

Fatigue Method Survey

Revision A

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Introduction

I recently performed an informal survey where I simply asked engineers which fatigue methods they used. 61 engineers responded. I then tabulated the keywords for software, methods and standards in Tables 1, 2 and 3, respectively. If someone used the same keyword more than once, then I only counted it one time per respondent.

I did mention in the survey that I use ASTM E 1049-85, section 5.4.4, for time domain rainflow counting. I then feed the results into the Miner's cumulative damage summation. And also that I use the Dirlik, Single Moment, and similar spectral moment-derived methods for frequency domain fatigue calculations. So some engineers replied that they use the same methods.

In addition, I have recorded their responses in Appendix A, minus their names and company. The respondents represent both U.S. and Europe. They are also from a number of industries including aerospace, automotive, wind power, nuclear energy, offshore, etc.

Results

Code	Respondents
Nasgro (fracture)	8
nCode	8
Unspecified Nastran	5
Ansys	4
Fe safe	4
MSC Nastran	3
ABAQUS	3
Patran	2
Femap	2
NX Nastran	2
Autodesk Nastran	1
Comsol Multiphysics	1
FEMFAT	1
WAFO	1
Matlab	1

Method	Respondents
Miners	30
Rainflow	18
Dirlk	9
Steinberg	7
Rayleigh	5
Coffin-Manson	2
Engelmaier	2
Goodman	2
Lalanne	1
VRS	1
Jiao and Moan	1
Alpha 0.75	1
Benasciutti	1
Soderberg	1
Paris-Erdogan	1
Hobbacher	1
ESDU	1
Fatemi-Socie	1

Reference	Respondents
ASTM E 1049	5
ASME BPVC	2
DNV RP-C203	2
MMPDS-01	2
RTCA DO-160	1
BS7910	1
API-RP-579	1
ESA Requirements	1
DNV-OS-J101	1
Eurocode 3	1
GOST 25.502-79	1
GOST 23207-82	1
ISO TS 10811	1
Welding Institute	1
GSFC-STD-7000	1
AISI	1
AISC	1
MIL-HDK-5	1

APPENDIX A

1	<p>For the SLS Core Stage, we are using heritage cycle counting programs from the shuttle program for coupled loads low frequency transient cycle counting. For high frequency, we are using the Dirlik methodology for specific calculations of selected items. For first cut general approximations, we use simplified Rayleigh approximations.</p>
2	<p>I have been using both nCode Glyphworks (Lalanne) and Vibration Research's Fatigue Damage Spectrum. Both tools apply Miners rule with an SN curve to yield very similar results.</p>
3	<p>There are 3 major commercial codes the North American industry seems to use the most, nCode, fe-safe and MSC</p> <p>As far as frequency based fatigue calculations this is very specialized, I have used the Dirlik method most of the time, in fact I believe this is the default algorithm with nCode and fe-safe. I have also used Kam and Dover, Wirsching and Spectral-Moment Derived methods like the one developed by Neil Bishop who I believe still works for MSC.</p>
4	<p>Here's how I've been doing it (random vibe, mainly per RTCA DO-160 sec 8):</p> <ol style="list-style-type: none">1. Determine unit stresses from FEA model.2. From PSD, generate VRS.3. From VRS, use 1 sigma, 2 sigma, and 3 sigma acceleration loads to determine corresponding stresses.4. Determine number of cycles at each stress level, assuming the system oscillates at the W_n for the duration.5. Miner's rule, summing damage for each stress level.

5	<p>We use a similar method to what you have described below... Rainflow analysis and Miner's cumulative damage summation for duty cycle type load spectra. For random vibration we generally use a normal distribution for calculation of 1-, 2- and 3-sigma stresses, although we also sometimes use the Rayleigh distribution. Again, Miner's rule is used for calculation of cumulative damage.</p> <p>In recent months, we have begun investigating N-Code as an add-on for our Ansys FEA package.</p>
6	Fe-safe
7	<p>Our structures are generally not fatigue critical, so the fatigue approach that we use tends to be conservative. We typically use the qualification level PSD and duration along with the Steinberg three band approach, assuming a Gaussian distribution. Then we sum up the Miners cumulative damage summation for all 3 excited axes and apply a 4x safety factor on fatigue life.</p>
8	<p>I am using Ansys Workbench-15 to determine 1-sigma stress in Random Vibration analysis and max stress in Harmonic Vibration analysis. Then I feed results into the Miners cumulative damage calculator (Excel spread sheet of my creation).</p>
9	I use ASTM E 1049 for rainflow counting also.
10	We use nCode glyphworks/designlife
11	We only perform fatigue analysis for the circuit boards designed in house. The fatigue analysis is using Steinberg's book, no analysis tool is used.
12	The only fatigue calculations are made are simply based on S-N curves from quasi-static tests (5 Hz, compressive and tensile for porous materials, 3-point bending in composites). This is not high cycle fatigue.
13	IMAT – in house tool for crack initiation. ASTM E 1049 for rainflow counting.

14	<p>I am working in the Oil & Gas industry. Here is a summary of the fatigue assessment methods we use.</p> <p>Stationary, Narrow-banded, Gaussian process: Classical spectral fatigue formula for Rayleigh distributed stress ranges</p> <p>Stationary, Bimodal, Gaussian process: Spectral fatigue method of Jiao and Moan (Bimodal response is typical for floating offshore structures)</p> <p>Stationary, Arbitrary Bandwidth, Gaussian process: Dirlik's method or alpha.75 method</p> <p>Stationary, Narrow-banded, nongaussian process: Classical spectral fatigue formula with kurtosis correction</p> <p>Stationary, Arbitrary Bandwidth, nongaussian process: Time-Domain Rainflow counting according to ASTM 1049-85. Could also use spectral method suggested by Benasciutti)</p> <p>Arbitrary data: Time-Domain Rainflow counting according to ASTM 1049-85</p> <p>Arbitrary data, going beyond S-N fatigue: crack growth using fracture mechanics according to BS7910, API-RP-579, or ASME BPVC, Section VIII Div 3, Article KD-4</p>
15	<p>We use several:</p> <ul style="list-style-type: none"> MSC Fatigue & Dirlik Method S-N & e-N Miner's Cum. Damage 3-Band Technique (popularized by Steinberg?) Spreadsheets (using combination of above)

16	I performed transient dynamic analysis using ABAQUS. The results of elastic force in connection (modeled as elastic spring) were then analyzed by rainflow counting. I then used simple form of Miner's rule to justify fatigue life of the connection.
17	In principle our company (as supplier to mainly ESA) complies with ESA requirements. However in practice, in the cases that we cannot avoid to do a fatigue analysis, we mainly use 'back of the envelope calculations' based on stress values from FEA and estimated number of cycles in combination with Miner's Rule.
18	We are using DNV RP-C203 and in most of the cases design for infinite fatigue life. In case we have to estimate fatigue life, we use Dirlik.
19	1) At our company we used the following software for fatigue analysis: FEMAP with NX Nastran. 2) Methods we use: a. Maritime Industry. For steel structures we usually use: Eurocode 3: Design of steel structures – Part 1-9: Fatigue. This code a bit conservative... but we know it and for weld structures it works Ok. b. For some parts in agricultural industry we use some specific GOSTS: i. GOST 25.502-79. Calculations and strength test in machinebuilding. Methods of mechanical test of the materials. Methods of fatigue tests. ii. GOST 23207-82. Calculations and fatigue tests. Calculation methods of fatigue resistance.
20	During my PhD research I worked on stochastic fatigue analysis using Dirlik and spectral moments. For the implementation I used Comsol Multiphysics along with Matlab. This is an article of this research: Sobczyk, K., Perros, K., Papadimitriou, C. (2010). "Fatigue Reliability of Multi-Vibratory Degrading Systems under Random Loading." Journal of Engineering Mechanics (ASCE), 136(2), 179-188.
21	We use ISO TS 10811-2 & TS 10811-1.
22	I'm not able to provide a useful answer here, as the vibration fatigue analysis that I have done over the past few years has focused exclusively on EEE part solder joints. We have the classic Steinberg semi-empirical methods as the basis, though we have implemented some of our own methodologies for predicting deflections in PWAs and have developed a non-linear solution process for high solder strains.

23	<p>1- For sinusoidal vibration:</p> <ul style="list-style-type: none"> - Use FE Nastran code to calculate Von Mises stress. - Use S-N curve to determine fatigue life based on the VM stress. - If there is no S-N curve, Coffin-Manson equation is used to determine fatigue life. - Apply Miner's rule to calculate CDI (cumulative damage index) <p>2- For random vibration:</p> <ul style="list-style-type: none"> - Use FE Nastran code to calculate Von Mises stress. - Use S-N curve to determine fatigue life based on the VM stress. - If there is no S-N curve, Coffin-Manson equation is used to determine fatigue life. - Apply Miner's rule to calculate CDI (cumulative damage index) using 3-band method (1, 2, and 3 sigma) or using an equivalent sigma value (e.g. 2.2-sigma for AL 6061-T6).
24	<p>Structural dynamics always get stuck feeding nasgro but the final outputs and what they do with them are a mystery to me (the materials goons always ride herd over nasgro).</p>
25	<p>I do very little fatigue analysis. On the occasions I do, I use our software - Autodesk Nastran. It is a relatively simple Soderberg Line calculation.</p>
26	<p>We don't do much fatigue analysis on satellite side and even less on the missile side. Primarily because composite materials don't lend themselves to a rational fatigue solution. When we have something where fatigue does matter (something small and aluminum) we would do just what you outlined.</p> <p>Rainfall counting to get the number of cycles (NASTRAN).</p> <p>Some dynamic frequency based forcing function to get stress as a function of frequency.</p> <p>Miners rule to get a cumulative damage.</p>
27	<p>I use a reference such as MMPDS-01 for the fatigue test data, and use Miner's Rule to show fatigue damage is less than 25% (to meet the typical FS=4 over life of the system).</p> <p>For fatigue crack propagation I use Nasgro or hand calculation techniques such as the Paris-Erdogan method. I have trouble locating the Paris parameters, C and m, at times though.</p>
28	<p>I have not used fatigue here at NASA but in previous work experience I used the same approach you described with rain flow and Miners rule. At NASA, I have used the NASGRO software for crack growth for facture control issues.</p>

29	<p>At the moment we are using a custom made Excel template implemented from a popular european aircraft manufacturer. What we do is to perform eigenfrequency analysis using Nastran finite element models. From the eigenfrequency analysis we extract modal participating mass. The maximum directional modal participating mass is used and multiplied by several amplification factors depending on the aircraft engine. As a first step the resulting acceleration is compared to the static acceleration of an emergency load case. If the static load case acceleration is 5 times higher than the resulting dynamic one, no fatigue calculation is performed. If the acceleration is lower than five times, stress analysis using detailed finite element models is performed. Maximum principal stress is extracted from the model and multiplied by the acceleration factors. Finally this stress together with the mean stress is used in a Stress-Number of cycles to failure curve in order to actually apply the Miner rule in the most common form. Actually the interesting thing is that till now Miner rule still seems to be the most common calculation method.</p>
30	<p>We often cooperate with Prof. Cianetti of University of Perugia who has a huge experience about random fatigue.</p> <p>They mainly use Rainflow counting in time domain and Dirlik in frequency domain even if they have developed new approaches. Their expertise is about the integration of modal modelling of components (Craig/Bampton) into Multibody simulation.</p>
31	<p>For powertrain applications in the automotive industry we use the entire gamut of Fatigue methods and algorithms for the Diesel engine development. We have several material types to deal with and each one has its own algorithm that has been refined and (re)calibrated over the years.</p> <p>As for fatigue software, we use feSafe, FEMFAT and nCode and our sanity check fatigue calcs are done in Excel.</p>

32	<p>I haven't done a lot of fatigue calculations in the last five years as I am mainly involved with nonlinear dynamics, low velocity impact these days.</p> <p>Previously I have used the strain-life approach, calculating small plastic strains with FEA due to thermal loading, using a cyclic stress-strain curve and working out a fatigue life based on measured strain-life data and Miner's Law.</p> <p>I still try to keep up to date with fatigue methods and I believe the Welding Institutes Guidelines are very good for high cycle fatigue problems. The level of FEA guidance provided by the Welding Institute and the different methods for obtaining stresses (nominal, hot-spot stresses and effective notch stresses) stand out as being particularly useful.</p> <p>I am also familiar with the Dirlik frequency domain method which is very clever but I've never used it in anger. I once wrote a code to inversely determine loading based on the Dirlik method, I think the answers were reasonable but we've never used it for anything else!</p>
33	<p>The fatigue critical components I look at are low cycle type as in attitude control system thrusters and others that encounters hundreds of load conditions few being vibration-induced; but mostly because of takeoff and landing, maneuvers, and pressurization cycles for example.</p> <p>The vibration-induced fatigue I simplify to a 68.2%, 27.2%, and 4.2% 1SIG, 2SIG, 3SIG distribution. Rarely do I go as far as rain flow counting. But when I do I take the same approach as you do.</p>
34	<p>I've been doing fatigue analysis at Remy for the past 7 years. In the first couple years I've used a simple excel based calculator that takes strain from the FEA model and calculates number of reversals based on Coffin-Manson-Basquin strain based fatigue method. As basic it is, good results could be achieved.</p> <p>We've acquired Fe-Safe a few years ago. The process changed a little bit. We run an analysis (ANSYS) with multiple load steps where one load step is typically unloaded the other one is a loaded case for the structure. Then these results will be imported to Fe-Safe, where the surfaces in scope will have material models assigned. After setting up the loading scenario the software runs in a couple seconds. Results can later be evaluated in ANSYS.</p> <p>There is another method. A harmonic response analysis can be conducted. Later the real and imaginary components can be imported to Fe-safe and analyzed with a help of a modal block. I did test tension bars with vibration input and I've had great success correlating the time to failure with FE-Safe. In this case failure was defined as 5% drop in response on a given modal frequency (because we've used a narrow band for excitation (to crank out more cycles at a given time) once the part starts to fail that characteristic natural frequency will drop out of the narrow excitation band) and we can run it @ "forever" it'll not fail.</p>

35	<p>I recover peak rms stresses from typically random vibration loads. I then use a spreadsheet I created to determine fatigue damage based upon peaks having a Rayleigh distribution. I typically add additional K_t on top of FE K_t results. I typically calculate allowable cycles based upon $NS^b=C$ equation knowing F_{tu}.</p> <p>I determine damages in 4 regions - 0-1 sigma, 1-2 sigma, etc. I use Miner's rule to sum damage. I use Goodman equation to account for mean stress.</p>
36	<p>Respect to the CAE based tools, several years ago (2004 aprox.) I used MSC/Fatigue under PATRAN for metallic components (initially from nCode being a partner of MSC). Recently has been implemented in MSC/NASTRAN too, "MSC Nastran Embedded Fatigue (NEF)".</p> <p>But nCode has also other alliances with other partners like Altair (Hyperworks).</p>
37	<p>Our tasks are dominated by the static-stress philosophy, that being "fatigue" begins at the weakest points at the structure. Namely welds.</p> <ol style="list-style-type: none"> 1. Using Hobbacher's document on "Recommendations for fatigue design of welded joints and components" (2008) we design to the S-N Curve given a FAT Class for a particular weld. 2. From measurements we measure the stress-field (dynamic strain sensors) in a particular area close to the "welds in question" where the stress does not vary too much. 3. Perform a modal analysis, currently we adopt ANSYS 15.0 Workbench. 4. Scale the modal shape, linearly, to the measurements to obtain the stress field near the weld in question. (No damping in this model and we have an assumption that the force response for the components at this eigenfrequency is equivalent to a scaled version of the mode shape. All the other modes are insignificant as a modal summation). 5. Usually we look at the normal stress, on the FE mode, along a perpendicular path to the weld. 6. Estimate the stress value at the weld toe. 7. Look along S-N curve for HCF case to obtain the number of cycles which then yields lifetime value <p>This is still work in progress and the preferred method, since we do not have load cases for the dynamic case and are not comfortable with force localization methods just yet.</p>

38	<p>I've been supervising in recent years a doctoral student working with a big player in the renewable energy sector, specifically on the performance of offshore wind turbines. In this case the industry standard methodology for fatigue analysis is to perform time domain rainflow counting with Miner's cumulative damage summation and the appropriate S-N curves applied, based on DNV-OS-J101- design of offshore wind turbine structures and DNV-RP-C203 - fatigue design of offshore steel structures.</p>
39	<p>The methods I use are different depending on the project but the process is similar:</p> <ul style="list-style-type: none"> - Spectrum derivation (measurements or calculations) - Spectrum counting based on ASTM E1049-85 for rainflow counting - Local stress/loads calculations based FEM or hand calculations (or both) to assess thru stress (tension/bending/shear) and fastener loads and direction - Assess total stress concentration and K_c/K_t using Peterson, ESDU or similar and/or detailed FEM - Clocking around hole or critical plane calculation to derive critical direction for analysis (based on Timoshenko and Mohr Circle) - Assess equivalent spectrum when bearing to bypass stress ratio vary over spectrum (in development) - Damage calculations based on Stress-Life (SN) or Strain-Life (eN) approach - Damage summation using Miner rule <p>I do also some sonic fatigue analyses using the ESDU methods.</p> <p>When the Sound Pressure Level (SPL) map will be available after testing (SPL and acceleration response of the structure), results will be used to calibrate a dynamic FEM. Methods for life calculation are still tbd.</p>

40	<p>I use FEA to pull alternating and mean stresses, then calculate life using Goodman's equation, scatter factor, and confidence level. Finally, I use Miner's for cumulative damage.</p> <p>For random vibs, I look for the modes with the highest mass participation and use those for my cycle count.</p>
41	<p>Regarding fatigue life estimation, I use Rainflow counting for time domain analysis and Dirlik for frequency domain analysis.</p>
42	<p>I also use Miner's cumulative damage using the S-N equations from MMPDS. Also NASGRO for fracture analysis.</p>
43	<p>When I was on the Space Shuttle team, we used a routine that picked the peaks using a slope logic to find the peaks and valleys that would ignore smaller peaks and valleys that was limited by a converted endurance limit. This was done to the various interesting regimes of flight. We then used the Shuttle mission profile in order to determine time spent on condition to assemble number of conditions and order. We then blocked the peaks and valleys using a program developed by an Englishman working on the B-1 program for North American. Once the blocked load spectra were compiled, the stress group took them and converted them to stress spectra via transfer functions for the critical parts on the Orbiter. Nasgro was the program used to perform the crack growth analysis which verified the suitability of design for 100 missions.</p> <p>I'm not sure what is meant by frequency domain fatigue. Is there a relationship to fatigue and rate of loading? That would be quite advanced to what we performed on the Space Shuttle program as you can see from my discussion. We wanted the stress group to perform unit solutions for all critical parts so that we could give them the stress spectra rather than the loads spectra, but alas, they were fully engaged in other projects when we asked for the help.</p>
44	<p>We used plastic strain-fatigue methods like Manson-Coffin or Engelmaier for solder thermally induced creep fatigue failure.</p>
45	<p>My company is specialized in space electronics boxes and radios. I use Steinberg methods for both thermal fatigue and vibration fatigue calculations on electronic components. I've heard that his methods are a bit too conservative but that is the only method I currently know.</p>

46	<p>Generally, the rainflow counting and the PSD or ASD spectrum are provided to me by other dept. such as structural dynamics dept. I as a general stress engineer receive the input PSD, and do finite element analysis (using Patran/Nastran or Abaqus). The FEA includes the frequency and modal analysis, and the random vibration analysis most of time. For a simple structure which can be represented as a single mass spring system, I use miles equation to come up with an equivalent inertial accelerations.</p> <p>Once I obtains the stress values and evaluating the stress ratio, R. Then, I look up the S-N curves to estimate the number of cycle to failure. For a structure which goes though different load cycles, I then use the Miner's rule to combine the damage index.</p>
47	<p>We mostly use life calculation using Miner's rule and rain flow counting. For board random vibration Steinberg's three band approach.</p>
48	<p>For structural fatigue, we usually just default to the Steinberg methodology. The things we produce are electronics boxes, so the PBAs are the most critical item in the units that we make. Therefore, we usually just do a Steinberg type analysis to determine the acceptability of the PCB, components, leads, etc. The aluminum housings usually have very low stresses, so if we do need to do anything to show that those are fine as well, we will just show the maximum three sigma stresses compared to the aluminum S-N curve, and that has pretty much always shown to be acceptable for the expected cycles.</p> <p>We also have to analyze things for thermal fatigue, and that usually relies on FEMs or on an Engelmaier type analysis.</p> <p>After these are completed, we sum these two items using Miners rule, and verify that the "life" is not used up.</p>
49	<p>I analyze spacecraft structures - the assumption is fracture not fatigue. The analysis tool is Flagro/Nasgro. Flow down to metal component procurement is based on NDI (Dye penetrant and X-Ray) for a defined minimum (detectable) flaw size. Hope this helps- and thank you for all the good guidance on your website</p>
50	<p>Been using rainflow + miners rule since the mid-1980s.</p> <p>Railroad tank car experts have evolved around much more complicated crack growth approach since about mid-90s, however. (Not my sub-field)</p>
51	<p>I use the banded approach along with Miners</p>
52	<p>I generally calculate fatigue in the time domain using the ANSYS fatigue module. According to the ANSYS structural analysis guide: "The fatigue calculations rely on the ASME Boiler and Pressure Vessel Code, Section III (and Section VIII, Division 2) for guidelines on range counting, simplified elastic-plastic adaptations, and cumulative fatigue summation by Miner's rule."</p>

53	<p>I haven't documented my process completely, but I am using Miner's Rule modified to add the kurtosis of real systems. So, when non-linear structural responses, impacting, etc. occur, we are basing our analysis on the 4- and 5-sigma responses so we can compare the damage potential of those extreme events to the typical 3-sigma responses calculated in random vibration stress based on FEA. I wrote a paper at the lab describing the approach, but because it was for a specific instrument they did not publish it. I may try to do something from my company, we'll see if I can get the time to do that.</p> <p>I am just getting my M&P Intl VibPilot Data Acquisition System and SmartOffice/Analyzer up and running after having it waiting for me to get the time to put everything together for upgrading our testing. So, I will be able to start getting back into the dynamics testing and analysis with 'real data', now. I gave a presentation to SolidWorks regarding Shock Response Spectra, and associated tools they could provide, and they included the SRS capability in the next release the following year! I was amazed, and I have used it successfully, to diagnose shock problems we otherwise would have had to collect data onboard PCBs with very little (or no room). With the SRS tool I can get the 80% (or better) solution to diagnose and compare different approaches to structural and PCB support, component staking, etc.</p>
54	<p>I've worked with the rainflow calculations previously, however, our current fatigue approaches are more consistent with what you would find in Steinberg. We design and build space instruments which are subjected to sine and random vibration testing of less than a few minutes duration. Our fatigue requirements are per GSFC-STD-7000 (GEVS) - we assume our loads are repeated at spacecraft and launch, so we expect to be conservative. Fatigue damage is computed using a Miners approach.</p>
55	<p>Below is the summary that was returned from our research group.</p> <ul style="list-style-type: none"> - Random fatigue loading. Software WAFO to manipulate and generate these random loadings. - Own developed model for damage accumulation processes and fatigue life prediction under the assumption that failure is produced by damage accumulation (as expected in our structural systems). The model is implemented (plugged) into Abaqus and have the following features: <ul style="list-style-type: none"> - Available for the general case: non-proportional loading, non-narrow band processes and multiaxial loading. - Based on critical plane model: Fatemi-Socie model. - Rainflow incorporated (coded) in the code. Standard rainflow model ASTM E 1049-85. - Damage parameter evolution law based on Miner's rule.
56	<p>I don't perform fatigue analysis in my actual activity. In the past we managed the nCode product lines that includes a special module for fatigue analysis</p>
57	<p>I work in engineering consultancy and we do not seem to use any other method than prescriptive methods.</p> <p>ASME, AISI and AISC codes and design rules require reduction in stress capacity by certain percentage for particular number of cycles.</p>

58	<p>I have to admit I don't do a great deal of fatigue, I would say 99% of the time I do 3-Sigma of the area under the curve, apply as static load and if there it tons of margin down the road I go. We are small company (~10 people) so would have tough time talking owner into a big \$\$ software that gets used every couple years. So occasionally when I have customers that have a fatigue analysis as a REQR I typically treat it this way: (hopefully you are not cringing at my approach and I have not been doing something really dumb)</p> <ul style="list-style-type: none"> (a) Perform a random dynamic using the supplied random input to get the RMS stress values. (b) Do a 3Sigma value of those stresses and the ## positive crossings to get a cycle count. (c) Sum using Miners for summation of damage. (d) Compare to S-N curve. (e) drink beer and wish I could have just used 3-Sigma value area under the curve as static load <p>Software is FEMAP for pre/post processor and Nx Nastran as solver.</p>
59	<p>Given the blocks a feed into fea program, I mostly use NASTRAN, may do some re-starts depending on analysis. Create a principal stress array that includes stress intensity factors (as needed) and respective cycles and proceed to evaluate using S/N data from MIL-HDK-5 (wrote myself in FORTRAN; tells you a bit about my vintage)</p> <p>Then Miners cumulative.</p> <p>If I need to evaluate crack growth following fatigue I use NASA guidelines (can't remember the report no.) for min. crack size and use NASGROW for crack propagation evaluation.</p>
60	<p>We use the Rainflow Method for cycle counting on time history and PSD data. Then we use Miner's rule for damage and also NASGRO for fracture. This is the most common methods I use.</p>
61	<p>The company I'm working with uses n-code for their fatigue analyses.</p>