



U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Fatigue Life of Nickel Powder
Rotating Life-Limited Parts

Date: 8/15/23

AC No: 33.70-4

Initiated By: AIR-625

1 **PURPOSE.**

This advisory circular (AC) provides guidance that may be used to demonstrate compliance with Title 14, Code of Federal Regulations (14 CFR) 33.70 for rotating life-limited engine parts made of nickel powder. Section 33.70 contains requirements applicable to the design and life management of engine life-limited parts, including high-energy nickel powder rotating parts.

2 **APPLICABILITY.**

- 2.1 The guidance in this AC is for aircraft engine manufacturers, modifiers, Federal Aviation Administration (FAA) engine type certification engineers, and FAA designees.
- 2.2 The contents of this AC do not have the force and effect of law and are not meant to bind the public in any way, and this AC is intended only to provide information to the public regarding existing requirements under the law or agency policies. Conformity with this guidance is voluntary only, and nonconformity will not affect rights and obligations under existing statutes and regulations. This AC describes an acceptable means, but not the only means, for showing compliance with § 33.70 for nickel powder rotating life-limited parts. When the method of compliance in this AC is used, terms such as “should,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. The FAA will consider other means of showing compliance that an applicant may elect to present. If, however, the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the agency may require additional substantiation as a basis for finding compliance.
- 2.3 This material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, existing regulatory requirements.

3 RELATED READING MATERIAL.

The following materials are referenced in this document. Unless otherwise indicated, you should use the current edition if following the method of compliance set forth in this AC.

3.1 Title 14, Code of Federal Regulations.

- 14 CFR 33.4, *Instructions for Continued Airworthiness*.
- 14 CFR 33.15, *Materials*.
- 14 CFR 33.19, *Durability*.
- 14 CFR 33.27, *Turbine, compressor, fan, and turbosupercharger rotor overspeed*.
- 14 CFR 33.63, *Vibration*.
- 14 CFR 33.75, *Safety analysis*.

3.2 FAA Publications.

- AC 33.4-1, *Instructions for Continued Airworthiness*.
- AC 33.4-2, *Instructions for Continued Airworthiness: In-Service Inspection of Safety Critical Turbine Engine Parts at Piece-Part Opportunity*.
- AC 33.14-1, *Damage Tolerance for High Energy Turbine Engine Rotors*.
- AC 33.70-1, *Guidance Material for Aircraft Engine Life-Limited Parts Requirements*.
- AC 33.70-2, *Damage Tolerance of Hole Features in High-Energy Turbine Engine Rotors*.

3.3 Technical Publications.

- R Craig McClung, Michael P Enright and Wuwei Liang, “Integration of NASA-developed lifing technology for PM alloys into DARWIN®,” NASA/CR-2011-216977, March 2011.
- Paul G Roth, Jean C Murray, Joan E. Morra and Jack M. Hyzack, “Heavy liquid separation: a reliable method to characterize inclusion in metal powder”, in “Advances in Powder Metallurgy & Particulate Materials: Characterization, Testing and Quality control”, Vol 2, 1994.

4 DEFINITIONS.

The following list of definitions apply to this AC.

- **Approved Life.** The mandatory replacement life of a part that is approved by the Administrator, and is listed in the airworthiness limitation section (ALS) of the instructions for continued airworthiness (ICA).

- **Engine Life-Limited Parts.** The definition of engine life-limited parts, as defined in § 33.70, applies to this AC.
- **Engineering Plan.** A plan that includes the assumptions, technical data, and actions required to establish and maintain the life capability of an engine life-limited part. The engineering plan is established and executed as part of the pre and post-certification activities.
- **Failure.** Separation of a part into two or more pieces or into a condition so that it is no longer whole or complete. Examples of failures include disk or case bursts.
- **ICA.** Instructions for Continued Airworthiness (ICA), as required by § 33.4.
- **Life Limit.** An operational service exposure limit characterized by the application of a finite number of flights or flight cycles. For rotating parts, it is equal to the minimum number of flight cycles required to initiate a crack equal to approximately 0.030 inches in length by 0.015 inches in depth. For life-limited pressure-loaded static parts, the life limit may be based on the crack initiation life plus a portion of the residual crack growth life.
- **Life Management.** A series of interrelated engineering, manufacturing, and service support activities that ensure that engine life-limited parts are removed from service prior to the development of a hazardous engine effect.
- **Low Cycle Fatigue (LCF).** The process of progressive and permanent local structural deterioration occurring in a material subject to cyclic variations in stress and strain and number of repetitions of sufficient magnitude to initiate a crack. The process will culminate in a detectable crack initiation typically within 10E+05 cycles. A detectable crack initiation is defined as 0.030 inches in length by 0.015 inches in depth.
- **Manufacturing Plan.** A plan that identifies the part-specific manufacturing process constraints that should be included in the manufacturing definition (drawings, procedures, specifications, etc.) needed to consistently produce each engine life-limited part with the attributes required by the engineering plan.
- **Service Management Plan.** A plan that defines the in-service maintenance processes and the limitations to repair cracks associated with each engine life-limited part such that the part will maintain the attributes required by the engineering plan. These processes and limitations become part of the ICA.

5 **BACKGROUND.**

- 5.1 This AC describes the aspects of nickel powder metallurgy materials that require special measures when establishing and maintaining the approved life of rotating life-limited engine parts made of nickel powder in gas turbine engines. Powder metal manufacturing introduces inherent anomalies into the material, usually in the form of inclusions or pores, which are generally microscopic. During fatigue loading, cracks can nucleate from these anomalies. Therefore, when determining the approved life of a rotating part, the applicant should identify the possibility of an anomaly occurring at a highly stressed location and nucleating a fatigue crack.
- 5.2 While assessments are made for the rare occurrence of a melt anomaly in the traditional cast and wrought material, the likelihood of an occurrence is so low that establishing the probability of the presence of such an anomaly is based on a combination of the following inspections.
- In-service inspections (cracking or fractures);
 - Manufacturer inspections; and
 - Supplier inspections.

By contrast, the inherent nature of the inclusions and porosity in powder metal is such that a more systematic approach can be taken, as discussed in this AC. The applicant should consider the elements of a test program that are required to establish the capability of the material, recognizing that while an extreme size anomaly can occur in production quantities, it is unlikely it will be present in the limited volume of material tested. A method for determining the fatigue capability of powder material is developed from these tests, which can be used to demonstrate the integrity of parts.

6 **INTRODUCTION.**

6.1 **Life Management Activities.**

- 6.1.1 Since the failure of an engine life-limited part is likely to result in a hazardous engine effect, as defined in § 33.75(g)(2) and (3), the applicant must meet specific integrity requirements by performing a series of life management activities (see § 33.70(a), (b), and (c)).
- 6.1.2 Section 33.70 requires the applicant to establish the integrity of each engine life-limited part by developing and implementing an engineering plan, a manufacturing plan, and a service management plan. These three plans form a closed-loop system that links the assumptions made in the engineering plan to the manufacture of the part and finally to the in-service maintenance. Applicants should ensure that the engineering, manufacturing, and service management plans function as an integrated system, and recognize that the actions in one area could affect the entire system. AC 33.70-1 provides additional information on these three plans.

6.2 Introduction of Nickel Powder.

Nickel powder materials have been introduced to allow the use of highly alloyed materials that would be difficult, if not impossible, to produce through a conventional melt route due to segregation (the non-uniform distribution of alloying elements in the forging). Instead, with nickel powder materials, small particles of the material are produced, which cool so quickly that levels of segregation are microscopic, producing a consistent alloy composition. The powder particles are then consolidated into a single monolithic piece of material.

6.3 Inherent Inclusions and Porosity.

The methods for producing the particles and consolidating the material introduce anomalies, such as small inclusions and porosity (caused by trapped gas), both of which are inherent to the process. While fatigue testing on components made of powder metallurgy will often fail from grain facet features, similar to conventional cast and wrought alloys, there will also be occasional failures nucleating from the inherent inclusions or porosity.

- 6.3.1 When establishing the fatigue life and safe operation for such a component, the applicant should consider the possibility of fatigue fracture from both grain facets and anomalies such as inclusions and pores that cannot be found during nondestructive inspections (see Figure 1). The NASA/CR-2011-216977 report also provides a thorough discussion of issues in lifing powder alloys (see paragraph 3.3 of this AC).

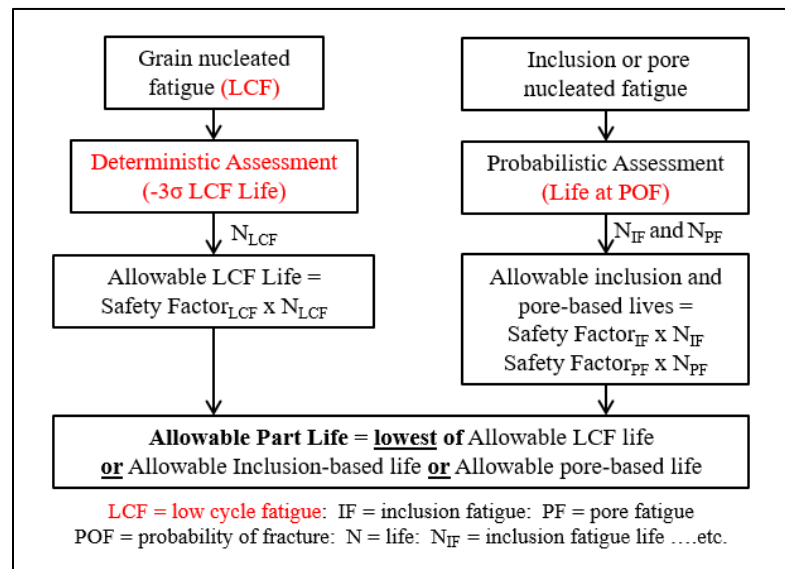


Figure 1. Lifing Assessments Performed on Powder Nickel Materials

7 **PROCESSING OF POWDER MATERIALS.**

7.1 **Powder Metal in the Molten State.**

A powder alloy is produced from the molten state. After the alloy is melted to the desired chemical composition, the liquid metal is poured through a nozzle and atomized into a fine spray of droplets. These droplets quickly solidify and cool in a collection vessel. The particles are then passed through a sequence of sieves to eliminate the larger particles, resulting in a uniform size distribution of powder.

7.2 **Inclusion Creation.**

Inclusions in the microstructure of powder metallurgy components are typically small pieces of ceramic that have spalled from the interior surfaces of crucibles, nozzles, and other ceramic components used in the metal melting and pouring processes. Ceramic spalling is caused by the stresses of thermal cycling and erosive molten metal flow. Consequently, small particles of ceramic lining material released are collected with solidified powder metal. These inclusions are generally tiny, perhaps measured in microns, but occasionally larger inclusions can get through the sieve. These inclusion particles may be larger in one dimension than the sieve gauge and can be acicular, allowing them to pass through the sieve. Inclusion particles larger than the sieve dimensions are found on rare occasions, similar to those of anomalies in conventional cast and wrought materials. These larger (rogue) inclusions often appear as unique individual distributions relative to the inclusion size, which can still be present after the sieving process. Applicants should evaluate the potential effects the rogue inclusions may have on component life.

7.3 **Hot Compaction Methods and Heat Treatment.**

The consolidation of powder materials is achieved by hot compaction methods at high temperatures and pressures. This consolidation results in plastic flow and diffusion, bonding the particles and producing a material structure suitable for subsequent processing. The consolidated material may then be subjected to additional hot deformation by shearing the compact through a die to produce an extrusion or through tightly controlled ~~radial~~ forging processes. This process will produce a billet followed by isothermal forging to a shape that is close to the final component. The deformation breaks up and elongates the ceramic inclusions and porosity present. The material may also be used in an as-compacted form (such as post-Hot Isostatic Pressing (HIP)) to manufacture components.

7.4 **Final Machining.**

After heat treatment, the forging or as-compacted form is then machined to remove the surface layers through a series of shapes, allowing inspection before the component is machined to the required profile for engine use.

7.5 **Inspection Techniques.**

7.5.1 Ultrasonic Inspection.

Ultrasonic inspection can usually achieve a high standard of detectability because the overall processing route of the material delivers a uniform small grain size with low noise levels. Determining the sequence of inspection relative to heat treatment and the direction of scan(s) are reasonable considerations when developing the Manufacturing Plan.

7.5.2 Etch and Fluorescent Penetrant Inspections.

Etch and fluorescent penetrant inspections are routinely applied to the machined component to check the conformity of microstructure and to confirm the absence of cracks or crack-like anomalies on the surface. Because etching can adversely affect the integrity of the finished material surface at smooth or notched features, the applicant should understand and include the impact of etching practices into its fatigue management program. Adverse effects of etching can be eliminated by subsequent shot peening of machined and etched surfaces.

7.6 **Traceability of Powder.**

The applicant should also ensure that the powder produced is traceable, and of a consistent high quality. This is a prerequisite for a reliable lifing system for powder alloys.

8 **DEVELOPING THE LIFING SYSTEM.**

8.1 **Life System Approval.**

- 8.1.1 For an applicant to use a life system, the FAA must first approve the engineering plan required by § 33.70. The applicant should develop and submit a formal written lifing system plan to the FAA for approval. The plan should identify the techniques and controls used to establish and maintain the life-limits. Section 33.70 states, “By a procedure approved by the FAA, operating limitations must be established which specify the maximum allowable number of flight cycles for each engine life-limited part.” Therefore, the applicant must submit all proposed life system changes to the FAA for approval, and the FAA must approve all life system changes before use. See AC 33.70-1 for additional information.

8.2 **Certification Process Overview.**

8.2.1 Methodology.

The first step in developing a lifing system is to characterize the different mechanisms of crack initiation (or nucleation) in the material, which can typically be from—

- Grain facets (similar nucleation mechanism to conventional alloys); or
- Anomalies, such as inclusions (both inherent and rogue inclusions) and porosity resulting from inert gas trapped in the powder.

8.2.2 The characterization of the active crack nucleation mechanisms can only be done by fractographic examination of the failure surfaces. This examination should include a sufficient number of fatigue specimens tested at component-representative strains and temperatures.

8.2.3 The declarable component life will be the lowest result from separate life assessments performed for the mechanisms, as shown in figure 1.

8.2.4 Crack Nucleation Factors.

8.2.4.1 For each nucleation mechanism, the applicant should examine the significant parameters driving the LCF life. Cycle-related parameters may include:

- Applied stress or strain levels, their degree of multiaxiality, and any non-linear deformation from plasticity and/or creep; and
- Cycle temperature and the applied component loads. It would be expected that nucleation of a propagating crack will depend on the peak stress. However, if the peak temperature occurs simultaneously or at some other point in the engine cycle, this may influence cycle temperature and applied component load. This will certainly influence the crack propagation phase after crack nucleation.

8.2.4.2 For nucleation from grain facets, the significant parameters are usually identical to those of a conventional cast and wrought alloy with the same chemistry. Therefore, applicants may apply the same type of lifing models.

8.2.4.3 In addition to the cycle-related factors described above, the fatigue behavior of anomalies may also depend on the following variables:

- Size of the anomaly, including its aspect ratios and orientation;
- Composition of the anomaly and its effect, if any, on the substrate material;
- Proximity of the anomaly to a surface of the component because this affects the balance of the stresses in the microstructure around the anomaly and how easily it can incubate a propagating crack; and
- Surface treatment of the component because of the shot peening process. For example, shot peening will distort the microstructure at a surface or very near surface anomaly, and the residual stresses may affect potential crack nucleation and propagation.

8.2.4.4 The simplest approach to determine the fatigue life of the part would be to treat all anomalies as initial cracks of a size equal to the projected area normal to the largest principal tensile stress. In practice, especially for smaller anomalies, there is a significant life before the anomaly behaves and/or can be modeled like a propagating crack (this life is often referred to as the nucleation life). The smallest inclusions will probably never nucleate a propagating crack in a large volume of parts, such as engine rotating components.

8.2.5 Probabilistic Assessment.

8.2.5.1 A probabilistic component lifing model is likely to be the most appropriate for fatigue failures originating from anomalies such as inclusions and porosity, demonstrating that the probability of a fracture from an extreme size of anomaly present in a highly stressed portion of a component is acceptably low. This evaluation follows the same lines as an assessment for melt anomalies in conventional cast and wrought materials. Figure 2 shows a sample probabilistic assessment method.

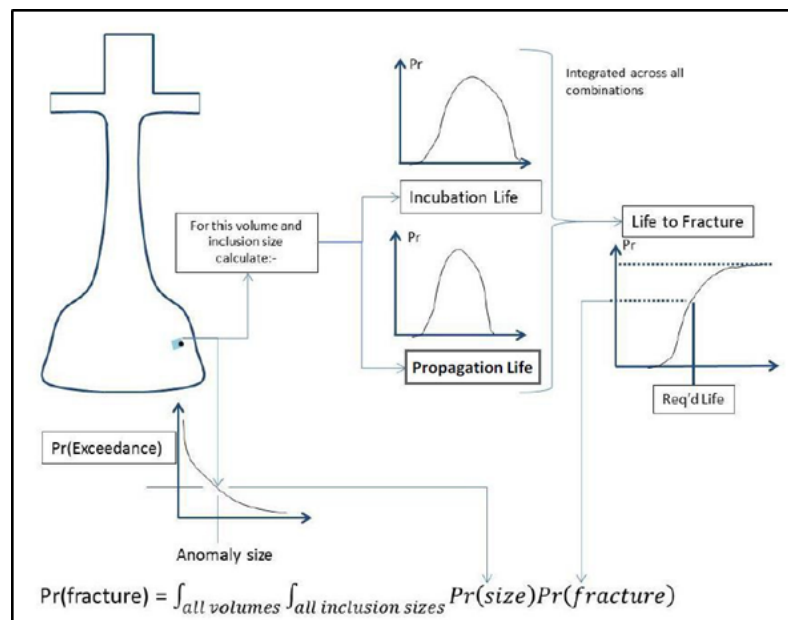


Figure 2. Probabilistic Assessment Method for Fracture from Inclusions

8.2.5.2 The probabilistic model will be based on a two-stage representation of fatigue life consisting of the following key inputs—

- Crack propagation life as a function of the engine cycle variables and considering, if near surface, residual stresses from machining and/or surface treatment are present;

- Nucleation life as a function of size and type of anomaly, and proximity to a surface, and as a function of cycle and material variables, such as applied strain or stress, temperature (peak and its phasing with the applied loads), loading multiaxiality, and inelastic (creep and plastic) strain levels, if applicable; and
- Size and frequency distribution of the powder material anomalies.

8.2.5.3 Methods for determining the anomaly distributions and nucleation lives are discussed in paragraphs 9 and 10. Although these paragraphs focus on inclusions, the applicant may use the same principles to assess the risk of porosity-related failure with some minor differences.

9 CHARACTERIZING THE INCLUSION SIZE DISTRIBUTION IN POWDER MATERIALS.

9.1 Establishing Inclusion Size.

9.1.1 All powder materials will be characterized using the same mechanical and physical measurements used for conventional cast and wrought materials. In addition, it is necessary to extract data to make a prediction of the largest size of inclusion that could occur in a given volume of material. Predicting the largest size is based on measuring inclusions above a detectable limit in known volumes of material. If the number of inclusions found using a particular inspection process is known and a size distribution is fitted to those found, then it is relatively simple to predict the likelihood of finding a large inclusion in any volume of material. Nevertheless, this is complicated, because—

- There is a lower detectable limit below which inclusions may simply be missed. This may be because 1) the inclusion size is small, in which case the inclusion is unlikely to be life limiting; or 2) the shape and orientation of the inclusion is such that the area presented to the inspection plane is small, in which case the inclusion could be life limiting. Consequently, the applicant should define the inspection plans to maximize inspection capability, accounting for the deformation of the material during forging. The applicant should also ensure that the inspection plan identifies the inspection limits when fitting the anomaly rate, size, and orientation distributions.
- Sieving is designed to remove larger inclusions, but long acicular inclusions with a lower cross-sectional area may still pass through. The size distribution at powder creation may be smooth, but will become less populated at large sizes due to sieving.

9.1.2 It is not clear what upper limit to the inclusion size should be used, especially when rogue inclusion sizes may be present. Methods for detecting and measuring the sizes of rogue anomalies will be required to account for them in the lifing process.

9.2 Inclusion Characterization Methods

9.2.1 Given the various complications in gathering inclusion distribution information, the applicant should include several processing methods for detecting and measuring inclusion sizes and orientations as provided below.

9.2.1.1 **Fractographic examination of powder material.** Applicants would perform metallographic examination of billet or forged material, which would show any effects of forging on inclusions. This method is desirable since inclusions may deform and elongate during forging. Due to the effort required to section and polish material, only small volumes of material can be inspected using this approach. Therefore, there is a degree of extrapolation up to a volume representative of all highly stressed material in production quantities of components.

9.2.1.2 **Large bar tensile tests.** Applicants should remember that it is assumed the bar will fail at the largest inclusion. By testing enough large tensile specimens, each with a known volume at the ultimate stress, applicants can measure the largest inclusion on the fracture surface. This also assumes the critical dimension is normal to the direction of the tensile stress. This method can examine a relatively large total volume of material, comparable to a small number of engine disks. The specimens are usually cut from billet material, but may be taken from forgings. The only information obtained from these tests is the size of the largest inclusion in each volume. Gumbel statistics are useful in deriving the underlying rate and size distribution for forward extrapolation up to larger volumes.

9.2.1.3 **Large specimen fatigue tests.** A possibility is to systematically test fatigue of powder alloys on larger specimens than typically used for conventional alloys. Applicants would extract large specimens from forgings and choose their size based on forging size and fatigue test machine capability. In this manner, the volume of material tested in fatigue would increase, as would the probability of failure from a large inclusion. When the specimen fails from an inclusion, this inclusion is obviously the most detrimental for fatigue resistance in the tested volume. This failure can be related to the size of the inclusion plus scatter coming from its interaction with the local microstructural environment. By measuring the size of the inclusion at the fracture origin on each specimen and testing enough large specimens, the underlying rate and size distribution of inclusions can be derived using similar techniques as described for large bar tensile tests. These large specimen fatigue test results can also be used to characterize the nucleation life from inclusions.

- 9.2.1.4 **Heavy liquid separation.** By passing the basic powder through a liquid with a density between those of the alloy and the inclusions, the inclusion particles will float while the alloy will sink. This examines the material before consolidation and forging. A model is required that relates the sizes of particles found to what will be missed and, therefore, could remain in the forged component. However, the examination and measurement of the particles is relatively easy and can include all three dimensions, which is not easily achieved by the other methods. Depending on local health and environmental regulations, the use of heavy liquid separation may be restricted due to the toxicity of the material necessary to reach an intermediate density between the ceramic inclusions and the nickel alloy powder. Alternative techniques are also available, such as water separation. Further aspects of heavy liquid separation are discussed by Roth et al. (see paragraph 3.3 of this AC).
- 9.2.1.5 **Acid digestion.** Applicants may accomplish this method by using an acid to remove metallic material while the inclusions are not attacked and left as remnant particles at the end of the process. Tungsten-bearing alloys, however, have proven difficult to evaluate by this technique due to the formation of tungstic acid and its subsequent effect on laboratory hardware.
- 9.2.1.6 **Cut-up characterization of ultrasonic indications.** Applicants would perform 2D and 3D characterization of the anomalies detected by the ultrasonic inspection. This method also gathers information relative to porosity and other issues, such as proximity of anomalies and the rogue size population.

The applicant should use more than one of the above approaches for both the initial determination of the inclusion size distribution and the continued monitoring of the powder production process to confirm that the initial size distribution remains appropriate for lifing throughout the life of the product.

10 **FATIGUE TEST STRATEGY TO CHARACTERIZE THE LIFE FROM INCLUSIONS IN POWDER MATERIALS.**

10.1 **Sample Strategies for Determining the Life.**

Fatigue testing small specimens of material can give rise to widely varying results. If the tested volume is free of inclusions, the behavior will appear significantly better than when a large inclusion is present. As the volume under high-stress increases, it becomes more likely that fracture will nucleate at an inclusion, but even large disks may not always fracture from inclusions. To establish the fatigue implications of inclusions, the testing approach should consider how a sufficient number of failures could be generated to demonstrate that the service operation of powder materials can avoid fracture.

10.1.1 Strategy 1- Large Volumes of Material.

Fatigue testing of large volumes of material such that a significant number of fractures from inclusions are generated would be the simplest approach. However, in practice, this would be very expensive since, as noted above, even large disks do not always fracture from inclusions. Tests should also be conducted at a wide range of temperatures and load levels to ensure that the material behavior has been characterized appropriately through the full-service usage envelope.

10.1.2 Strategy 2 - Seeded Material.

Fatigue testing of seeded material where artificial inclusions of a known size and rate are introduced at the powder stage is another approach. The seeds should be representative of the actual inclusions in composition and behavior. Specimens and components manufactured from seeded material are much more likely to fail from the artificial seeds than through conventional LCF. This allows a fatigue model for the inclusions to be generated based on a relatively modest test program.

10.2 **Defining Equivalent Crack Size.**

10.2.1 Regardless of how the applicant performs the tests, the applicant should define an equivalent crack size that corresponds to the end of the nucleation phase of life and the start of crack growth. The applicant could show equivalency in various ways, for example:

- Engineering crack size (0.030" x .015" for surface cracks, but less easily defined for sub-surface cracks);
- The actual size of the anomaly from which the fatigue failure nucleated (determined by fractography); or
- The actual size of the anomaly from which the fatigue failure nucleated, plus an allowance for diffusion or other interaction between the anomaly and the surrounding material.

10.2.2 Determining the nucleation life is likely to involve back calculations using fracture mechanics of the number of cycles from either test piece, failure, or crack detection (of a known size) to the equivalent crack size at the end of the nucleation life.

10.2.3 For crack nucleation from porosity, the applicant should show equivalency as described in paragraph 10.2.1. It may be possible to show that the size and frequency distribution for porosity can be determined directly from conventional specimens because pores are often more frequent than inclusions and have a lower scatter in size. The applicant may also consider seeding studies, using methods such as atomizing powder at off-nominal conditions to generate porosity at higher rates than at the nominal conditions. The stress component (von Mises or worst principal, for example) that best describes crack nucleation needs to also be defined.

Note: The stress component may be different for a pore, an inclusion, or a grain facet.

11 CALIBRATION AND VALIDATION OF THE PROBABILISTIC SYSTEM FOR INCLUSIONS.

- 11.1 As a probabilistic system integrates a significant number of parameters (related to the size distribution and life model) that are often identified independently, applicants should verify that the probabilistic system produces sensible results once these are combined. As part of achieving this, the inclusion size distribution may be slightly adjusted in the domain that is too small to be easily characterized experimentally.
- 11.2 The confirmation of the accuracy of the probabilistic system for inclusions can be made using fatigue test results from specimens or components made from unseeded material. Although only a fraction will fracture from inclusions, applicants should ensure that these occurrences are sorted to correlate the various probabilities that the probabilistic system can calculate. For example, applicants should consider the following:
- Conditional probabilities of failure from surface, sub-surface, and internal inclusions;
 - Probabilities of failure from inclusions within a given size interval; and
 - The global failure probability distribution from inclusions as a function of cycles at a given loading condition.
- 11.3 It is important that applicants run a test campaign to show the accuracy or at least the conservatism of the probabilistic system. In addition to fatigue specimen tests, this should include tests that represent the behavior of components. Spin tests are useful in such campaigns to provide information on how to account for component characteristics, such as volume of material under stress, multiaxial loading, and residual stresses.
- 11.4 The results from the component-representative tests should fall within the population of predicted lives at the test conditions.

12 SUGGESTIONS FOR IMPROVING THIS AC.

If you have suggestions for improving this AC, you may use the [Advisory Circular Feedback Form](#) at the end of this AC.

DANIEL J.
ELGAS

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Subject: _____

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Please mark all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph _____ on page _____.

☐ Recommend paragraph _____ on page _____ be changed as follows:

☐ In a future change to this AC, please cover the following subject:
(*Briefly describe what you want added.*)

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: _____ Date: _____