

# Subject Index

## A

- Advisory Group for Aerospace Research and Development (AGARD), 11
- Airborne stores
  - fatigue spectra development for, 135–149
  - approach, 137
  - background, 135–137
  - data base development, 140, 143
  - data compaction and spectra development, 143–145, 148
  - outlook for, 148
  - service life for, 137, 139
- Aircraft
  - fatigue loading on
    - tactical, 19–21
    - transport, 21–22
  - service load spectra
    - characteristics of, 219–220
- Analytical load spectra, 49
- ASTM standards
  - E 647–83, 125–126, 211
  - E 647–86, 127
  - E 1049–85, 150
- ASTM variable-amplitude test results, 173, 175
- Automated procedure
  - for creating flight-by-flight spectra, 79–98
  - data base of cyclic loads, 80–81
  - flight profiles, 86–88
  - form of data storage, 82, 84, 86
  - load factor spectrum, 93
  - load factor spectrum generation, 88–89, 91–93
  - load factor to stress transformation, 93, 95–96
- Automobile industry, application of histogram summarization techniques in, 199

## B

- Bandwidth effects, and racetrack filtering, 180–189

- Bandwidth measures, and distributions of
  - local mean and amplitude, 181–182
- Binary-coded marker loading, 228–229
- Block loading, implications of, 177–178
- Block size control, 91–93

## C

- Car, 8
- Center block structure, modeling of, 71–72
- Combined net stress and *K*-control, 219
- Common Load Sequences (COLOS), 99
- Component stress analysis, 198
- Computer-aided design (CAD), 198
- Computer-controlled servohydraulic test machines, 3
- Computers, impact of, on engineering design, 198
- Constant-amplitude fatigue test, 3
- Constant amplitude loading
  - crack growth rate under, 213
  - K*-controlled testing under, 216
- Corrosion fatigue behavior
  - relevance of, to standard load spectra, 111–113
  - in-air fatigue studies, 111–112
  - seawater tests, 112–113
- Crack closure, 112
  - measurement of, 213, 226–228
  - relationship between stress level and, 218–219
- Crack growth analysis, 173
- Crack growth calculations, comparison of, with and without sequence effects, 191–193
- Crack growth retardation effects, 49
- Crack initiation life estimates, 173
- Creep, 75
- Cross-channel synchronization of data, 199–200
- Cumulative damage analysis, usefulness of rainfall analysis in, 220, 223, 225–226
- Cycle grouping, 56–57
- Cyclic loads, data base of, 80–81

**D**

Distinct overloads, 193–195  
 dK-da, significance of, 213–216

**E**

Eight-step blocked program test, 3, 15  
 Electrode potential, 113  
 Engine disk, loading standardization of, 20  
 Engineering design, impact of computers on, 198  
 Engineering structures, service load environment for, 211  
 ENSTAFF (ENvironmental fighter aircraft loading STandard For Fatigue evaluation, 8, 14, 17, 20, 26  
 European approaches in standard spectrum development, 17–35  
 European Working Group on Standardized Loading Sequences for Offshore Structures (*see* Wave Action Standard History (WASH) Working Group)

**F**

Fail-Safe, impact of spectrum loading threshold on, 229  
 FALSTAFF (Fighter Aircraft Loading Standard for Fatigue), 5–6, 8, 11–12, 17, 20, 28, 81, 84, 100  
   short, 8, 12  
 Fatigue analysis, narrow-band load models and sequenceless, 178–180  
 Fatigue crack growth, in rotating disk evaluated with TURBISTAN mission spectra, 121–134  
 Fatigue crack propagation testing  
   under complex load sequences, 211–230  
     binary-coded market loading, 228–229  
     crack closure measurement, 226–228  
     *K*-control under spectrum loading, 213–219  
     on-line fatigue cycle analysis, 219–220, 223, 225–226  
 Fatigue damage and crack growth  
   variable-amplitude load models for, 172–197  
     analysis including sequence effects, 195  
     analysis neglecting sequence effects, 195  
     background, 173–177

bandwidth effects and racetrack filtering, 180–189  
 distinct overloads, 193–195  
 implications of block loading, 177–178  
 narrow-band load models for sequenceless fatigue analysis, 178–180  
 sequential simulation of random loadings, 189–191  
 timing for including sequence effects, 196  
 without sequence effects, 191–193

Fatigue loading  
   description of, 18  
   use of time domain techniques for, 18  
 Fatigue spectra development  
   for airborne stores, 135–149  
     approach, 137  
     background, 135–137  
     data base development, 140, 143  
     data compaction and spectra development, 143–145, 148  
     outlook for, 148  
     store service life, 137, 139  
 Fatigue studies, application of histogram summarization techniques in, 199  
 Fatigue testing, development of wave action standard history (WAVE) for, tubular structures in North Sea, 99–120  
 Felix, 4–5, 12–14, 17, 24, 26, 161–162  
   analysis of, 155–156  
   general description of, 156–157  
   mini, 8  
   upper/lower bound analysis of, 160  
 Fighter aircraft loadings, 175  
 Finite element analysis (FEA), 198  
 First principal component analysis, 72  
 Flight-by-flight spectra  
   automated procedure for creating, 79–80  
   data base of cyclic loads, 80–81  
   flight profiles, 86–88  
   form of data storage, 82, 84, 86  
   load factor spectrum, 93  
   load factor spectrum generation, 88–89, 91–93  
   load factor to stress transformation, 93, 95–96  
 From/to format data base, 92–93

**G**

Gauss, 6, 8, 10  
 Gaussian distribution, 103, 106

Gaussian sea-state distribution, 117  
GAUSSIAN STANDARD, 26  
Gauss-Markow processes, 190–191  
Ground-Air-Ground (GAG) transition, 19–20  
Ground-to-Air Cycle (GAC), 219  
Gumbel distribution, 106  
Gust loads, 45  
Gust velocity, 81

## H

Helicopter fatigue loading spectra, 22–24  
simplified analysis of, 150–171  
analysis of helix and felix, 155–156, 159–160  
details of upper/lower bound calculations, 166–168  
local strain approach, 151–155  
peak/valley reconstruction of helix, 161, 163–165  
Helix, 4–5, 8, 12–14, 17, 24, 26, 158–161, 163  
analysis of, 155–156  
general description of, 156–157  
and helicopter fatigue loading spectra, 155–157  
detailed local strain analysis of, 159–160  
upper/lower bound analysis of, 160  
mini, 8  
peak/valley reconstruction of, 161, 163–165  
rain-flow cycle counting for, 155  
range-mean matrix for, from rain-flow cycle counting, 156  
upper/lower bound analysis of, 160  
Histogram summarization techniques, 199  
Histogram-type summaries, 198

## I

In-air fatigue studies, 111–112  
Industrieanlagen-Betriebsgesellschaft (IABG), 6, 10  
In-flight load sequences  
characteristics and elements  
center block, 68–69  
final block, 69  
initial block, 68  
characteristics and elements of, 67–69  
Instrumentation/Navigation (I/N) fighter spectrum, 215

## J

Jet transport airframe fatigue test spectra, 36–37  
base mission selection, 44  
conclusions on, 60, 63–64  
governing parameters, 39, 42, 44  
load/flight sequence generation, 55–56, 58–59  
load spectra representation, 46, 49–50  
operational condition representation, 45–46  
philosophy of, 37–39  
supporting tests, 59–60  
test flight type definition, 50, 52–53, 55

## K

K-control  
combined net stress and, 219  
procedure for, 216–219  
under spectrum loading, 213–219

## L

Laboratorium für Betriebsfestigkeit (LBF), 6–8, 10  
Laplace distribution, 102–103, 109, 117  
Level crossing counting methods, 28  
Linear elastic fracture mechanics, 173  
Linear wave theory, 102  
Load acquisition exercises, in engineering design, 198–199  
Load cycles, 79–80  
Load factor, 80–81  
Load factor spectrum, 93  
Load factor spectrum generation  
basic procedure, 88  
highest spectrum loads, 89  
exceedance format data base, 89, 91  
range/mean format data base, 91–92  
from/to format data base, 92–93  
program controls and operations, 89  
Load factor to stress conversion, 93, 95–96  
Loading standard, structure of, 31–32  
Load sequence, 91  
characteristics and elements of in-flight, 67–69  
definition of typical, 69–71  
fatigue crack propagation testing under complex, 211–230  
binary-coded market loading, 228–229  
crack closure measurement, 226–228  
K-control under spectrum loading, 213–219

Load sequence, fatigue crack propagation testing under complex—*Continued*  
 on-line fatigue cycle analysis, 219–220, 223, 225–226  
 generation of, 117, 119  
 reconstruction of, 32  
 and rainflow counting, 33  
 Load statistics, after racetrack filtering, 182–187  
 Local strain approach, 152  
 to helicopter fatigue loading spectra, 151–153  
 bounds on mean stress effect, 154–155  
 life calculations neglecting mean stress effects, 153–154  
 life predictions by, 153  
 Low cycle fatigue, 173  
 Low cycle fatigue (LCF) damage, 65  
 Low-load truncation, 91–93

## M

Maneuver and taxi loads, 45–46  
 MANITURB, 122  
 Markov chain approach, 110, 115  
 Markov matrix, and fatigue loading, 28–29  
 Markov matrix-type techniques, 199  
 Mean stress, 3  
 Mean stress effects  
 life calculations neglecting, 153–154  
 simplified life calculations for upper/lower bounds on, 154–155  
 Miner's rule, 65  
 MINITURB, 122–123, 125–132, 134  
 Minitwist, 8, 10, 17, 22, 26  
 Mission mix problem, solution to typical, 72, 74  
 Morison's equation, 101–103, 117  
 Multiaxis fatigue problems, tracking time in service histories for, 198–210  
*M V Famita*, 100

## N

Narrow-band load models, and sequence-less fatigue analysis, 178–180  
 NASTRAN finite element program, 95  
 National Aeronautical Laboratory, fatigue crack propagation testing at, 211–230  
 Net stress effects, significance of, 213–216  
 Neuber's rule, 153  
 North Sea, development of wave action standard history for fatigue testing relevant to tubular structures in, 99–120

## O

Offshore structures  
 fatigue loading in, 24–26  
 fatigue testing relevant to, in North Sea, 99–120  
 Omission dilemma, 5  
 On-line fatigue cycle analysis, 219–220, 223, 225–226  
 using rainflow cycle counting technique for, 229  
 On-line spectrum editing, 213, 219, 225

## P

Pagoda-roof counting method, 28–31  
 Palmgren-Miner analysis, 150–151, 153, 173, 179  
 Parametric crack growth simulations, 173  
 Paris regime, 225  
 Peak counting methods, 28  
 Peak-picking algorithm, 202  
 Peak/valley reconstruction of helix, 161, 163–165  
 Pothole event, original and condensed history versions of, 203  
 Power spectral density functions, 107–108  
 Power Spectral Density (PSD), 26  
 Proving ground event, signal segment of, 202

## R

Racetrack damage, comparison of predicted and simulated, 188–189  
 Racetrack filtering, 173  
 bandwidth effects and, 180–189  
 load statistics after, 182–187  
 Racetrack threshold selection and comparison with rainflow counting, 189  
 Rainflow analysis, 32–34  
 usefulness of, in cumulative damage analysis, 220, 223, 225–226  
 Rainflow counted histograms, 199  
 Rainflow counting, 28–31, 150, 154  
 for Helix, 155–156  
 on-line fatigue cycle analysis using, 229  
 racetrack threshold selection and comparison with, 189  
 Random loadings, sequential simulation of, 189–191  
 Random load models, 173  
 Range counting methods, 28  
 Range/mean format data base, 91–92  
 Range-mean matrix, for Helix from rainflow cycle counting, 156  
 Range/mean tables, compilation of, 84

Range-pair-range counting method, 28–31  
 Rayleigh distribution, 100, 102, 117, 179, 180–181, 183  
 Resonances, effect of, and fatigue testing, 106–108  
 Rotating disk, evaluation of fatigue crack growth in, with TURBISTAN mission spectra, 121–134

## S

Safe-Life, impact of spectrum loading threshold on, 229  
 Sea-state  
   distribution of, 105–106  
   duration of, 106  
   evolution of, 115  
   load sequences in, 116  
   spectral density function in, 115  
 Seawater fatigue testing, 112–113  
 Segmentation technique, 217  
 Sequence effects  
   analysis including, 195  
   analysis neglecting, 195  
   comparison of crack growth calculations with and without, 191–193  
   determining inclusion of, 196  
 Service histories, tracking time in, for multiaxis fatigue problems, 198–210  
 Service load environment, for engineering structures, 211  
 Servohydraulic testing machines, advent of, 211  
 Sink speed, 81  
 Society of Automatic Engineers (SAE)  
   sponsored test series, 5–6  
 Spectrum editing, 219, 225  
 Spectrum loading  
   *K*-controlled testing under, 216–217  
   *K*-control under, 213–219  
 Spectrum loading threshold, future application of, 229  
 Spindle arm, 205  
 Standardized stress-time histories, 3–4  
   applications for, 7  
   listing of, 8  
   present availability of, 7–8, 10–14  
   requirements to be met by, 4–6  
   under development, 14–15  
 Standard load sequence, requirements for, 66–67  
 Standard load spectra  
   corrosion fatigue behavior relevant to, 111–113  
   in-air fatigue studies, 111–112  
   seawater tests, 112–113

Standard spectrum development  
   data analysis techniques, 28  
   level crossing counting methods, 28  
   peak counting methods, 28  
   rainflow counting method, 28–31  
   range counting methods, 28  
   European approaches in, 17–18  
   loading characteristics, 18–19  
   for helicopters, 22–24  
   for horizontal axis wind turbines, 24  
   for off-shore structures, 24–26  
   for tactical aircraft, 19–21  
   for transport aircraft, 21–22  
   loading standards, 26–28  
   synthesis procedures, 31–34  
 Stress amplitude, 3  
 Stress corrosion cracking, 112  
 Stress level, relationship between crack closure and, 218–219  
 Stress transfer functions, 80  
 Structural damage accumulation, 79  
 Supporting crack growth tests, 38, 59–60

## T

Time, tracking, in service histories, for multiaxis fatigue problems, 198–210  
 Time domain techniques, 18  
 Transport aircraft spectrum loading, 215  
 Truncation dilemma, 5  
 Tubular structures, development of wave action standard history for fatigue testing relevant to, in North Sea, 99–120  
 TURBISTAN, 14, 26  
   basic approach in the development of, 65–66  
   characteristics and elements of in-flight load sequences 67–69  
   definition of typical load sequence, 69–71  
   description of load sequences, application problems, 74–75  
   modeling the center block structure, 71–72  
   requirements for standard load sequence, 66–67  
   solution to typical mission mix problem, 72, 74  
   cold, 4, 5, 8, 13, 17, 20–21, 123  
   fatigue crack growth in rotating disk evaluated with, 121–134  
   hot, 4, 8, 14, 18, 21, 76  
 TWIST (Transport Wing Standard Spectrum), 5, 7–9, 17, 22, 26, 38, 50, 52–53

## U

- Upper/lower bound calculations, 166–168
  - details of, 166–168
  - simplified for, on mean stress effect, 154–155

## V

- Variable-amplitude load models
  - for fatigue damage and crack growth, 172–197
    - analysis including sequence effects, 195
    - analysis neglecting sequence effects, 195
  - background, 173–177
  - bandwidth effects and racetrack filtering, 180–189
  - comparison of crack growth calculations with and
    - distinct overloads, 193–195
  - implications of block loading, 177–178
  - narrow-band load models and sequenceless fatigue analysis, 178–180
  - sequential simulation of random loadings, 189–191

timing for including sequence effects, 196

without sequence effects, 191–193

Variable-amplitude loads, 172

Variable-amplitude testing, use of, in automobile industry, 15

## W

Walz, 8, 14–15

WASH (Wave Action Standard History), 8, 14, 18, 25

development of, for fatigue testing relevant to tubular structures in North Sea, 99–120

Wave Action Standard History (WASH) Working Group, 4, 99, 100

Wave loading, of tubular members, 100–105

Weibull distribution, two-parameter, 117

Wind turbine, fatigue loading on horizontal axis of, 24

Wirsching's equation, 107–8, 110, 115

WISPER (WInd turbine reference SPeEctRum), 8, 14, 18, 24