Notification of a Proposal to issue a Certification Memorandum

Cold Dwell Fatigue in Titanium Rotor Critical Parts

EASA CM No.:Proposed CM-PROP-003 Issue 01 issued 10 June 2026

Regulatory requirement(s): CS-E 515

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Log of issues

Issue	Issue date	Change description
001	10.06.2026	First issue.

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1. .0Identification of Issue

1.1. Purpose and scope

The purpose of this Certification Memorandum is to provide additional guidance for applicants when demonstrating compliance with CS-E 515 for titanium rotating critical parts.
This guidance presents acceptable means of compliance which can be used to address the risk of premature failure due to titanium Cold Dwell Fatigue (CDF). This approach supplements the existing “safe-life” process for high-energy rotors to produce an enhanced life management process. In the context of damage tolerance, this guidance is not intended to allow operation beyond the component manual life limit set using the existing safe-life approach which limits the useful rotor life to the minimum number of flight cycles required to initiate a crack.

2. Applicability

Turbine Engine Critical Parts made from Titanium alloys. This Certification Memorandum affects applicants for new turbine engine Type Certification (TC) when showing compliance with CS-E 515, as well as major changes to TCs that would impact CDF susceptibility.

2.1. Background.

The AIA Rotor Integrity Steering Committee (RISC) and the Jet Engine Titanium Quality Committee (JETQC) have worked with the FAA and EASA to prioritize development of an appropriate methodology for consideration of CDF for titanium alloy rotor disks. The history of CDF related events, OEM experience and understanding of the mechanism is discussed in more detail in FAA/DOT/TC23-40 [4].

The findings from both research and field experience indicate that the characteristics of CDF include the following:

- CDF failures generally show a characteristic flat, quasi-cleavage (progressive) faceted fracture at the origin. The size of these faceted regions are typically commensurate with the size of the underlying Micro Textured Region (MTR) for alpha + beta processed and heat treated alloys or colonies for beta processed or heat treated alloys.
- Crack nucleation can also occur directly from a micropore or cluster of micropores within an MTR. Microporosity (clean or contaminated) has been seen on fracture surfaces associated with most CDF initiation sites in both fielded components and in rig tests (DOT/FAA/TC-23/40 section 8.1 and 8.2).
- Crack origins are not necessarily at the highest operating stress locations and tend to be sub-surface. The CDF crack origin location may be affected by local MTR/colony characteristics, underlying bulk residual stress, presence of microporosity co-located within an MTR/colony, etc. CDF cracks can nucleate within MTRs at significantly lower stress than expected from non-dwell laboratory coupon test results.
- Crack growth within MTRs exhibit an accelerated crack growth rate versus the material beyond the MTR where fatigue crack growth rate is expected to be captured by traditional fatigue crack growth rate models.
- CDF behavior is known to be impacted by loading conditions (i.e. load controlled vs. strain controlled)
- Repeated tests indicate high scatter in life in both specimens and components.

Failure due to CDF is a multi-stage and hierarchical process connecting atomic scale deformation mechanisms to early crack nucleation, followed by rapid short crack propagation across the initiating MTR/colony through to final fracture.

To support the method development, JETQC carried out a survey on negative CDF experience for all rotor applications in all titanium alloys which included the following factors:

- Spin test and field experience
- Whether negative CDF experience was below the proposed CDF Default Threshold.
- The dwell time at the relevant condition for CDF
- The temperature at the relevant condition for CDF
- Whether microporosity was present and if yes, was it clean microporosity, contaminated microporosity or unknown
- Whether CDF had occurred at a stress concentrating feature

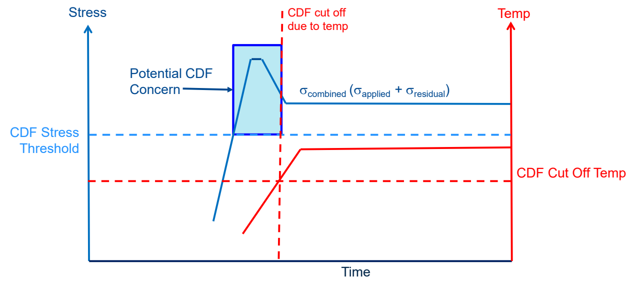
The results from this survey were used to establish the criteria in this document. Based on the current level of understanding, no Titanium alloy should be exempt from a CDF assessment.

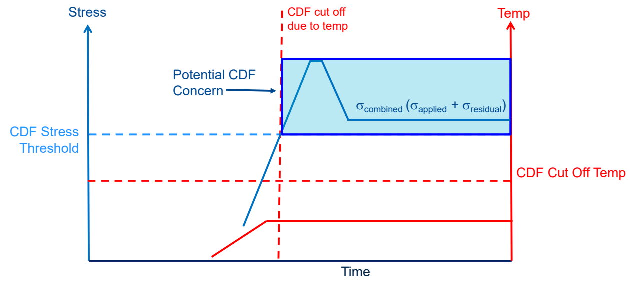
3. EASA Certification Policy

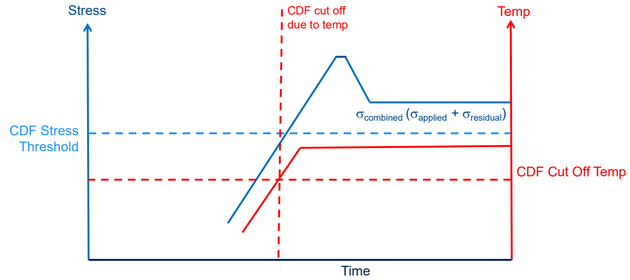
3.1. Determining CDF Susceptibility

All critical Titanium parts should use methods of manufacture (MoM) consistent with the guidance in FAA Advisory Circular (AC) 33.15-1A. The application of a threshold to the engine flight cycle of the part is used to establish Regions of Interest (ROI) which have potential susceptibility to CDF. The threshold consists of a CDF temperature cut off and a maximum stress limit. The threshold is exercised against the engine flight cycle by identifying the times within the engine flight cycle when the part temperature is below the CDF temperature cut off while the combined stress ($\sigma_{combined}$) is above the maximum stress limit. The default industry provided Titanium combined stress threshold for CDF is 50% of the material's typical 0.2% proof strength (average yield stress) accounting for temperature at each engine flight cycle timepoint while operating at a temperature below the upper temperature limit of 200°C (400°F). Any feature which does not operate within this regime is not expected to be susceptible to CDF during their part service life. Locations on the part that meet the criterion at any point within the duty cycle for a duration of at least 2 seconds are expected to be ROI with respect to CDF and require further action, see Section 3.1.1. A simple schematic of combined stress and temperature plotted *versus* time for a mission is used in this guidance to illustrate the process and explain when the combined stress and temperature result in a ROI that has potential CDF susceptibilty (see Figure 1 for example schematics).

<table>
<tr><th>Description</th><th>Schematic image</th></tr>
<tr><td><u>Susceptible to CDF</u>

$\sigma_{combined}$ > CDF Threshold for times with Temperature < CDF cut off</td><td>
</td></tr>
<tr><td><u>Susceptible to CDF</u>

$\sigma_{combined}$ > CDF Threshold with entire mission below CDF cut off temperature</td><td>
</td></tr>
<tr><td><u>Not Susceptible to CDF</u>

$\sigma_{combined}$ > CDF Threshold but Temperature > CDF cut off</td><td>
</td></tr>
<tr><td><u>Not Susceptible to CDF</u>

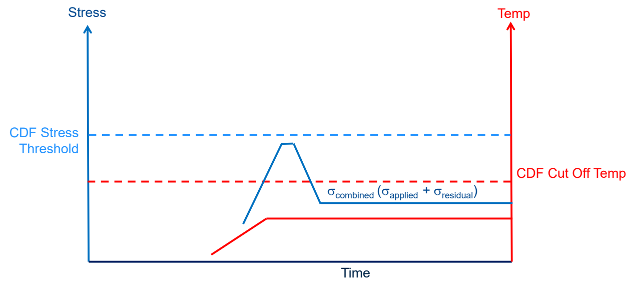
$\sigma_{combined}$ < CDF Threshold</td><td>
</td></tr>
</table>

Figure 1. Schematics of Stress and Temperature vs. Time for CDF Susceptiblity

3.1.1. Acceptable Means of Compliance

If a component is found to have Regions of Interest (ROI) susceptible to Titanium CDF, there are two acceptable Means of Compliance (MOC) for assessing Titanium CDF outlined in this guidance. One MOC is a threshold approach outlined in Section 3.2, which consists of an OEM developed threshold. The second MOC is the establishment of a CDF Assessment Methodology, outlined in Section 3.3. An applicant may use either approach when assessing Titanium CDF on specific Regions of Interest (ROI) of a component. Using one MOC for one ROI on a component would not restrict the use of an alternate MOC on another ROI.

3.1.2. Factors Affecting CDF Susceptibility

There are many factors that can impact the CDF susceptibility of a part. Three primary categories for these factors are:

- The engine flight cycle of the part
- The alloy composition of the part and its residual stress
- The material structure of the part

3.1.2.1. Engine Flight Cycle of the Part

3.1.2.1.1. Stress

CDF susceptibility is understood to be dependent on stress, with lower stress resulting in lower susceptibility. It is important to assess CDF susceptibility using applied stress throughout the flight cycle(s) based on a structural analysis that is consistent with current standards used to establish the safe life of the part. Consideration should be given for multiaxial stress states which may cause differences in CDF performance.

3.1.2.1.2. Features to Assess for CDF

Consideration of CDF susceptibility should be applied to all features in the hoop continuous region, including stress concentration features. For Integrally Bladed Rotors (IBRs) and impellors, any feature below the Airfoil-Rotor Interaction Zone (ARIZ) line should be considered. For blade attachment slots, any feature above the hoop continuous region that would be predicted to have a crack trajectory into the hoop continuous portion of the disk should also be considered. The volume of a feature may affect its susceptibility to CDF with larger features typically resulting in a higher susceptibility. It is important to consider stressed volume when assessing a feature.

3.1.2.1.3. Temperature

CDF susceptibility is understood to be dependent on temperature with the majority of negative experience below 200°C/400°F. The maximum CDF impact on life can sometimes be seen at temperatures above room temperature, so it is important to assess CDF sensitivity at the relevant temperature to the engine flight cycle of the part. Variation in actual utilization can impact mission temperatures, so consideration should be given to lower rated operations with respect to the upper temperature limit.

3.1.2.1.4. Dwell Time

CDF susceptibility is understood to be dependent on dwell time, with longer dwell time resulting in higher susceptibility. It is important to assess CDF sensitivity at the dwell time of the engine flight cycle of the part, noting that dwell times as short as 2 seconds can result in CDF failures.

3.1.2.2. Alloy Composition and Residual Stress

3.1.2.2.1. Alloy Type (Class)

The CDF susceptibility of titanium alloys is known to be influenced by the specific alloy type. Based on historical industry manufacturing routes and design domains, near alpha alloys such as Ti-834, Ti-829, Ti-685, and Ti-6242 have been shown to have the highest CDF susceptibility, with Ti-64 having medium susceptibility, and Ti-6246 and Ti-17 having low CDF susceptibility. However, based on the current level of understanding, no titanium alloys can be considered as exempt from CDF susceptibility.

3.1.2.2.2. Residual Stress

Bulk tensile residual stress has been demonstrated to be an important factor affecting CDF susceptibility. The applicant should consider how residual stress may impact CDF susceptibility in terms of the combined stress used in the assessment and MTR characteristics of the part.

3.1.2.3. Material Structure

3.1.2.3.1. MTR/Colony Characteristics

MTR/colony size, shape, density, frequency, orientation, orientation spread, neighboring region characteristics, volume fraction, and primary alpha volume fraction are important parameters when characterizing MTR features for $\alpha+\beta$ processed and heat treated alloys. These features may be statistical in nature and are known to impact CDF capabilities. The applicant should understand the MTR characteristics of the part, including the potential impacts of alternate methods of manufacture. For β processed or heat treated alloys, relevant colony parameters should be evaluated.

3.1.2.3.2. Microporosity

Microporosity has been demonstrated to increase CDF susceptibility when present in the vicinity of MTRs or colonies. Both clean and contaminated pores have been identified at the origin of CDF originated cracks in both components and specimens. The applicant should consider the impacts of microporosity on the part and the MTR/Colonies Characteristics.

3.1.2.3.3. Method of Manufacture (MOM)

CDF susceptibility is understood to be significantly impacted by the MOM. Melt method, feedstock input, differences between forging/billet vendors, changes to billet manufacturing process or diameter, changes to forging method, and changes to heat treatment methods are a few examples of things that an applicant should consider for the part and CDF characterization.

3.1.2.3.4. Intra-part (Location) Variability

MTR or colony characteristics within a part are known to be a function of manufacturing thermomechanical history (e.g. strain, strain-path, strain-rate, temperature) and hence consideration should also be given to the specific locations from which samples are extracted in a billet or forging. The applicant should understand the potential variability of MTR or colony characteristics throughout the part, accounting for radial and circumferential variation.

3.1.2.3.5. Other Adverse Features

The applicant should consider any other potential adverse features that may impact CDF susceptibility of the part. Reference FAA/DOT/TC23-40 for potentially adverse features.

3.1.3. Data Gathering Options

It must be ensured that all of the factors affecting CDF susceptibility outlined in Section 3.1.2 have been accounted for during the data gathering process to establish the Means of Compliance and understanding of CDF suscepctibility. Coupon testing is valuable in establishing a basis of knowledge such as trends in behavior and characteristics for a given alloy. Component validation provides a meaningful shift in the material understanding because of the incorporation of many of the factors discussed in Section 3.1.2. Field experience is valuable for capturing the known behavior of a wide array of components and operational variation. The strategy for incorporating the data gathered into the MOC for a component shall be clearly outlined for the agency.

3.1.3.1. Coupon Testing

CDF coupon testing may be used to determine sensitivity to key factors impacting CDF (temperature, stress, dwell time, etc.). Consideration should be given for gauge section volume of the specimen to ensure adequate MTR/colony (and/or adverse condition) sampling occurs during the testing. Due to observed component scale behavior (e.g. volume effects, loading effects, material processing, etc.), it is generally recognized that specimen testing should be augmented by additional data.

3.1.3.2. Component Testing

Component testing has the potential to sample much larger volumes of material than specimen testing. Component test article(s) should be as representative as possible of full-scale components in terms of the important factors given in Section 3.1.2 and account for the variation in these factors.

3.1.3.3. Field Experience

Field experience, both positive and negative, can also offer important understanding into CDF capability. It is important that the applicability of the field experience is understood with respect to the important factors affecting CDF listed in Section 3.1.2 and the application to which the field experience is being applied.

3.1.4. Material Monitoring (Manufacturing Plan)

For any means of compliance other than the industry provided default threshold, ongoing monitoring of the material structure produced during manufacturing will be required. The applicant should provide details in the Manufacturing Plan for monitoring the key factors affecting susceptibility to CDF.

3.2. OEM-Specific Titanium Cold Dwell Fatigue Threshold Methodology

The Titanium Cold Dwell Fatigue failure mechanism occurs under specific stress and temperature conditions. Thresholds for both stress and temperature can be established that define when CDF is not expected to be more limiting than the LCF life. An applicant may establish their own threshold(s) using the available data gathering options. The threshold typically is defined as both an upper temperature limit (CDF temperature cut off) and a maximum stress (may be described as percentage of yield stress) limit and should be clearly documented in the Engineering Plan. The applicant should address each of the key factors affecting CDF susceptibility to ensure that the established thresholds are applicable to the part (see Section 3.1.2). The threshold(s) should include component validation (see Section 3.1.3) based on the agreed data gathering options with the agency such that the model provides consistency with actual test rig and/or fleet experience. The process defining an OEM specific threshold(s) should be incorporated into the Engineering Plan.

3.3. Establishing CDF Assessment Methodologies

CDF Assessment Methodologies address the risk for CDF. The applicant should address each of the key factors affecting CDF susceptibility (see Section 3.1.2) to ensure that the methodologies are applicable to the part. The Engineering Plan of CS-E 515 (a) should account for the assumptions made, and treatment of these factors in establishing the Approved Life of the part.

Predictive modelling tools relating CDF performance to variables such as material structure, temperature, stress, dwell time, stressed volume, small crack effects, life scatter, etc. should be calibrated against the available data. The model should include component validation based on the agreed data gathering options with the agency such that the model provides consistency with actual test rig and/or fleet experience (e.g. predicted numbers of failures).

Manufacturing and in-service inspections are options available to reduce the risk of titanium alloy CDF. The manufacturing inspections assumed in the assessment should be incorporated into the Manufacturing Plan. The applicant should identify the intervals for each specified in-service inspection if needed to achieve a desired risk level. Historical engine removal rates and module and part availability data could serve as the basis for establishing an inspection interval. Likewise, the assumed in-service inspection procedures and intervals should be integrated into the Service Management Plan.

4. Supporting Data

4.1. References

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Reference	Title	Code	Issue	Date
1	AC 33.70-1, “Guidance Material for Aircraft Engine Life-Limited Parts Requirements,”	FAR	---	July 31, 2009
2	BEA2017-0568, BEA Investigation Report, Accident to the AIRBUS A380-861 registered F-HPJE and operated by Air France on 30/09/2017	---	---	September 2020
3	AC 33.15-1A “Manufacturing Process of premium Quality Titanium Alloy Rotating Engine Components”	FAR	---	September 2025
4	FAA/DOT/TC23-40 https://rosap.ntl.bts.gov/view/dot/77938	---	---	2024
5	INDUSTRY-WIDE LEARNING AND PERSPECTIVES ON MANAGEMENT OF COLD DWELL FATIGUE CAPABILITIES A Pilchak et al, 15th World Conference on Titanium, Ti-2023.	---	---	2023
6	CONTINUOUS, INDUSTRY-WIDE EFFORTS TO IMPROVE THE SAFETY OF TITANIUM ALLOY TURBINE ENGINE ROTORS, A Woodfield et al, 15th World Conference on Titanium, Ti-2023.	---	---	2023
7	A COMPARATIVE STUDY OF DWELL FATIGUE OF Ti-6Al-2Sn-4Zr-xMo (x=2-6) ALOYS ON A MICROSTRUCTURAL-NORMALISED BASIS’ J Qiu et al, Metallurgical Materials Transactions A, 45, pp6075-6087, 2014	---	---	2014
8	DREAM.3D workflows for MTR characterization https://rosap.ntl.bts.gov/view/dot/78565	---	---	---
9	TOOLS AND METHODS FOR MICROTEXTURE CLASSIFICATION AND PHYSICS BASED DWELL FATIGUE LIFE PREDICTION IN TI-6AL-4V, V Venkatesh et al, 15th World Conference on Titanium, Ti-2023	---	---	2023

4.2. Abbreviations

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4.3. Definitions

Airfoil-Rotor Interaction Zone (ARIZ)	Root section of an integrally bladed rotor (IBR) or centrifugal impellor airfoil where cracks have been shown to propagate into the disc body due to steady and vibratory loads (from both airfoil and disc modes).
Bulk Residual Stress	Stresses partially remaining in the volume of the finished part from manufacturing processes.
Cold Dwell Fatigue (CDF)	A failure mechanism in titanium alloys whereby a reduction in fatigue life occurs when a hold (dwell) at stress is imposed under relatively low temperature conditions. Technical details are provided in the Background Section and FAA/DOT/TC23-40.
CDF Threshold	The combination of a temperature and stress threshold where susceptibility to the CDF failure mechanism is reduced such that the risk of failure due to CDF is acceptable.
Colony	A colony is a microstructural feature in titanium near-alpha and alpha+beta alloys consisting of a series of parallel platelets (also called laths or lamellae) of alternating alpha and beta phase. This feature is formed when the material is cooled from above the beta transus which may occur following forging in the beta phase field or during cooling from a solution heat treatment above the beta transus following forging in the alpha+beta region. Similar to MTRs, colonies are also known to impact CDF capabilities.
Combined Stress	Combined stress ($\sigma_{combined}$) is the maximum principal stress resulting from the combination of applied and residual stress tensors.
Component	A part which may contain multiple sets of features.
Damage Tolerance	An element of the life management process that recognizes the potential existence of component imperfections that are the result of inherent material structure, material processing, component design, manufacturing, or usage. Damage tolerance addresses this situation through the incorporation of fracture resistant design, fracture mechanics, process control, or non-destructive inspection.
Engine Flight Cycle	The flight profile or combination of profiles on which the approved life is based.
Microporosity	Microporosity in titanium alloys are voids in the material with sizes less than ~25 micrometers (~0.001”). These features may be clean inside or may be contaminated with potassium, calcium, and potentially other alkali- or alkali-earth metals and metal halides. The presence of contamination makes the pores more likely to survive subsequent thermomechanical processing compared to clean voids which may be sealed during forging.
Microtextured Region (MTR)	A localized region in an alpha/beta converted billet or an alpha/beta processed component forging where neighboring alpha grains and/or secondary alpha platelets have similar crystal orientations such that the feature may act as a larger structural unit during deformation and crack growth. These features are known to impact CDF

	capabilities. MTRs are also sometimes referred to as 'macrozones;' or 'primary alpha colonies' in CDF literature.
Region Of Interest (ROI)	A zone or volume of the component that can be represented by a similar set of geometric, material, and flight cycle characteristics.
Spin Rig Testing	A component which is tested under alternating speeds to simulate fatigue cycling and which may have an intentional hold at peak stress to simulate CDF.
Safe Life	A low cycle fatigue-based process in which life-limited components are designed, manufactured, and substantiated to have a specified service life or life limit, which is stated in operating flight cycles, operating hours, or both. The "safe life approach" requires that components be removed from service prior to the development of an unsafe condition (i.e. crack initiation). When a component reaches its published life limit, it is retired from service. The safe life approach only applies to components which define crack initiation as the limit of the useful life such as rotating parts.
Test Coupons	A generic term used to represent mechanical test coupons or specimens machined to simple geometries that generally follow ASTM standards.

5. Remarks

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **10th of July 2026**. Comments received after the indicated closing date for consultation might not be taken into account.
2. Official comments to the proposed CM are to be filed through the EASA Comment Response Tool.
3. For any question concerning the technical content of this EASA Certification Memorandum, please contact:
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   Function: Project Certification Manager - Propulsion
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