VEXTEC

Durability & Reliability Simulations

Accelerated FAA Certification With Virtual Life Simulations

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Special Recognition

VEXTEC extends its appreciation to EB Airfoils, LLC

EB Airfoils had the foresight to recognize the benefits of using Computational Simulations to dramatically reduce the Cost and Time associated with FAA certification

www.ebairfoils.com

Executive Summary

- VEXTEC Virtual Life Management (VLM) Simulations can be used in place of traditional time consuming and expensive physical testing presently associated with FAA certification.

- The time required in preparation of FAA certification can be reduced to 60 – 90 days due to the use of a full fleet reliability simulations.

- At the blade operating conditions, the EB Airfoils repaired blade has similar fatigue durability as a pristine (unrepaired) blade.

- The fatigue lives of the blades in the vibratory modes of interest are statistically equivalent in terms of mean and standard deviation.

VEXTEC Corporation

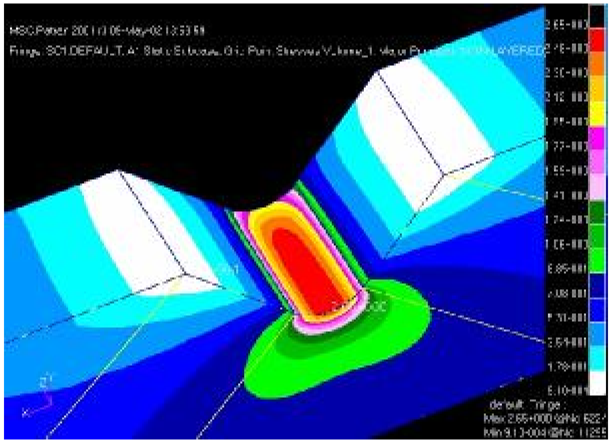
By simulating how materials behave at the microstructural level….

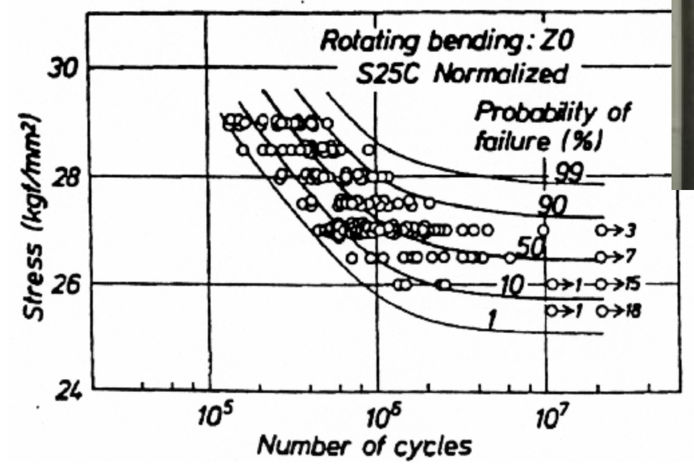
VEXTEC accurately predicts the durability and true lifetime cost of a single part…a whole product line…or an entire fleet

- **Component Durability Life Cycle Simulations**
  Simulate full durability life with limited testing
- **System Level & Reliability Simulations**
  Simulate long term reliability and sustainment affects

Traditional Fatigue Analysis

Empirical Methods





Fatigue Life ← $N_f = A s_a^b$

- **Traditional life analysis requires <u>significant testing</u> at various loads to establish S-N curves**
- **Each test is <u>discrete</u> – *not applicable to "What If" scenarios***

Good Only for Tested Geometry/Conditions

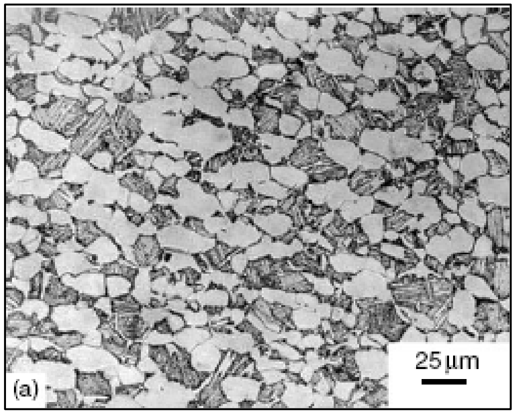
VEXTEC Technology Approach

Ø Physics Based Microstructural Modeling

- ü **Models the material at a fundamental level**
- ü **Loading and environment become extrinsic to the material model**
- ü **Established material libraries used directly in fatigue analysis**

Ø Computationally Efficient

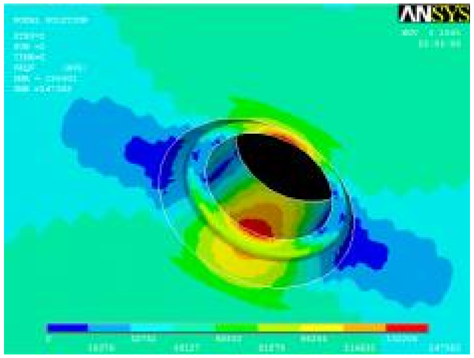
- ü **Probabilistic analysis of material properties**
- ü **VBE™: Variability-Based Engineering**
- ü **Analysis performed on Personal Computers**



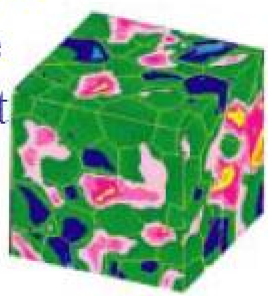
VEXTEC Generic Ti 6-4 SEM

VEXTEC Physics of Failure Modeling

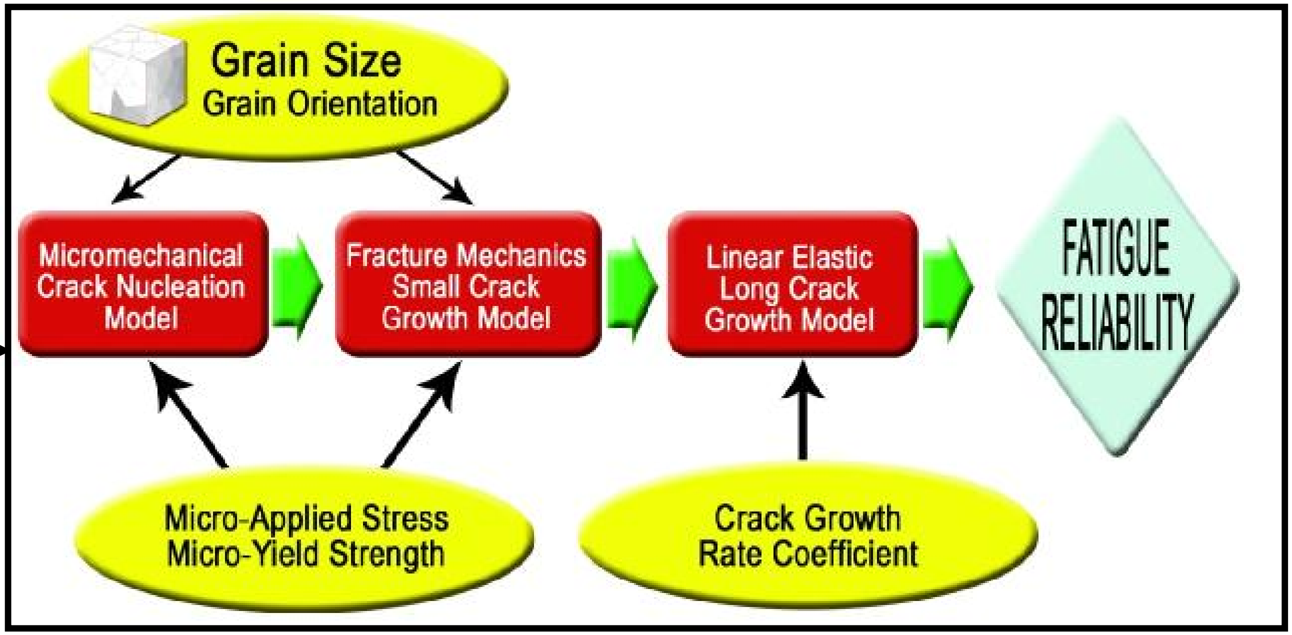
Global Stress Model



Statistical Volume Element



- **Physics-based** microstructural model
- Combine **computational** and **statistical** methods
- **Statistically** representative elements
- **Micromechanics**



Not Limited by Geometry or Loading

Engine Blade Repair Simulation

for EB Airfoils, LLC

Program Objective

- EB Airfoils has developed a repair process for the 1st Stage Fan Blade and contracted VEXTEC to determine the durability of one of the repaired blades in parallel to their normal evaluation process

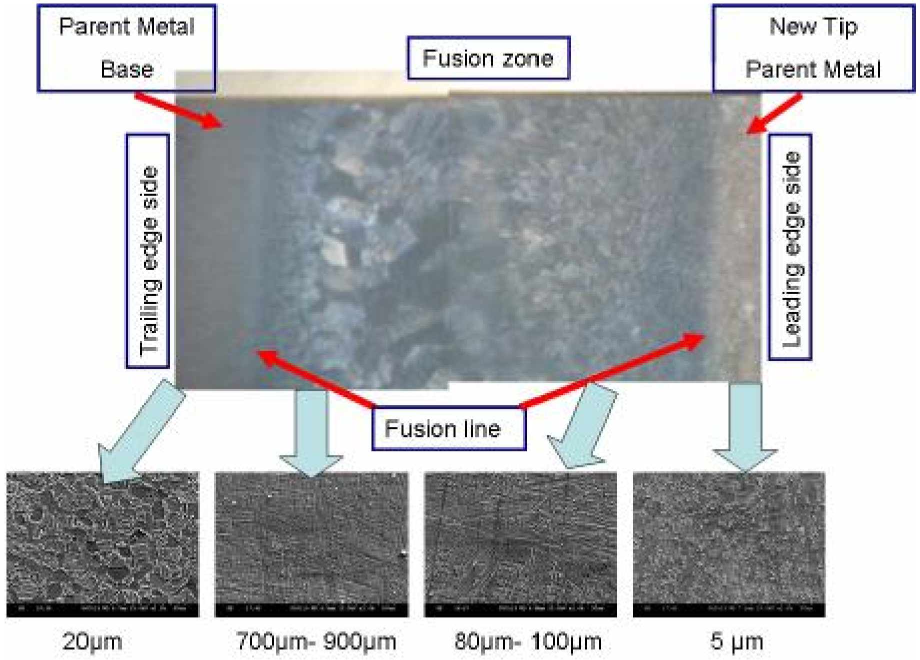
- VEXTEC Objectives:
  - Develop microstructure-based, probabilistic model for the pristine (original) and repaired blade
  - Construct Durability simulations to compare both blade conditions

Objectives were met !

VEXTEC Material Model is Accurate

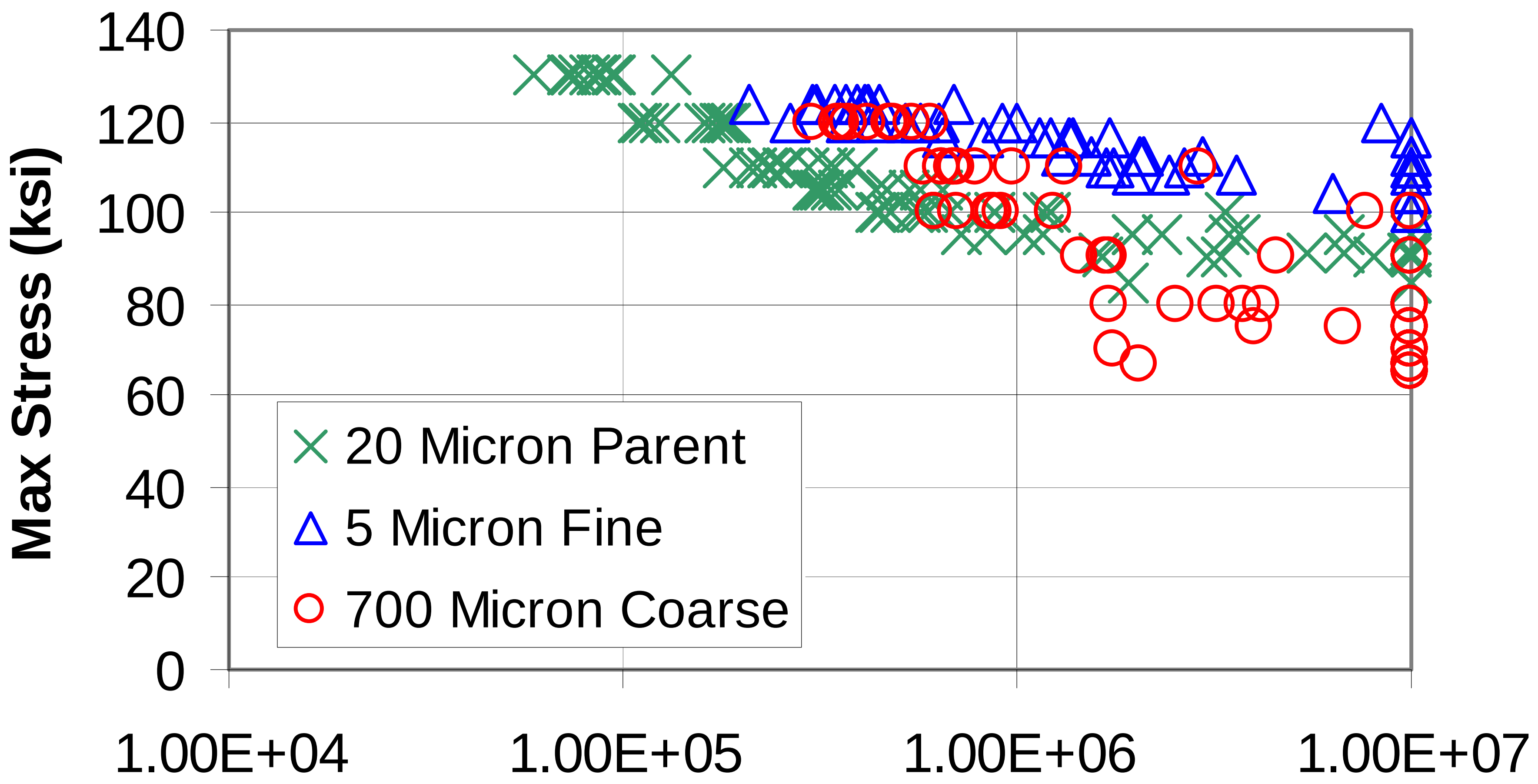
- Performed Lab Work on Repair
  - Optical metallography
  - SEM of weldment

- Outcome of Lab Evaluation
  - A gradient microstructure exists both chord-wise and span-wise



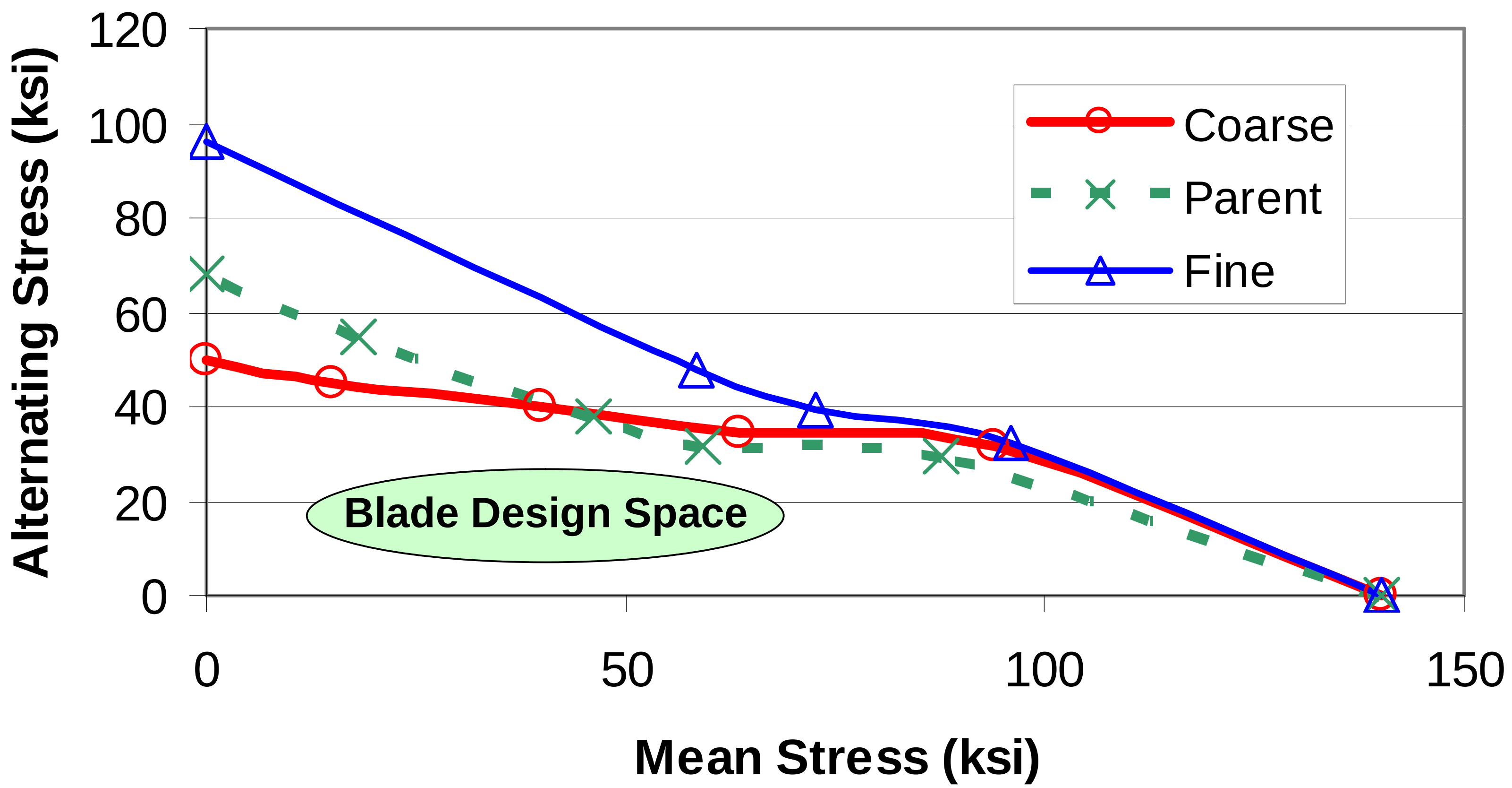
- Conclusion
  - Existing VEXTEC Ti 6-4 micromechanics model is appropriate and can accurately evaluate the gradient microstructure

S-N Curve as Expected



üFine Grain Better in HCF; Coarse Grain Better in LCF

Design Space well within Limits



Existing Design is Well Within Operating Limits

Simulation Results as Expected

- Simulations produced for Parent Metal, Coarse Grain and Fine Grain Microstructures

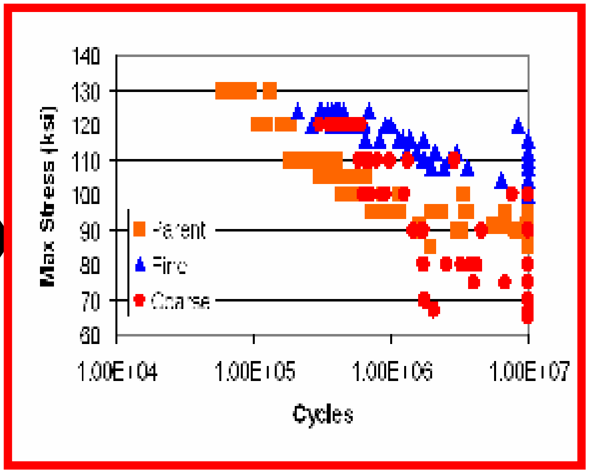
- Outcome of Micromechanical Predictions
  - The coarse grain microstructure damage tolerance is generally better than parent material
  - Conversely, the fine grain microstructure fatigue behavior is generally better than parent

Grain size variability can impact the fatigue behavior

Blade Simulation Process

Specific Material Models → Specific Micromechanical Models → Fan Blade S/N Curves

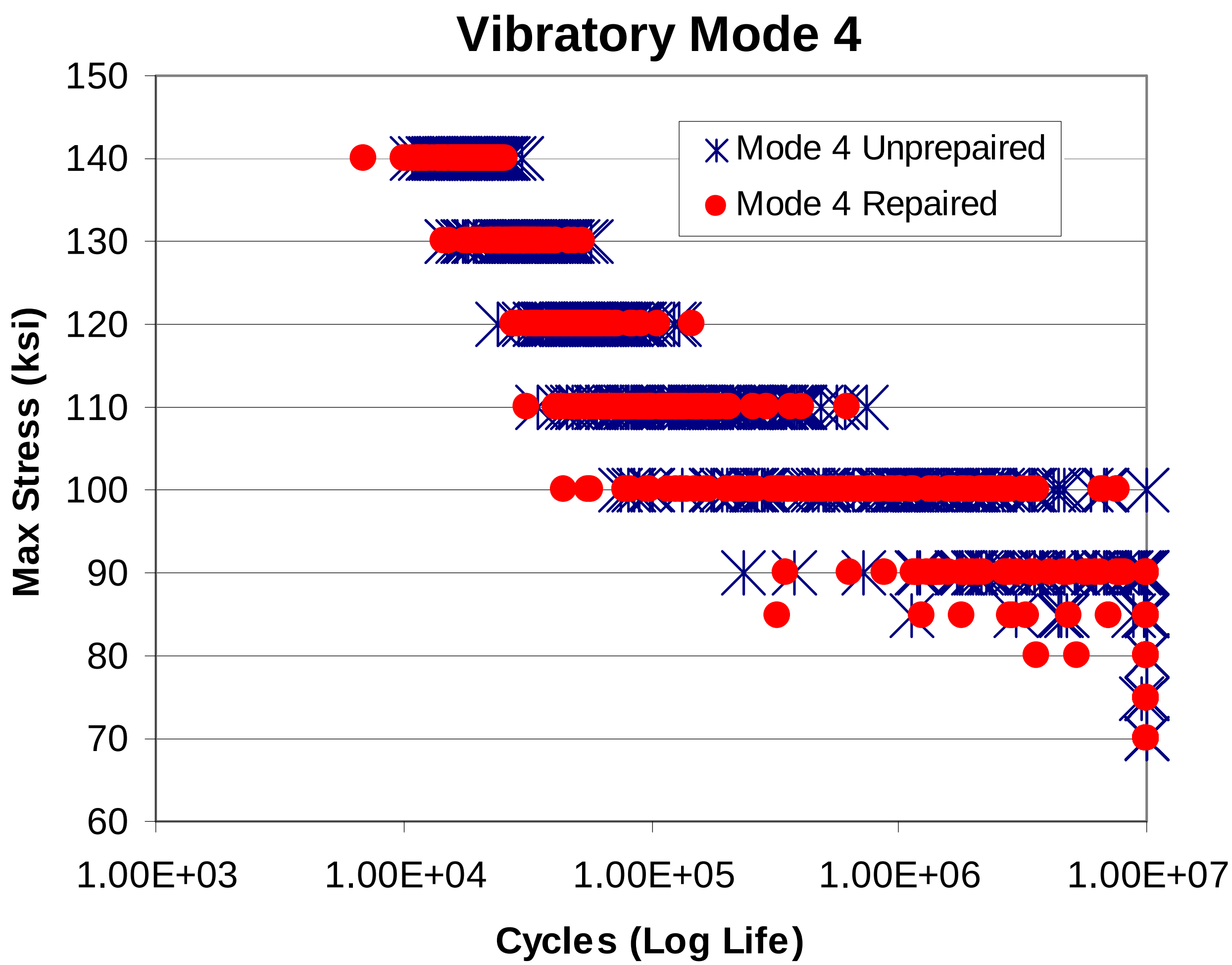
Specific FEA Models → Specific Micromechanical Models



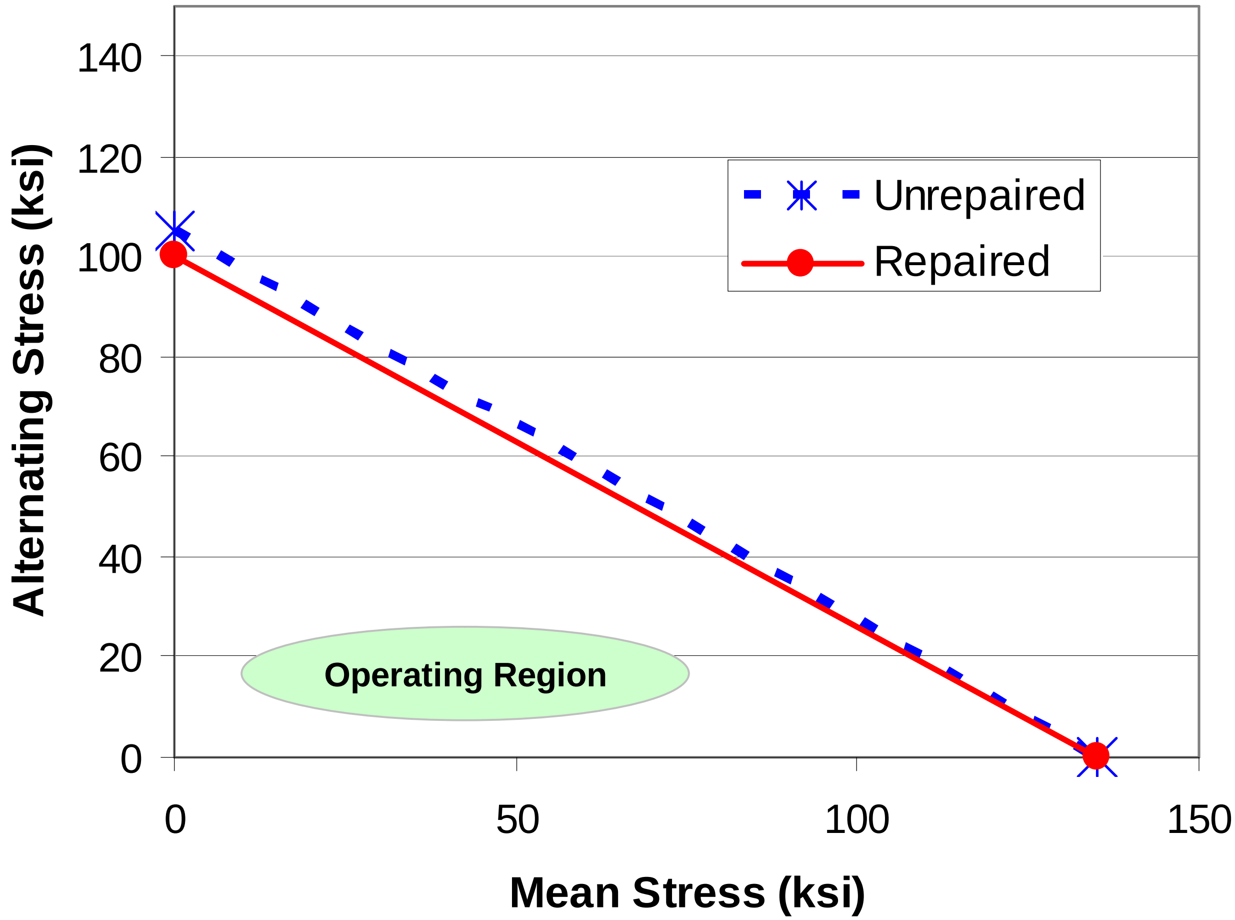
Fan Blade S/N Curves

- Vibratory modes 4 and 7 analyzed
- Fan Blade Durability Simulation
  - Produced S-N curves in each mode for ***100 blades at each stress level***

Repaired Blade as good as Pristine Blade

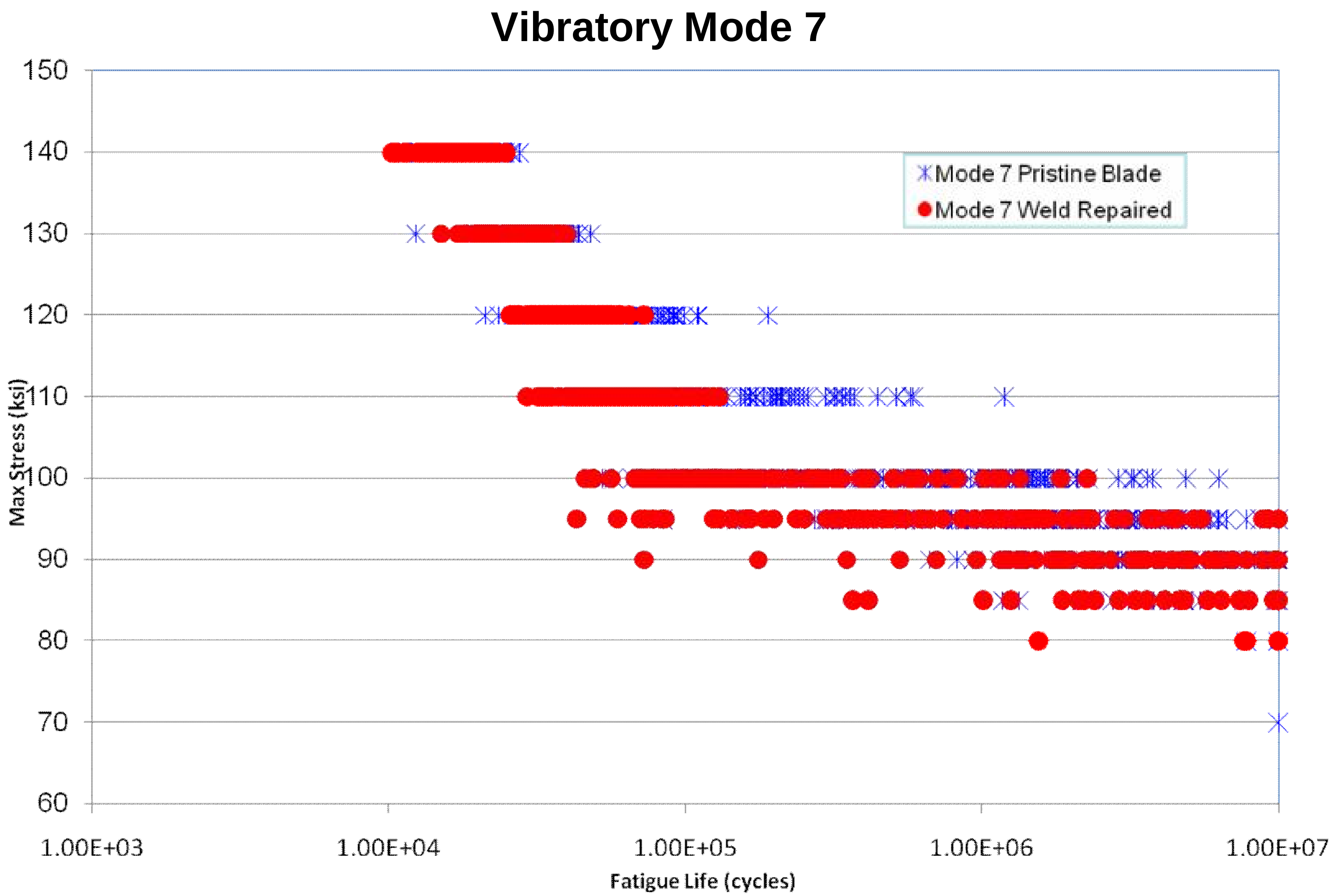


Mode 4: Goodman Diagram Acceptable

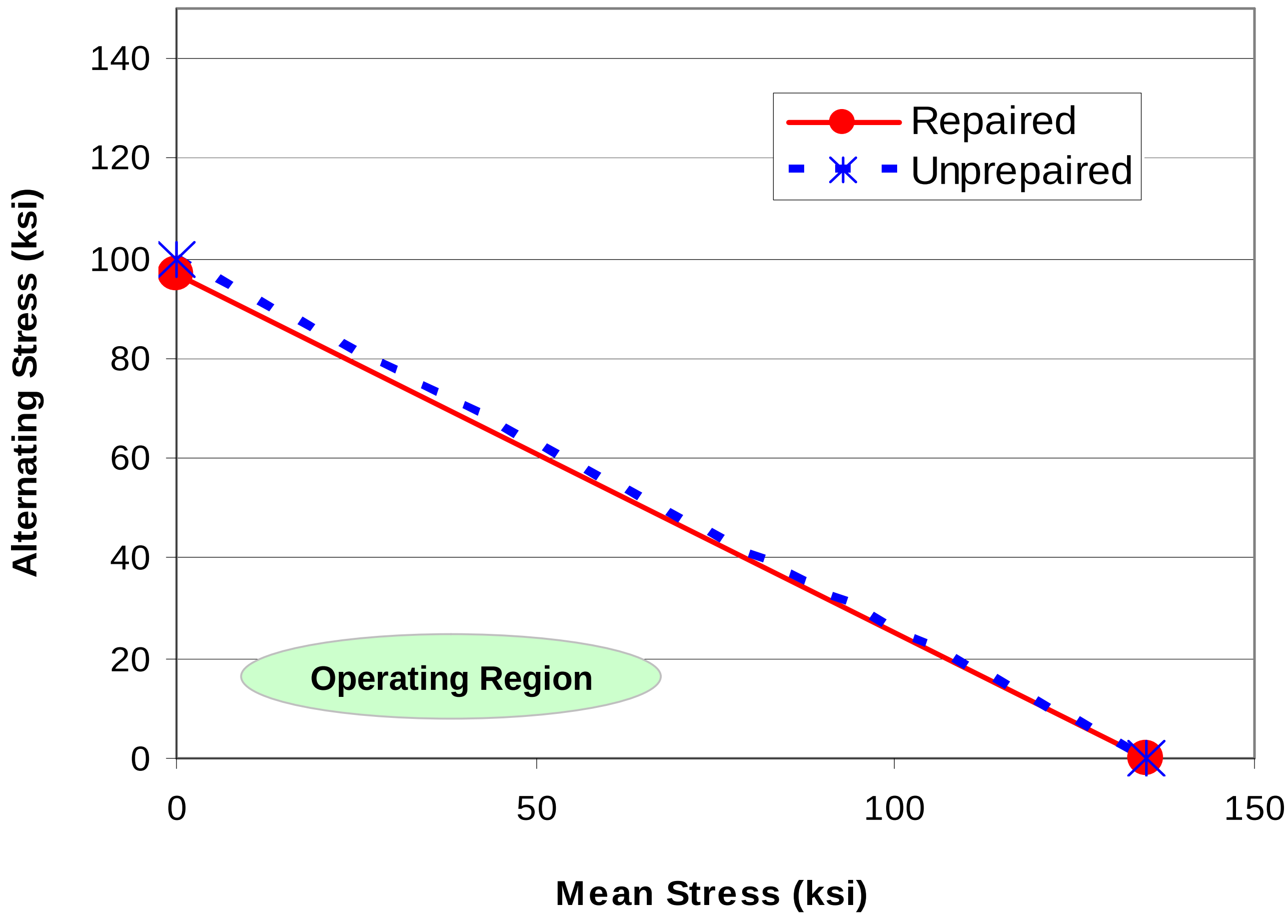


Operating Region is conservative for Mode 4 relative to predicted capability

Repaired Blade as good as Pristine Blade



Mode 7: Goodman Diagram Acceptable



Operating Region is also conservative for Mode 7 relative to predicted capability

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EB Airfoils – Summary

- At the blade operating conditions, the EB Airfoils repaired blade has similar fatigue durability as a pristine (unrepaired) blade.
- The fatigue lives of the blades in the vibratory modes of interest are statistically equivalent in terms of mean and standard deviation.
- VEXTEC Virtual Life Management (VLM) Simulations can be used in place of traditional time consuming and expensive physical testing presently associated with FAA certification.
- VEXTEC Simulations provide for virtual testing of an entire fleet under expected operating conditions instead of a limited number of physical specimen samples.

FAA Certification Process for Major Engine Repairs 14 CFR Part 33

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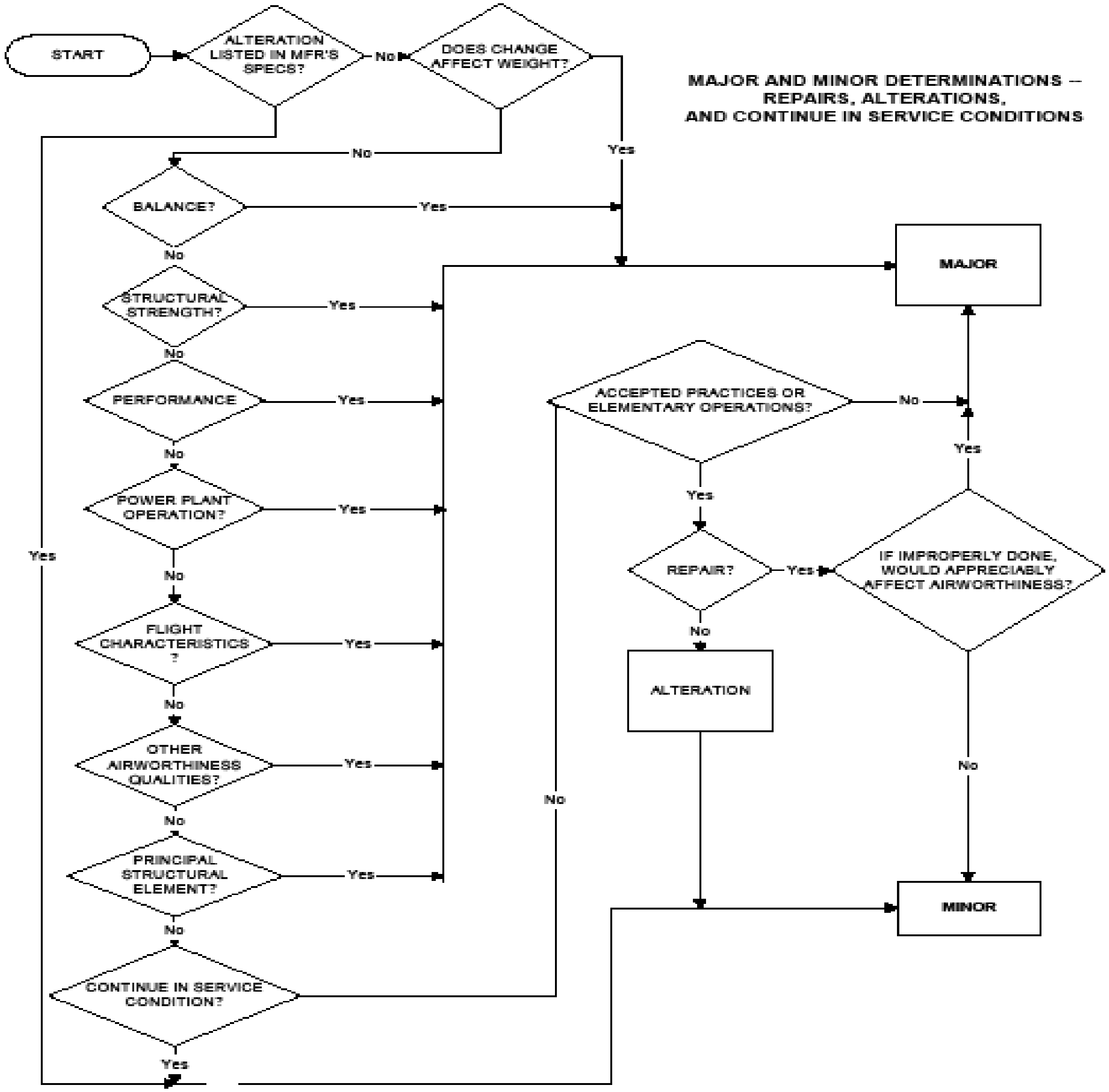
Applicable FAA National Policies and Guidance

- FAA Order(s) 8110.37D, 8110.54, 8300.14
- FAA Advisories AC 33.2B, AC 33draft XX, AC 33-75-1, AC 43-18 Chg 1, AC 43-210, & AC 120-77

APPENDIX 1. MAJOR AND MINOR DETERMINATIONS—REPAIRS, ALTERATIONS, AND CONTINUE-IN-SERVICE CONDITIONS

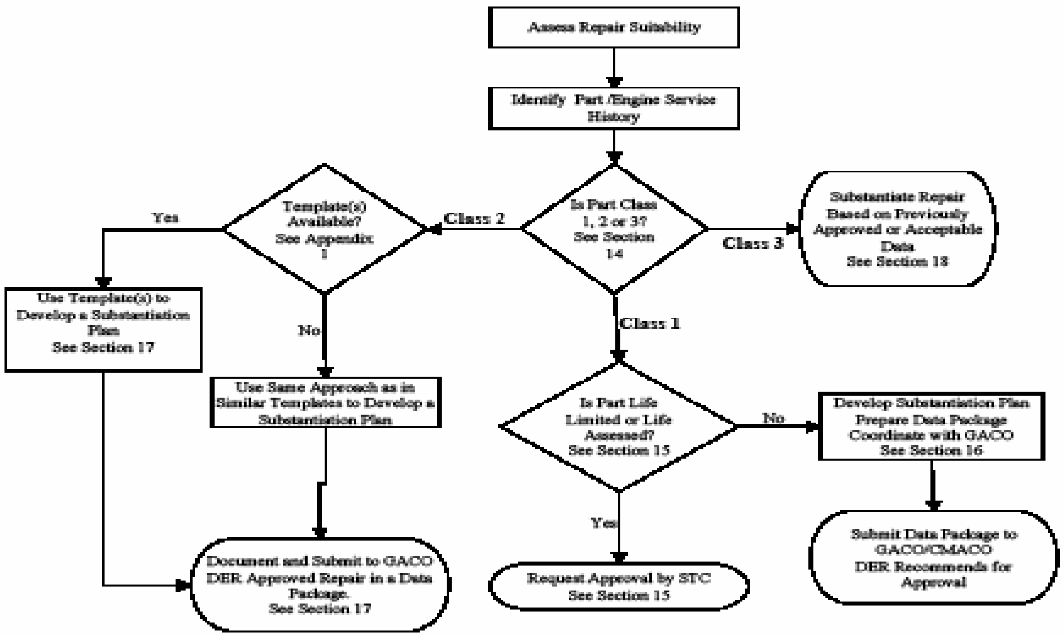


AC120-77

AC 120-77 Maint

DRAFT
(Public comments phase SEPTEMBER 2004)

FIGURE 1 - This flowchart outlines the decision process to help identify the requirements for the development and approval of a part repair or alteration.



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This document does not represent final agency action on this matter and should not be viewed as a guarantee that any final action will follow in this or any other form.

AC 33draft

AC33draft Appendix

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(Public comments phase SEPTEMBER 2004)

Template 3

REPAIR SUBSTANTIATION CHECKLIST – LOW PRESSURE COMPRESSURE (LPC) – HIGH PRESSURE COMPRESSURE (HPC) BLADE PART FAMILY

Categories of LPC / HPC Blade Part Family Repair. Determine which repair description best fit the repair proposal based. If no repair description is appropriate, contact the FAA Advisor for guidance.

CATEGORIES OF REPAIRS	REPAIR DESCRIPTION
1.	Strip and Re-coat Repair • This repair removes and replaces any and all types of coatings
2.	Weld or Braze Repair (excludes detail parts replacement) • This repair includes restoration of airfoil tip and chord length
3.	Weld or Braze Repair • This repair includes detail parts replacement
4.	Assembly or Disassembly • This repair removes and replaces detail parts without the use of permanent attachment techniques (i.e.: welding or brazing) but assembly is either bolted or riveted.
5.	Blend Repair
6.	Remove and Restore Anti-gallant Coating
7.	Dimensional Restoration by Coating or Plating
8.	Straightening, Re-twist or Re-forming Repair • This repair includes dent repair
9.	Surface Treatment Repair • This repair includes shot-peen, glass bead peen, vibratory tumble (e.g. restoration of surface finish/texture)

AC 33 draft XX – Template 3- LP/ HP Comp Blades

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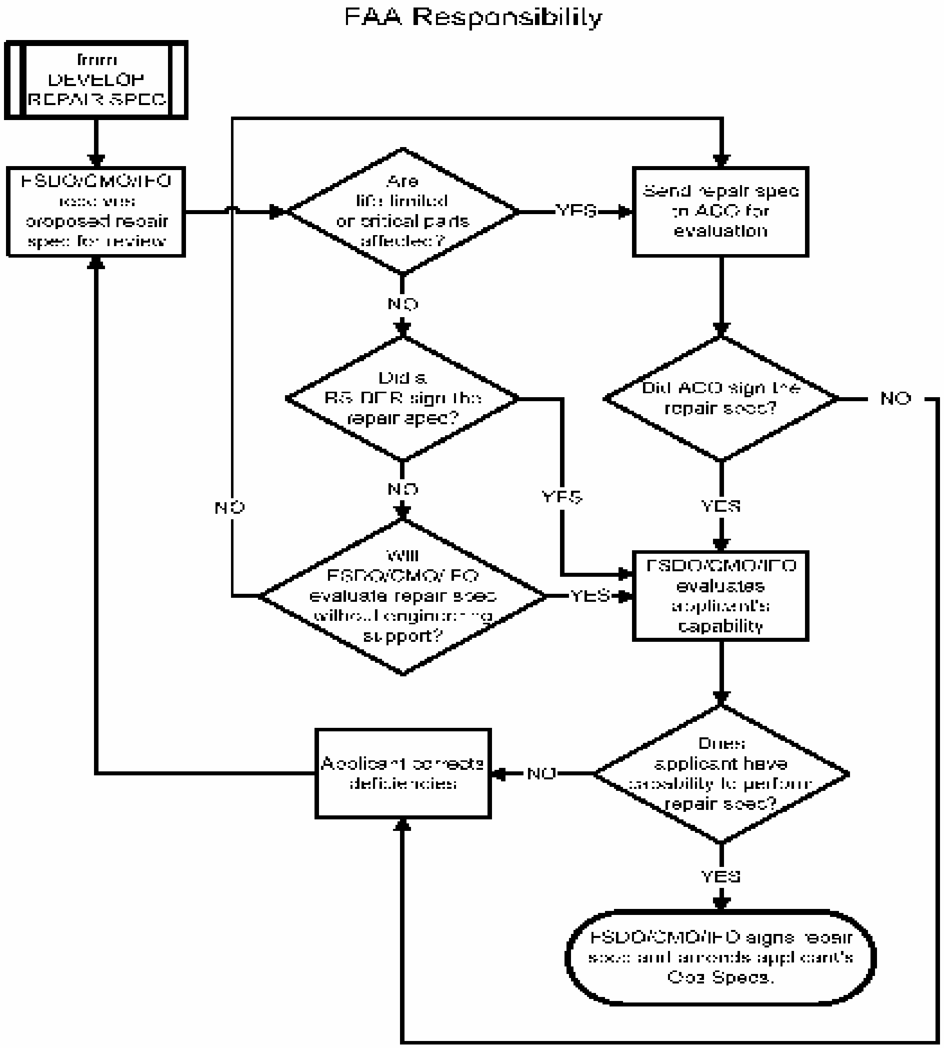
Appendix C. Flowchart: Approve a Repair Specification

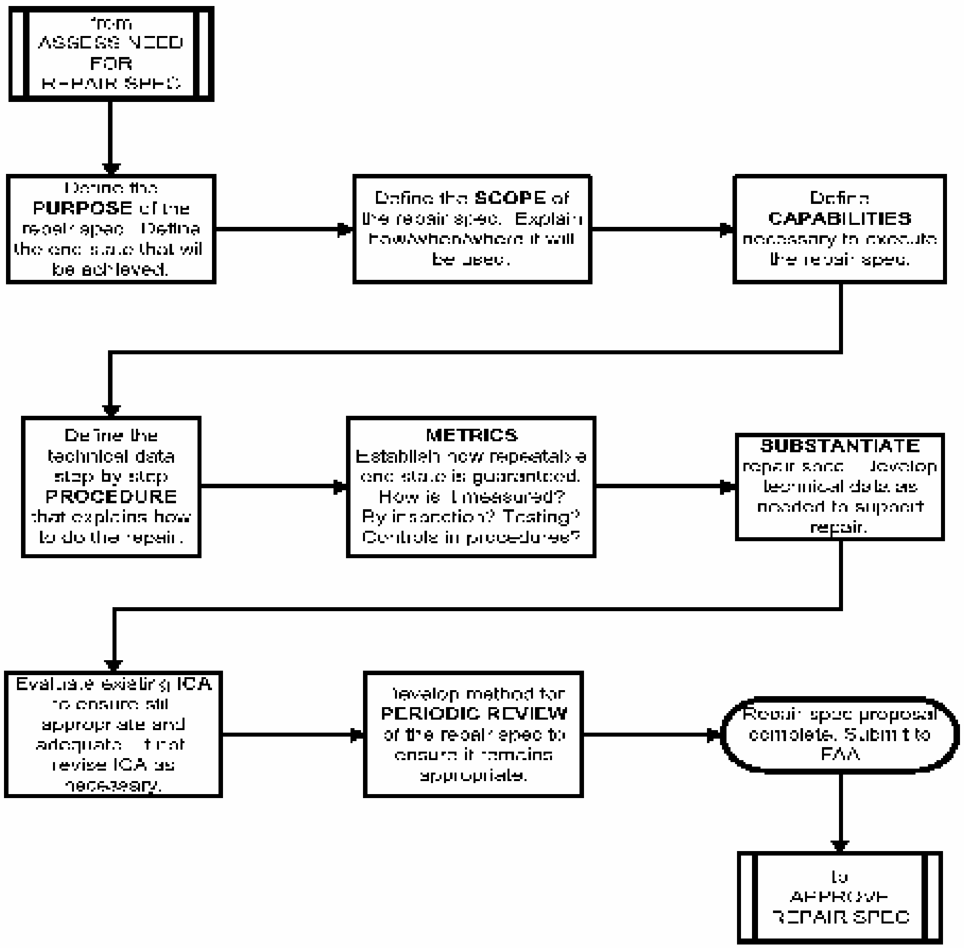


FAA Order 8300.14

FAA Order 8300.14

Appendix B. Flowchart: Develop a Repair Specification

Applicant Responsibility



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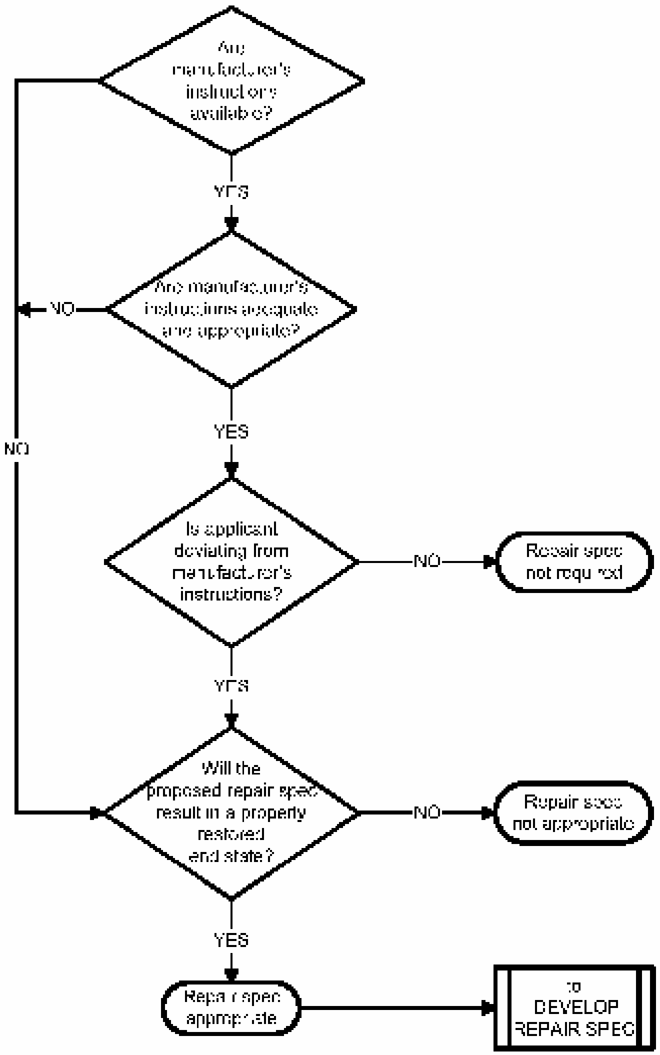
FAA Order 8300.14

Appendix A. Flowchart: Assess the Need for a Repair Specification

Applicant Responsibility



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FAA Order 8300.14

b. The FAA is Responsible for:

(1) Working with the applicant during the planning phase,

(2) Coordinating between offices within the FAA during planning and evaluation of the repair specification,

(3) Evaluating the applicant's capability to use the repair specification, and

(4) Evaluating and authorizing (or rejecting with explanation) the applicant's repair specification.

Figure 1-1. Roles of FAA and Applicant in Repair Specifications

Applicants:	FSDO/CMO/IFOs:	ACOs:	DERs:
• Determine if a repair specification is appropriate. • Contact the FSDO/CMO/IFO for planning repair specifications. • Develop repair specification. Include all applicable elements identified in chapter 2, par. 4. • Develop data to substantiate repair specification. • Utilize DERs as needed to support repair specification substantiation. • Submit proposed repair specification to the geographically responsible FSDO/CMO/IFO • Maintain capabilities in order to use authorized repair specification. • Perform periodic review of repair specification and revise as needed. **See App. A and B for more details.**	• Ensure compliance with regulations, programs, standards, and procedures on issuing authorization for repair specifications. • Help applicant in planning repair specification. • Evaluate applicant's capability to use repair specification. • Coordinate as needed with ACO for technical review and approval of data used to substantiate repair specification. • Issue or deny the repair specification authorization. • **See Ch. 2 and Appendix C flowchart for more details.**	• Evaluate and approve (or delegate) test plans and witness (or delegate) tests at their discretion. • When requested by FSDO/CMO/IFO evaluate and approve data used to substantiate repair specifications. • Approve the engineering aspects of repair specifications, when adequate. • Evaluate and approve, when adequate, all repair specs affecting life-limited or critical parts. • Evaluate and approve qualified candidates as Special Authorization Repair Specification DERs. • **See Chapter 3 for more details.**	• When appropriately rated and delegated by ACO: • Evaluate and approve test plans and witness tests. • Evaluate and approve data used to substantiate repair specifications. • Approve the engineering aspects of repair specifications, when adequate. • **See Chapter 4 for more details.**

FAA MAJOR REPAIR CERTIFICATION PLAN

1. Determine the certification basis of the component
2. Determine the Part Classification per FAA National Policy [AC 33 draft XX, AC 120-77 and AC 43-18]
3. Determine if any unresolved SDR's
4. Determine if any applicable AD's
5. Determine with your project ACO if CMACO coordination will be required
6. Determine extent of test plan and analysis
7. Determine with your ACO designee authority and involvement for the project data approvals
8. Communicate with cognizant FAA FSDO on project
9. Post Approval review

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Thank you!

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