

MSC.Software Corporation

2 MacArthur Place
Santa Ana, CA 92707, USA
Tel: (714) 540-8900
Fax: (714) 784-4056
Web: <http://www.mscsoftware.com>

Tokyo, Japan

Tel: 81-3-3505-0266
Fax: 81-3-3505-0914

United States

MSC.Patran Support
Tel: 1-800-732-7284
Fax: (714) 979-2990

Munich, Germany

Tel: (+49)-89-43 19 87 0
Fax: (+49)-89-43 61 716

АНАЛИЗ ДОЛГОВЕЧНОСТИ И УСТАЛОСТНОЙ ПРОЧНОСТИ ПРИ ПОМОЩИ MSC.Fatigue

Курс лекций PAT318

Март 2002

DISCLAIMER

MSC.Software Corporation reserves the right to make changes in specifications and other information contained in this document without prior notice.

The concepts, methods, and examples presented in this text are for illustrative and educational purposes only, and are not intended to be exhaustive or to apply to any particular engineering problem or design. MSC.Software Corporation assumes no liability or responsibility to any person or company for direct or indirect damages resulting from the use of any information contained herein.

User Documentation: **Copyright© 2001 MSC.Software Corporation.** Printed in U.S.A. All Rights Reserved.

This notice shall be marked on any reproduction of this documentation, in whole or in part. Any reproduction or distribution of this document, in whole or in part, without the prior written consent of MSC.Software Corporation is prohibited.

MSC and MSC. are registered trademarks and service marks of MSC.Software Corporation. NASTRAN is a registered trademark of the National Aeronautics and Space Administration. MSC.Nastran is an enhanced proprietary version developed and maintained by MSC.Software Corporation. MSC.Marc, MSC.Marc Mentat, MSC.Dytran, MSC.Patran, MSC.Fatigue, MSC.Laminate Modeler, and MSC.MVision are all trademarks of MSC.Software Corporation.

All other trademarks are the property of their respective owners.

PAT318 Course Director:

Abdur.Razzaque@MSCSoftware.com

СОДЕРЖАНИЕ

<u>Section</u>	<u>Page</u>
1.0 Обзор методов анализа долговечности и усталостной прочности	
Company Overview	1-3
Course Schedule	1-9
MSC.Fatigue Features	1-10
MSC.Fatigue User Interface	1-11
Computer Aided Engineering Solutions	1-12
Durability Management	1-13
What is Durability	1-15
What Drives Durability Management	1-18
Traditional Approach without CAE: Build it, Test it, Fix it	1-21
Add CAE: Analyze and Optimize	1-22
Predicting Product Life 1 –Build and Use	1-23
Predicting Product Life 2 – Add Sign-off Testing	1-24
Predicting Product Life 3 – Add Simulation Testing	1-25
Predicting Product Life 4 – Add CAE	1-26
Integrated Durability Management Activities	1-27
Integration	1-28
Design Approaches	1-29
History of Fatigue – Early Days	1-30
A Short History of Fatigue -1	1-31
A Short History of Fatigue -2	1-34
A Short History of Fatigue -3	1-37
A Short History of Fatigue -4	1-39
Fatigue Life Calculation Methods	1-40
S-N Method Similitude	1-42
Crack Initiation (Strain –Life) Method Similitude	1-43
Crack Propagation Method Similitude	1-44
Fatigue Failure and Training	1-45

СОДЕРЖАНИЕ

<u>Section</u>	<u>Page</u>
1.0 Обзор методов анализа долговечности и усталостной прочности	
The Physical Basis for Fatigue	1-46
Slip and Stage I Growth	1-47
Initiation and Propagation	1-48
Use of Fatigue Technology	1-50
Fatigue Calculations in	1-51
Who does what Fatigue Calculations	1-52
Design against Fatigue	1-53
Exploiting Fatigue Analysis – the 5 box trick	1-55
Durability Tools for Analysis and Test	1-57
Integrated Approach to Durability	1-58
How Testing supports Analysis	1-59
How Analysis supports Testing	1-60
2.0 Обзор MSC.Fatigue	
What's in MSC.Fatigue	2.3 Life
Prediction Process	2-5
Elastic Stress or Strain Prediction Methods	2-7
Transient Dynamic Case	2.16
Frequency Domain	2.17
Vibration Fatigue Methods	2.18
FE Mesh Considerations	2.19
MSC.Fatigue Analysis Process	2.20
MSC.Fatigue Main Form	2.21
Geometry/Stress –Strain Results	2.24
Materials Database Manager	2.26
Loading Time History Database Manager	2.29
Stress Life Analysis (S-N)	2.32
Crack Initiation Analysis (E-N)	2.33

СОДЕРЖАНИЕ

Section

Page

2.0 Обзор MSC.Fatigue

Crack Growth Analysis (LEFM)	2.34
Post-Processing: Results	2.36
Post-Processing: design Optimization	2.39
Advanced Features: MSC.Fatigue Spot weld	2.41
MSC.Fatigue Software Strain Gauge	2.47
MSC.Fatigue Utilities	2.52
MSC.Fatigue Vibration	2.54
Multiaxial Fatigue	2.59

3.0 Интерфейс пользователя MSC.Fatigue

The Five Box Fatigue Analysis Trick	3.3
Overview of MSC.Fatigue Analysis Process	3.4
Running an FEA using MSC.Patran	3.5
Or Import the model and results	3.6
MSC.Fatigue Main Form	3.7
Loading Information Form	3.8
Material Information Form	3.9
Solution Parameters Form	3.10
MSC.Fatigue Files	3.11
Job Control Form	3.13
Results Form	3.14
Graphical Display of Fatigue Results	3.15

СОДЕРЖАНИЕ

Section

Page

4.0	Обзор MSC.Patran	
	Building a model using Patran	4.3
	Step 1 - Analysis Preferences	4.4
	Step 2 - Import/Build Geometry	4.6
	Step 3 – Creating an Analysis Model	4.7
	Step 4 – Perform the Analysis	4.12
	Step 5 – Evaluate Results	4.13
	Customization	4.15
	Starting MSC.Patran	4.16
	MSC.PATRAN File Option	4.17
	MSC.Patran Files	4.18
	The Main Form	4.19
	Typical Widgets used in MSC.Patran	4.21
	System Icons	4.22
	Entity Picking	4.24
	Viewing/Model Manipulation	4.29
	List Processor	4.30
	Entity ID Syntax	4.31
	MSC.Patran Standards	4.32
	Online Help	4.33

СОДЕРЖАНИЕ

Section

Page

5.0 Геометрическое моделирование

Topological Structures	5.3
Geometry Building Blocks	5.4
Importing, Exporting Geometry and FEM	5.12
MSC.Patran Database Access	5.17
File Export Options	5.21
Geometry Construction	5.24
Geometry Form Anatomy	5.25
Select Menu	5.26
Geometry Entities – Point	5.27
Geometry Entities – Curve	5.33
Geometry Entities – Surface	5.44
Geometry Entities – Solid	5.59
Solid Geometry Boolean	5.66
Geometric Entities – Coordinate frame	5.67

6.0 Построение КЭ сеток

Finite Element	6.3
Introduction to Finite Element Meshing	6.5
MSC.Patran Meshing Algorithms	6.6
Iso (Mapped) Mesher)	6.7
Paver (Free) Mesher for Surfaces	6.10
Iso (Mapped) Mesh Vs. Paver (Free) Mesh	6.12
Meshing Control using Mesh Seeds	6.16
Tetrahedral Mesher TET Mesh	6.17
Sweep Mesher	6.19
Association of Finite Elements to Geometry	6.21
Finite Element Form	6.22

СОДЕРЖАНИЕ

Section

Page

6.0 Построение КЭ сеток

Where to Start with Meshing	6.23
Mesh Seeding	6.24
Meshing Parametric Solids	6.28
Tetmeshing Solids	6.29
Tetmeshing from 2D Elements surrounding Volume	6.31
FEM Creation Tool Transform	6.32
Sweep Meshing	6.33
FEM Creation Tool Element/Edit	6.35
Equivalence – Tie Elements Together	6.37
Irregularity Checks	6.40
FEM Editing – Node/Move	6.41
FEM Editing – Node/Offset	6.42
FEM Editing – Node/Project	6.43
Node Editing Example	6.44

7.0 Визуализация

Viewing	7.3
Transformations of View	7.4
Fit Model to Screen and Select New Center	7.5
Select Corners (Local Zoom) and Zoom by Factor	7.6
Specify View using Angles	7.7
User Defined Views	7.8
General Clipping Planes	7.9

СОДЕРЖАНИЕ

Section

Page

8.0 Группы

- Introduction to Groups 8.3
- Example of Groups 8.4
- Groups Terminology 8.5
- Group Manipulation 8.6
- Creating a Group 8.7
- Method of Creating a Group 8.8
- Display a Group 8.9
- Modifying Groups 8.10
- Moving or Copying between Groups 8.11
- Setting Current Group 8.12
- Transforming Groups 8.13
- Deleting Groups 8.14
- Notes on Groups 8.15

9.0 Отображение модели (Display)

- Display 9.3
- Entity Type Display 9.4
- Group Display 9.5
- Plot/Erase 9.6
- Highlighting 9.8
- Geometric Attributes 9.9
- Finite Element and LBC/Element Property Display Attributes 9.11
- Titles Example 9.12
- Spectrums 9.13

СОДЕРЖАНИЕ

<u>Section</u>	<u>Page</u>
10.0 Установка параметров решения (Analysis Setup)	
Analysis Setup	10.3
Setting up the Analysis	10.4
Results Translation Back into MSC.Patran	10.5
Reading a MSC.Nastran Bulk Data File	10.6
11.0 Списки	
Lists Overview	11.3
How to Create a List	11.4
Boolean Operations	11.5
Boolean Example	11.6
12.0 Графические окна	
Viewports	12.3
Why use Viewports	12.4
Creating Viewports	12.5
Current Viewport	12.6
Viewports and Groups	12.7
13.0 Результаты	
Results Introduction	13.3
The Results Main Form	13.6
Results Plot Types	13.7

СОДЕРЖАНИЕ

13.0 Результаты

Quick Plot Form	13.11
Quick Plot Animation Form	13.12
Results Post-processing Procedure	13.13
Select Results Form	13.14
Target Entities Form	13.16
Display Attributes Form	13.18
Plot Options Form	13.19
Fringe Plot Options	13.22
Deformed Shape Plots	13.32
Vector Marker Plot	13.33
Marker Display Attributes	13.34
Create Results Form	13.35
X-Y Graph Plotting	13.37
Text Report Writer	13.38
Freebody Results	13.41
Creating a Range	13.43
Results with Multiple Viewports	13.46
Results Animation	13.47
Quick Plot Animation	13.49
Animation Control Setup	13.50
Animation Options Form	13.51
Animation Control	13.52
Setting up Non-Quick Plot Animation	13.53

СОДЕРЖАНИЕ

14.0 Построение графиков

X-Y Plot	14.3
XY Plot Terminolgy	14.4
Curve Data from File	14.5
Scale and Range	14.6
Titles	14.7
Modify Display Parameters	14.8
Modify XY Window	14.9
Modify Curve	14.10

15.0 Файлы MSC.Patran

MSC.Patran Files	15.3
Reverting your Database	15.4
Rebuilding a Database	15.5
MSC.Patran Files - Generating Hardcopy Plots	15.6
MSC.Patran Files – Customization Files	15.7

СОДЕРЖАНИЕ

16.0 Теория методов многоциклового усталости

Stress-Life (S-N) Theory	16.3
Some Definitions	16.4
S-N Analysis	16.5
S-N Curve	16.6
S-N Approach	16.9
S-N Curves	16.11
Component S-N Curves	16.15
S-N Method Similitude	16.18
Variable Amplitude Loads –Miner’s Rule and Rainflow Counting	16.20
Miner’s Rule – Block Loading	16.21
Nonlinear Damage Theory	16.26
Rainflow Cycle Counting	16.29
Analysis Route – An Overview	16.35
Influence on Fatigue Life	16.36
Mean Stresses Corrections	16.40
Component Size	16.46
Type of Loading	16.49
Notches	16.51
Surface Treatment & Finish	16.63
How do we get pre-compression?	16.69
Stress Life in MSC.Fatigue	16.70
Goodman based Factor of Safety (f)	16.71
Summary of Total Life Method	16.73
Example Problem	16.75
Exercise	16.82

СОДЕРЖАНИЕ

17.0 Теория методов малоциклового усталости

Strain-Life (E-N) Theory	17.3
Strain Life Testing	17.8
The S-N and E-N Life Curves	17.11
Materials Characterization	17.12
The Bauschinger Effect	17.16
Masing's Hypothesis (Stabilized) Hysteresis Loop)	17.18
Strain Control Vs. Stress Control	17.20
Cyclic Softening	17.21
Cyclic Hardening	17.22
Cyclic Stress-Strain Curve Determination	17.23
Strain Life Results from a series of LCF Tests	17.27
Coffin-Manson-Basquin Equation	17.29
Transition Fatigue Life Calculation	17.31
Variability in Material Behaviour and the effects on Fatigue Life Prediction	17.33
Variable Amplitude Loads – Counting Cycles	17.34
Rainflow Counting and Stress/Strain Space	17.38
Mean Stress Corrections	17.40
Exercise	17.44
Elastic-Plastic Correction and Local Geometry	17.45
Use of K_f in Strain Life Modeling	17.48
E-P Correction including K_f	17.50
Refinement to the Neuber Method	17.51
Seeger-Beste Method and Mertens-Dittman Method	17.54
Surface factors	17.58
Stress Strain Tracking, Neuber Analysis, Material memory and Damage Calculation	17.60
Example Problem: E-N Analysis of a “Spider”	17.73
Exercise	17.77

СОДЕРЖАНИЕ

18.0 Анализ долговечности в условиях сложного многоосного нагружения

Why do Multiaxial Fatigue Fatigue Calculations?	18.3
The Life Prediction Process E-N Approach	18.4
Tensor Representation of Stress State	18.7
Stress Tensor Rotation	18.10
Principal Stresses (and Strains)	18.11
Free Surface Stresses	18.16
Multiaxial Assessment	18.17
Example: Near Proportional Loading	18.18
Example: Non-Proportional Loading	18.21
Effect of Multiaxiality on Plasticity, Notch Modeling and damage Modeling	18.23
Exercise	18.24
Deviatoric Stresses	18.25
Yield Criteria	18.26
Equivalent Stress and Strain Methods	18.30
Some Equivalent Stress/Strain Criteria	18.32
S-N with Equivalent Stress	18.33
E-N with Equivalent Strain	18.34
Comments on Equivalent Strain Methods	18.38
ASME Pressure Vessel Code	18.40
Notch Rules for Proportional Loading	18.43
Extending Neuber to Non-Proportional Loadings	18.49
Multiaxial Fatigue Theory	18.55
MSC.Fatigue Multiaxial Analysis	18.58
Normal Strain Method	18.61
Shear Strain Method	18.62

СОДЕРЖАНИЕ

18.0	Анализ долговечности в условиях сложного многоосного нагружения	
	Smith-Topper-Watson-Bannantine Method	18.63
	Fatemi-Socie Method	18.64
	Wang-Brown Method	18.66
	Dang-Van Method	18.72
	Summary of Approach	18.80
	A Multiaxial Assessment	18.81
	Exercise	18.85
19.0	Распространение усталостных трещин	
	Fatigue Crack Propagation (LEFM) Method	19.3
	Crack Stress Concentration	19.6
	Modes of Crack Opening	19.7
	Mechanics of Cracks	19.8
	K Controlled fracture	19.12
	Stages of fatigue Crack Growth	19.14
	Factors Affecting Crack Growth Rate	19.19
	Crack Tip Plasticity	19.20
	Mean Stress (R-Ratio) Effects	19.22
	Variable Amplitude Loads	19.24
	Environment	19.25
	Calculating Lifetimes	19.26
	Crack Growth Laws	19.27
	MSC.Fatigue Crack Growth Analysis Steps	19.29
	Summary of Approach	19.32
	MSC.Fatigue Crack Growth Analysis - Applications	19.33
	Example Problem: Crack Propagation Analysis	19.34
	Exercise	19.40

СОДЕРЖАНИЕ

20.0	Прогнозирование долговечности соединений, выполненных точечной сваркой	
	Motivation	20.3
	Structural Stress Based Method	20.5
	How do we model Spotwelds	20.7
	Structural Stress Calculations	20.9
	Fatigue Properties – Typical Test Specimen	20.11
	Damage Calculation Procedure	20.13
	Results Postprocessing Options	20.14 Polar Plot
	of Damage	20.16
	Example Problem: A Spotweld Analysis	20.17
	Exercise	20.22
21.0	Программный датчик деформаций в MSC.Fatigue	
	Software Strain Gauge	21.4
	Correlation Applications	21.6
	Welded Structure Analysis	21.8
	Gauge Definition	21.10
	Implementation	21.11
	Example Problem: A Software Strain gauge	21.12
	Correlation Techniques	21.16
	Exercise	21.17

СОДЕРЖАНИЕ

22.0	Виброусталость	
	Overview	22.3
	Benefits of Vibration Fatigue	22.5
	How do we Calculate Damage	22.6
	What is a PSD	22.10
	Expected Zeroes, Peaks and Irregularity Factor from a PSD	22.12
	Probability Density Functions (PDF'S)	22.14
	Dirlik Solution	22.15
	Other Solution Methods	22.16
	Summary of Features	22.18
	Example Problem: Vibration Fatigue	22.20
	Exercise	22.26
23.0	Утилиты MSC.Fatigue	
	Utilities Overview	23.3
	PTIME (Time History Manager)	23.5
	Time History Manipulation Tools	23.6
	Graphical Editing of Data – “GED”	23.13
	Time History Analysis/Statistics	23.14
	Filtering	23.17
	Frequency Analysis	23.19
	Peak Valley regeneration – “REGEN”	23.12
	Fatigue Analysis (local or test based) Tools	23.23
	Other Fatigue Related Tools	23.24
	Time Correlated Damage – “TCD”	23.26
	Stress Concentration Library “KTAN”	23.27
	Rosette Analysis – “SSA”	23.28
	Data Conversion and other Utilities	23.29
	Exercise	23.30