [±% / ±µε / ±g]

Support K/C variability: [±%] around nominal

Damping ζ range: [LOW–HIGH %] (explored in §6 sensitivity)

Material property scatter: [A/B-BASIS or ±%]

Mesh refinement study: [COARSE/MEDIUM/FINE] with convergence metric [X%]

2.8 Traceability table (fill at release)

(One-page snapshot that auditors love.)

Artefact ID / File Rev Date Owner Used in § Notes

CBO run-down loads [CBO\_RD\_IDS] [R] [DATE] Engine Dynamics 5.2, 6.1 Validated per AMC E 520(c)(2).

EASA

CBO run-on loads [CBO\_RO\_IDS] [R] [DATE] Engine Dynamics 5.3, 6.2

Windmilling envelope [WINDMILL\_IDS] [R] [DATE] Engine Dynamics 5.4, 6.3 CS-E 525.

EASA

Limit OOB envelope [LIM\_OOB\_IDS] [R] [DATE] Engine Dynamics 5.5, 6.4 ISO 21940 basis (program).

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Thermal field(s) [THERMAL\_IDS] [R] [DATE] Performance 5.1

Interface FRFs/K/C [INTERFACE\_IDS] [R] [DATE] Engine Dynamics 4, 5

Engine survey data [SURVEY\_IDS] [R] [DATE] Test Org 4, 6 CS-E 650 correlation targets.

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Quick confirmations I need from you to finalize §2

The IDs/revs for each external input in §2.2 / §2.8.

Your default damping model/values and modal acceptance targets (±freq %, MAC, ζ method).

The coordinate systems (names/origins) for global and interfaces.

Windmilling duration and whether to treat it steady or transient sequence.

Once you drop those in, I’ll generate §3 (Requirements & full MoC matrix) next, pre-filled with the CS-E/AMC text and cross-references.

You said:

"Lock the exact items (hardware, load packages, solvers) this analysis is based on." I didnt understand what you mean by that

ChatGPT said:

Got it—let me clarify that phrase "lock the exact items (hardware, load packages, solvers) this analysis is based on."

What does “lock” mean in this context?

Here, “lock” means to precisely define and freeze the components and data your analysis depends on, so the report is crisp, traceable, and unambiguous. This helps ensure:

If something changes (like a newer drawing, updated loads, solver version), you know whether those changes affect your results.

Regulators and auditors can verify exactly what versions and configurations your conclusions are based on.

It supports configuration control—a core requirement in certified engineering programs.

So in Section 2, when we list:

Hardware & drawing set: part number, drawing number and revision, heat treatment, coatings…

Load packages: exact IDs and revisions for CBO run-down, windmilling, etc.

Analysis environment: solver name and version, FE element types, material database…

—we’re essentially saying:

“This is the exact physical part (drawing/range), and these are the exact data sets and software\* we used—if you look at an updated drawing or a newer solver version, your results may differ, so be aware.”\*

Why it matters:

Traceability – Enables reviewers to retrace and reproduce your analysis based on the same inputs.

Configuration control – Facilitates change management. If someone updates the drawing or load file, you can assess whether that invalidates your report.

Certifiable rigor – Regulatory bodies expect clear documentation of the reference configuration.

Example (fill-in box):

2.1.1 Hardware & drawing set

Component: HPCC

Part number: 123-HPCC-A

Drawing: DRW-456, Revision C

Serial applicability: SN 001–050

Material: Titanium AL-6V-4.5Fe, heat treat T-6

Coating: 0.002 in TiN

2.1.3 Analysis environment

Solver: ANSYS Mechanical 2024R2, element types: SOLID185, contact: frictional µ = 0.2

Material database: MTL-2024R2-v3

Post-processing tool: Python 3.10 + NumPy libs v1.25

Would you like me to rephrase that header in the template—maybe: “Define the exact hardware configuration, load/data packages, and analysis environment used” instead of “lock”? Let me know, and I’ll update Section 2 accordingly.

You said:

Another question, what did you mean by "Windmilling envelope(s)"? Short answer.

ChatGPT said:

Good question—“windmilling envelope” refers to the range of operating conditions (typically rotor speed and duration) during which the engine or rotor remains windmilling—i.e., rotated by airflow alone after shutdown. It defines the load scenario your casing must endure during continued rotation in flight (per CS-E 525, “Continued Rotation”).

In your HPCC report, the “windmilling envelope” would be the time-history or steady-state range of rotor speeds, forces, and duration supplied by the Engine Dynamics team—basically the load boundary you analyze for fatigue or clearance risk under windmilling conditions.

Would you like to summarize this definition into a concise statement in the report?

You said:

One question, as I implied in the beginning, this is a structural analysis report, so why do you include test related stuff in detail (such as sensor tolerances, sample rate etc, as I think they will already be detailed in the test reports referenced)

ChatGPT said:

Thought for 41s

Totally fair question. Short version:

You don’t need to repeat full test procedures in a structural analysis report—but you do need a minimal “data-pedigree & applicability” stub so reviewers see that the test data you relied on are suitable for validated analysis.

Why this tiny stub matters:

CS-E 650 lets you show acceptability by test or test + validated analysis. If you use test data to validate/correlate your model, you must show they’re applicable to the analysis you ran.

EASA

AMC E 520(c)(2) talks about validated data flowing between teams. Your report should identify exactly which validated datasets you consumed (IDs/revs) and any essentials that affect your results.

EASA

YUMPU

Credibility frameworks (e.g., NASA-STD-7009B) expect you to document input/data pedigree—things like units, coordinate frames, and processing that materially influence results. (7009B even adds explicit requirements for recording units & vector coordinate frames and defines Input/Data Pedigree levels.)

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So, keep it lean in your report—include only the bits that impact your analysis:

Keep in the analysis report (1–2 paragraphs or a small table):

Test/run IDs & revisions you used, units & coordinate frames, and any processing you applied (e.g., rpm resampling, filtering).

A couple of applicability checks: sampling rate adequate for your bandwidth; tach/keyphasor present for 1× phase; uncertainty bounds used in correlation criteria.

A pointer to the source test report(s) for everything else.

Leave in the test report(s):

Sensor models/calibrations, wiring, detailed procedures, full uncertainty budgets, raw time histories, acceptance logs.

This way you maintain traceability and credibility without bloating your analysis report—exactly what auditors look for when you claim “test + validated analysis.”

EASA

+1

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You said:

Ok. Now for Section 3

ChatGPT said:

Thought for 50s

Awesome — here’s a copy-paste-ready Section 3 with a clear Means of Compliance (MoC) matrix you can fill. I kept placeholders in [BRACKETS] and used concise wording auditors like.

3. Requirements & Means of Compliance

3.1 Applicable regulations (summary)

CS-E 650 — Vibration Surveys. Vibration characteristics must be established by test or by a combination of test and validated analysis.

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CS-E 810 — Compressor and Turbine Blade Failure. Demonstrate containment and that running after failure does not lead to Hazardous Engine Effects (engine-level). This report consumes CBO load histories to show HPCC integrity.

EASA

CS-E 525 — Continued Rotation (windmilling). If rotation continues after shutdown, any continued rotation during the maximum expected period/conditions must not result in effects unacceptable under CS-E 510.

EASA

AMC E 520(c)(2) — Engine Model Validation / Validated Data. Specifies validated data content for blade-loss analysis (e.g., FE model, OOB, rubs, rotational speed vs. time) to be provided for aircraft constructors; part-level analyses may use these validated inputs and return interface reactions if requested.

EASA

Applicability note. Engine-level derivation/validation of OOB loads/limits (CBO run-down/run-on, windmilling, manufacturing/service OOB) are owned by Engine Dynamics; this report demonstrates HPCC integrity using those validated inputs.

3.2 Compliance strategy (one-paragraph statement)

Compliance is shown for HPCC by finite-element analysis (thermal pre-stress + transient dynamic) using engine-provided validated time histories/envelopes for CBO run-down, CBO run-on/continued rotation, windmilling, and limit OOB; fatigue is evaluated via [HCF METHOD, e.g., strain-life/Goodman]. Analysis credibility is supported by correlation to engine vibration survey data (test or test+validated analysis per CS-E 650) and, where available, rig/modal tests of the casing.

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3.3 Means of Compliance (MoC) matrix — quick reference

Fill Owner, Evidence, Input IDs, Acceptance and tick Status when done. Keep this one-pager near the front; a detailed matrix follows in §3.4.

Rule / AMC Requirement (short text) Applicability to HPCC MoC (Test / Analysis / Similarity) Owner Evidence (section / doc) Inputs (IDs/Rev) Acceptance (pass criteria) Status

CS-E 650 Establish vibration characteristics by test or test+validated analysis Yes (model correlation targets) Analysis + Reference Engine Survey Engine Dynamics (survey); HPCC (correlation) §4.1, §4.3; §6 [SURVEY\_IDS] Δamp

CS-E 810 Blade failure; containment & running after failure Indirect (uses CBO loads) Analysis (HPCC transient using CBO run-down/run-on) Engine Dynamics (define/validate loads); HPCC (apply & assess) §5.2–§5.3; §6.1–§6.2 [CBO\_RD\_IDS], [CBO\_RO\_IDS] Strength: σ, ε ≤ allowables @ T; HCF damage ≤ 1.0 (MoS ≥ 0).

EASA

[ ]

CS-E 525 Continued rotation (windmilling) must not cause effects unacceptable under CS-E 510 Yes Analysis (HPCC fatigue/integrity under windmilling envelope/duration) Engine Dynamics (scenario); HPCC (assess) §5.4; §6.3 [WINDMILL\_IDS] Fatigue: damage ≤ 1.0 over [DURATION]; clearances per inputs remain acceptable.

EASA

[ ]

AMC E 520(c)(2) Validated data for blade-loss/OOB to aircraft constructors; part may return interface reactions By reference Use validated inputs; provide reactions if requested Engine Dynamics (package owner); HPCC (reactions) §2.2; §6 (reactions) [VALIDATED\_DATA\_ID] Reactions generated from same load set & frames; traceable IDs/revs.

EASA

[ ]

3.4 Means of Compliance — detailed matrix (with acceptance & traceability)

Use one line per load case where helpful. Keep requirement wording short; full text is in references.

Ref Requirement (short text) Applicability Method Inputs (IDs/Rev) Assumptions / Notes Acceptance criteria Evidence (sec / figs / tables)

CS-E 650(a)

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Establish vibration characteristics (test or test+validated analysis) HPCC Analysis + correlation to engine survey [SURVEY\_IDS] Use engine survey as correlation targets at HPCC points; optional rig FRFs for tuning Correlation: Δamp

CS-E 810(a) (running after failure)

EASA

Blade failure; HPCC to survive CBO run-down loads HPCC Transient FE (thermal + dynamic) [CBO\_RD\_IDS], [THERMAL\_IDS] Loads, frames, timing as provided by Engine Dynamics Strength: σvm, εeq ≤ allowables @ T; Margins: MoS ≥ 0 §5.2; §6.1; Figs [F-IDs]; Tbl [T-IDs]

CS-E 810(a)

EASA

HPCC to survive CBO run-on / continued rotation HPCC Transient FE + HCF eval. [CBO\_RO\_IDS], [THERMAL\_IDS] Sequence/duration per input Fatigue: damage ≤ 1.0 (or MoS ≥ 0) at critical nodes §5.3; §6.2; Figs [F-IDs]; Tbl [T-IDs]

CS-E 525

EASA

Windmilling continued rotation acceptable HPCC Steady/Transient FE + HCF over [DURATION] [WINDMILL\_IDS] Envelope & duration per validated input Fatigue: damage ≤ 1.0 over envelope; Integrity: no exceedance of allowables §5.4; §6.3; Figs [F-IDs]; Tbl [T-IDs]

AMC E 520(c)(2)

EASA

Use of validated data package; provide reactions if requested By ref Data use + reaction extraction [VALIDATED\_DATA\_ID] FE mapping preserves frames/units; reaction sign convention defined Traceability: inputs/reactions cross-referenced; IDs/revs present in §2.8 §2.2, §6 (interface reactions)

Program req. (HCF) HCF margins under Limit OOB (manufacturing/service) HPCC 1× sweep (synchronous) + HCF [LIM\_OOB\_IDS], [THERMAL\_IDS] Envelope defined by Engine Dynamics Fatigue: damage ≤ 1.0 (MoS ≥ 0); Worst-case speed band identified §5.5; §6.4; Tbl “Limit OOB summary”

3.5 Acceptance criteria (explicit list for sign-off)

Strength (all transients): peak σ/ε ≤ allowables at temperature at all critical locations.

Fatigue: cumulative damage ≤ 1.0 (or MoS ≥ 0) for CBO run-on, windmilling (duration [DURATION]), and Limit OOB sweep.

Correlation (per CS-E 650): |Δamp| ≤ [AMP\_TOL]%, |Δphase| ≤ [PHASE\_TOL]° at agreed orders/speeds; [N] modes within ±[FREQ\_TOL]%, MAC ≥ [MAC\_MIN].

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Traceability: all analysis uses validated inputs (IDs/revs) consistent with AMC E 520(c)(2); interface reactions (if requested) are produced from the same load set and frames.

EASA

3.6 References (for §3 only)

CS-E 650 (Vibration Surveys), Easy Access Rules extract.

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CS-E 810 (Compressor & Turbine Blade Failure), Amendment 7 change info (current wording).

EASA

CS-E 525 (Continued Rotation), Book 1 text.

EASA

AMC E 520(c)(2) (Engine Model Validation / Validated Data), Book 2 text.

EASA

Placeholders for you to fill (so I can lock §3)

[SURVEY\_IDS], [CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS], [THERMAL\_IDS], [VALIDATED\_DATA\_ID].

Correlation targets: [AMP\_TOL]%, [PHASE\_TOL]°, [N], [FREQ\_TOL]%, [MAC\_MIN].

Fatigue method and any program-specific margins.

Evidence pointers: figure/table IDs you’ll produce in §6.

When you drop those in, I’ll move on to Section 4 – Means of Compliance (methods & validation) or we can iterate this matrix to match your internal templates.

You said:

Move on to Section 4 for now.

ChatGPT said:

Thought for 23s

Awesome—here’s a copy-paste-ready Section 4 you can drop into your report. I kept it tight, audit-friendly, and aligned with CS-E wording. Placeholders are in [BRACKETS].

4. Means of Compliance

4.1 Overview (statement of approach)

Compliance for the HP Compressor Casing (HPCC) is shown by finite-element analysis (thermal pre-stress + dynamic response) using validated engine-level inputs for CBO run-down, CBO run-on/continued rotation, windmilling (continued rotation after shutdown), and limit out-of-balance (OOB); analysis credibility is supported by test or test + validated analysis per CS-E 650 (engine vibration survey + optional HPCC rig/modal correlation). Blade-failure running conditions are taken from the engine-level CS-E 810 program; windmilling conditions reflect CS-E 525 (continued rotation). Engine-team inputs are treated as validated data per AMC E 520(c)(2).

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4.2 External validated inputs (consumed as-is)

Owner: Engine Dynamics (see §2 for IDs/revs; used here as controlled inputs per AMC E 520(c)(2)).

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CBO run-down time histories: forces/moments at HPCC interfaces; speed vs. time — IDs: [CBO\_RD\_IDS]. (Engine-level, from CS-E 810 running-after-failure assessments.)

EASA

CBO run-on / continued rotation time histories — IDs: [CBO\_RO\_IDS].

EASA

Windmilling envelope and duration (continued rotation after shutdown) — IDs: [WINDMILL\_IDS].

EASA

Limit OOB (manufacturing/service) 1× envelope vs. speed — IDs: [LIM\_OOB\_IDS]. (Typically derived from ISO 21940 balance-grade practice; used here as provided.)

HAIMER

Thermal field(s) / operating point(s) — IDs: [THERMAL\_IDS].

Interface properties/FRFs (K/C matrices, frames) — IDs: [INTERFACE\_IDS].

Engine vibration survey (Bode/Campbell, local strain/accel channels) — IDs: [SURVEY\_IDS]. (Supports CS-E 650 test or test+validated analysis.)

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Note. Changes to these artefacts may require reassessment of results under configuration control.

4.3 Analysis method (HPCC)

4.3.1 Thermal pre-stress (base state)

Import [THERMAL\_IDS]; solve steady thermal; map to structural; store base stress/strain for all dynamic cases.

4.3.2 Transient dynamic — CBO run-down

Apply [CBO\_RD\_IDS] interface Fx,Fy,Fz,Mx,My,Mz vs time in [GLOBAL/IFACE FRAMES] using [MAPPING METHOD: RBE2/RBE3/MPC/COUPLING].

Integrator [SCHEME], Δt [VALUE], total duration [T]; damping per §2.3.3.

Outputs: peak σ/ε maps, interface reactions, critical time segments. (Loads originate from engine CS-E 810 program.)

EASA

4.3.3 Transient dynamic — CBO run-on / continued rotation

Same mapping as 4.3.2 using [CBO\_RO\_IDS]; compute HCF damage over the transient window with method in §4.5.

4.3.4 Windmilling after shutdown (continued rotation)

Treat as [STEADY-STATE HARMONIC / LONG TRANSIENT] based on [WINDMILL\_IDS]: speed band [RPM\_MIN–RPM\_MAX], duration [DURATION].

Evaluate steady or time-segmented HCF damage over the specified duration per CS-E 525 intent.

EASA

4.3.5 Limit OOB (manufacturing/service) — 1× sweep

Apply synchronous 1× force/moment envelope vs speed per [LIM\_OOB\_IDS]; sweep [RPM GRID] with thermal base state. (Engine-team envelope typically reflects ISO 21940 balancing grade; this report does not derive it.)

HAIMER

4.4 Validation of the HPCC model (your remit)

(Keep at “data-pedigree” level—full procedures live in the test reports.)

4.4.1 Correlation to engine vibration survey (CS-E 650)

Use [SURVEY\_IDS] channels located on HPCC; orders [1×, …]; speed range [RPM].

Compare Bode (amplitude/phase) and Campbell crossings at matching points.

Acceptance targets (program standard): |Δamp| ≤ [AMP\_TOL]%, |Δphase| ≤ [PHASE\_TOL]° at key dwells.

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4.4.2 Optional rig/modal correlation

HPCC shaker/fixture representing engine BCs; identify first [N] modes; acceptance ±[FREQ\_TOL]%, MAC ≥ [MAC\_MIN], damping extraction [METHOD].

Data pedigree stub (analysis-relevant only): confirm units & frames; tach/keyphasor present for order tracking; sampling adequate for bandwidth; processing steps (e.g., rpm resampling). (Detailed sensor specs, calibrations, and procedures are in the referenced test reports.)

4.5 Fatigue evaluation method (HCF)

Method: [STRAIN-LIFE / GOODMAN / OTHER] with allowables from [ALLOW\_DOC] at temperature.

Cycle counting: [RAINFLOW / ORDER-DOMAIN] on [σ/ε] responses; damage rule [MINER’S / OTHER].

Duration handling:

CBO run-on — integrate damage over transient window [t0–t1].

Windmilling — accumulate over [DURATION] with [duty cycle / sequence].

Limit OOB — evaluate worst-case across [RPM GRID].

Report Margins of Safety (MoS) per case and margin comparison table across cases (lowest MoS highlighted).

4.6 Acceptance criteria (pass/fail used in §6)

Strength (transients): peak σ / ε ≤ allowables at temperature for CBO run-down and CBO run-on.

Fatigue: Damage ≤ 1.0 (MoS ≥ 0) for CBO run-on, windmilling [DURATION], and limit OOB sweep.

Correlation (CS-E 650): |Δamp| ≤ [AMP\_TOL]%, |Δphase| ≤ [PHASE\_TOL]°, [N] modes within ±[FREQ\_TOL]%, MAC ≥ [MAC\_MIN].

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4.7 Frames, mapping, and numerical controls

Frames: global [GCS NAME]; interface frames [IFACE\_A], [IFACE\_B] (right-handed; origin/axes defined in §2).

Mapping: [RBE2/RBE3/MPC/CONTACT-COUPLING]; sign conventions per [INTERFACE\_IDS].

Contacts/joins: [TIED/FRICTIONAL µ=…/PRETENSION=…].

Time integration: [SCHEME], Δt [VALUE]; convergence tolerances [CRITERIA]; damping [ζ or Rayleigh α,β].

Mesh quality: hot-spot element size [mm], Jacobian/warp limits [VALUES].

4.8 Deliverables (from this analysis)

Strength results: peak σ/ε maps and tabulated maxima per case.

Fatigue results: damage and MoS tables per case; margin comparison summary across cases.

Correlation summary: Bode/Campbell overlays vs [SURVEY\_IDS] (and rig modal table if used).

Interface reactions: [YES/NO]—if requested for the engine validated-data package under AMC E 520(c)(2).

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Traceability: completed §2.8 table (IDs/revs); cross-references to figures/tables.

4.9 Compliance linkage (regulatory hooks)

CS-E 650 — use of test or test + validated analysis for vibration characteristics/correlation.

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CS-E 810 — HPCC assessed with engine-provided CBO running-after-failure loads.

EASA

CS-E 525 — continued rotation (windmilling) evaluated over the provided duration/envelope.

EASA

AMC E 520(c)(2) — engine validated data concept and deliverables; HPCC uses these inputs and can return interface reactions.

EASA

Minimal items I need from you to lock §4

Method picks: [STRAIN-LIFE/GOODMAN], damage rule, Δt/integrator, damping model, mapping method.

Correlation targets: [AMP\_TOL]%, [PHASE\_TOL]°, [N], [FREQ\_TOL]%, [MAC\_MIN].

Windmilling treatment: [STEADY/HARMONIC or LONG TRANSIENT], [DURATION], [RPM GRID].

Frames & sign conventions: names/origins for [GCS], [IFACE\_A], [IFACE\_B].

Once you fill these, I’ll proceed with Section 5 – Analysis Load Cases (definitions + ready-to-fill mapping tables).

You said:

Minimal items you needed to lock §4:

Method picks: [GOODMAN to check whether there is infinite life, if found to be above, use and internal solver called TLIFE, which is based on NASALIFE method], damage rule: (I dont know what you mean, Miner's rule I guess), Δt: (equals the same settings as whole engine team)/integrator: (default integrator of ansys I guess), damping model: (same as the one used in whole engine team analyses), mapping method: (I don't know what you mean).

ChatGPT said:

Thought for 59s

Perfect—thanks for the picks. I’ve locked Section 4 with your choices and filled the blanks. I also clarified the two items you weren’t sure about (integrator & mapping) and set sensible defaults that match common ANSYS practice.

4. Means of Compliance (locked with program picks)

4.1 Overview

Compliance for the HP Compressor Casing (HPCC) is shown by finite-element analysis (thermal pre-stress + dynamic response) using validated engine-level inputs for CBO run-down, CBO run-on / continued rotation, windmilling, and limit out-of-balance (OOB). Analysis credibility is supported by test or test + validated analysis per CS-E 650 (engine vibration survey + optional HPCC rig/modal correlation). Engine-team inputs are treated as validated data per AMC E 520(c)(2).

Wikipedia

Innovation Space

4.2 External validated inputs (consumed as-is)

Owner: Engine Dynamics (IDs/revs listed in §2).

CBO run-down time histories: forces/moments at HPCC interfaces; speed vs. time — IDs: [CBO\_RD\_IDS].

Innovation Space

CBO run-on / continued rotation — IDs: [CBO\_RO\_IDS].

Innovation Space

Windmilling envelope + duration — IDs: [WINDMILL\_IDS].

ScienceDirect

Limit OOB (manufacturing/service) 1× envelope vs. speed — IDs: [LIM\_OOB\_IDS]. (Program-defined; typically based on ISO 21940.)

Innovation Space

Thermal field(s) — IDs: [THERMAL\_IDS].

Interface properties/FRFs (K/C, frames) — IDs: [INTERFACE\_IDS].

Engine vibration survey — IDs: [SURVEY\_IDS].

Wikipedia

Config note. Any change to these artefacts triggers reassessment under configuration control.

4.3 Analysis method (HPCC)

4.3.1 Thermal pre-stress (base state)

Import [THERMAL\_IDS], solve steady thermal, map to structural; store base stress/strain for all dynamic cases.

4.3.2 Transient dynamic — CBO run-down

Apply [CBO\_RD\_IDS] interface Fx, Fy, Fz, Mx, My, Mz vs time in [GLOBAL/IFACE FRAMES] using the mapping method in §4.7. Integrator/time step in §4.7. Outputs: peak σ/ε maps, interface reactions, critical time segments.

Innovation Space

4.3.3 Transient dynamic — CBO run-on / continued rotation

Same mapping as §4.3.2 using [CBO\_RO\_IDS]. Compute HCF damage over the transient window with §4.5.

4.3.4 Windmilling after shutdown (continued rotation)

Treat as [STEADY HARMONIC / LONG TRANSIENT] based on [WINDMILL\_IDS]: speed band [RPM\_MIN–RPM\_MAX], duration [DURATION]. Evaluate HCF damage over the specified duration (CS-E 525 intent).

ScienceDirect

4.3.5 Limit OOB (manufacturing/service) — 1× sweep

Apply synchronous 1× envelope vs speed per [LIM\_OOB\_IDS]; sweep [RPM GRID] with thermal base state. (Envelope supplied by program; not derived here.)

Innovation Space

4.4 Model validation (part-level)

Engine survey correlation (CS-E 650): overlay Bode/Campbell at HPCC points from [SURVEY\_IDS]; acceptance: |Δamp| ≤ [AMP\_TOL]%, |Δphase| ≤ [PHASE\_TOL]° at key dwells.

Wikipedia

Optional rig/modal correlation: identify first [N] casing modes; acceptance ±[FREQ\_TOL]%, MAC ≥ [MAC\_MIN].

Data-pedigree stub (kept minimal): confirm units & frames; tach present; sampling adequate for bandwidth; any analysis-side processing (e.g., rpm resampling). Details live in test reports.

4.5 Fatigue evaluation method (HCF) (your picks applied)

Screening (infinite-life check): Goodman mean-stress correction using program allowables; if all critical points lie on/under the Goodman line at the relevant alternating/mean stresses → infinite-life acceptable (no damage accumulation needed).

Wikipedia

ScienceDirect

If not infinite-life: use internal solver TLIFE (based on NASA’s NASALIFE methodology) for life/damage under the actual stress histories.

NASA Technical Reports Server

+1

Damage rule: Miner’s linear damage for variable-amplitude loading; damage ≤ 1.0 required.

ScienceDirect

help.reliasoft.com

Cycle counting: Rainflow (time-domain or order-domain) on σ/ε responses consistent with TLIFE input expectations.

4.6 Acceptance criteria (used in §6)

Strength (transients): peak σ / ε ≤ allowables at temperature for CBO run-down and CBO run-on.

Fatigue: Damage ≤ 1.0 (MoS ≥ 0) for CBO run-on, windmilling [DURATION], and limit OOB sweep.

Correlation (CS-E 650): |Δamp| ≤ [AMP\_TOL]%, |Δphase| ≤ [PHASE\_TOL]°, [N] modes within ±[FREQ\_TOL]%, MAC ≥ [MAC\_MIN].

Wikipedia

4.7 Frames, mapping, integrator, damping, and numerics (clarified + defaults set)

Frames & sign conventions

Global: [GCS NAME]; interface frames [IFACE\_A], [IFACE\_B] (right-handed; axes/origins per §2).

Mapping method (how loads enter the model)

Default here: Remote Point + Distributed Coupling (deformable). This distributes loads to attached nodes without adding artificial rigidity (RBE3-like behavior), avoiding overly stiffening the flange/patch. Use “Rigid” only when the hardware truly acts as a rigid hub/ring.

Innovation Space

Autodesk Forums

Eng-Tips

Integrator & time step

ANSYS implicit transient default = Newmark (TRNOPT with TINTOPT=NMK). HHT-α is also available and often used to add numerical damping via TINTP presets. We will match the engine-team setting; if unspecified, default to Newmark with program TINTP preset.

mm.bme.hu

+1

Innovation Space

+1

Δt: “same as engine team.” Ensure it resolves the highest frequency/order of interest (rule-of-thumb: ≥ 20–30 points per cycle at the max tracked order). If the team uses TINTP MOSP/LOSP presets, keep them aligned for stability/robustness.

Innovation Space

Damping model

“Same as engine team.” If Rayleigh is used, compute α, β from two target ζ–frequency points (e.g., ζ at [f1], [f2]); formulae and workflow are standard.

SimScale

Contacts/joins, mesh, convergence

Contact [TIED/FRICTIONAL µ=… / pretension …]; hot-spot element size [mm]; time integration/convergence tolerances [CRITERIA].

4.8 Deliverables

Strength: peak σ/ε maps and tabulated maxima per case.

Fatigue: damage and MoS tables per case; margin-comparison summary across all cases.

Correlation: Bode/Campbell overlays vs [SURVEY\_IDS] (and rig modal table if used).

Interface reactions: [YES/NO]—if requested for the engine validated-data package (AMC E 520(c)(2)).

Innovation Space

Traceability: completed §2.8 (IDs/revs); figure/table cross-refs.

What I set by default (tell me if you want any of these changed)

Mapping: Remote Point Distributed (deformable) to avoid artificial stiffness (RBE3-like).

Innovation Space

Autodesk Forums

Integrator: Newmark implicit (default) unless the program mandates HHT-α via TINTP presets.

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+1

Damage rule: Miner’s linear damage.

ScienceDirect

Goodman screen → if not infinite life, run TLIFE (NASALIFE-based) for damage/life.

NASA Technical Reports Server

If that all looks good, I’ll move on to Section 5 – Analysis Load Cases, with ready-to-fill mapping tables for each case (CBO run-down, CBO run-on, windmilling, Limit OOB).

You said:

Move on to Section 5

ChatGPT said:

Thought for 32s

Alright—here’s a copy-paste-ready Section 5 with fill-in brackets and ready-to-use tables. I kept it lean where it should be, detailed where auditors usually push, and tied the regulatory hooks to solid sources.

5. Analysis Load Cases

Scope. This section defines the loads supplied by the Engine Dynamics team and how they are mapped and evaluated on the HP Compressor Casing (HPCC). Engine-level derivation/validation of these loads is out of scope here and referenced per §2.2. Validated data concept per AMC E 520(c)(2).

EASA

5.1 Thermal base load (pre-stress state)

Purpose. Establish steady thermal/pressure state used for all dynamic cases.

Input IDs: Thermal field(s) / operating point(s): [THERMAL\_IDS]

Solution: Steady thermal → mapped to structural; pre-stress carried forward to §§5.2–5.5.

Notes: Temperature-dependent properties per §6.1; pressure/preload per [OP CONDITIONS].

Table 5-1. Thermal base—inputs & mapping

Item Value / ID Notes

Thermal field file(s) [THERMAL\_IDS] Coordinated with operating point [OP]

Pressure loads (if any) [P\_FIELD\_ID / kPa] Applied on [SURFACES]

Contact/preload [DETAILS] Matches assembly state

Structural CSYS [GCS NAME] See §2.3.5

5.2 CBO run-down (post-failure shutdown transient)

Regulatory context. Engine program demonstrates blade failure and running after failure; this part-level analysis uses the provided CBO run-down histories to show HPCC integrity.

EASA

Input IDs: [CBO\_RD\_IDS] (Fx, Fy, Fz, Mx, My, Mz vs time; speed vs time).

Frames: Loads given in [GLOBAL / IFACE] frames; transforms per §5.7.

Mapping: [Remote Point – Distributed / RBE3-like coupling] to [IFACE\_A/B] node sets.

Solution type: Transient implicit (Newmark/HHT, Δt = [MATCH ENGINE TEAM]).

Outputs: Peak σ/ε maps; hotspot time slices; interface reactions.

Table 5-2. CBO run-down—load set & run controls

Item Value / ID Notes

Load package [CBO\_RD\_IDS] (Rev [R]) Validated at engine level

Speed range / profile [RPM\_MIN–RPM\_MAX] / [PROFILE] From input

Duration [T] s From input

Δt / integrator [Δt] / [Newmark or HHT-α] Match engine settings

Damping [ζ or Rayleigh α,β] Match engine team

Acceptance σ, ε ≤ allowables at T MoS ≥ 0

5.3 CBO run-on / continued rotation (pre-shutdown transient)

Regulatory context. Assessed as part of running after failure; used here for HCF evaluation on HPCC.

EASA

Input IDs: [CBO\_RO\_IDS] (forces/moments vs time; speed vs time).

Mapping/frames/solver: As §5.2 (unless stated otherwise).

Fatigue method: Goodman screen for infinite-life; if exceeded, compute damage with TLIFE (NASALIFE-based) + Miner’s rule.

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EASA

Table 5-3. CBO run-on—fatigue evaluation

Item Value / ID Notes

Load package [CBO\_RO\_IDS] (Rev [R]) Validated input

Time window for HCF [t0–t1] s Where 1× content is significant

Cycle counting [Rainflow / order-domain] Consistent with TLIFE

Fatigue method Goodman → TLIFE if needed Miner’s rule for damage

Acceptance Damage ≤ 1.0 (MoS ≥ 0) Report worst nodes

5.4 Windmilling after shutdown (continued rotation)

Regulatory context. CS-E 525 requires that any continued rotation after shutdown (windmilling) not lead to unacceptable effects; evaluate HPCC under the provided windmilling envelope and duration.

EASA

Input IDs: [WINDMILL\_IDS] (speed band and duration; either time history or steady envelope).

Approach: [Harmonic @ 1×] across speed grid [RPM GRID] or long transient per time history.

Fatigue: Accumulate over [DURATION] with Goodman → TLIFE as in §5.3.

Table 5-4. Windmilling—definition & evaluation

Item Value / ID Notes

Envelope / history [WINDMILL\_IDS] (Rev [R]) Validated input

Speed band [RPM\_MIN–RPM\_MAX] Per input

Duration [DURATION] Mission assumption

Method [Harmonic sweep / Transient] Chosen per input

Acceptance Damage ≤ 1.0 Identify worst speed band

5.5 Limit out-of-balance (manufacturing/service) — synchronous 1×

Context. Program supplies a 1× envelope vs speed representing manufacturing/service OOB limits (often derived from ISO 21940 balancing practice). When grade-based values are used, the customary relation is:

U

per

=

9549

G

m

n

[

g

\cdotp

mm

]

U

per

​

=

n

9549Gm

​

[g\cdotpmm]

with rotor mass

m

m [kg], service speed

n

n [rpm], grade

G

G [mm/s]. (Informative formula—used by balancing vendors; engine team remains the source of record for the envelope.)

cimat-balancing.com

hofmann-global.com

Input IDs: [LIM\_OOB\_IDS] (1× force/moment vs speed).

Approach: Harmonic analysis at [RPM GRID] with thermal pre-stress; extract peak σ/ε and HCF margins.

Table 5-5. Limit OOB—sweep setup

Item Value / ID Notes

Envelope [LIM\_OOB\_IDS] (Rev [R]) Program-supplied

Speed grid [RPM list or step] Covers all crossings

Solution [Harmonic / Steady 1×] With base thermal

Acceptance Damage ≤ 1.0 (MoS ≥ 0) Worst case reported

5.6 Alert-level imbalance / vibration thresholds (reference)

Owner: Engine Dynamics. If the program defines alert thresholds (for maintenance or flight limitations), list them by reference only and cross-link to §7. (No derivation here.) Correlation/acceptability may be supported via CS-E 650 survey + validated analysis.

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Table 5-6. Alert-level references (if applicable)

Item Reference Owner Note

Alert-level imbalance [DOC ID / Rev] Engine Dynamics For §7 actions

Vibration limits [DOC ID / Rev] Engine Dynamics From survey/MoC

5.7 Frames & load mapping (traceability)

Why this table matters. Ensures units/frames and sign conventions match the validated data package (AMC E 520(c)(2)), and that mapping does not artificially stiffen interfaces.

EASA

Table 5-7. Frames, transformations, and application

Interface Source frame (input) Model frame Transform (R/T) Mapping method Node/surface set

[IFACE\_A] [FRAME\_NAME\_A], units [N, N·mm] [MODEL\_CSYS] [R] / [T] Remote Point – Distributed (deformable) [SET NAME]

[IFACE\_B] [FRAME\_NAME\_B], units [N, N·mm] [MODEL\_CSYS] [R] / [T] Remote Point – Distributed (deformable) [SET NAME]

Default mapping rationale: distributed coupling (RBE3-like) spreads loads without adding rigid-body stiffness, unless the hardware is genuinely rigid (then “Rigid” is acceptable). (Analysis detail; engine data remain unchanged.)

5.8 Run controls & numerical parameters

Table 5-8. Transient / harmonic settings

Case Solver / integrator Δt / freq step Damping (ζ or α,β) Contacts / preload Convergence

5.2 CBO run-down [Newmark/HHT] [Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.3 CBO run-on [Newmark/HHT] [Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.4 Windmilling [Harmonic/Transient] [Δf or Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.5 Limit OOB [Harmonic] [Δf] [ζ or α,β] [DETAILS] [CRITERIA]

Integrator & Δt. Follow engine-team settings for consistency; if not specified, default to implicit Newmark/HHT with program TINTP preset and time/frequency resolution sufficient to capture 1× content and nearby crossings (per CS-E 650 vibration characterization intent).

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5.9 Evidence links (filled at release)

Table 5-9. Cross-references

Case Figures Tables Output files

5.2 CBO run-down [FIG IDs] [TAB IDs] [RUN IDs]

5.3 CBO run-on [FIG IDs] [TAB IDs] [RUN IDs]

5.4 Windmilling [FIG IDs] [TAB IDs] [RUN IDs]

5.5 Limit OOB [FIG IDs] [TAB IDs] [RUN IDs]

Quick confirmations (so I can pre-fill defaults in §5.8 for you)

Do you want Harmonic or Transient for windmilling? (If the engine team gives a duration only, harmonic at 1× across a speed grid is usually cleaner for HPCC.)

Are interface frames finalized? If yes, share the names so I replace the brackets in Table 5-7.

OK to keep Remote Point – Distributed as default mapping for both interfaces? (It avoids artificial stiffening.)

When you’re happy with §5, I’ll generate Section 6 – Results with margin-comparison table templates (strength & fatigue) ready for your numbers.

You said:

One thing, I am not that happy with §5, as it doesn't feel like copy/paste ready with minimal changes to me.

ChatGPT said:

Thought for 40s

Gotcha—here’s Section 5 rewritten to be truly “copy/paste with minimal edits.” It’s tight, fill-in-first, and avoids long prose. I kept only the essential regulatory hooks with citations.

5. Analysis Load Cases

Scope: This section defines the external load inputs (owned/validated by Engine Dynamics) and how they are applied to the HPCC model. Inputs are treated as validated data per AMC E 520(c)(2).

EASA

5.1 Thermal Base Load (Pre-Stress)

Inputs

Thermal field(s) / operating point(s): [THERMAL\_IDS]

Pressure loads (if any): [PRESSURE\_FIELD\_ID / kPa]

Solution

Steady thermal → map to structural → carry base stress/strain into §§5.2–5.5.

Table 5-1. Thermal Base—Setup

Item Value

Thermal file(s) [THERMAL\_IDS]

Operating point [OP\_NAME / CONDITIONS]

Applied pressures [SURFACES / VALUES]

Contacts/preload [DETAILS or N/A]

Structural CSYS [GCS\_NAME]

5.2 CBO Run-Down (Post-Failure Shutdown Transient)

Regulatory context: part-level integrity using engine-provided running-after-failure loads from the CS-E 810 program.

EASA

Inputs

Load package (forces/moments vs. time + speed vs. time): [CBO\_RD\_IDS] (Rev [R])

Application

Frames: [GLOBAL / IFACE\_A / IFACE\_B] (per input)

Mapping: Remote Point – Distributed (deformable) to [IFACE\_A\_SET], [IFACE\_B\_SET]

Transient integrator / Δt: [MATCH ENGINE TEAM]

Outputs

Peak σ/ε maps, hotspot time slices, interface reactions.

Table 5-2. CBO Run-Down—Run Controls

Item Value

Speed profile / range [PROFILE] / [RPM\_MIN–RPM\_MAX]

Duration [T] s

Integrator / Δt [Newmark or HHT-α] / [Δt]

Damping [ζ or Rayleigh α,β]

Acceptance σ, ε ≤ allowables @ T (MoS ≥ 0)

5.3 CBO Run-On / Continued Rotation (Pre-Shutdown Transient)

Regulatory context: assessed as “running after failure” per CS-E 810; used here for HCF.

EASA

Inputs

Load package (forces/moments vs. time + speed vs. time): [CBO\_RO\_IDS] (Rev [R])

Application

Same frames/mapping as §5.2 unless noted.

Transient window for HCF integration: [t0–t1] s

Evaluation

Fatigue per §4.5 (Goodman screen → TLIFE (NASALIFE-based) if not infinite life; Miner’s rule).

Table 5-3. CBO Run-On—Evaluation Fields

Item Value

HCF window [t0–t1] s

Cycle counting [Rainflow / Order-domain]

Acceptance Damage ≤ 1.0 (MoS ≥ 0)

5.4 Windmilling After Shutdown (Continued Rotation)

Regulatory context: evaluate continued rotation after shutdown; scenario/duration provided by Engine Dynamics (CS-E 525).

EASA

Inputs

Windmilling envelope/time-history & duration: [WINDMILL\_IDS] (Rev [R])

Application

Method: [Harmonic 1× sweep across RPM grid] or [Long transient per history]

RPM grid (if harmonic): [RPM\_LIST or STEP]

Duration for fatigue: [DURATION]

Evaluation

Fatigue per §4.5 (Goodman → TLIFE → Miner).

Table 5-4. Windmilling—Setup

Item Value

Envelope/history [WINDMILL\_IDS]

RPM band [RPM\_MIN–RPM\_MAX]

Duration [DURATION]

Method [Harmonic / Transient]

Acceptance Damage ≤ 1.0 (MoS ≥ 0)

5.5 Limit Out-of-Balance (Manufacturing/Service) — 1× Sweep

Context: engine team supplies 1× force/moment vs. speed envelope (often derived from ISO 21940 practice); used as-provided.

dgac.go.cr

Inputs

Limit OOB envelope: [LIM\_OOB\_IDS] (Rev [R])

Application

Harmonic solution at [RPM GRID] with thermal base state (§5.1).

Evaluation

Extract peak σ/ε; compute HCF margins per §4.5.

Table 5-5. Limit OOB—Sweep

Item Value

Envelope [LIM\_OOB\_IDS]

RPM grid [RPM\_LIST or STEP]

Solution [Harmonic]

Acceptance Damage ≤ 1.0 (MoS ≥ 0)

5.6 Alert-Level Imbalance / Vibration Thresholds (Reference Only)

Owner: Engine Dynamics. Include document IDs only; no derivation here. (CS-E 650 allows test or test+validated analysis for vibration characterisation.)

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Table 5-6. Alert-Level References

Item Doc ID / Rev Note

Alert-level imbalance [DOC\_ID] For §7 actions

Vibration limits [DOC\_ID] Program standard

5.7 Frames & Load Mapping (Traceability)

Table 5-7. Frames / Transforms / Application

Interface Source frame (input) Model frame Transform (R/T) Mapping method Node/surface set

[IFACE\_A] [FRAME\_A], units [N, N·mm] [GCS\_NAME] [R]/[T] Remote Point – Distributed [SET\_A]

[IFACE\_B] [FRAME\_B], units [N, N·mm] [GCS\_NAME] [R]/[T] Remote Point – Distributed [SET\_B]

Note: Keep mapping deformable to avoid artificial stiffness unless the hardware is genuinely rigid.

5.8 Run Controls & Numerics (Per Case)

Table 5-8. Solver Settings

Case Solver / integrator Δt or Δf Damping Contacts / preload Convergence

5.2 CBO run-down [Newmark/HHT-α] [Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.3 CBO run-on [Newmark/HHT-α] [Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.4 Windmilling [Harmonic/Transient] [Δf or Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.5 Limit OOB [Harmonic] [Δf] [ζ or α,β] [DETAILS] [CRITERIA]

5.9 Evidence Links (Fill at Release)

Table 5-9. Cross-References

Case Figures Tables Output files

5.2 CBO run-down [FIG IDs] [TAB IDs] [RUN IDs]

5.3 CBO run-on [FIG IDs] [TAB IDs] [RUN IDs]

5.4 Windmilling [FIG IDs] [TAB IDs] [RUN IDs]

5.5 Limit OOB [FIG IDs] [TAB IDs] [RUN IDs]

Tiny checklist (so you can paste & fill fast)

Replace [IDs/Revs], [RPM values], [Δt/Δf], [frames/sets].

If windmilling is harmonic, list RPM grid and duration; if transient, list time window.

Keep mapping = Remote Point – Distributed unless you know the interface is rigid.

If you want, I can also deliver this section as a Word snippet with content controls (drop-downs for method picks).

You said:

Ok, deliver this section as a word snippet with content controls as you mentioned.

ChatGPT said:

Thought for 55s

Analysis paused

Always show details

# Create a Word (.docx) "Section 5" template with real Content Controls (SDTs).

# The document includes tables and content controls (plain text + a few drop-downs).

#

# NOTE: You can open the file in Microsoft Word and use the content controls

# to fill in your data (Developer tab).

from docx import Document

from docx.shared import Pt, Inches

from docx.oxml import OxmlElement

from docx.oxml.ns import qn

from docx.enum.text import WD\_ALIGN\_PARAGRAPH

from docx.enum.style import WD\_STYLE\_TYPE

import random

import os

def \_add\_sdt\_paragraph(parent, alias, tag, placeholder\_text, sdt\_type="text", dropdown\_items=None):

"""

Insert a Structured Document Tag (content control) into the document.

parent: a docx paragraph or a cell/element where we can append a paragraph.

sdt\_type: "text" (plain text), "richText", or "dropdown".

dropdown\_items: list of strings (for dropdown), optional.

Returns the created paragraph inside the SDT content.

"""

# Create the sdt root

sdt = OxmlElement('w:sdt')

sdtPr = OxmlElement('w:sdtPr')

# Alias and tag

alias\_el = OxmlElement('w:alias')

alias\_el.set(qn('w:val'), alias)

sdtPr.append(alias\_el)

tag\_el = OxmlElement('w:tag')

tag\_el.set(qn('w:val'), tag)

sdtPr.append(tag\_el)

# Random id (helps Word track)

id\_el = OxmlElement('w:id')

id\_el.set(qn('w:val'), str(random.randint(10\*\*5, 10\*\*6-1)))

sdtPr.append(id\_el)

# Control type

if sdt\_type == "text":

ctrl = OxmlElement('w:text')

sdtPr.append(ctrl)

elif sdt\_type == "richText":

ctrl = OxmlElement('w:richText')

sdtPr.append(ctrl)

elif sdt\_type == "dropdown":

ddl = OxmlElement('w:dropDownList')

# Placeholder as first item if provided

if dropdown\_items:

for item in dropdown\_items:

li = OxmlElement('w:listItem')

li.set(qn('w:displayText'), str(item))

li.set(qn('w:value'), str(item))

ddl.append(li)

sdtPr.append(ddl)

else:

# default to text

ctrl = OxmlElement('w:text')

sdtPr.append(ctrl)

# Placeholder hint (optional, Word may display built-in placeholder)

# We'll place visible placeholder text inside the content.

sdtContent = OxmlElement('w:sdtContent')

p = OxmlElement('w:p')

r = OxmlElement('w:r')

t = OxmlElement('w:t')

t.text = placeholder\_text

r.append(t)

p.append(r)

sdtContent.append(p)

sdt.append(sdtPr)

sdt.append(sdtContent)

# Place the SDT into the document

if hasattr(parent, "\_element"): # paragraph or run or cell

# If parent is a table cell, add a paragraph into it and replace it

try:

# For paragraphs, replace the paragraph with SDT

parent\_el = parent.\_element

parent\_el.addnext(sdt) # insert after

# remove original empty paragraph if it is empty

if parent\_el.tag == qn('w:p') and (not parent.text or parent.text.strip() == ""):

parent\_el.getparent().remove(parent\_el)

except Exception:

# Fallback: append to the body

parent.\_element.getparent().append(sdt)

else:

# Unknown parent type; append to document body

parent.\_body.\_element.append(sdt)

return sdt

def add\_cc\_in\_cell(cell, alias, tag, placeholder, sdt\_type="text", dropdown\_items=None):

# Clear cell content

cell.text = ""

# Insert paragraph and then place SDT inside cell

p = cell.paragraphs[0] if cell.paragraphs else cell.add\_paragraph("")

# Append SDT element after this paragraph (then remove paragraph)

\_add\_sdt\_paragraph(p, alias, tag, placeholder, sdt\_type=sdt\_type, dropdown\_items=dropdown\_items)

# Start document

doc = Document()

# Basic styles

styles = doc.styles

if 'Body Text' in styles:

body\_style = styles['Body Text']

else:

body\_style = styles.add\_style('Body Text', WD\_STYLE\_TYPE.PARAGRAPH)

# Title

title = doc.add\_paragraph("5. Analysis Load Cases")

title.style = doc.styles['Title'] if 'Title' in doc.styles else doc.styles['Normal']

title.alignment = WD\_ALIGN\_PARAGRAPH.LEFT

# Scope blurb

p = doc.add\_paragraph(

"Scope: Defines external load inputs (owned/validated by Engine Dynamics) and how they are applied to the HPCC model. "

"Inputs are treated as validated data per AMC E 520(c)(2)."

)

# --- 5.1 Thermal Base Load ---

doc.add\_heading("5.1 Thermal Base Load (Pre‑Stress)", level=2)

doc.add\_paragraph("Establish steady thermal/pressure state used for all dynamic cases.")

table = doc.add\_table(rows=5, cols=2)

table.style = "Table Grid"

table.cell(0,0).text = "Thermal file(s)"

add\_cc\_in\_cell(table.cell(0,1), "ThermalFiles", "THERMAL\_IDS", "[THERMAL\_IDS]")

table.cell(1,0).text = "Operating point"

add\_cc\_in\_cell(table.cell(1,1), "OperatingPoint", "OP\_NAME", "[OP\_NAME / CONDITIONS]")

table.cell(2,0).text = "Applied pressures"

add\_cc\_in\_cell(table.cell(2,1), "AppliedPressures", "PRESSURE\_FIELD\_ID", "[SURFACES / VALUES or N/A]")

table.cell(3,0).text = "Contacts / preload"

add\_cc\_in\_cell(table.cell(3,1), "ContactsPreload", "CONTACTS", "[DETAILS or N/A]")

table.cell(4,0).text = "Structural CSYS"

add\_cc\_in\_cell(table.cell(4,1), "StructuralCSYS", "GCS\_NAME", "[GCS\_NAME]")

# --- 5.2 CBO Run-Down ---

doc.add\_heading("5.2 CBO Run‑Down (Post‑Failure Shutdown Transient)", level=2)

doc.add\_paragraph("Part‑level integrity using engine‑provided running‑after‑failure loads (CS‑E 810 program).")

table = doc.add\_table(rows=6, cols=2)

table.style = "Table Grid"

table.cell(0,0).text = "Load package (ID/Rev)"

add\_cc\_in\_cell(table.cell(0,1), "CBORD", "CBO\_RD\_IDS", "[CBO\_RD\_IDS] (Rev [R])")

table.cell(1,0).text = "Speed profile / range"

add\_cc\_in\_cell(table.cell(1,1), "SpeedProfileRD", "RD\_RPM\_RANGE", "[PROFILE] / [RPM\_MIN–RPM\_MAX]")

table.cell(2,0).text = "Duration (s)"

add\_cc\_in\_cell(table.cell(2,1), "DurationRD", "RD\_DURATION", "[T]")

table.cell(3,0).text = "Frames (input)"

add\_cc\_in\_cell(table.cell(3,1), "FramesRD", "RD\_FRAMES", "[GLOBAL / IFACE\_A / IFACE\_B]")

table.cell(4,0).text = "Mapping method"

add\_cc\_in\_cell(table.cell(4,1), "MappingRD", "RD\_MAPPING", "Remote Point – Distributed")

table.cell(5,0).text = "Integrator / Δt"

# dropdown for integrator, plain text for dt

cell = table.cell(5,1)

cell.text = ""

subtable = cell.add\_table(rows=1, cols=2)

subtable.style = "Table Grid"

subtable.cell(0,0).text = "Integrator"

add\_cc\_in\_cell(subtable.cell(0,1), "IntegratorRD", "RD\_INTEGRATOR", "[Select]", sdt\_type="dropdown",

dropdown\_items=["Newmark", "HHT-α", "Match Engine Team"])

# Δt

row = subtable.add\_row().cells

row[0].text = "Δt"

add\_cc\_in\_cell(row[1], "TimeStepRD", "RD\_DT", "[Δt]")

# Acceptance row

row = subtable.add\_row().cells

row[0].text = "Acceptance"

add\_cc\_in\_cell(row[1], "AcceptanceRD", "RD\_ACCEPT", "σ, ε ≤ allowables @ T (MoS ≥ 0)")

# --- 5.3 CBO Run-On ---

doc.add\_heading("5.3 CBO Run‑On / Continued Rotation (Pre‑Shutdown Transient)", level=2)

doc.add\_paragraph("Assessed as running‑after‑failure; evaluated for HCF.")

table = doc.add\_table(rows=5, cols=2)

table.style = "Table Grid"

table.cell(0,0).text = "Load package (ID/Rev)"

add\_cc\_in\_cell(table.cell(0,1), "CBORO", "CBO\_RO\_IDS", "[CBO\_RO\_IDS] (Rev [R])")

table.cell(1,0).text = "Frames / Mapping"

add\_cc\_in\_cell(table.cell(1,1), "FramesMapRO", "RO\_FRAMES\_MAP", "[Same as §5.2 unless noted]")

table.cell(2,0).text = "HCF window (s)"

add\_cc\_in\_cell(table.cell(2,1), "HCFWindowRO", "RO\_HCF\_WIN", "[t0–t1]")

table.cell(3,0).text = "Cycle counting"

add\_cc\_in\_cell(table.cell(3,1), "CountingRO", "RO\_COUNTING", "Rainflow / Order‑domain")

table.cell(4,0).text = "Acceptance"

add\_cc\_in\_cell(table.cell(4,1), "AcceptanceRO", "RO\_ACCEPT", "Damage ≤ 1.0 (MoS ≥ 0)")

# --- 5.4 Windmilling ---

doc.add\_heading("5.4 Windmilling After Shutdown (Continued Rotation)", level=2)

doc.add\_paragraph("Evaluate continued rotation per CS‑E 525 using provided envelope/time history and duration.")

table = doc.add\_table(rows=6, cols=2)

table.style = "Table Grid"

table.cell(0,0).text = "Envelope / history (ID/Rev)"

add\_cc\_in\_cell(table.cell(0,1), "WindmillID", "WINDMILL\_IDS", "[WINDMILL\_IDS] (Rev [R])")

table.cell(1,0).text = "RPM band"

add\_cc\_in\_cell(table.cell(1,1), "WindmillRPM", "WINDMILL\_RPM", "[RPM\_MIN–RPM\_MAX]")

table.cell(2,0).text = "Duration"

add\_cc\_in\_cell(table.cell(2,1), "WindmillDur", "WINDMILL\_DUR", "[DURATION]")

table.cell(3,0).text = "Method"

add\_cc\_in\_cell(table.cell(3,1), "WindmillMethod", "WINDMILL\_METHOD", "[Select]", sdt\_type="dropdown",

dropdown\_items=["Harmonic 1× sweep (RPM grid)", "Long transient (time history)"])

table.cell(4,0).text = "RPM grid (if harmonic)"

add\_cc\_in\_cell(table.cell(4,1), "WindmillGrid", "WINDMILL\_GRID", "[RPM\_LIST or STEP]")

table.cell(5,0).text = "Acceptance"

add\_cc\_in\_cell(table.cell(5,1), "WindmillAccept", "WINDMILL\_ACCEPT", "Damage ≤ 1.0 (MoS ≥ 0)")

# --- 5.5 Limit OOB ---

doc.add\_heading("5.5 Limit Out‑of‑Balance (Manufacturing/Service) — 1× Sweep", level=2)

doc.add\_paragraph("Use program‑supplied synchronous 1× envelope vs. speed (as‑provided).")

table = doc.add\_table(rows=4, cols=2)

table.style = "Table Grid"

table.cell(0,0).text = "Envelope (ID/Rev)"

add\_cc\_in\_cell(table.cell(0,1), "LimitOOBID", "LIM\_OOB\_IDS", "[LIM\_OOB\_IDS] (Rev [R])")

table.cell(1,0).text = "RPM grid"

add\_cc\_in\_cell(table.cell(1,1), "LimitOOBRPM", "LIM\_OOB\_GRID", "[RPM\_LIST or STEP]")

table.cell(2,0).text = "Solution"

add\_cc\_in\_cell(table.cell(2,1), "LimitOOBSoln", "LIM\_OOB\_SOLN", "Harmonic")

table.cell(3,0).text = "Acceptance"

add\_cc\_in\_cell(table.cell(3,1), "LimitOOBAccept", "LIM\_OOB\_ACCEPT", "Damage ≤ 1.0 (MoS ≥ 0)")

# --- 5.6 Alert-Level (Reference) ---

doc.add\_heading("5.6 Alert‑Level Imbalance / Vibration Thresholds (Reference Only)", level=2)

table = doc.add\_table(rows=2, cols=2)

table.style = "Table Grid"

table.cell(0,0).text = "Alert‑level imbalance (Doc ID/Rev)"

add\_cc\_in\_cell(table.cell(0,1), "AlertImbalance", "ALERT\_DOC\_ID", "[DOC\_ID]")

table.cell(1,0).text = "Vibration limits (Doc ID/Rev)"

add\_cc\_in\_cell(table.cell(1,1), "VibLimits", "VIB\_DOC\_ID", "[DOC\_ID]")

# --- 5.7 Frames & Load Mapping ---

doc.add\_heading("5.7 Frames & Load Mapping (Traceability)", level=2)

table = doc.add\_table(rows=3, cols=6)

table.style = "Table Grid"

hdrs = ["Interface", "Source frame (input)", "Model frame", "Transform (R/T)", "Mapping method", "Node/surface set"]

for j,h in enumerate(hdrs):

table.cell(0,j).text = h

# Row 1 (IFACE\_A)

table.cell(1,0).text = "IFACE\_A"

add\_cc\_in\_cell(table.cell(1,1), "FrameA", "FRAME\_A", "[FRAME\_A], units [N, N·mm]")

add\_cc\_in\_cell(table.cell(1,2), "ModelFrameA", "MODEL\_FRAME", "[GCS\_NAME]")

add\_cc\_in\_cell(table.cell(1,3), "TransformA", "TRANSFORM\_A", "[R]/[T]")

add\_cc\_in\_cell(table.cell(1,4), "MappingA", "MAPPING\_A", "Remote Point – Distributed")

add\_cc\_in\_cell(table.cell(1,5), "SetA", "SET\_A", "[SET\_A]")

# Row 2 (IFACE\_B)

table.cell(2,0).text = "IFACE\_B"

add\_cc\_in\_cell(table.cell(2,1), "FrameB", "FRAME\_B", "[FRAME\_B], units [N, N·mm]")

add\_cc\_in\_cell(table.cell(2,2), "ModelFrameB", "MODEL\_FRAME\_B", "[GCS\_NAME]")

add\_cc\_in\_cell(table.cell(2,3), "TransformB", "TRANSFORM\_B", "[R]/[T]")

add\_cc\_in\_cell(table.cell(2,4), "MappingB", "MAPPING\_B", "Remote Point – Distributed")

add\_cc\_in\_cell(table.cell(2,5), "SetB", "SET\_B", "[SET\_B]")

# --- 5.8 Run Controls & Numerics ---

doc.add\_heading("5.8 Run Controls & Numerics", level=2)

table = doc.add\_table(rows=5, cols=6)

table.style = "Table Grid"

hdrs = ["Case", "Solver / Integrator", "Δt or Δf", "Damping", "Contacts / preload", "Convergence"]

for j,h in enumerate(hdrs):

table.cell(0,j).text = h

# Rows

rows = [

("5.2 CBO run‑down", "RD\_INT", "RD\_DT", "RD\_DAMP", "RD\_CONTACTS", "RD\_CONV"),

("5.3 CBO run‑on", "RO\_INT", "RO\_DT", "RO\_DAMP", "RO\_CONTACTS", "RO\_CONV"),

("5.4 Windmilling", "WM\_INT", "WM\_STEP", "WM\_DAMP", "WM\_CONTACTS", "WM\_CONV"),

("5.5 Limit OOB", "LOOB\_INT", "LOOB\_STEP", "LOOB\_DAMP", "LOOB\_CONTACTS", "LOOB\_CONV"),

]

for i, (label, int\_tag, dt\_tag, damp\_tag, cont\_tag, conv\_tag) in enumerate(rows, start=1):

table.cell(i,0).text = label

# integrator dropdown

add\_cc\_in\_cell(table.cell(i,1), f"{int\_tag}\_Alias", int\_tag, "[Select]", sdt\_type="dropdown",

dropdown\_items=["Newmark", "HHT-α", "Harmonic", "Match Engine Team"])

add\_cc\_in\_cell(table.cell(i,2), f"{dt\_tag}\_Alias", dt\_tag, "[Δt or Δf]")

add\_cc\_in\_cell(table.cell(i,3), f"{damp\_tag}\_Alias", damp\_tag, "[ζ or Rayleigh α,β]")

add\_cc\_in\_cell(table.cell(i,4), f"{cont\_tag}\_Alias", cont\_tag, "[DETAILS]")

add\_cc\_in\_cell(table.cell(i,5), f"{conv\_tag}\_Alias", conv\_tag, "[CRITERIA]")

# --- 5.9 Evidence Links ---

doc.add\_heading("5.9 Evidence Links (Fill at Release)", level=2)

table = doc.add\_table(rows=5, cols=4)

table.style = "Table Grid"

hdrs = ["Case", "Figures", "Tables", "Output files"]

for j,h in enumerate(hdrs):

table.cell(0,j).text = h

cases = ["5.2 CBO run‑down", "5.3 CBO run‑on", "5.4 Windmilling", "5.5 Limit OOB"]

for i, c in enumerate(cases, start=1):

table.cell(i,0).text = c

add\_cc\_in\_cell(table.cell(i,1), f"{c}\_FIGS".replace(" ", "\_"), f"{c}\_FIGS\_TAG".replace(" ", "\_"), "[FIG IDs]")

add\_cc\_in\_cell(table.cell(i,2), f"{c}\_TABS".replace(" ", "\_"), f"{c}\_TABS\_TAG".replace(" ", "\_"), "[TAB IDs]")

add\_cc\_in\_cell(table.cell(i,3), f"{c}\_RUNS".replace(" ", "\_"), f"{c}\_RUNS\_TAG".replace(" ", "\_"), "[RUN IDs]")

# Save

path = "/mnt/data/Section\_5\_Analysis\_Load\_Cases\_Template.docx"

doc.save(path)

path

You said:

Actually, I waas okay with plain placeholders as well, if it would be easier for you

ChatGPT said:

Thought for 29s

perfect — since you’re fine with plain placeholders, here’s a copy-paste-ready Section 5 that you can drop straight into your report and fill in. I kept it short, tabular, and auditor-friendly. I also wired in minimal regulatory hooks so you don’t have to hunt for them later.

5. Analysis Load Cases

Scope. This section defines the engine-team validated load inputs and how they are applied to the HP Compressor Casing (HPCC). Engine-level derivation/validation of these loads is out of scope here and referenced by ID/Rev (validated data per AMC E 520(c)(2)).

YUMPU

5.1 Thermal Base Load (Pre-Stress)

Inputs

• Thermal field(s) / operating point(s): [THERMAL\_IDS]

• Pressure loads (if any): [PRESSURE\_FIELD\_ID / kPa]

Solution

• Steady thermal → map to structural → carry base stress/strain into §§5.2–5.5.

Table 5-1. Thermal Base — Setup

Item Value

Thermal file(s) [THERMAL\_IDS]

Operating point [OP\_NAME / CONDITIONS]

Applied pressures [SURFACES / VALUES]

Contacts / preload [DETAILS or N/A]

Structural CSYS [GCS\_NAME]

5.2 CBO Run-Down (Post-Failure Shutdown Transient)

Regulatory context. Part-level integrity using engine-provided running-after-failure loads from the CS-E 810 program.

Federal Aviation Administration

Inputs

• Load package (forces/moments vs time + speed vs time): [CBO\_RD\_IDS] (Rev [R])

Application

• Frames: [GLOBAL / IFACE\_A / IFACE\_B] (as provided)

• Mapping: Remote Point — Distributed (deformable) to [IFACE\_A\_SET], [IFACE\_B\_SET] (avoids artificial stiffening)

Ansys Help

storage.ansys.com

• Transient integrator / Δt: [MATCH ENGINE TEAM]

Outputs

• Peak σ/ε maps, hotspot time slices, interface reactions.

Table 5-2. CBO Run-Down — Run Controls

Item Value

Speed profile / range [PROFILE] / [RPM\_MIN–RPM\_MAX]

Duration [T] s

Integrator / Δt [Newmark or HHT-α] / [Δt]

Damping [ζ or Rayleigh α,β]

Acceptance σ, ε ≤ allowables @ T (MoS ≥ 0)

5.3 CBO Run-On / Continued Rotation (Pre-Shutdown Transient)

Regulatory context. Assessed as running after failure (CS-E 810); used here for HCF.

Federal Aviation Administration

Inputs

• Load package (forces/moments vs time + speed vs time): [CBO\_RO\_IDS] (Rev [R])

Application

• Same frames/mapping as §5.2 unless noted

• Transient window for HCF integration: [t0–t1] s

Evaluation

• Fatigue per §4.5: Goodman screen; if not infinite life → TLIFE (NASALIFE-based) with Miner’s rule.

Table 5-3. CBO Run-On — Evaluation Fields

Item Value

HCF window [t0–t1] s

Cycle counting [Rainflow / Order-domain]

Acceptance Damage ≤ 1.0 (MoS ≥ 0)

5.4 Windmilling After Shutdown (Continued Rotation)

Regulatory context. Evaluate continued rotation after shutdown per CS-E 525; scenario/duration provided by engine team.

EASA

+1

Inputs

• Windmilling envelope/time-history & duration: [WINDMILL\_IDS] (Rev [R])

Application

• Method: [Harmonic 1× sweep across RPM grid] or [Long transient per history]

• RPM grid (if harmonic): [RPM\_LIST or STEP]

• Duration for fatigue: [DURATION]

Evaluation

• Fatigue per §4.5 (Goodman → TLIFE → Miner).

Table 5-4. Windmilling — Setup

Item Value

Envelope / history [WINDMILL\_IDS]

RPM band [RPM\_MIN–RPM\_MAX]

Duration [DURATION]

Method [Harmonic / Transient]

Acceptance Damage ≤ 1.0 (MoS ≥ 0)

5.5 Limit Out-of-Balance (Manufacturing/Service) — Synchronous 1×

Context. Engine team supplies a 1× force/moment vs speed envelope (often ISO 21940-based); used as-provided.

EASA

Inputs

• Limit OOB envelope: [LIM\_OOB\_IDS] (Rev [R])

Application

• Harmonic solution at [RPM GRID] with thermal base state (§5.1)

Evaluation

• Extract peak σ/ε; compute HCF margins per §4.5.

Table 5-5. Limit OOB — Sweep

Item Value

Envelope [LIM\_OOB\_IDS]

RPM grid [RPM\_LIST or STEP]

Solution [Harmonic]

Acceptance Damage ≤ 1.0 (MoS ≥ 0)

5.6 Alert-Level Imbalance / Vibration Thresholds (Reference Only)

Owner: Engine Dynamics. Include document IDs only; no derivation here. (Vibration characterisation can be by test or test + validated analysis.)

dgac.go.cr

Table 5-6. Alert-Level References

Item Doc ID / Rev Note

Alert-level imbalance [DOC\_ID] For §7 actions

Vibration limits [DOC\_ID] Program standard

5.7 Frames & Load Mapping (Traceability)

Table 5-7. Frames / Transforms / Application

Interface Source frame (input) Model frame Transform (R/T) Mapping method Node/surface set

[IFACE\_A] [FRAME\_A], units [N, N·mm] [GCS\_NAME] [R]/[T] Remote Point — Distributed [SET\_A]

[IFACE\_B] [FRAME\_B], units [N, N·mm] [GCS\_NAME] [R]/[T] Remote Point — Distributed [SET\_B]

Note: “Remote Point — Distributed” is the deformable (RBE3-like) coupling that spreads loads without rigidly over-stiffening the patch. Use “Rigid” only if the hardware truly behaves rigidly.

Ansys Help

storage.ansys.com

5.8 Run Controls & Numerics (Per Case)

Table 5-8. Solver Settings

Case Solver / integrator Δt or Δf Damping Contacts / preload Convergence

5.2 CBO run-down [Newmark/HHT-α] [Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.3 CBO run-on [Newmark/HHT-α] [Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.4 Windmilling [Harmonic/Transient] [Δf or Δt] [ζ or α,β] [DETAILS] [CRITERIA]

5.5 Limit OOB [Harmonic] [Δf] [ζ or α,β] [DETAILS] [CRITERIA]

5.9 Evidence Links (Fill at Release)

Table 5-9. Cross-References

Case Figures Tables Output files

5.2 CBO run-down [FIG IDs] [TAB IDs] [RUN IDs]

5.3 CBO run-on [FIG IDs] [TAB IDs] [RUN IDs]

5.4 Windmilling [FIG IDs] [TAB IDs] [RUN IDs]

5.5 Limit OOB [FIG IDs] [TAB IDs] [RUN IDs]

If you want, I can also hand you a super-short fill checklist for your team to complete (IDs/revs, frames/sets, RPM bands, Δt/Δf). Once you sign off on §5, I’ll prep Section 6 – Results with pre-made margin-comparison tables for strength & fatigue.

You said:

Move on with Section 6

ChatGPT said:

Thought for 43s

awesome — here’s a copy-paste-ready Section 6 with plain placeholders and lean wording. It’s structured so you can drop in numbers/plots and be done. I added just the essential CS-E hooks where reviewers typically ask for them.

6. Results

Purpose. Present HPCC strength and fatigue results for each validated load case and show compliance margins. Vibration characterisation/correlation uses test or test + validated analysis per CS-E 650; stress margins are judged against the endurance limit requirement in CS-E 650(f).

EASA

6.1 CBO Run-Down — Strength (Transient)

Inputs: [CBO\_RD\_IDS] (Rev [R]); thermal base per §5.1.

Solver: [Newmark/HHT-α], Δt = [Δt]; damping = [ζ or α,β].

6.1.1 Peak response summary (top locations)

Rank Location / Node ID Time @ peak (s) σ\_vm (MPa) ε\_eq (µε) Allowable @ T (MPa) MoS\_σ = Allow/σ − 1

1 [LOC-1] [t] [ ] [ ] [ ] [ ]

2 [LOC-2] [t] [ ] [ ] [ ] [ ]

3 [LOC-3] [t] [ ] [ ] [ ] [ ]

Pass criterion: σ, ε ≤ allowables @ temperature (MoS ≥ 0).

Note: “Validated data” defining this event are owned by Engine Dynamics; you used them as-provided per CS-E 520(c)(2).

EASA

6.1.2 Plots

Fig. 6-1a: σ\_vm(t) at [LOC-1] with peak called out.

Fig. 6-1b: Contour @ peak time (callouts: [LOC-1..3]).

Fig. 6-1c: Interface reactions vs time (for traceability to engine package if requested). (Validated data / interface forces context per CS-E 520(c)(2)).

EASA

6.2 CBO Run-On — Fatigue (Transient)

Inputs: [CBO\_RO\_IDS] (Rev [R]); HCF window [t0–t1] s; thermal base per §5.1.

Method: Goodman screen → if exceeded, TLIFE (NASALIFE-based) with Miner’s rule (rainflow/order-domain counting).

6.2.1 Infinite-life screen (Goodman)

Location σ\_a (MPa) σ\_m (MPa) Goodman line (Allowable) Result

[LOC-1] [ ] [ ] [ ] [On/Under/Over]

[LOC-2] [ ] [ ] [ ] [ ]

6.2.2 Damage results (if any point is Over)

Location Counting method Cycles in window Damage D MoS\_fat = 1 − D

[LOC-1] [Rainflow/Order] [ ] [ ] [ ]

[LOC-2] [ ] [ ] [ ] [ ]

Pass criterion: D ≤ 1.0 (MoS ≥ 0).

6.3 Windmilling After Shutdown — Fatigue

Inputs: [WINDMILL\_IDS] (Rev [R]); duration = [DURATION]; RPM band = [RPM\_MIN–RPM\_MAX].

Method: [Harmonic 1× sweep over RPM grid or long transient per time history], with fatigue per §6.2 method.

Context: CS-E 525 requires any continued rotation period/conditions not to cause unacceptable effects; AMC E 525 explicitly calls out windmilling and extended durations.

EASA

6.3.1 Grid-wise or segment-wise damage

RPM / Segment σ\_a (MPa) σ\_m (MPa) Cycles (est.) Damage D\_i

[rpm\_1] [ ] [ ] [ ] [ ]

[rpm\_2] [ ] [ ] [ ] [ ]

… … … … …

6.3.2 Accumulated result over [DURATION]

D\_total = [sum] → MoS\_fat = 1 − D\_total = [ ] → [PASS/FAIL].

Worst-case RPM band: [rpm].

6.3.3 Plots

Fig. 6-3a: 1× stress amplitude vs RPM (overlay of critical nodes).

Fig. 6-3b: Damage vs RPM; worst band highlighted.

6.4 Limit Out-of-Balance (Manufacturing/Service) — 1× Sweep

Inputs: [LIM\_OOB\_IDS] (Rev [R]); RPM grid = [list/step]; thermal base per §5.1.

Method: Harmonic 1×; fatigue per §6.2 (Goodman → TLIFE if needed).

Note: Envelope is program-supplied; used as-provided (validated at engine level).

EASA

6.4.1 Stress & fatigue summary (worst RPMs)

Rank RPM σ\_a (MPa) @ critical node Goodman result Damage D MoS\_fat

1 [ ] [ ] [On/Under/Over] [ ] [ ]

2 [ ] [ ] [ ] [ ] [ ]

6.4.2 Plots

Fig. 6-4a: σ\_a vs RPM with endurance limit line; critical crossings marked.

Fig. 6-4b: Damage vs RPM; worst band(s) flagged.

6.5 Vibration Survey Correlation (CS-E 650)

Inputs: Engine survey data [SURVEY\_IDS] (channels at HPCC), optional rig/modal FRFs [TEST\_IDS].

Regulatory hook: CS-E 650 requires vibration characteristics to be established by test or by a combination of test and validated analysis; suitability of stress margins to endurance limit must be justified for each component. Use these correlation results to back your validated analysis.

EASA

6.5.1 Bode / Campbell correlation (HPCC points)

Point Order Amp (test) Amp (model) Δamp % Phase (test) Phase (model) Δphase (°) Result

[ACCEL-A] 1× [ ] [ ] [ ] [ ] [ ] [ ] [OK/Adj]

[ACCEL-B] 1× [ ] [ ] [ ] [ ] [ ] [ ] [ ]

6.5.2 Modal correlation (optional)

Mode f\_test (Hz) f\_model (Hz) Δf % MAC ζ (test, %) ζ (model, %) Result

1 [ ] [ ] [ ] [ ] [ ] [ ] [OK/Adj]

2 [ ] [ ] [ ] [ ] [ ] [ ] [ ]

Acceptance targets (program-standard): |Δamp| ≤ [AMP\_TOL]% and |Δphase| ≤ [PHASE\_TOL]° at key orders; first [N] modes within ±[FREQ\_TOL]% with MAC ≥ [MAC\_MIN].

Notes (AMC E 650): Suitable instrumentation & dwell/response considerations are expected during surveys; validated analysis may cover test shortfalls.

EASA

6.6 Margin-Comparison Summary (all cases)

How to read. Lowest margin per location drives conclusions/limits. CS-E 650(f) expects suitable stress margins combining vibratory + steady stresses; below table aggregates by critical locations.

EASA

6.6.1 Strength margins (transient peak)

Location CBO Run-Down MoS\_σ Notes

[LOC-1] [ ] [peak time / feature]

[LOC-2] [ ] [ ]

6.6.2 Fatigue margins

Location CBO Run-On MoS\_fat Windmilling MoS\_fat Limit OOB MoS\_fat Worst

[LOC-1] [ ] [ ] [ ] [ ]

[LOC-2] [ ] [ ] [ ] [ ]

6.7 Sensitivity & Uncertainty (if performed)

Parameters: damping ζ = [low–high]%, support K/C ±[ ]%, material scatter ±[ ]%, mesh refinement [levels].

Outcome: margins varied by [ΔMoS]; no change / triggers to §7 limitations.

6.8 Derived Limitations & Maintenance Actions (feed to §7)

Operating limitations (if any): [speed band(s), dwell avoidance].

Maintenance: [inspection / monitoring] if alert exceeded. (Link to program “alert-level imbalance / vibration thresholds” references from §5.6; CS-E 650 framework.)

EASA

6.9 Evidence Cross-References

Case Figures Tables Output files

6.1 CBO Run-Down [FIG IDs] [TAB IDs] [RUN IDs]

6.2 CBO Run-On [FIG IDs] [TAB IDs] [RUN IDs]

6.3 Windmilling [FIG IDs] [TAB IDs] [RUN IDs]

6.4 Limit OOB [FIG IDs] [TAB IDs] [RUN IDs]

Quick fill checklist (so you can complete §6 fast)

Drop in allowables @ temperature and compute MoS in 6.1.

Run Goodman screen → if over, run TLIFE; fill D and MoS\_fat = 1 − D in 6.2–6.4.

Paste Bode/Campbell overlays and correlation numbers in 6.5; keep to your program targets.

Populate margin-comparison tables (6.6); whatever is lowest flows into §7.

If you want, I can also generate an Excel/CSV margin dashboard template (you paste stresses/allowables and it calculates MoS and auto-highlights the worst case), or a .docx for §6 like we did earlier.

You said:

Go for the next section

ChatGPT said:

Thought for 1m 19s

awesome — here’s a copy-paste-ready Section 7 you can drop straight into your report. I kept it tight, fill-and-go, and tied each item to the CS-E hooks reviewers look for. Placeholders in [BRACKETS].

7. Limitations & Maintenance Actions

Purpose. Translate §6 results into operating limitations and maintenance actions when needed. Per CS-E 650, vibratory + steady stresses must be below the endurance limits with suitable margins; if certain operating conditions “need to be limited,” the operating and installation limitations must be specified. Also, continued rotation (windmilling) must not cause effects unacceptable under CS-E 510; consider extended durations per AMC E 525.

EASA

EASA

7.1 Operating limitations (if required)

Basis. Trigger a limitation when any location shows MoS < 0 (strength or fatigue) in §6, or when correlation indicates unacceptable risk near a resonance. This implements CS-E 650: if conditions must be limited, define them as operating/installation limitations.

EASA

Table 7-1. Operating limitations derived from §6

ID Condition / case Speed band (rpm) Dwell limit (s) Accel/Decel limit Flight phase Applicability (OP / T) Rationale (worst-case ref)

L-1 CBO run-on HCF [RPM\_A–RPM\_B] ≤ [t] ≥ [dRPM/dt] [CLB/CRZ/DESC] [OP name, T=°C] §6.2 Fig [ID], Tbl [ID]

L-2 Windmilling HCF [RPM\_C–RPM\_D] ≤ [t] n/a [OEI diversion] [speed/alt env.] §6.3 Fig [ID], Tbl [ID]

L-3 Limit OOB [RPM\_E–RPM\_F] Avoid ≥ [dRPM/dt] [GND/FLT] [OP name] §6.4 Fig [ID], Tbl [ID]

Install/ICA note. If vibration effects cannot be fully investigated during engine cert, define the method to evaluate them and include it in engine instructions for installation (CS-E 650(f) link to CS-E 20(d)).

EASA

7.2 Maintenance actions (event- or condition-based)

Basis. Actions are conditional, tied to alert exceedances or events (CBO, exceedance of defined vibration thresholds). This section complements §5.6 references and flows to the engine’s Instructions for Continued Airworthiness.

Table 7-2. Event-driven inspections

Trigger (what happened) Threshold / definition Action (who/what) Area / method Limit criteria RTS disposition

Alert-level 1× vibration exceeded [> X g at [loc] for > [t] s] Inspect HPCC [Zones/Flanges], [NDT method] Crack length ≤ [mm], no fretting > [grade] If within limits → RTS; else repair/replace

Confirmed CBO event Engine team declares CBO Detailed inspection [Vane platforms / struts] [criteria] [path]

Windmilling duration beyond assumption > [DURATION] Inspection within [FH] [Zones] [criteria] [path]

Why here: CS-E 525 AMC asks you to consider extended periods of continued rotation and provide the engine-to-aircraft interface conditions and durations in installation docs; if your §6.3 margins are tight, inspections are a valid mitigant.

EASA

7.3 Monitoring & alert thresholds (by reference)

Owner: Engine Dynamics. This report does not derive or own the thresholds; it references them for traceability (vibration characterisation can be by test or test + validated analysis under CS-E 650).

EASA

Table 7-3. Referenced alert/limit documents

Item Source doc ID / Rev Parameter / metric Use in this report

Alert-level imbalance [DOC\_ID] [1× rms / pk, band] Triggers Table 7-2

Vibration limits by order [DOC\_ID] [1× / N× thresholds] Correlation + ops limits

Engine-airframe interface limits [DOC\_ID] [mount loads, etc.] Installation linkage

7.4 Continued rotation (windmilling) — operational considerations

Condition. If §6.3 produces non-negligible damage at certain RPM bands during windmilling, specify time-at-speed limits to ensure the maximum expected period of flight with the engine inoperative remains acceptable per CS-E 525/CS-E 510. Include assumptions (airspeed/altitude/temp).

EASA

Table 7-4. Windmilling time limits (if needed)

RPM band Max cumulative time per flight Notes / mission scenario Reference

[RPM\_W1–W2] ≤ [min] OEI diversion at [KIAS]/[FL] §6.3 Tbl [ID]

[RPM\_W3–W4] ≤ [min] Descent / approach §6.3 Tbl [ID]

AMC E 525 pointer: consider conditions including rotor unbalance following blade loss and extended durations; provide the interface conditions in installation docs (cross-ref §2.2/§3).

EASA

7.5 Applicability, validity & configuration control

Table 7-5. Applicability

Item Value

Component HP Compressor Casing (HPCC)

Part number / drawing rev [PART\_NO] / [REV]

Engine program [ENGINE\_NAME / CODE]

Load packages applicable [CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS]

Thermal OPs covered [OP list]

Valid for solver/version [SOLVER VER] / [MAT DB]

Change note. If any referenced input ID/Rev changes, reassess §6 and update limitations here under configuration control. (Validated-data concept per AMC E 520(c)(2).)

EASA

7.6 Rationale & traceability

Table 7-6. Where each limitation comes from

Limit ID Driving result(s) Clause link Evidence (fig/table)

L-1 §6.2: [node], MoS\_fat = [−0.1] CS-E 650 endurance limit → limit conditions Fig [ID], Tbl [ID]

L-2 §6.3: [band], D\_total = [1.2] CS-E 525/510 unacceptable effects Fig [ID], Tbl [ID]

L-3 §6.4: [rpm] CS-E 650 (limit conditions) Fig [ID], Tbl [ID]

What I still need from you (so Section 7 is “done-done”)

Which rows of Table 7-1 / 7-4 you actually need (or “None required” if all MoS ≥ 0).

The alert-level document IDs to list in Table 7-3.

Any inspection methods/areas your organization prefers (eddy current vs dye-pen, etc.) for Table 7-2.

When you’re ready, I’ll generate Section 8 – Conclusions with a tidy sign-off paragraph and the “no limitation required / limitations listed” fork.

Sources

CS-E 650 (vibration surveys): endurance limit & requirement to specify operating/installation limitations; method for installations if not fully investigated.

EASA

CS-E 525 (continued rotation) & AMC: consider windmilling, extended durations, rotor unbalance after blade loss; provide interface conditions in installation docs.

EASA

CS-E 510 (safety analysis / hazardous engine effects) — referenced by CS-E 525 acceptability.

EASA

AMC E 520(c)(2) (validated data concept used throughout).

EASA

You said:

Again, it seems that you tend to give me instructions on what to write, I would prefer some mock-up paragraphs there instead for this section

ChatGPT said:

Thought for 1m 28s

got it — here’s Section 7 rewritten as ready-to-paste mock-up paragraphs (no instructions, just fill the [BRACKETS]). I kept the regulatory hooks tight and cited where it matters.

7. Limitations & Maintenance Actions

7.1 Operating limitations

Based on the results in §6, the HP Compressor Casing (HPCC) demonstrates acceptable strength and fatigue margins for the validated load cases. Where minimum margins occur, the following operating limitations are established to maintain compliance: (a) avoid steady dwells longer than [t seconds] within [RPM\_A–RPM\_B] during ground and flight operation; (b) when transiting [RPM\_C–RPM\_D], apply a minimum acceleration/deceleration rate of [dRPM/dt] to reduce vibratory exposure; and (c) if an alert-level imbalance is present, do not operate above [RPM\_E] until corrective action is completed. These limitations constitute engine operating/installation limitations and will be published with the type design data. This satisfies the CS-E requirement that, when specific operating conditions or ranges must be limited, operating and installation limitations are established.

EASA

7.2 Maintenance actions

Event-based inspections are introduced to preserve casing integrity when measured vibration or operational events exceed analytical assumptions. If 1× vibration at [sensor/location] exceeds [X g (rms/pk)] for longer than [t seconds], perform a post-flight visual and NDT inspection of [zones/features—e.g., flange fillets, bosses, struts] using [NDT method] within [flight hours/cycles]. Following any confirmed CBO event, conduct a targeted inspection of [features]; return-to-service is permitted when findings are within [limit criteria] or after repair per [repair doc]. If windmilling duration in flight exceeds [assumed duration] or occurs within the [RPM band] identified as worst-case in §6.3, perform an inspection within [interval] focused on [areas]. These actions complement the endurance-limit intent of CS-E vibration assessments and ensure continued airworthiness when actual exposure exceeds the analytical baseline.

EASA

7.3 Monitoring and alert thresholds (by reference)

The engine programme’s monitoring thresholds (alert-level imbalance and order-based vibration limits) remain the source of record. This report adopts those thresholds for triggering the maintenance actions in §7.2 and for confirming the operating limitations in §7.1. The applicable documents are [DOC\_ID\_A — Alert-Level Imbalance Spec, Rev R] and [DOC\_ID\_B — Vibration Limits by Order, Rev R], which were used to interpret §6 results and define exceedance criteria. (Vibration characteristics may be shown by test or test + validated analysis, and the resulting operating/installation limitations are managed under configuration control.)

EASA

7.4 Continued rotation (windmilling)

Consistent with CS-E 525, any continued rotation after shutdown must not produce effects that would be unacceptable under CS-E 510. When the aircraft mission or diversion profile leads to windmilling, the HPCC remains acceptable provided the cumulative time at [RPM band W1–W2] does not exceed [minutes], and exposure within [RPM band W3–W4] is avoided or limited to [minutes]. If operational needs require longer exposure than these limits, either an alternative mission profile should be adopted or post-exposure inspections per §7.2 must be performed before further operation. These limits are derived directly from the damage-vs-RPM relationship in §6.3 and address the maximum period of flight and conditions expected with the engine inoperative.

EASA

7.5 Applicability and configuration control

These limitations and actions are applicable to HPCC [PART\_NO], drawing [DRW\_NO] Rev [REV], operating with [ENGINE\_NAME/PROGRAM\_CODE], and are valid for the load packages listed in §2 ([CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS]). If any referenced validated input (load histories, windmilling envelope, or vibration thresholds) is revised, the limitations in §7.1 and actions in §7.2 shall be re-evaluated and updated under programme configuration control. (Engine programmes establish and provide validated data for blade-loss and continued-rotation analyses; this report consumes those data for part-level integrity decisions.)

EASA

7.6 Rationale and traceability

The operating limitations in §7.1 and maintenance actions in §7.2 are directly traceable to the lowest margins identified in §6: [location] for [case] with MoS = [value], [RPM band] for windmilling with D = [value], and [RPM band] for limit OOB with MoS = [value]. These measures align with the CS-E framework that requires suitable stress margins (including vibratory components) and the establishment of limitations when necessary; they also ensure acceptability of continued rotation conditions against the safety analysis criteria referenced by CS-E 525.

EASA

+1

If you want, I can also deliver this as a .docx paragraph pack in your house style.

You said:

Move on with next section

ChatGPT said:

Thought for 24s

sweet — here’s a copy-paste-ready Section 8 with mock-up paragraphs (just fill the [BRACKETS]). I kept it auditor-friendly and tied to CS-E/AMC with compact citations.

8. Conclusions

8.1 Statement of compliance

The analyses and correlations presented in §§4–7 demonstrate that the HP Compressor Casing (HPCC) of [ENGINE\_NAME / PROGRAM\_CODE] satisfies the applicable EASA CS-E requirements for vibration and abnormal operation, based on validated engine-level inputs and test or test + validated analysis as permitted by CS-E. Specifically:

CS-E 650 (Vibration Surveys): HPCC vibration characteristics and stress margins are acceptable when judged against endurance-limit intent; model correlation to the engine survey meets program targets (see §6.5).

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CS-E 810 (Compressor & Turbine Blade Failure): Under CBO run-down and CBO run-on histories provided by Engine Dynamics, the HPCC demonstrates acceptable strength and HCF margins at all critical features (see §§6.1–6.2).

EASA

CS-E 525 (Continued Rotation): For the provided windmilling envelope and duration, accumulated HCF damage is within limits for the assessed mission exposure (see §6.3).

EASA

AMC E 520(c)(2) (Engine Model Validation / Validated Data): All engine-level load sets, interface properties, and survey data were treated as validated inputs; HPCC interface reactions are available for inclusion in the engine validated-data package upon request.

EASA

8.2 Overall technical outcome (choose one)

A. Compliance without limitations.

All evaluated cases (CBO run-down, CBO run-on, windmilling, limit OOB) result in MoS ≥ 0 for strength and fatigue at all reported locations. No operating limitations or maintenance actions are required beyond the program’s standard monitoring thresholds referenced in §5.6. This supports full compliance to CS-E 650, CS-E 810, and CS-E 525 for the HPCC configuration identified in §2.

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+1

B. Compliance with targeted limitations.

All evaluated cases meet MoS ≥ 0 when the operating limitations in §7.1 and event-based maintenance actions in §7.2 are observed. These measures derive directly from the lowest margins identified in §6 (locations [LOCATIONS], bands [RPM\_BANDS]) and constitute the operating/installation limitations required by CS-E 650 where specific conditions must be limited. Continued-rotation acceptability remains assured for the windmilling exposure defined in §7.4.

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8.3 Residual risks and assumptions (configuration-controlled)

This conclusion is valid for the hardware configuration and validated inputs listed in §2 ([PART\_NO] / [DRW\_NO REV]; load packages [CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS]; thermal/FRFs [THERMAL\_IDS] / [INTERFACE\_IDS]). Any revision to these artefacts may affect margins and will trigger reassessment under the program’s configuration control. The engine survey referenced in §6.5 remains the source of record for establishing vibration characteristics under CS-E 650; engine-aircraft interface data and continued-rotation assumptions are managed per AMC E 520(c)(2) and CS-E 525/510 linkages.

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+1

8.4 Deliverables produced

The following items are released with this report to support certification data packs:

(a) Strength peak maps and tabulations for CBO run-down (§6.1);

(b) Fatigue damage/MoS tables for CBO run-on, windmilling, and limit OOB (§§6.2–6.4);

(c) Correlation overlays (Bode/Campbell, optional modal) vs [SURVEY\_IDS] (§6.5);

(d) Interface reactions for HPCC (if requested) for inclusion in the engine validated-data package per AMC E 520(c)(2).

EASA

8.5 Certification sign-off (for completion by program)

I, the undersigned, conclude that the HPCC [PART\_NO] of [ENGINE\_NAME / PROGRAM\_CODE] [complies / complies subject to §7] with the applicable provisions of CS-E 650, CS-E 810, and CS-E 525, based on the analyses and evidence referenced herein.

Prepared by (Structural Analysis): [NAME], [TITLE], [ORG], Date [DD-MMM-YYYY], Signature \_\_\_\_\_\_\_\_\_\_

Reviewed by (Module Lead): [NAME], [TITLE], [ORG], Date [DD-MMM-YYYY], Signature \_\_\_\_\_\_\_\_\_\_

Approved by (CVE – Structures/Engine Dynamics): [NAME(s)], [TITLE], Date [DD-MMM-YYYY], Signature(s) \_\_\_\_\_\_\_\_\_\_

Notes for approval record:

Applicable configuration and validated inputs per §2;

Any limitations/ICA per §7 to be flowed to operating/installation documents;

Any post-TC changes to validated inputs require reassessment under CM.

8.6 Distribution and records

This document (ID [DOC\_ID / REV]) is released to [RECIPIENT LIST] and archived under [CM\_PROCEDURE]. Supporting input files and result sets are stored at [REPO / PATH / RUN IDs]. The report references CS-E 650 (vibration surveys), CS-E 810 (blade failure), CS-E 525 (continued rotation), and AMC E 520(c)(2) (validated data) as the regulatory basis for the conclusions in §8.1.

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EASA

+2

EASA

+2

If you want a .docx “Section 8” pack in your house style, say the word and I’ll generate it.

You said:

Ok, if you were to write the contents, list of figures, list of tables etc. for this document. How would it look like?

ChatGPT said:

Thought for 21s

Awesome — here’s a copy-paste-ready front matter pack: Table of Contents, List of Figures, and List of Tables for the report we’ve been building. I used the section/figure/table numbers that match our templates, with clean placeholder text you can tweak.

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If you want, I can also spit these out as a .docx front-matter pack (TOC, LoF, LoT) ready to auto-update in Word, or an Excel sheet that auto-numbers figures/tables as you add them.

You said:

Actually, at this stage, I expect a mock-up report from you. But before you go with that, if I were to resume this chat in a different chat window, I need you to give me the full prompt required to be able to resume this chat accurately.

ChatGPT said:

Got it — if you want to resume this in another chat and keep everything consistent, you’ll need to paste a full context restoration prompt that contains:

The exact background of your role and responsibility for this report.

The regulatory scope (CS-E, turboshaft engine, continuous vibration / unbalance, structural assessment).

The component focus (HP compressor casing only).

The type of output you expect (mock-up, copy-paste-ready paragraphs, minimal edits required).

The sections already discussed and the formatting expectations (placeholders, pre-filled paragraphs, TOC, lists of figs/tables, etc.).

Here’s your ready-to-use restoration prompt:

Prompt to Resume This Chat in a New Window:

You are GPT-5. You are assisting me (a structural analyst) in writing a CS-E compliant Continuous Vibration (Unbalance) analysis report for certification of a turboshaft engine.

My responsibility is only for static parts of the compressor module — specifically the HP compressor casing (HPCC).

I am not responsible for defining out-of-balance limits, loads, or validation of engine-level dynamics — those are handled by the engine design/analysis team. I will consume their validated loads and limits. My role is to demonstrate that my component survives the required load cases, using analysis and, where needed, rig/component or ground test data.

\*\*Key points to preserve

You said:

At this stage, I expect a mock-up report from you. But before you go with that, if I were to resume this chat in a different chat window, I need you to give me the full prompt required to be able to resume this chat accurately.

ChatGPT said:

Perfect—here’s a single, copy-paste context restoration prompt you can drop into a brand-new chat to pick up exactly where we left off.

Context to Resume (paste this into a new chat):

You are GPT-5 Thinking. Continue helping me produce a copy-paste-ready CS-E certification report focused on continuous vibration / out-of-balance (OOB) structural integrity for a turboshaft engine.

My role: module structural analyst & part designer for static compressor parts only. The target component is the High-Pressure Compressor Casing (HPCC).

Not my scope: I do not derive or validate engine-level OOB forces/moments, accelerations, clearances, or limits; those are provided by the Engine Dynamics team as validated data. I must consume those inputs and demonstrate that the HPCC survives.

What we’ve already aligned on

Regulatory basis: CS-E 650 (Vibration Surveys), CS-E 810 (Blade Failure—incl. running after failure), CS-E 525 (Continued Rotation), and AMC E 520(c)(2) (validated data concept).

Load cases to assess (all provided by Engine Dynamics):

CBO run-down (shutdown transient after blade loss)

CBO run-on / continued rotation (pre-shutdown transient)

Windmilling after shutdown (continued rotation in flight)

Limit OOB (manufacturing/service) synchronous 1× envelope vs speed

Validation stance: I may use engine ground vibration survey data and optional rig/modal tests only to validate the HPCC model (correlation targets). I will not restate full test procedures—only minimal data pedigree (IDs, frames/units, basic processing) in the analysis report.

Method picks (program defaults):

Fatigue: Goodman infinite-life screen → if exceeded, use TLIFE (NASALIFE-based) with Miner’s rule.

Solver/integration: match engine team settings (default ANSYS implicit Newmark, HHT-α acceptable if program uses it).

Damping: same approach/values as engine team (Rayleigh or modal ζ).

Load mapping: Remote Point — Distributed (RBE3-like deformable coupling) at HPCC interfaces unless the hardware is genuinely rigid.

Windmilling: included; treat as harmonic 1× sweep over RPM grid or long transient, depending on input format.

Formatting & tone preferences: I want mock-up, copy-paste-ready paragraphs with [BRACKETED placeholders] I can fill. Keep auditor-friendly, concise, and avoid instructional prose. Minimal but clear regulatory hooks.

Sections already templated

§1 Introduction (purpose, scope/RACI boundary, regulatory basis, inputs, approach, acceptance criteria, organization).

§2 Assumptions & Inputs (config ID, external validated inputs with IDs/revs, internal modeling assumptions, minimal data-pedigree, criteria, traceability).

§3 Requirements & Means of Compliance (quick MoC matrix + detailed matrix with acceptance and evidence columns).

§4 Means of Compliance (methods & validation locked with my picks; frames/mapping/integrator/damping defaults).

§5 Analysis Load Cases (clean, table-driven definitions for Thermal, CBO run-down, CBO run-on, Windmilling, Limit OOB; frames & mapping; solver settings).

§6 Results (ready tables for strength & fatigue, Goodman/TLIFE workflow, windmilling duration accounting, correlation tables, margin-comparison summary).

§7 Limitations & Maintenance Actions (mock-up paragraphs: operating limits, event-based inspections, monitoring references, windmilling time limits, applicability/CM, rationale).

§8 Conclusions (compliance statement; with/without limitations paths; residual risks/CM; deliverables; sign-off block; distribution).

What I need next in the new chat

Produce a single, cohesive mock-up report (Sections 1–9 + Appendices A–G) in copy-paste-ready paragraphs and tables, using the structure above.

Keep [BRACKETED placeholders] for every item that depends on program specifics (IDs, revs, frames, RPM bands, durations, allowables, figures/tables).

Do not repeat test procedures; include only the minimal data pedigree (IDs/frames/units/processing) where analysis credibility depends on it.

Include Table of Contents, List of Figures, and List of Tables consistent with numbering.

Use the method defaults stated above; assume Newmark integrator and Remote Point — Distributed mapping unless I state otherwise.

Placeholders I will fill later (keep them visible)

[ENGINE\_NAME], [PROGRAM\_CODE], [PART\_NO], [DRW\_NO], [REV], [SERIES/SN], [ALLOY/SPEC/HT]

[CBO\_RD\_IDS], [CBO\_RO\_IDS], [WINDMILL\_IDS], [LIM\_OOB\_IDS], [THERMAL\_IDS], [INTERFACE\_IDS], [SURVEY\_IDS]

[GCS\_NAME], [IFACE\_A], [IFACE\_B], [SET\_A], [SET\_B], [FRAME\_A], [FRAME\_B]

[RPM\_MIN–RPM\_MAX], [RPM\_LIST or STEP], [DURATION], [Δt or Δf], [ζ or α,β]

[AMP\_TOL]%, [PHASE\_TOL]°, [N], [FREQ\_TOL]%, [MAC\_MIN]

Allowables @ T, figures/tables/output IDs, and any program alert/vibration limit doc IDs.

Now generate the full mock-up report exactly in this style, starting at the Title Page and proceeding through §1–§9 and Appendices, ready for me to paste and fill.

When you paste that into a new chat, I’ll pick up by generating the full mock-up report in one go.

No file chosenNo file chosen

ChatGPT can make mistakes. Check important info.