Verification and Validation of Life Prediction Software – An Engineering Service Provider Perspective

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Infosys is a Global Business Consulting, IT and Engineering Services Company that provides business solutions to diverse industry segments

Partnering for Technology Led Business Transformation

- **150, 000+ Employees** of **75 different Nationalities** … and growing;
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- **18,000+ Engagements** across the Globe since 1995
- **95%+ Repeat Business**;
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- **Pioneered** and continually expanding the integrated **Global Delivery Model (GDM)**
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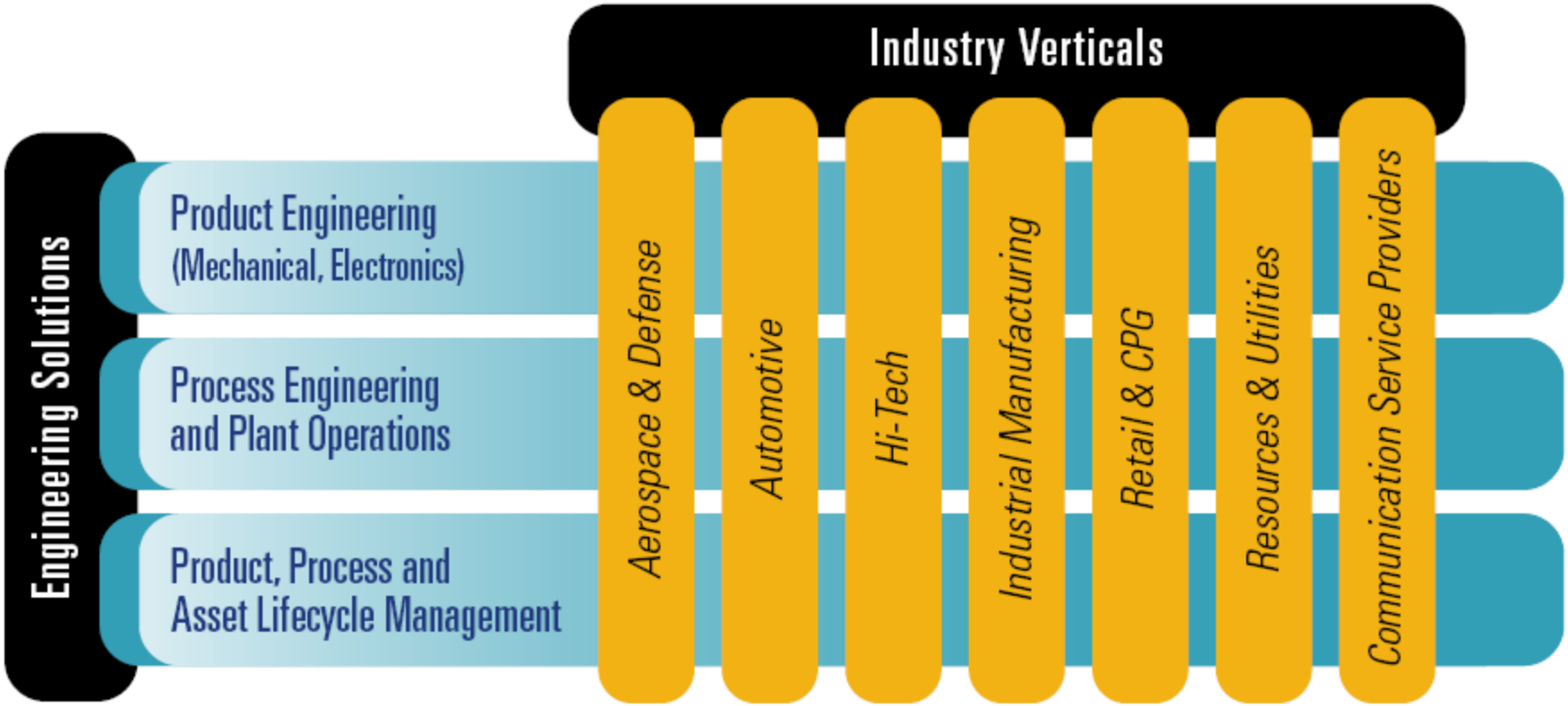
- Recognized **for highest standards for corporate ethics and governance**

Infosys offers a comprehensive portfolio of Engineering solutions across the Industry landscape…



Introduction

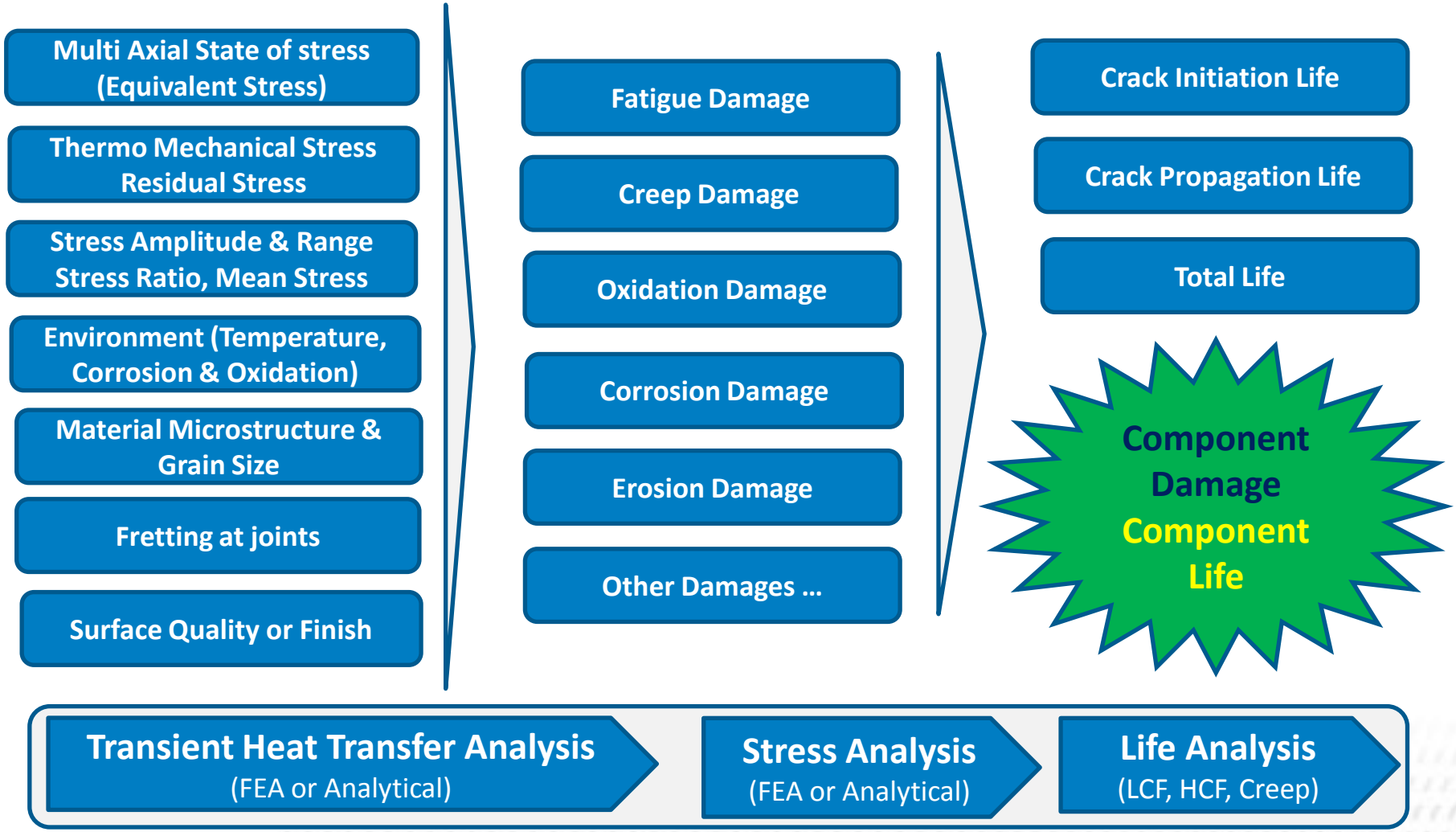
- Component life, Safety and Warranty are major design drivers for many industries
- Governed by Regulatory Bodies

Industry	Components	Design Drivers
Airframe	Wing/Fuselage skins, Frames, Ribs, Spar, Engine struts, Landing gear struts etc.	Low Cycle Fatigue, Sonic Fatigue, Thermo-Mechanical Fatigue, Damage tolerance, Engine shut wind milling frequency,…
Gas Turbine Engines	Gas turbine blades, Disks, Vanes, Casing assemblies etc.	Thermo-Mechanical Fatigue, Low Cycle Fatigue, High Cycle Fatigue, Creep, Corrosion,….
Automotive	Chassis, Super charger components, Suspension System, Brake pedal system etc.	Low/High Cycle Fatigue, Thermo mechanical Fatigue, Fretting Fatigue,…
Turbo-Machinery	Cylinder blocks, Cylinder heads, pistons, connecting rods etc	Low/High Cycle Fatigue, Thermo-Mechanical Fatigue, Creep, Corrosion, …
Heavy Engineering	Boilers, Pressure Vessels, Earth Moving equipment etc.	Low/High Cycle Fatigue, Thermo-Mechanical Fatigue, Creep, Corrosion, …
Marine	Ship hulls, Frames, Skins etc.	Low/High Cycle Fatigue, Corrosion, Erosion, …
Piping Industry	Pipelines, Storage Facilities, Pumps etc.	Fatigue, Corrosion, Erosion, …

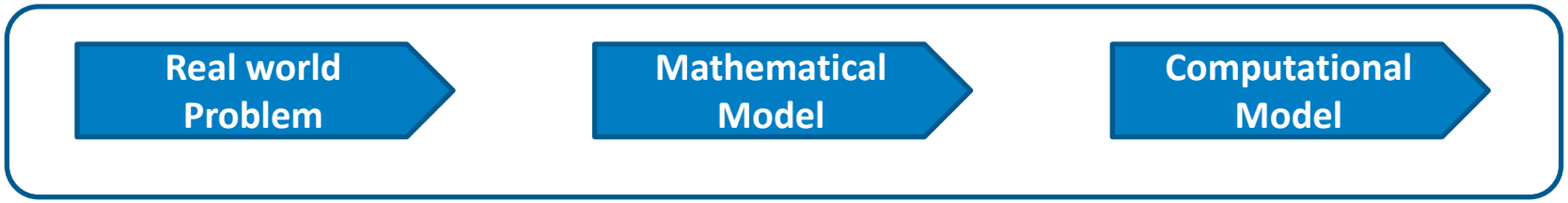
Fatigue, creep and environmental damages have significant influence on safety & warranty.
Life prediction software plays an important role in engineering components and systems.

Overview of Life Prediction Analysis

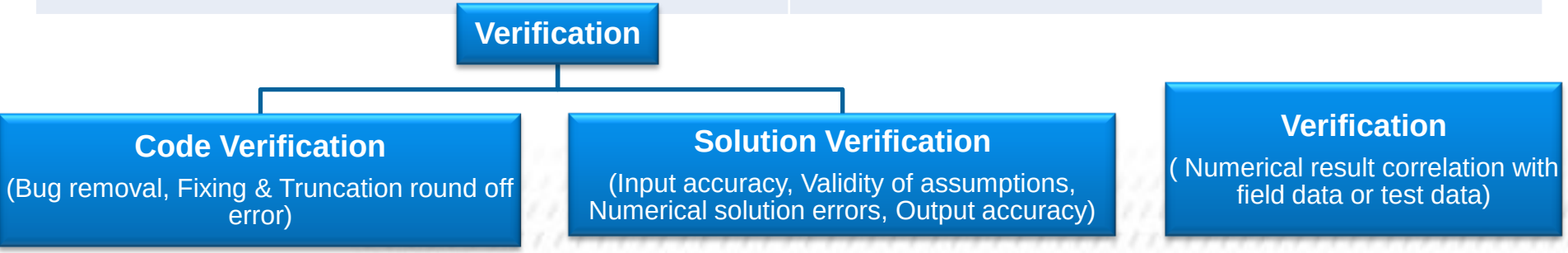
- Life predictions based on Fatigue and Damage Tolerance philosophies
- Commercial and In House Tools used for Life Predictions



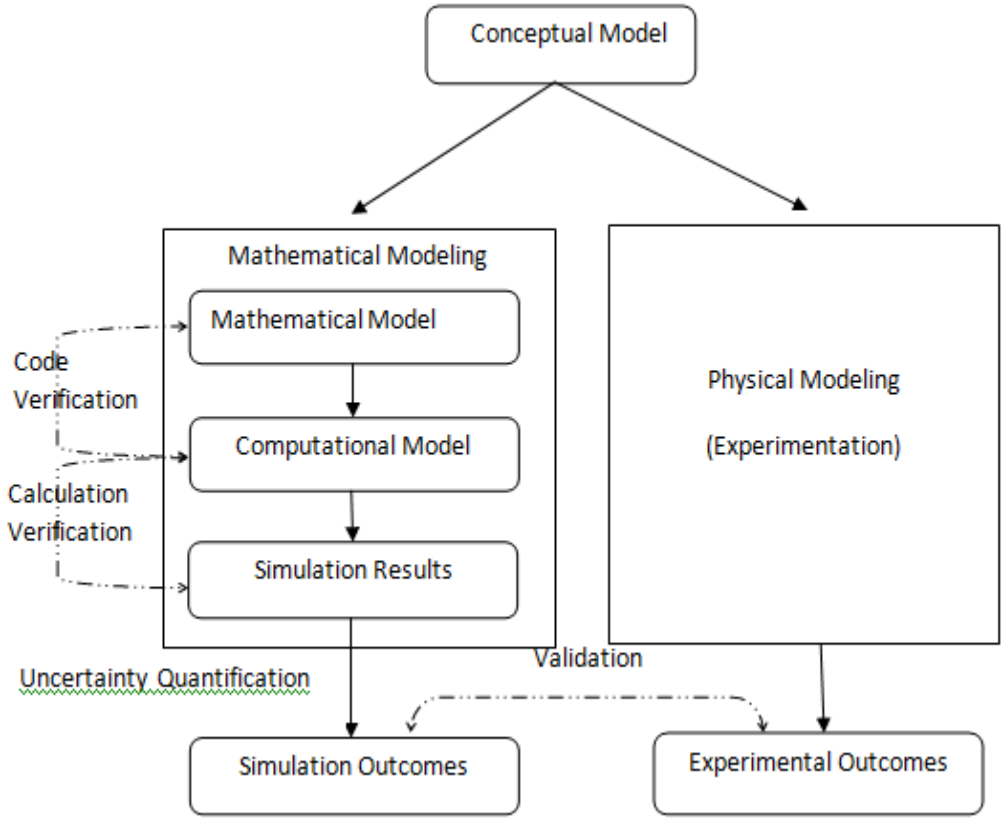
Verification and Validation of Life Prediction Software

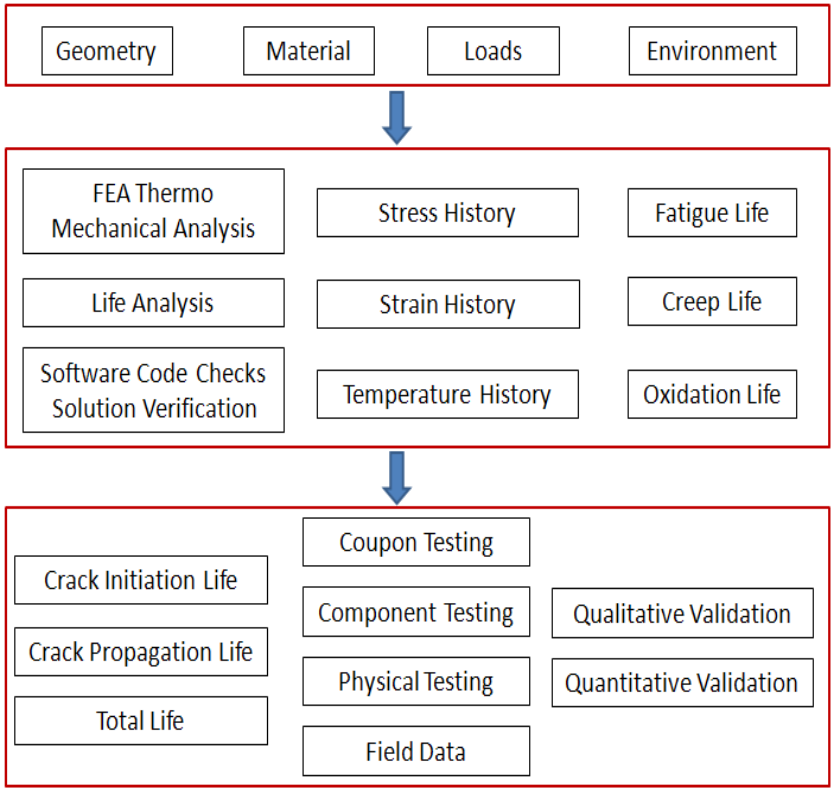


Verification	Validation
Verification is a process of determining a computational model accurately represents the underlying mathematical model and its solution	Validation is a process of determining the degrees to which a model is an accurate representation of the real world from the perspective of the intended uses of the model
Verification is the domain of mathematics	Validation is the domain of physics
Verification ensure that the computational model representing the conceptual model is solved correctly and accurately. Hence can be described as solving the equations correctly and accurately	Validation ensures that the mathematical model accurately relates to real world experimental test or field measurements. Hence can be described as "solving the right equations.
Verification precedes validation	



Verification and Validation of Life Prediction Software (Contd..)





Broad Verification and Validation Activities of Life Prediction Software

V &V Life Estimation Software Challenges of Engineering Service Providers

Life Estimation Software Development Service provider

Software Code Verification Challenges

- Handling of large size codes and its verification for various operating systems
- Verification for software and system upgrades
- Many functional and non-functional feature adds complexity to verification like
  - ✓ Options to build own fatigue, crack models
  - ✓ Incorporation of both probabilistic and deterministic life estimation models
  - ✓ Large database and integration with external data
  - ✓ Features to include all types of joints & welds
  - ✓ Features to import various FE results from COTS
  - ✓ Features to import physical test data & compare
  - ✓ Advanced post processing techniques
  - ✓ Ease of operation and Speed benchmarking

Life Analysis & Design Service Provider

- Multiple industries and multiple tools poses many challenges which include
  - ✓ In-depth knowledge of the structure under study, its operational/environmental conditions
  - ✓ Various fatigue and life estimation models
  - ✓ Various crack and crack growth models
  - ✓ Material characteristics
  - ✓ Physical test data and data analysis
  - ✓ Various joints & welds and its behaviour under fatigue loading
  - ✓ Multiple COTS and its formats
  - ✓ Deterministic and probabilistic models
  - ✓ Life assessment close to reality is challenge

V &V Life Estimation Software Challenges of Engineering Service Providers (Contd..)

Life Estimation Software Development Service provider

Solution Verification and Validation Challenges

- Many variables and large scatter in predicted life
- Simulation of number of benchmark problems for solution validation and solving discretization errors
- Assessment of many fatigue and life prediction parameters for their sensitivities
- Sample size & convergence criteria for probabilistic models
- Time consuming verification
- Non-availability of benchmark problems in each industry
- Non-availability of industry specific experimental data
- Non-availability of material data
- Inability to generalize effect of various parameters on fatigue and life estimation

Life Analysis & Design Service Provider

- ✓ Knowledge of customer specific methods, procedures and tools for fatigue and life estimation
- ✓ Need for people with multiple skill sets
- ✓ Consistency of units and applicable constants

Needs of Engineering Service Provider

Standardization of Methods	Standardization of Fatigue and life estimation methods and procedures for various industries interacting with OEMs, suppliers, service providers, MROs, certification bodies,……
Tools and Infrastructure	Standardization of life estimation tools; Guidelines and procedures to certify tools; Development/Enhancements of tools to incorporate new and advanced materials ,……
Physical Testing	Facilitate sharing of physical test data across industries; Provide benchmark test cases and its results for various industries for validation
Training and Certification	Facilitate training and certifications to people; Develop skills and create talent pool
Collaboration Environment	Facilitate and develop collaborating environments like portals, communities of practices, social networks to share best practices of fatigue and life estimation procedures
Research & Technology Development	Advanced research on fatigue and damage tolerance of new materials, composites, hybrids etc.; Integrated probabilistic and deterministic procedures and life estimation techniques

Concluding Remarks

- Engineering service providers work in multi-industry and multi-tool environments & provide analytical and testing services for life prediction of structural components
- Life prediction involves large number of variables compared to stress analysis and hence variability of predicted life values is likely to be high
- Accurate and reliable component life prediction can bring down maintenance, repair and replacement costs
- Major OEMs use in house life prediction tools and verify and validate these tools for intended usage
- Commercial life prediction software need to be validated for the intended usage
- V&V of life prediction software is laborious and time consuming
- Lack of standards and guidelines for life prediction software V&V poses many challenges for engineering service providers
- Bodies like ASTM can play important role in
  - Standardization of verification and validation for life prediction software
  - Recommendation of Life Analysis Methods, Tools and Infrastructure
  - Physical Testing Procedure coupon, component and assemblies
  - Life Prediction training and certification
  - Creation of collaboration environment
  - Research & Technology development

References

1. Schwer, L. E., An overview of the PTC 60/V&V 10 Guide for verification and validation in computational solid mechanics, The American Society of Mechanical Engineers (ASME)
2. Guide for the verification and validation of computational fluid dynamics simulations, AIAA G-07-1998
3. Standard for verification and validation in computational fluid dynamics and heat transfer, ASME V&V 20-2009
4. Zhuang, W. Z. and Swansson, N. S., Thermo-Mechanical Fatigue Life Prediction: A Critical Review, DSTO-TR-0609, 1998
5. Alam, A. M. and Remy, L., A lifetime prediction model for single crystal super alloys subjected to thermo mechanical creep-fatigue-oxidation damage 1, ICF11, pp1-6, 2005.
6. Thacker, B.H., M.C. Anderson, P.E. Senseny, and E.A. Rondriguez. The Role of Nondeterminism in Computational Model Verification and Validation. Proceedings of the AIAA/ASME/ASCE/AHS/ASC 46th Structures, Structural Dynamics, and Materials (SDM) Conference, Texas, April 2005.
7. Z. Hashin and A. Rotem, “A fatigue failure criterion for fiber reinforced materials,” Journalof Composite Materials, vol. 7, 1973, p. 448.
8. M. Kawai, S. Yajima, A. Hachinohe, and Y. Takano, “Off-axis fatigue behavior ofunidirectional carbon fiber-reinforced composites at room and high temperatures,” Journalof Composite Materials, vol. 35, 2001, pp. 545-576.
9. J. Awerbuch and H. Hahn, “Off-axis fatigue of graphite/epoxy composite,” Fatigue ofFibrous Composite Materials, San Francisco: ASTM, 1981, pp. 243-273
10. J. Petermann and A. Plumtree, “A unified fatigue failure criterion for unidirectionallaminates,” Composites: Part A, vol. 32, 2001, pp. 107-118.
11. Riha, D.S., Thacker, B.H., Hall, D.A., Auel, T.R. and Pritchard, S.D., “Capabilities and Applications of Probabilistic Methods in Finite Element Analysis”, Proceedings of the Fifth International Conference on Reliability and Quality in Design, August 11-13, 1999.

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