CAEfatigue Software (Cf)

Technical FAQ

This document provides a number of technical questions and answers that cover a wide range of topics. The **Cf User Guide** also provide more theoretical background information that can be referenced to answer additional questions.

Disclaimer

Please consult the **Release Notes** file that comes with the installation package for latest software updates.

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Materials Related Questions

What if I do not have materials data and I want to get a quick assessment of my model?

Answer: CAEfatigue provides the capability to automatically generate SN or EN fatigue material properties based on the material Ultimate Tensile Strength (UTS) and knowledge of the material code number i.e., Ferrous = Code 99, Aluminum = Code 100, Titanium = Code 300, all other Codes. This is called AUTOSN/EN in the Materials box. However, care should be taken when using these approximate estimates as they are (most likely) do not reflect the actual fatigue material properties of your mode.

Where do I get the materials data from?

Answer: CAEfatigue has a materials database with standard materials data sets for common materials (typically steels, aluminium and alloys). New materials data may be obtained by testing and Hexagon can put you in contact with a materials test service. A reputable test laboratory would also be able to carry to materials tests to obtain the raw data. However, great care must be taken in obtaining any materials data since incorrect data will produce erroneous results. In addition, there is some published data, but care must be taken to ensure the data is well founded and is appropriate to the actual material being analysed.

Can I use CAEfatigue to calculate fatigue lives of composite materials?

Answer: CAEfatigue supports 2 damage accumulation models which may be used to estimate the life of a component. The stress-life (S-N) method models damage by considering the global effect of cyclic loading rather than microstructural mechanics. Consequently, this method can cope with composite materials unlike the strain-life (e-N) method which considers the elastic-plastic response of a small volume ahead of the crack. However, the way in which mean stress influences the degradation of a composite is not well defined and is unlikely to be modelled correctly using the Goodman or Gerber mean stress correction methods available for metals. In addition, from Cf v2021.2, a quasi-static fatigue analysis capability for short fibre reinforced composite was introduced by coupling Digimat, MSC Nastran, and CAEfatigue. Please refer to Quick Reference Guide for details.

How does CAEfatigue deal with thermal fatigue problems?

Answer: There could be four important effects of temperature on product life. They are:

1. *Thermal Creep - this will cause crack extension (this is not covered by CAEfatigue).*
2. *Materials Properties - these will change with temperature (the ability to included multi temperature S-N data is planned for a future release).*
3. *Oxidation/Corrosion - may enhance or retard crack growth (there are some surface finish corrections included in CAEfatigue).*
4. *Thermally Induced Stresses - may be calculated with FEA and included in the CAEfatigue analysis.*

Currently, CAEfatigue can handle the situations covered in 3 & 4.

Can I use my own materials data in CAEfatigue?

Answer: Yes, certainly. You will need to obtain the correct parameters which must include Young's modulus, E and the UTS as well as the fatigue properties. These properties can be added as User generated materials within the Material Database. It is very important to ensure that the materials properties are of the highest quality and that the source is reliable.

Does CAEfatigue have fatigue damage estimation models for welded structures?

Answer: Yes. The fatigue of welded structures has traditionally been modelled using the stress-life (S-N) method where the S-N curves have been obtained by testing real welds of various configurations (also called component S-N curve). This avoids the problem of the uncontrolled variables in a weld such as material microstructure, porosity, cracks, residual stress, undercut and post treatments such as shot peening.

The British Standard, BS5400 part 10 (or BS7608) defines a set of S-N curves and a method for estimating fatigue life for welds. These data sets are included in CAEfatigue. The user may also enter weld S-N data from other sources such as the ASME codes. In addition, the Seam Weld analysis functionality has been added to CAEfatigue which includes a more generic treatment of welding types. Furthermore, the fatigue analysis of spot welds that is commonly used in automotive industry to connect two or three shin-shell parts can also be carried out with a special modelling approach and special component S-N curves obtained from spot-welded components.

How can I include the effect of variation in material specification in the fatigue calculation?

Answer: The changes in material specification will, of course, cause changes in the fatigue response of a material. From the Cf v2021.2 release, CAEfatigue introduced the "Reliability Mode" feature that allows the User to define statistical variations into several parameters and then rerun CAEfatigue dozens / hundreds of times to see the effect of variation on the stress and damage outputs. From the Cf v2022.1 release, CAEfatigue also introduced the "Robust Design" capability that allows the User to define statistical variation into the Nastran parameters. The expectation for a future release is to incorporate Reliability Mode into Robust Design, to provide a complete end to end solution for variation in the design and analysis process.

What capability is in CAEfatigue for defining your own materials? Can I develop my own, or am I limited to our predefined materials?

Answer: You can add your own materials in many different forms. CAEfatigue accepts S-N curves (in parameter or table form), and strain-life/stress-strain data. These materials can be added to the internal Materials Database if so desired.

What is the physical mean of Material Cutoff? Is it the Fatigue limit of the material?

Answer: Not necessarily. In many cases it is very dangerous to use a fatigue limit in calculations, e.g. in variable amplitude loadings, fatigue damage can occur for cycles below the constant amplitude fatigue limit. Nevertheless, a cut off is usually set for numerical reasons at 10^{18} *or* 10^{30}*.*

As I understand it CAEfatigue can handle the effect of thermally induced stresses, but not temperature dependent material properties; is this correct? Is this something what will change in the future?

Answer: CAEfatigue can deal directly with thermally induced stresses and temperature dependant material properties will be supported in a future release. The user will need the S-N or E-N (material property) curves at different temperatures then they can us these in the same analysis.

Surface Finish/Environment Related Questions

How is the effect of surface finish taken into account within CAEfatigue?

Answer: The surface finish of a component will change the fatigue life because the surface is where most fatigue cracks initiate. So, the surface finish (roughness) will act like a stress concentration. In this way it is possible to calculate a surface stress concentration factor from test data for different surface treatments. CAEfatigue allows the correct factor for each surface to be entered. This factor is also dependent on the material strength and so UTS is used in computing the correct surface stress concentration factor.

Loading Time History Related Questions

What do I do if I do not have a load time history?

Answer: There is no reliable way of calculating fatigue life unless loading data is available in terms of cycles with a given amplitude and mean of loading in terms of a time history of loads or a power spectra and probability distribution. CAEfatigue includes facilities for signal generation such as sine wave summation (based on Fourier theory), interactive signal creation using a loads scheduler and a point-by-point signal creator which allows the designer to supply a set of discrete amplitude values (block loading).

I have loading described in the form of a power spectrum (or amplitude spectrum). Can CAEfatigue use this?

Answer: A full implementation of fatigue calculations using power spectral density functions is included in CAEfatigue and is called frequency domain fatigue analysis. The User can also calculate advanced Random output including displacements, velocities and accelerations without the need for fatigue material properties.

What kinds of loading are supported by CAEfatigue?

Answer: CAEfatigue supports the following list of load cases: Static load, Point load, Pressure, Temperature, Acceleration, Member load, Displacement and Rotation. It is important that any load case which contributes to the fatigue damage can be described not only in terms of direction and point of application, but also as a time varying quantity.

How many simultaneous load cases can CAEfatigue handle?

Answer: CAEfatigue can handle virtually any number of independently varying load cases. However, if a number of loadings do not vary in magnitude and phase one from another, then they can be combined in the FE analysis and also represented by one loading time history. Non-varying, static load cases may be applied simultaneously in a single FE analysis and their effect on fatigue life is simply to change the mean stress level.

How does CAEfatigue handle multiple load cases?

Answer: Multiple load cases are dealt with by carrying out an FE analysis for each independently varying load case. The local stresses are scaled according to the description of the load case with time (or frequency). These stresses are superimposed for all load cases at a given time step and corrected for non-linear stress-strain behaviour where appropriate. Finally, the stress derivative (e.g., max absolute principal stress or von-Mises) is computed. In this way a local stress (or strain) time history is obtained for each node or element and this time history is used to compute fatigue life. The complexity of this task used to result in significant processing times for multi-location analysis but CAEfatigue now makes this task much more practical.

What system of units does CAEfatigue work in?

Answer: CAEfatigue has been made to work in the same units as the user defines for the FE analysis. In general, the unit system supported is SI, Imperial, and cgs. Internally all units are converted to MPa during calculations. Material properties and loading time histories can be defined in the user's choice of units.

Analysis / Performance / Memory Related Questions

We currently undertake random vibration fatigue analyses. Our present method is:

- **Apply 1g sine vibration sweep and determine areas of highest stress.**
- **Perform random vibration analysis outputting rms stresses at areas of interest.**
- **Predict fatigue damage based on rms stresses, number of positive crossings, test duration and the material S-N curve. The fatigue damage is predicted via proprietary software based on the Lambert approach.**

- **Fatigue damage is defined as n / N (Actual number of cycles) divided by (Number of cycles to cause failure at predicted rms stress).**

Can CAEfatigue do something similar to the above? Does one do a separate random vibration analysis, or is it all done inside CAEfatigue? If the work is done inside CAEfatigue, can one recover the RMS stresses? What advantages does CAEfatigue offer over our current method?

Answer: NASTRAN (as well as other solvers) produce the stress responses to unit inputs at specified locations. This is done in NASTRAN (for example) by doing a SOL111 (FRF) analysis. For this analysis you will typically use the FREQ1 and/or FREQ4 cards to 'fill in' your frequency band of interest. The subcase locations will be the loading locations on your model. CAEfatigue then reads in these stresses (usually from the OP2 file) and rotates them on to the Principal (Stress) axes. As of Cf 2022.1, CAEfatigue also has a Multiaxial Assessment feature to provide guidance on the nature of the loading.

The loading PSD's corresponding to the input locations are then applied (including any Cross PSD's to account for dependency between load inputs). Using this information CAEfatigue then computes the response stress PSD's over the entire model and predicts fatigue life (or damage) from these using a variety of methods including narrow band, Steinberg and the recommended Dirlik approach.

For very large models we recommend a 2 stage approach where a crude set of FREQ1 and FREQ4 points are used to characterise the transfer functions. Then either the whole model, or sub models, is analysed to find the critical (hot spot) regions. These can then be reanalysed using more refined transfer functions. Because CAEfatigue is very computationally efficient this 2 stage approach is rarely necessary but a good process to follow for very large models.

With regards to step 1, CAEfatigue will enable you to get results for your whole model in one operation by including in your fatigue analysis our powerful and user friendly sine sweep feature called SINESW. The SINESW results should be a lot more accurate than what you due in step 1 because (A) better fatigue algorithms are available when using SINESW and (B) the calculation of principal stress PSD's is more accurate. In addition, you should find the manipulation tools inside CAEfatigue give you more control over the whole process.

Below is a description of how we simulate the full body fatigue behaviour of our trucks: How can CAEfatigue help improve our working practices?

1. *We run ADAMS models of our trucks that include FEA representations of the cab and frame (using Adams/Flex).*
2. *We are able to run the truck models over different roads such as proving grounds and extract time histories of all the loads acting on the cab (4 mount locations x 3 components [x,y.z] = 12 time histories).*
3. *We typically view these time histories as plots and decide at which point in time, we would like to view the stresses on the cab.*
4. *We then output all the loads acting on the cab (12 in total) at that point in time to our FEA solver.*
5. *We perform the FEA on the cab using the Adams forces and an inertial relief solution.*
6. *We review the stresses.*

Below is a description of what we would like to do with CAEfatigue for step 3 onwards:

3. *Output the time histories to CAEfatigue along with the FEA model of the cab.*
4. *CAEfatigue processes the time histories and calculates the fatigue life of the cab.*
5. *We view fatigue life contours of the cab FEA mesh.*

Answers: Our responses to the new steps are below:

3. *CAEfatigue can read time history data in various forms. Depending on how you are capturing the data, you can either read them into CAEfatigue as a ASCII text file (multi-channel file) or as an RPC file produced by MTS testing machines. Using CAEfatigue will eliminate the need to look at the time histories to extract the peak value. This has probably been an overconservative method.*
4. *CAEfatigue can handle 100's of independent time varying loads. You no longer will have to worry about the actual forces you apply to your FE model - only the location and direction. CAEfatigue will normalize all forces to create stress distributions due to unit loads and then scale them by the actual measured or simulated time histories.*
5. *CAEfatigue provides a graphical interface to view output results including Fringe plots, PSD plots, Event plots, FFT plots, PSDM plots and more that can be used to identify critical locations.*

The CAEfatigue User Guide gives an excellent overview of this for both time and frequency domain approaches.

The simple explanation is that CAEfatigue takes the FE load case stresses, normalizes them due to a unit load; multiplies them by the time variation (time history); sums all load cases together (linear superposition); resolves the components of the resulting stress or strain tensor time history down to a single scalar value such as maximum absolute principal; rainflow cycle counts this time history; performs any corrections it needs such as surface finish/treatment, elastic/plastic correction, mean stress, proportional loading, etc.; looks up damage on the appropriate damage curve; sums the damage and reports it.

The procedure is basically the same in the frequency domain except you are starting with input load PSDs. The linear superposition is replaced by matrix multiplication and of course you must run frequency response analysis to recover transfer functions of stress instead of linear static jobs.

There are many methods in existence for performing random fatigue analysis. We have seen references to the so-called Square Root Method, what is this? Why is CAEfatigue better?

Answer: The "Square Root Method" describes a technique which assumes all loadings are uncorrelated and so this will give an upper bound on damage. It also assumes that the peaks (and stresses) are Rayleigh distributed. This is the same as making the so-called "narrow band assumption", which also tends to overestimate stress ranges.

CAEfatigue overcomes both of these limitations, whilst still working in the frequency domain by using the following 2 advances.

> *Advance 1:* *The "rainflow" cycles of stress are computed from the spectral moments of the response PSD. We then calculate the probability density function distribution of the stress cycles by using (typically) the Dirlik Method. Dirlik undertook extensive Monte Carlo simulation and by using many paired results (PSD moments for set 1, rainflow curve shape parameters for set 2) he derived an empirical relationship for rainflow stress ranges. Dirlik's work is extensively described in his PhD thesis, T.Dirlik, Application of computers in Fatigue Analysis, University of Warwick Thesis, (1985). Dr Neil Bishop spent some time on Dirlik's work and eventually confirmed the results theoretically in the second paper noted below.*
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> > *[1]. N W M Bishop and F Sherratt, Fatigue life prediction from power spectral density data. Part 1, traditional approaches and Part 2, recent developments. Environmental Engineering, 2,(1989).*
> >
> > *[2]. N.W.M.Bishop and F.Sherratt, A theoretical solution for the estimation of rainflow ranges from power spectral density data. Fat. Fract. Engng. Mater. Struct., 13, 311-326, (1990). Dirliks results are now well accepted*
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> *Advance 2:* *CAEfatigue is the ability to resolve random vibration results onto principal stress planes. This can be done for correlated, uncorrelated or partially correlated results. This is also a very important and unique capability in CAEfatigue.*

So, both of the limitations of the Square Root Method are addressed in CAEfatigue.

I am performing a vibration fatigue analysis and wonder what are my analysis options?

Answer: It may be the case that, because of the nature of the structure you are analysing, your analysis route is already determined. For instance, many deep water offshore oil platforms can only be satisfactorily designed in the frequency domain, thereby producing frequency domain results. In this case a frequency based fatigue calculation is the only option.

Alternatively, the nature of the fatigue damage mechanism, or the structural system, may determine that only a time based approach is applicable. If either of these scenarios is true, then the correct approach is already defined. More usually there is a choice, or perhaps both approaches in parallel are appropriate. In which case the additional questions below need to be addressed.

When we want to do full vehicle durability analysis, what modules of CAEfatigue do they need?

Answer: For full vehicle analysis in the Time Domain the TIME package is needed. For the same calculation in the frequency domain the FREQUENCY package is needed. Please note the FREQUENCY package includes all capabilities of the TIME and RANDOM packages.

The more advance PREMIUM PACKAGE will allow you to do full vehicle analysis in both Time and Frequency domain. PLUS, spot weld or seam weld analysis in the frequency domain is also included along with advanced RANDOM analysis output results to do calculations like “collision detection” (Rattle) assessment between parts.

Do advantages of working in the frequency domain outweigh possible errors?

Answer: If a frequency based fatigue predictor is coupled up with a frequency based load predictor, such as an FEA program, then a designer has the ability to undertake rapid design optimisation. He may then choose to use a time based calculation for the final ‘proving’ analysis calculation or stay in the frequency domain. In such a case any loss of accuracy involved in working in the frequency domain is far outweighed by the increased design capability. CAEfatigue recommends using the Frequency Domain whenever possible due to the significant advantages that can be realized.

I am doing vibration fatigue analysis work and want to do some QA checks on the results. How do I do this?

Answer: If you want to compare linear results out of, say, NASTRAN (such as stresses or input displacements) with PSD's then a good rule of thumb is to take the square root the area of the response PSD and then multiply this value by 3. The number you get will have units of MPa (if it was a stress PSD) and can be equated with the maximum amplitude of an equivalent sine wave, i.e. the NASTRAN result.

Another suggestion is to focus on one small part of the model (hopefully a critical location) and see if you can get equivalence between the frequency response results from NASTRAN and the forced vibration results from CAEfatigue for the same location. Remember that the response PSD is the input PSD times the frequency response results squared. NB: Run the model for one input loading first to make sure you understand what is going on.

I am performing a vibration fatigue analysis and I am not sure whether sequence effects are important for my particular application.

Answer: If the designer is dealing with a stress response history, which is random in nature, it is important to note that only the statistics of the process are of any importance. In other words, any one time history of sequencing that may have been recorded is only one sample from an infinite number of possible samples which could have been recorded. The sequence effects in one sample may well be very different from the sequence effects in another. Furthermore, it is highly unlikely, for vibration fatigue problems, that sequence effects are of any significance.

I am performing a vibration fatigue analysis and I am not sure whether low cycle plasticity effects are important for my particular application. How do I tell?

Answer: Vibration fatigue problems are predominantly high cycle situations using Stress-Life (SN) material properties. It is therefore reasonable to ignore low cycle plasticity effects. There are, however, some special circumstances where this is not the case. CAEfatigue fully supports the Strain-Life (EN) approach for vibration fatigue calculations. CAEfatigue recommends using Strain-Life material properties whenever possible.

I am performing a vibration fatigue analysis. If I am directly measuring my response data (stress or strain), is it stationary, Gaussian and random?

Answer: These are probably the issues which cause the most concern to design engineers.

Firstly, on the question of how Gaussian (sometimes referred to as 'normality') particular data is: If we calculate the percentage of time that response data spends within a particular stress bin and plot this as a probability density function (pdf) we require that its pdf follows the Gaussian bell shape. Fortunately, there is a theoretical explanation to explain why nearly all engineering components and structures exhibit Gaussian behaviour. This is called the Central Limit Theorem. This theorem states, in very general terms, that the response of any system will be Gaussian as long as the number of processes contributing to this system response is reasonably large and that no one process dominates. This is true even if the individual processes are not Gaussian. Practical fatigue calculations have shown that CAEfatigue is very robust to some variation from a strictly Gaussian signal. Furthermore, the Dirlik method (used as default within CAEfatigue) seem to be quite robust to even quite non-Gaussian data.

If the signal is stationary it means that the general characteristics, such as rms, do not change with time. For most engineering processes this is true. Furthermore, even where the signal characteristics are changing slowly with time, the complete response process can usually be broken up into a number of shorter stationary processes. CAEfatigue includes a very advanced load conditioning tool which can help to make time signals stationary.

Finally, and perhaps most importantly, is the signal random? If it is not random, then a time based approach is probably most appropriate. For instance, if a small number of transients dominate the fatigue damage, then it is difficult for a frequency based approach, to properly identify frequency content of these very short events. This is perhaps an example, such as that referred to in the Central Limit Theorem, where one process dominates the rest. However, even in this situation sometimes these transients can be collected together into one sample in order to create a longer time signal, which can be transformed into the frequency domain. However more research is needed in this area.

What determines if any data conforms to the assumptions Stationary, Random and Gaussian?

Answer: The only real test, in the context of a fatigue calculation, is how accurate is the estimated fatigue result from the frequency domain compared to the time domain results. If the time signals are completely stationary, random and Gaussian and we convert those time signals to PSDs, we would expect that the fatigue results between the frequency domain and the time domain to be within a factor of 2.0. This would be considered a very good result. A factor of 2.0 change in damage is equivalent to a 7% change in stress for typical high strength steels (with S-N curve slopes of b=10), so being out by 7% is generally very acceptable between the two analysis methods.

Is the frequency domain analysis linear?

Answer: Before we can consider this, we need to consider in more detail, what is involved in computing a structural response estimate using, for instance, an FEA package. To obtain the output response PSD of any system we need its transfer function.

This transfer function then obeys the following,

equals the input PSD multiplied by the transfer function

There are a number of experimental and analytical ways of obtaining the transfer function. The simplest and easiest method to visualise the transfer function is to use the so-called sine sweep. Using this method, the response of a system to a particular sine wave of a particular magnitude is calculated. The frequency of the sine wave is then incremented by a small amount and the magnitude of response is calculated again. By repeating the process, a response versus frequency plot for all frequencies of interest can be produced which can then be used directly to evaluate the transfer function.

An alternative way of obtaining the transfer function is to apply an input of white noise which has a flat topped PSD over all frequencies of interest. The response to this random input can be used directly to obtain the transfer function by dividing the output PSD by the (constant) height of the white noise input PSD.

These experimental techniques have their analytical equivalents. For instance, a series of unit load steady state (harmonic) analysis computations can be used to obtain the required transfer function ordinates. Alternatively, a time domain analysis can be performed using white noise as the input and the response obtained can then be used to obtain the transfer function. It should be clear from the above that the transfer function is a characteristic of the system or structure. It is not until the transfer functions have been established that the actual loadings are applied. This highlights the usefulness of frequency domain spectral techniques because the computational effort involved in computing the responses is trivial compared to that of computing the transfer functions themselves.

How does CAEfatigue deal with 'Sonic Fatigue'?

Answer: The term 'sonic fatigue' is similar to 'vibration fatigue' but the loading environment is acoustic (pressure) loading. Sometimes a significant non-linearity is present which must be accounted for.

Do you know the Railways British Standard Code of Practice for fatigue design and assessment of steel structures (BS 7608)? Does CAEfatigue include a reference to it?

Answer: CAEfatigue includes a full implementation of BS7608. This includes the following:

- *BS7608 design S/N curves implemented in the CAEfatigue materials database as standard,*
- *A Miner-Palmgren Linear damage summation as specified in BS7608.*

The procedure of calculating the fatigue life by the S/N stress life technique if as follow:

1. *A finite element model is loaded into the analysis software. This model has the results of a series of linear finite element stress/strain analyses, with stress result locations corresponding to the reference stress location for the weld. The analysis can take in both static and transient results cases.*
2. *The analyser takes in a time history associated with each set of stress/strain results. These are used to scale the stresses with regard to the input loads*
3. *Since the stress/strain results are linear elastic results, the results of the multiple time histories may be summed, once they have been multiplied by the time histories.*
4. *This creates a stress / strain tensor time history at every node or element.*
5. *If finite element strain results are to be used in an S/N analysis, they are converted to stresses.*
6. *The stress tensor time histories are then converted to invariant values: either von-Mises, maximum principal, component values, depending on the users choice.*
7. *The resulting stress time history is rainflow counted and a stress range-mean-number of cycles histogram is obtained.*
8. *The values in the stress histogram is compared with the appropriate S-N curve. The mean stress correction methods available are: None; Goodman; and Gerber.*
9. *Each value of damage is summed according to linear damage summation, to give a total value of damage for each location.*
10. *The reciprocal of damage is calculated, this is the fatigue life.*

11. *CAEfatigue then allows graphical post processing of fatigue life and damage across the structure, and a number of additional post processing options.*

Is a particular meshing of the welding joint necessary?

Answer: Precise meshing of the joint is not necessary, the stresses used in the weld fatigue calculation are nominal stresses at the weld reference location (called hotspot location which is away from the weld toe). Note: the term hotspot has different meaning than the HOTSPOT filter capability provided in the software. This is important because the BS7608 S/N curves already include stress concentration factors due to the welded detail and are intended for use with nominal (reference) stresses only.

For the weld problem, we use nominal stress value away form the welds. How about if we have hole near the weld? The hole may also cause stress concentration. Can you tell me some trick to get away from this?

Answer: The hole will cause stress concentration. It is our understanding that for weld classes, which are component S-N curves, they are based on the geometry of the weld. If you introduce a hole in the weld, you are changing the geometry and therefore invalidating the S-N curve for that weld. You will need to either create a new S-N curve or perhaps if you have some way of knowing the stress concentration, you can use this as an additional factor in the analysis.

There is no guideline for a weld mesh density in the area where the reference stress is taken. Have you verified the effect of mesh density to the accuracy of the result?

Answer: No but be aware that if the stresses at the hotspot location changes because of the mesh density, the life results will also change. Hopefully, the stresses will converge in the nominal area at a certain mesh density after which more refinement will not increase the stresses. This is a FE modelling issue more than it is fatigue analysis issue although it effects the results. Engineering judgement needs to be employed here.

How can I run CAEfatigue in batch mode?

Answer: Irrespective of the way you start and run the CAEfatigue software it uses, in the background, a control file to control the actions of the software that can be run in batch mode or through our GUI.

FEA Related Questions

Which FEA codes does CAEfatigue support?

Answer: CAEfatigue has been developed to be solver independent. Currently the supported solvers are MSC Nastran, ABAQUS, ANSYS, LS-DYNA, NX Nastran, Optistruct, and any Nastran type solver that writes a (PARAM,POST,-1) OP2 file. CAEfatigue also supports Nastran formatted H5 Marc nonlinear results or SOL400 results for a linear static analysis (LQSTATIC) or non-linear static analysis (NQSTATIC) with solid elements.

What model types does CAEfatigue work with (2D, 3D)?

Answer: There are no restrictions on the types of models which may be analysed. However, from a pre- and post-processing standpoint, only 2D and 3D elements are explicitly supported (shells and solids). Please refer to "Solver Supported Elements" in the CAEfatigue Quick Reference Guide for the specific 2D/3D elements of various FE Solver.

What kinds of analysis do I need to carry out in preparation to use CAEfatigue?

Answer: One can use linear static, normal modes, linear transient or frequency response analysis and use the stresses for a random or fatigue analysis depending on the analysis being performed in the time domain or frequency domain. Geometric non-linear and other non-linear analysis results should be used with extreme caution *in that the stress and strain components of the tensor may not vary proportionately with each other which would invalidate the fatigue calculations. In other words, non-linear analyses are not explicitly supported although you can still use the results in a fatigue calculation for mean load or fabrication induced stress fields.*

Are there any special concerns with the FE analysis that the engineer should be aware of when subsequently running a fatigue analysis?

Answer: Most definitely. The engineer should keep the following in mind when creating and analysing FE models.

1. *The geometry must be represented accurately.*
2. *Externally applied loads and constraints must also be represented accurately. Apparently insignificant changes to the way the loads and constraints are applied to the FE model can make surprisingly large changes to the deformation and hence the strains.*
3. *Shell elements must be used with care, and in particular, only where the structure is one which can reasonably be treated as a shell (i.e., where the thickness is small compared to significant geometric features).*
4. *It is important that elements are chosen with a view to generating accurate grid point stresses and strains as fatigue cracking usually starts at free surfaces and edges. In general, better results are likely to be achieved by using higher order elements, even if they are fewer in number. Use of higher order elements also permits better representation of geometric features.*
5. *Ideally, the mesh should be refined to a point where further refinement produces little change. The criterion used must be local stress and strain. There is little to be gained by excessive refinement in non-critical areas; the sole requirement in these parts is that they transfer loads correctly to the critical areas.*
6. *Use of triangular and wedge elements should be minimized and care should be taken with aspect ratios. The effect of joins between elements of different types and shells of different thicknesses need to be carefully considered as these have the capacity to act as fictitious stress raisers.*
7. *Wherever possible, verification of the FE calculated strains should be made by comparing with strain gage measurements.*

What element is recommended for a nugget, CBAR, CBEAM or CHEXA when doing a spot weld analysis?

Answer: Currently CAEfatigue supports CHEXA and the equivalent CBAR is derived from this. Direct specification of CBAR, CBEAM is planned for a later release.

Can torsion on the nugget be catered for?

Answer: This is included in the force data passed through to the spot weld solver but there are caveats concerning this.

When doing a spot weld analysis is there any recommendation size for shell elements for sheets? (the percentage for a nugget length, etc.).

Answer: Yes, there are modelling guidelines that should be consulted. An internet search will help locate those guidance's.

When doing a spot weld analysis, can you connect with RBE3 between a sheet and a nugget?

Answer: Yes. Spot weld modelling can be done with RBE3's between the sheet elements and a HEXA element representing the weld.

I'm looking for a proper answer to this question, "Why does CAEfatigue use absolute value of the maximum *principal* stress?

*Answer: CAEfatigue uses "**Absolute Maximum Principal**" stress as the default because it generally gives the most conservative answers in that it considers the entire stress range. For example, if the time series were:*

Time	*0*	*1*	*2*	*3*	*4*	*Max range*
Max Principal	*100*	*-100*	*200*	*-200*	*500*	*-200 to 500 = 700*
Min Principal	*50*	*-150*	*-500*	*-250*	*-10*	*-500 to 50 = 550*
Abs. Max. Principal	*100*	*-150*	*-500*	*-250*	*500*	*-500 to 500 = 1000*

You can see that using the Absolute Maximum Principal gives a larger outside stress range than just using Max or Min Principal. Remember that "absolute" does not mean that we take the sign away. We determine what the largest absolute value is and then take that number as is, leaving the sign.

Also, when using other stress combinations such as von Mises or shear, these values tend to be always positive which halves the actual stress range. Therefore, we use the sign of the Absolute Maximum Principal to "sign" the von Mises or shear values. So, if the Absolute Maximum Principal is negative at that point in time, so is the calculated von Mises value. Hence, you also have selections for signed von Mises and signed Shear.

Fatigue Analysis Related Questions

How do I know which stress parameter to use (e.g., von Mises, Absolute Maximum Principal, etc.)?

Answer: There is no commercial fatigue model to handle multi-axial fatigue crack problems. However, cracks tend to be created and driven by a dominant stress acting perpendicular to the crack direction. Consequently, an absolute maximum principal stress parameter is likely to give a sensible indication of the crack driving force. A signed maximum principal (or absolute maximum principal) stress is also a sensible parameter since cracks grow in proportion to the stress range i.e., from an absolute minimum to the maximum stress. In practice, the engineer should assess the life on at least two stress combination parameters. The most appropriate parameter may be gauged from the local stress directions.

How accurate are fatigue life predictions?

Answer: Traditionally the stress-life approach to fatigue life estimation is associated with a probability of survival based on the statistical significance of the stress- life curve drawn through the experimental stress-life data. The same approach can be used for strain-life (or local strain /critical location) method. However, the experimental materials data from which the strain-life curve is obtained exhibits substantially less scatter than is experienced with stress-life data. This is primarily due to the fact that the strain-life data are obtained from a test where the control parameter is the strain in the region where the crack is being created, i.e., the test is fully constrained. Strain life based fatigue life estimates are typically accurate with a factor of two (i.e. one half to two times the actual life).

You predicted a life of 2000 repeats. The component in test actually failed at 2500 repeats. Was your prediction good? Can you comment?

Answer: Fatigue life prediction is not an accurate science in the sense that stresses can be predicted to within 1% using FE analysis. There are many uncontrollable variables at work in a fatigue problem such as defect distribution, material microstructural orientation, manufacturing tolerances, surface finishes, actual loading events (perhaps the prediction was made using a typical load-time sequence). Fatigue is also a logarithmic process so the fact that a prediction can be made within a factor of two is actually very impressive. Consequently, to improve a design and *avoid a fatigue problem, the prediction model should predict a life of at least 10 times the required life, i.e. the inputs to fatigue must be modified to change the prediction by at least a factor of 10.*

What are the most common ways to improving fatigue life?

Answer: If there is a global fatigue problem then a change of material or improved surface finish would be appropriate. However, most fatigue problems are localized, and a local geometry change would be most appropriate change to make. However, a material change would also be an equally valid option with this kind of problem. In addition, a vibration may exist due to resonance which is causing fatigue failures. In this case it would be much better to modify the driving forces, i.e., change the dynamics, to eliminate the fatigue problem by modifying / eliminating the resonance.

When should I use the S-N method?

Answer: This method is still recognized by many design standards including SAE/BS/DIN standards as well as in-house company design guides. If the user has large quantities of S-N data which are pertinent to their components, then there may be a case for using the S-N method. Welds are still analysed for fatigue using S-N data obtained from tests carried out on real welded components or test coupons. These S-N data encapsulate the variability of a weld such as inclusions, porosity, undercut, etc. and so give the designer the most conservative design rules.

When should I use the strain-life (crack initiation) method?

Answer: The strain-life method allows the user to estimate the initiation life as opposed to the propagation or the total life (S-N). It also allows the user to investigate design options on a more fundamental level than the so called, component S-N method since the materials properties do not encode anything about the structure. In this way the likely effect of choosing a different material may be readily simulated. In the same way the local stress concentration and surface finish may be investigated together with changes in stress due to loading.

Does CAEfatigue allow me to see the way cracks grow through the FE grid?

Answer: No, CAEfatigue does not actually interact with the FE model. It only uses linear stress results from it.

Can I change the way in which mean stress is taken into account?

Answer: Yes, the mean stress correction methods for both stress-life and strain-life fatigue analyses are variable. CAEfatigue provide a number of mean stress correction options.

In calculating a cumulative damage, can I use a Miner sum other than 1?

Answer: There is no need to do this since the number 1.0 does not trigger a change in the code. If different values are needed, then another way of achieving this is to set the “Required Duration” in the sequence entry to a higher or lower value.

I am interested in crack growth - how can CAEfatigue help me with this?

Answer: CAEfatigue does not do crack growth and propagation. MARC might be a suitable alternative if one wants to evaluate the crack growth life starting from an initial crack.