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

Sreedhar D S, Venkatesha K S, Sundaresan P, Ravi Kumar G V V
Engineering Services, Infosys Limited
Electronics City, Hosur Road, Bangalore, India
Contents

• Infosys Overview
• Introduction
• Overview of Life Prediction Analysis
• Verification and Validation of Life Prediction Software
• V&V life prediction software challenges of Engineering Service Providers
  ✓ Challenges of life prediction software development services
  ✓ Challenges of life predictions services
• Needs of Engineering Service Provider
• Concluding Remarks
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;
- 700+ Clients (Over 70% Fortune 2000 Names)
- 18,000+ Engagements across the Globe since 1995
- 95%+ Repeat Business;
- Revenue of US$6.99 Billion for FY12; Strong, stable financial position
- 48 Sales Offices & 54 Development Centers in 26 Countries

Pioneer and Innovator

- Pioneered and continually expanding the integrated Global Delivery Model (GDM)
- Metrics driven standards for assuring predictability;
- Project based, emphasis on well defined deliverables and performance metrics and a track record of beating industry averages with 93% of our projects on time and within budget
- Global delivery is pervasive, highest offshore work content, 3 year average > 70%
- Quality standards driven with ITIL, AS/EN9100, BS15000, CMM L5, Six Sigma, ISO 9001 and others
- 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

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

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

- Multi Axial State of stress
  (Equivalent Stress)
- Thermo Mechanical Stress
  Residual Stress
- Stress Amplitude & Range
  Stress Ratio, Mean Stress
- Environment (Temperature, Corrosion & Oxidation)
- Material Microstructure & Grain Size
- Fretting at joints
- Surface Quality or Finish

- Fatigue Damage
- Creep Damage
- Oxidation Damage
- Corrosion Damage
- Erosion Damage
- Other Damages ...

- Component Damage
- Component Life

- Crack Initiation Life
- Crack Propagation Life
- Total Life

- Transient Heat Transfer Analysis
  (FEA or Analytical)
- Stress Analysis
  (FEA or Analytical)
- Life Analysis
  (LCF, HCF, Creep)
## Verification and Validation of Life Prediction Software

### Verification
- Verification is a process of determining a computational model accurately represents the underlying mathematical model and its solution.
- Verification is the domain of mathematics.
- 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.
- Verification precedes validation.

### Validation
- 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.
- Validation is the domain of physics.
- 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 Processes
- **Code Verification** (Bug removal, Fixing & Truncation round off error)
- **Solution Verification** (Input accuracy, Validity of assumptions, Numerical solution errors, Output accuracy)
- **Verification** (Numerical result correlation with field data or test data)
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)


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.


Authors would like to thank senior management of engineering services practice of Infosys Mr. Srinivasa Rao P and Mr. Abhishek for their continuous support and encouragement