FS2000

FS-OffFat Offshore Fatigue Analysis

Advanced Structural Analysis
for Windows
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1.0 Introduction

OffFat is a suite of program modules that interface with FS2000 for the deterministic fatigue damage analysis of framed structures under cyclic hydrodynamic wave loading. Solid elements can be included.

The fatigue modules may also be used to assess the fatigue damage to any other type of cyclic loading that can be represent by series of load cases.

FSWave is used to generate load cases corresponding to a wave being stepped through a structure. This produces load cases for each phase of the wave. These load cases are post-processed by a fatigue module that evaluates peak stress ranges at stress points within the structure as the wave passes through the structure. A number of waves (up to 6) are processed so that a relationship between wave height and peak stress is established for each wave direction.

For tubular joints, the geometric joint classification and associated SCFs are evaluated and used to generate the peak stress range data. This data is then used to evaluate peak stresses at all brace joints on both the chord and brace side of the joint at up to 12 circumferential points.

For non- tubular joints the peak stress data is evaluated on the nominal stress ranges at the element nodes. Individual SFCs may be defined for each node and stress point.

If finite elements i.e non beam elements are included in the model the fatigue stress ranges will be evaluated and fatigue lives evaluated accordingly.

This stress data is then combined with wave exceedance data and an appropriate SN curve to establish damage ratios based on Miners Rule.

Batch File Utility

The fatigue analysis modules are controlled by command line instructions that initiate the program modules and identify the control files to be used. These commands can become rather complex. This manual descries in detail the how the modules and their commands interact and how a batch control file should be set up. It is however, not essential to fully understand how control files are set up since a utility program is provided that will create all necessary control files and definition files to undertake a fatigue run. The use of the utility is described in Section 5.

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2.0 Basic Approach to Fatigue Analysis

Four separate program modules are employed to perform the deterministic fatigue analysis. These are

- FATIG1 (FATIG1S)
- FATIG2
- FATIG3
- FATIG4

The modules are activated using command line operation within a batch control file. The function and operation of each of these modules are described in detail in Section 4.

There are two basic stages in the fatigue analysis, the Analysis Phase (FATIG1 & FATIG2) and the Assessment Phase (FATIG3 & FATIG4). The output from the analysis phase are the Stress Point-Wave Height relationships, this is the time consuming stage. The Assessment phases uses the Stress Point-Wave Height relationships, the wave occurrence data, and the SN curves to evaluate the fatigue damage.

The Analysis Phase need only be carried out once on a given model configuration. The Assessment Phase is undertake for all sections of the model where different fatigue parameters are to be used eg SN curve and SCF.

The following section provides an overview of what these modules do and how they interact. Figure 1 in Appendix A illustrates the basic procedure.

2.1 Peak Stresses - FATIG 1 & FATIG1S

FS-Wave is used to evaluate a number of load cases (typically 12) to represent the loading as a wave is passed through the structure. From these load cases the peak stresses at all stress points are evaluated for each wave step. For tubular joints this process is undertaken by FATIG1. This module evaluates the SCF's and peak stresses at up to 12 locations at each brace end for both brace and chord side. For non-tubular joints this process is undertaken by FATIG1S

2.2 Peak Stress Ranges - FATIG 2

Once the peak stresses are evaluated at all points for all load cases it is necessary to establish for each point the maximum peak stress range as the wave passes through the structure. This is done by FATIG2.

2.3 Stress Range/Wave Relationship - FATIG 3

If the peak stresses are evaluated for a number of waves (typically 4, maximum 6) in the same direction then a relationship between stress range and wave height can be established. FATIG 3 establishes such a relationship by defining for each stress point a stress versus wave hight curve. It should be noted that the stress ranges evaluated from these waves are not explicitly used with the wave occurrence data, they are only used to generate the wave height stress range curve.

2.4 Stress Range/Occurrences Block Diagram - FATIG 3

For each wave direction it is necessary to establish a block diagram (or table) of wave height range against the number of occurrences from wave exceedance data. This table can be evaluated by the program based on a Weibull probability distribution or be defined by the use in terms of wave occurence blocks. Once such a table has been established the stress range/wave height relationship may be used to establish a stress range spectrum that relates stress range to the number of occurrences. FATIG3 is used to establish such a relationship.

2.5 S-N Curve Accumulative Damage Evaluation - FATIG 3

The cumulative damage ratio at all stress points for a given direction is evaluated using an appropriate S-N curve, Miners Rule and the stress range/ Occurrence blocks established in 2.4. FATIG 3 evaluates this damage ratio.

2.6 Total Accumulative Damage Ratio - FATIG 4

At all stress points the damage ratio is required to be summed for the different wave directions considered. This process is accomplished by FATIG 4, which also produces the final output data.

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3.0 Creating Models in FS2000

3.1 Units

OffFat reads the inputs and result files of models created and analysed by FS2000. To ensure units compatibility it is essential that the model be created in fundamental **S.I Units** or **US-Units**.

The stress and stress range data obtained from FATIG1 and FATIG2 will be in N/mm2 or Lbs/in2 depending upon the unit system employed.

S-N Curves

The S-N curves MUST be defined in the S.I. system (Stress in MPa). If US-Units models are used the stress ranges will be converted by the program. This enables the FS2000 supplied S-N curve data (ISO curves) to be used without the requirement to convert.

SI System

Wave Heights and Water Depths	m
Material Thickness	m
Joint Gap	m

US-Units

Wave Heights and Water Depths	ft
Material Thickness	ins
Joint Gap	ins

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3.2 Joint Type Recognition/Classification

All joints between tubular member are examined to identify chord and brace members. The member with the largest diameter is taken to be the chord member. All other members are regarded as braces.

It is not necessary for the chord to be continuous across the joint for the member to be identified as a chord. However, the chord continuation member will be recognised as such providing the member alignment is within about 15. The chord continuation member need not be the same diameter as the chord.

In joints in which chord and brace members are the same diameter it may be necessary to fractionally increase a member OD to ensure that the member is identified as the chord.

Individual brace joint classification is evaluated according to the loading pattern in the joint in the same plane as the respective brace or the geometric configuration of the brace. For braces which carry part of their load under different classifications their classification is based on interpolation of the respective portions of each in total.

By default all braces will be automatically classified but the user may re-classify any individual brace. See Sect 3.4 for brace classification methods.

They are geometrically classified as TY, K1, K2, KT or XT joints. If a brace has a member on the opposite side of the joint it is first classified as an X joint. If the brace has an adjacent brace on the same side it is re-classified as a K1 joint. If there are more than two braces on the same side the joint is re-classified as a KT joint, with the central brace (largest angle) being classified as a K2 joint.

Gaps for K type joints are assumed to be 50 mm. For a KT joint, the gap is based on the diameter of the K2 brace + 100 mm. If <.15 then the gap is proportion to make = .15. See Sect 3.4 & 3.5 for methods of explicit gap definition or using the program calculated gaps.

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3.3 Stress Concentration Factors (SCF)

Program evaluated Tubular Joint SCF's are evaluated in accordance with the following methods. Type 4 is the default method.

• Design Recommended Combination	Type 1
• UEG Recommended Parametric Equations	Type 2
• HSE Recommended	Type 3
• Ethymiou Parametric Equations DNV/API/EC3/ISO 1434	Type 4

Thes are described more fully in Section 4.3.

The increased joint wall thickness due to cans and stubs are accounted for using the same parameter file (.ECI) as used by the FS-TubeJoint. The user may re-define the SCF if the calculated SFC is not considered appropriate for the joint. The module FATIG1 evaluates the SCF data and the peak stresses. The following section describes how these values may be re-defined by the user.

The minimum SCF for a brace joint is:

1.5 Simple Joint (1.6 for Efthymiou eqations)

2.5 Ring Stiffened Joint

SCF evaluation for overlapped joints and ring stiffened joints are the same as simple joints. If joints are defined as ring stiffened the 2.5 min SCF is applied.

Member Joints

This module evaluates nominal stresses at elements nodes (no SCFs applied) i.e member joints using geometric property stress points. SCF factors may be included at the stress points by using the user defined pipework SIF factors (see Model Definition :Element Menu:Pipework).

The nominal stresses evaluated and associated lives are based on either the direct normal stresses (axial + bending) or the Von-Mises stress - See Sect 3.7

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3.4 User Defined SCF Data & SCFs

The FATIG1 module creates the **.EF1** file which shows how the joint was classified and the SCFs evaluated and used for the peak stress evaluation.

The file format for the EF1 file is shown on Sheet D1 Appendix E. This file is re-created for the first load case each time the module is run.

The user may re-define the SCF or certain parameters that define the SCF for any brace if it is considered that a more appropriate SCF is applicable e.g. for complex joints where parametric equations are not applicable or program interpretation is inappropriate.

A utility for the evalution of SFCs is described in Appendic D. This utility can also be used to output the parameters evaluated and used by the program.

Braces that are required to be modified are identified and defined in an **.UJClass** file. This is a user created file. The file format is given below (commas or spaces can be used a field delimiters). The entry is repeated for each brace. All data fields must be defined. Zero values will be ignored

JBC, *Node, Element , Gap, Classification, Multi,* α*Value, ACS, ACC, ABS, ABC, IPCC, IPBC, OPCS, OPBS*

Multi is not used by this module

Brace Gap Any non zero value will be used by the program

α**Value** Default value is 35. Any non zero value will be used by the program

Classification It is not possible to re-classify a brace to a classification with more braces than the number of braces established by the program. The following are possible

KT	>	TY, XT, K1 or KT
KT	>	TY, XT, K1
K1	>	TY, XT, K1
TY	<>	XT

Ring stiffened joints are identified by adding an S to the classification i.e.XTS

SCF Values Any non zero value will be used by the program

ACs = Axial Chord Saddle

ACc = Axial Chord Crown

ABs = Axial Brace Saddle

ABc = Axial Brace Crown

IPCc = In Plane Chord Crown

IPBc = In Plane Brace Crown

OPCs = Out Plane Chord Saddle

OPBs = Out Plane Brace Saddle

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3.5 Gap Codes & Individual Gap Definition (as FS-TubeJoint)

The .ECJ file contains gap codes. The gap codes may be used to define how brace gaps are to be defined. The following code are used

0 Use default values (0.05 m) or ξ = .15 if ξ < .15

1 Use GAP1 evaluated by the program

2 Use GAP2 evaluated by the program

Gap definition may also be specified by definition in the .UJClass (Joint classification file). Definition here will override the above codes. This file is also used by the static tubular joint codechecker.

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3.6 Calculated Joint Gaps File (.EJG) (as TJointCheck)

This file shows the brace gaps evaluated by the program. This file is not used by the program, its purpose to indicate how the program interprets the joint. This file is read by the Design Parameters - Graphics Module to show joint classification.

Overlapped joints may be identified by negative values.

The file format is;

Node Number, Element Number, Geometric Classification , GAP1, GAP2, GAP, e, e/d

Geometric Classifications are those established by the program.

GAP1 is the gap in a K brace

GAP2 is the gap, between central brace and the outer brace in a KT joint. Equal gaps at each side based on the default gap is assumed.

GAP is the gap used by the program

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3.7 Stresses in Non Tubular Joints

This evaluation of nominal stresses at element nodes i.e. non-tubular joints uses the geometric property code stress points. Two stress range options are available, the nominal direct stress or the equivalent stress (Von-Mises) as described below.

Stresses and associated fatigues in tubular joints are identified as either chord side or brace side. For non-tubular joints the chord side corresponds to the nominal direct stress and the brace side to the equivalent stress.

The nominal direct stress ranges evaluation is based on the direct normal stresses (axial stress + bending stress) at the stress point.

Local SCF factors may be included at the stress points by using defined pipework SIF factors but they are more often applied in assessments using the Selective Asssessments (see Sect 4.9). If SIFs are specified the mean of the SIOF and SIIF is applied to the axial stress. Note that SIFs are applied to both pipe and beam elements.

The Von-Mises stress option can be used to include the effects of shear and hoop. It does this by evaluating the stress range based on the following equivalent stress. The sign of the equivalent stress is based on the sign of the direct stress.

For beam elements

SEQ = ((SL**2 + 3St**2)**0.5 * SL * ABS(SL)

Where:

SL = SLP + SLA

SLA = F/A

SLB = ((io.Mo)**2 + (ii.Mi)**2) / Z

St = SQRT((Mtt / 2Z)**2+ (2Fy/ A)**2 + (2Fz/ A)**2)

For pipe elements

SEQ = ((SH**2 + SL**2 - SH.SL+ 3St**2)**0.5 * SL * ABS(SL)

Where:

SL = SLA + SLB

SLA = p.Do/4t + 4F/Pi.(Do**2 - d**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2) / Z

SH = p.Do / 2t

St = SQRT((Mtt / 2Z)**2+ (2Fy/ A)**2 + (2Fz/ A)**2)

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3.8 Stresses in Finite Elements

The component stresses in finite elements are evaluated in an identical manner to that done when post-processing a standard result case in FS2000.

The stresses ranges used for fatigue life prediction are based on two types of stress:

- Principle Stress
- Von-Mises Equivalent Stress

Principle Stress Ranges

To evaluate the stress range at a given stress point the range the following procedure is adopted:

1. The maximum absolute principle stress for each case is identified from the 3 principle stresses.
2. The sign of this maximum principle stress is maintained.
3. The stress range is based on the largest difference between the cases being considered.

Von-Mises Equivalent Stress

1. The Von-Mises stress at a stress point is evaluated. Note: A VM stress is a scalar quantity with only one value at a stress point.
2. This VM stress is signed to correspond to the sign of the maximum principle stress.
3. The stress range is based on the largest difference between the cases being considered.

Stresses and associated fatigues in tubular joints are identified as either chord side or brace side. For finite elements joints the chord side corresponds to the **principle stress** and the brace side to the **VM equivalent stress** .

Shell Element Stress Points

For shell element each element node will have 3 stress points corresponding to:

Pt 1 Mid
Pt 2 Top
Pt 3 Bottom

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4.0 Operation of the Fatigue Modules

This section of the manual describes the command line operation of the fatigue modules and the file formats.   The setting up of a fatigue analysis is can be somewhat tedious and error prone therefore a utility program is provided that not only sets up the fatigue analysis but also creates the batch control files to generate the basic WaveLoader load cases.

The use of the OffFat Batch Control File Utility is described in Section 5 . If this utility is used, it not essential to initially fully understand the operation of the fatigue modules described in this section since the utility sets up the commands for their operation and for the generation of all wave load data.

The remainder of the section describes the operation of the fatigue modules

The fatigue analysis batch file comprises of two basic sections.

- Analysis Phase
- Assessment Phase

The first section, the **Analysis Phase** produces the stress range data. This where all the load generation and analysis is undertaken, this a lengthy analysis process. The fatigue commands included in this section are FATIG1 and FATIG2.

The second section, is **Assessment Phase** where the fatigue assessments are undertaken. The fatigue commands included in this section are FATIG3 and FATIG4. The final output from the fatigue analysis is produced in FATIG 4 in the form of text data. On-geometry fatigue life plots can also be created. The assessment phase can be a global assessment where global all stress ranges are assessed using global parameters or a selective assessment where specific parameters are assigned. In selective assessments group attribute restricts the output and the output is assigned to its own case number.

The

All input and output data from the fatigue analysis modules is contained in text files. This enables the user to verify all aspects of the fatigue analysis. The various file formats are described in Appendix E.

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4.2 The Fatigue Solution Process

FS2000's post-processor creates the standard results file that are used by the Fatigue modules. FATIG1 or FATIG1S are the fatigue modules that read the elements forces contained in the result files created by the post processor.

The emphasis in this documentation is towards offshore wave fatigue analysis where the loading is generated using FS-Wave. A simplified flow for this type of analysis is:

FS-Wave

Solution

Post-Process

FATIG1 or FATIG1S - Peak Stresses

FATIG2- Stress Ranges

Post Stress Evaluation Assessments

FATIG3 - Damage Stress Range/Wave Occurrence/SN Curve

FATIG4 - Damage Summation

Non wave fatigue analysis may also be undertaken using any result case.A simplified flow for this type of analysis is:

Solution

Post-Process

FATIG1 or FATIG1S - Peak Stresses

FATIG2- Stress Ranges

FATIG3s - Damage Stress Range/No of Cycles/SN Curve

FATIG4 - Damage Summation

It is possible to combine damage from wave fatigue and other forms of fatigue damage e.g. wind turbine vibration, thermal cycling. An example of batch file that does this is given in Section 4.7.3.

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4.2.1 Generating Loads Cases from FS-Wave

The wave load files from the FSWave could be generated interactively in the WaveLoader but this would not really be practicable. To avoid setup errors it is essential to use the WaveLoader in Batch operation.

Note the Batch File Creation Utility described in Section 5 creates all the controls files and batch entries to do this.

It is essential that an appropriate Hydrodynamic Model Data File called **WAV** is saved in FS-Wave before using the fatigue Batch File Creation Utility.

The remainder of this section gives some additional background

When setting up the WaveLoader for batch operation there is requirement to set up environmental files for each wave for each direction. This requires that the WaveLoader batch control files **.BC ,** that create the incremental load cases for each stepped wave will also have to be set up for each direction.

FS-Wave requires that the Hydrodynamic Model Data **.WAV** file be linked to the **.BW** file. This means that multiple WAV files for each direction are required. In the fatigue batch file the primary WAV file is copied to the appropriate direction e.g. **.WAV** is coped to **.WAVF1** using the MFCOPY command. This avoids the requirement to manually create the identical directional WAV files.

The BCWAVF file are created by the Batch File Creation Utility and match the copied **WAV** file .

WAVF1

BC*WAVF1*

. . . .

. . . .

WAVF8

BC*WAVF8*

To reduce storage requirements on large models fatigue waves load case files can be re-created for each fatigue wave. A series of load cases representing the wave passing through the structure, say L70 to L81, for 12 steps could be created. The fatigue modules FATIG1 and FATIG2 can then be run to create the peak stress range data files for all joints i.e. ".Yw" files. Only these .Y files require to be saved for subsequent fatigue analysis.

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4.2.2 Solution

Linear Solution

When using OffFAT the most the default and most commonly used solver is the 3-D Standard (OFRAME). If the model employs non-linear elements there may be a requirement to change to the non-linear solver (PILE3D). Using the non-linear

Differences when using the Non-Linear Solver

The non-linear solver produces result cases and the Fatigue Module FATIG1 or FATIG1S read these. Therefore, there are no fundamental implications when using non-linear solvers to produce the results. However, there are considerations when using OffFat to create the fatigue batch file.

IMPORTANT - A load cases combination template must exist - see below.

The following shows the main difference between a linear solution and a non-linear solution, the non-linear solution uses Load Case Combination.

```
REM ****************** DIRECTION    1
REM ****************** WAVE         1
REM ****************** WAVE NUMBER 1
MFCOPY "WAV" "WAVF1"
WAVELOAD WAVF1
LOADA C70/1/2/
OFRAME
POST6 70-81
FATIG1S 8/70/81/
FATIG2 70/81/51/2/
REM ****************** DIRECTION    1
REM ****************** WAVE         2
REM ****************** WAVE NUMBER 2
MFCOPY "WAV" "WAVF2"
WAVELOAD WAVF2
LOADA C70/1/2
```

```
REM ****************** DIRECTION    1
REM ****************** WAVE         1
REM ****************** WAVE NUMBER 1
MFCOPY "WAV" "WAVF1"
WAVELOAD WAVF1
LOADA C70/0/0/0/1/
PILE3D
LOADA C71/0/0/0/1/
PILE3D
LOADA C72/0/0/0/1/
PILE3D
LOADA C73/0/0/0/1/
PILE3D
LOADA C74/0/0/0/1/
PILE3D
LOADA C75/0/0/0/1/
PILE3D
LOADA C76/0/0/0/1/
PILE3D
LOADA C77/0/0/0/1/
PILE3D
LOADA C78/0/0/0/1/
PILE3D
LOADA C79/0/0/0/1/
PILE3D
LOADA C80/0/0/0/1/
PILE3D
LOADA C81/0/0/0/1/
PILE3D
POST6 70-81
FATIG1 8/70/81/4/0/
FATIG2 70/81/1/1/
FATIG1S 8/70/81/
FATIG2 70/81/51/2/
REM ****************** DIRECTION    1
REM ****************** WAVE         2
```

The Load Case Combination are based on a user defined template. This template must be save as combination case 0. This combination should define the steady state loading condition of the structure prior to wave loading be applied. In linear analysis such a requirement is not necessary because wave load case can be run in isolation.

This combination must contain at least two load cases. The last load case in the combination represent the wave loading. When this template is used the load case number of the last load case will be replaced by the fatigue wave load case. The load factor of the last load in the template combination will be used, the load case number is irrelevant because it is replaced

The fatigue wave load case number in the combination is the load combination number +100.

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4.3 FATIG 1 & FATIG 1S

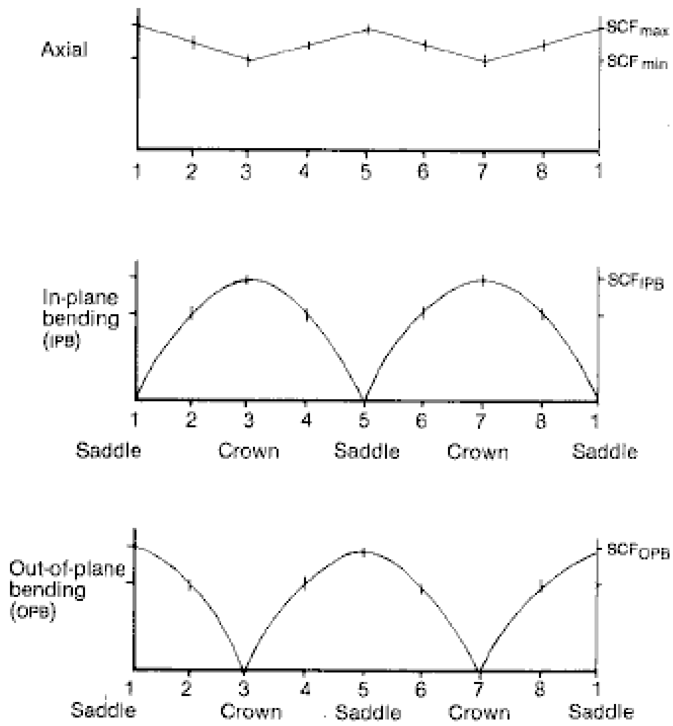
FATIG 1

This module evaluates the peak stresses at up to 12 locations (Stress Points) at the brace end of a tubular joint. SCF's and peak stresses at both the chord side and brace side of the weld are evaluated.

The peak stresses are obtained at each stress point using the following expression;

Stress = Axial x SCFa + Bendi x SCFi.Sin(θ) + Bendo x SCFo.Cos(θ)

SCFa is based on an interpolation of the the SCF at the saddle and crown for intermediate points between the saddel and crown.



Joints are classified by their geometric configuration.

The SCFs formulations currently available within the program are :

1) Design Reccomended Combination **Type 1**

These are commonly used parametric equations that are considered conservative for design (Early 1990s). They are based on;

K & KT Joints (axial & in-plane) - Kuangs Equations

TY, X and K & KT (out-plane) - Wordsworth & Smedley

2) UEG Reccommended Parametric Equations **Type 2**

3) HSE Reccommended **Type 3**

4) Ethymiou Parametric Equations DNV/API/EC3/ISO 1434 **Type4**

A utility for manual SCF evalauation is decribed in Appendix D . This shows the SCFs evaluated/used by the program. It can also be used to show other correlations and classifications using different joint parameters.

Validity Ranges

The program does not check for the validity ranges for the various SCF correlations.

The validity ranges for the Efthymiou equations are as follows:

$$0{,}2 \leqslant \beta \leqslant 1{,}0$$
$$0{,}2 \leqslant \tau \leqslant 1{,}0$$
$$8 \leqslant \gamma \leqslant 32$$
$$4 \leqslant \alpha \leqslant 40$$
$$20^\circ \leqslant \theta \leqslant 90^\circ$$
$$\frac{-0{,}6\beta}{\sin\theta} \leqslant \zeta \leqslant 1{,}0$$

The ISO 19902 code recommends the following for cases outside these ranges.

1) evaluate SCFs using the actual values of geometric parameters;
2) evaluate SCFs using the limit values of geometric parameters;
3) use the maximum of 1) or 2) above in the fatigue analysis.

FATIG 1S

This module evaluates nominal stresses at elements nodes (no SCFs applied) ie member joints using geometric property stress points. SCF factors may be included at the stress points by using the user defined pipework SIF factors (see Model Definition :Element Menu:Pipework).

The nominal stresses evaluated and associated lives are based on either the direct normal stresses (axial + bending) or the Von-Mises (signed) stress - See Section 3.7.

For stress evaluation in finite elements see Section 3.8

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4.3.1 Program Input

The inputs to this program modules are:

1) **Command Line Switches**
2) .ECJ Files - Optional user defined SCF definition data (see 3.4)
3) .F"n" files - Element Force Files Created in Post-Processor
4) .ECN files - Can and Stub wall thickness file (same as static joint design)
5) .EJG -Joint Configuration File (see 3.6)

FATIG1S only requires input Item 1

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4.3.2 Program Output

The output from these program modules are:

FATIG1

1)	.Z"n" files	-	Peak stresses at stress points for load case "n"
2)	.EF1 file	-	Program calculated SCF file
3)	.ECF	-	Chord(Can) and Brace(Stub) wall thickness file for SN Thickness Correction.

FATIG1S

1)	.Z"n" files	-	Peak stresses at stress points for load case "n"
2)	.ECFE		Shell element wall thickness for SN Thickness Correction

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4.3.3 Command Line Switches

FATIG1 C1/C2/C3/C4/

C1 Number of Locations (stress points) at Brace End (Up to 12)

C2 First Results Case Number (Element force file)

C3 Final Results Case Number

C4 SCF equations (1-Design Rec: 2-UEG Recommended: 3-HSE : 4-Efthymiou)

FATIG1S C1/C2/C3/

C1 Number of Locations (stress points) at Member End

C2 First Load Case Number (Element force file)

C3 Final Load Case Number

C4 Solid element stress type (1-Maximum Principle & Maximum Principle; 2- Maximum Principle & Signed Tresca ; 3-Maximum Principle & Signed VM)

If C4 is excluded the default is signed VM

Note the C1 in FATIG1S is only applied to pipe elements. Beam elements only have 4 stress points.

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4.4 FATIG 2

This module has a very simple function establishes the maximum peak stress range at all stress points from the load cases processed with FATIG 1.

FATIG 1 evaluates the peak stresses at each stress as the wave is passed through the structure and FATIG 2 scans the results of these cases to obtain the stress ranges. See Appendix A.

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4.4.1 Program Input

The inputs to this program modules are:

1) **Command Line Switches**
2) .Z"n" files - Peak stresses at stress points from FATIG 1 or FATIG1S
4) .ZF"n" files =Peak finite element stresses from FATIG1S
3) .ECF - Chord(Can) and Brace(Stub) wall thickness file

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4.4.2 Program Output

The outputs from this program module are:

1) .Y"w" files - Peak stress ranges at stress points from the range of .Z"n" files defined by C1 and C2. "w" is the Wave No.

2) .EC1 or .EC2 - Wall Thickness Data : EC1 for Tubular Joints, EC2 for Member Joints (See Command Line C4).

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4.4.3 Command Line Switches

FATIG2 C1/C2/C3/C4/

C1 First .Z file

C2 Final .Z file

C3 File ID ("w" wave number) number for .Y"w" file

C4 1 for Tubular Joints : 2 for Member Joints

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4.5 FATIG 3

This module evaluates for a given wave direction the cumulative damage ratio at all stress points. It uses the stress ranges data generated by FATIG2.

FATIG3 can be re-run with different parameters and result case numbers to check selective areas of a model **without** having to do repeat runs of FATIG1 & FATIG2, the time consuming stress data generation part.

Using defines wave occurrence data for each direction the program establishes a wave height/number of occurrence relationship. It then combines this with the stress range/wave height relationship to obtain a stress range/occurrence relationship. Using a SN curve and applying Miner rule the cumulative damage is thus obtained. See Appendix A flow chart.

Wave occurence data can be defined by the user (see 4.5.5) or it can be generated by the program using the following equation.

H = Ho(1- logN/logNo)

Where

Ho is the maximum wave height in the return period

No is the maximum number of wave in the same return period

Typicial wave exceedance data generated by the program is shown below.

Wave H	No of Occ
0.5	520400
1.5	262500
2.5	132400
3.5	66780
4.5	33680
5.5	16990
6.5	8570
7.5	4323
8.5	2180
9.5	1100
10.5	555
11.5	280
12.5	141
13.5	71
14.5	36
15.5	18
16.5	9
17.5	5
18.5	2
19.5	1

-o-

4.5.1 Program Input

The inputs to this program modules are:

1) Command Line Switches

2) DD"n" - Wave Data File for Direction (see 4.5.4)

3) .DB"n" - Explicit Block Wave Exceedance Data (Optional see 4.5.5)

3) .Y"w" - Peak stress ranges at all stress points

4) .EC1 or EC2 - Chord(Can) and Brace(Stub) wall thickness file for SN Thickness Corrction.

-o-

4.5.2 Program Output

Damage Result for Combination with other damage results (for processing by FATIG4)

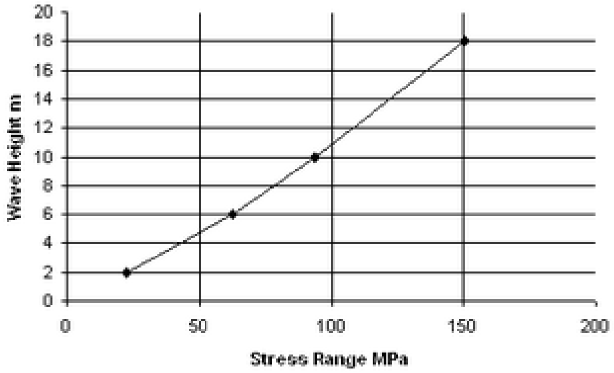
The outputs from this program module are:

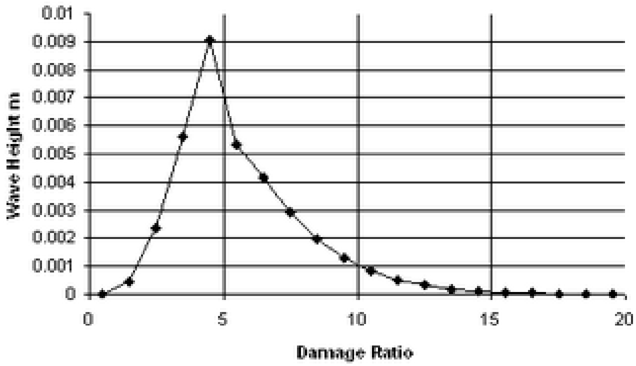
1) .D"d" files - Damage ratios at all stress points by direction (for processing by FATIG4)

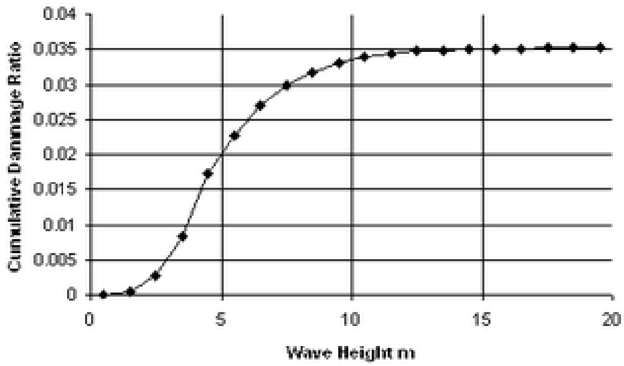
2) .~"d" - *Fatigue Blocks* (for processing by FATIG4)

Interactive Mode

The program can be operated in interactive mode (see 4.5.8). Its main use will be to show more detailed data for specific stress points for a given wave direction. The plots below show the most common use of the data. The plots were created in Excel from data copied from the interactive window and pasted in Excel.







-o-

4.5.3 Command Line Switches

FATIG3 C1/C2/C3/C4/C5/C6/C7/

C1 Start .Y"w" file. (w-Wave number)

C2 .D"d" damage output reference file number (related to direction)

C3 Wave Directional Data Number (n) for .DD"n" or .DB"n" files - see 4.5.4 and 4.5.5

C4 Additional global SFC

C5 S-N Curve Identification String (see 4.5.7)

C6 Interactive Switch (I for interactive)

C7 Wall thickness for SN Curve Correction - used for non-pipe joints (optional - default is SN curve reference thickness used for non-pipe elements)

If C7 is defined as a -ve value it will overwrite any model defined t for Member Joints including pipes (not applied to Tubular Joints).

-o-

4.5.4 Wave Data File Format (.DD"n")

The most common reason for editing this program-generated file is to:

- Modify the directional distribution factors - Distribution Factor;
- Define Ho=0 so that user defined wave blocks can be used (see 4.5.5);
- Define Ho and No by direction (and Distribution Factor = 1.0).

The file format for the .DD'n' files is:

Ho
No
Distribution Factor
Return Period in Years
Maximum Wave Height
Number of Wave Blocks
Number of Waves (nw)
H1
to
H"nw"

The directional Distribution Factor should only be a non unity value when Ho and No are based on omni-directional data i.e. maximum wave from all directions and total number of waves from all directions.

The output data will always show the number of waves per block on a 1-year basis regardless of the actual defined return period.

-o-

4.5.5 Optional Explicit Wave Exceedance Blocks

If the user requires to explicitly define the wave exceedance blocks then Ho in the above file should be specified as zero and a .DB"n" file defining the wave blocks must be created. When HO is zero the program will read the .DB"n" file.

The .DB"n" file format is simply two numbers, wave height and number of occurences to define each block, as shown below given below. This is a text file so ensure that any editor used can create pure text files.

Note that the **Return Period** and **Number of Wave Blocks** for this data must be defined in the .DD"n" data file and the number of blocks must match the number of blocks defined in the .DB(n) data file.

The fatgue output results will shows the number of waves per block on a 1-year basis regardless of the actual defined return period, just ensure that the return period defined in the .DD(n) files relates to the wave occurence data in the DB(n) files. The **No** (number of waves) and **Distribution Factor** in the .DD(n) file is ignored when block data is used.

.DB"n" File Format

Wave Height No of Occurrences

The following shows a few lines of a typical file **-** The file must be a plane text file with

```
0.5 5.204E+05
1.5 2.625E+05
2.5 1.324E+05
3.5 6.678E+04
4.5 3.368E+04
5.5 1.699E+04
6.5 8.570E+03
-
-
-
-
7.5 4.323E+03
```

-o-

4.5.6 Single Wave Fatigue Analysis

This approach is not recommended for design purposes.

If it is assumed that the relationship

Stress Range s = kH**h

can be used to evaluate the stress point stress range at all points than it is possible to undertake a fatigue analysis based on only the stress range from one wave for each direction.

Such an approach makes fatigue analysis considerably faster but at the expense of accuracy. A value of 1.4 for **h** with the 50 year storm wave as the reference wave is often used for North Sea conditions.

When using only one wave it is necessary to input the exponent constant **h**. This is input is defined into by appending it to the bottom of the .DD"n" file as indicated below.

Ho
No
Distribution Factor
Return Period
Maximum Wave Height
Number of Wave Blocks
Number of Waves (this would be set to 1)
H1
h (the exponent constant)

-o-

4.5.7 SN Data

Fatigue life damage based on the following expression

$LOG(N) = LOG(K2) - - mLOG(S/(tref/t)^{n})$

When t < tref, no thickness correction effects are applied.

The SN curve constants are read from a file named SNCURVE.DAT. This file **MUST EXIST** in the FS2000 directory. This file may be extended to include user-defined curves. Alternatively SN curves can be created in a model related file. If 'modelname'.USNC exists in the model directory it will be read in preference to the above DAT files.

There will be four SN curve data files in the FS2000 folder.

SN_ISO.DAT
SN_DNV.DAT
SN-EN.DAT
SNCURVE.DAT

The DNV/API and ISO curves both use a S suffix to identify a seawater curves e.g. in the ISO code F2 or F2S will be present.
The SNCURVE.DAT should be regarded as user defined file that can modified or added to be the user.

The file format for SN curves is given below. If curves do not exist in the distributed file they may be easily added.

The curve is described in two lines. The first line is the string description used for identification. The second line has 8 data fields. These are

$LOG(K2)_1$ m_1 StressChange $LOG(K2)_2$ m_2 EndLim tref n(tref exp)

Suffix 1 or 2 permit a two part SN Curve. The change point is defined by StressChange. EndLim is the fatigue endurance limit i.e. stress range below which fatigue damage does not occur.

```
B
15.0055    4     100.3172  17.00688  5   0    .022  .25
C
13.626     3.5   78.18847  16.46571  5   0    .022  .25
D
12.1817    3     53.36218  15.63617  5   0    .022  .25
E
12.0151    3     46.95698  15.3585   5   0    .022  .25
F
11.8004    3     39.82296  15.00067  5   0    .022  .25
F2
11.6342    3     35.05366  14.72367  5   0    .022  .25
G
11.3939    3     29.14965  14.32317  5   0    .022  .25
W
11.197     3     25.0611   13.995    5   0    .022  .25
T
12.1638    3     52.63401  15.60633  5   0    .032  .25
EN160
12.901     3     117    17.036       5   64   0.025 .25
```

```
EN140
12.751       3     104    16.786       5      57     0.025  .25
EN125
12.601       3     93     16.536       5      51     0.025  .25
EN112
12.451       3     83     16.286       5      45     0.025  .25
```

-o-

4.5.7.1 Thickness Correction (SN Curves)

Fatigue life damage based on the following expression

$$LOG(N) = LOG(K2) - mLOG(S/(tref/t)^{n})$$

t is the actual wall thickness and tref is the reference thickness associated with the SN curve.

When t < tref, no thickness effects are applied.

Tubular Joint Checks (FATIG1)

For tubular joint checks the value of t will be obtained when the FATIG1 module is run and will be saved (.ECF/.EC1 file) for future use when the wall thickness stress correction factor is evaluated for use with the SN Curves (FATIG3 & FATIG3S). The correction thicknesses used are defined in .EC1.

Member Joint Check (FATIG1S)

Because beam elements (non-pipes) do not have a specific single wall thickness the value of t is not available and the wall thickness to be used for wall thickness stress correction factor evaluation has to be specified as a global value i.e. for all elements. Pipes are not considered to be beams in this context and the element pipe wall thickness will be used .

If FATIG1 is run anytime prior to FATIG1S the wall thickness of joint brace and chord elements will be saved for wall thickness stress correction factor evaluation. If defined, this thickness will be the stub thickness used in joint design. Note that this does not include the increased thickness of joint chord cans, only the nominal wall thickness of the chord element will be included.

The SN curve correction thicknesses used are defined in .EC2. Note that zero entries (t<tref) indicate that no thickness correction will be applied. Only non-pipe beams should have zero entries.

The .EC2 file can be edited but it will be overwritten whenever FATIG2 is run. So a renamed copy will be required to be employed if this strategy is to be adopted. The recommended approach is to use selective assessments when t is required to be defined.

For non pipe beams a good strategy is to use a high global value based on a maximum t value and refine as necessary if specific joint are assessed with too short a life.

-o-

4.5.8 Interactive Operation

Interactive operation of this module enables the user to obtain more detailed fatigue analysis results on individual stress points. If C6 = I then prompts for the interactive form shown below will appear.

This is used to show more explicit fatigue damage data. Its main use is to show;

- The relationship between wave height and stress range
- The relationship between wave height and damage ratio

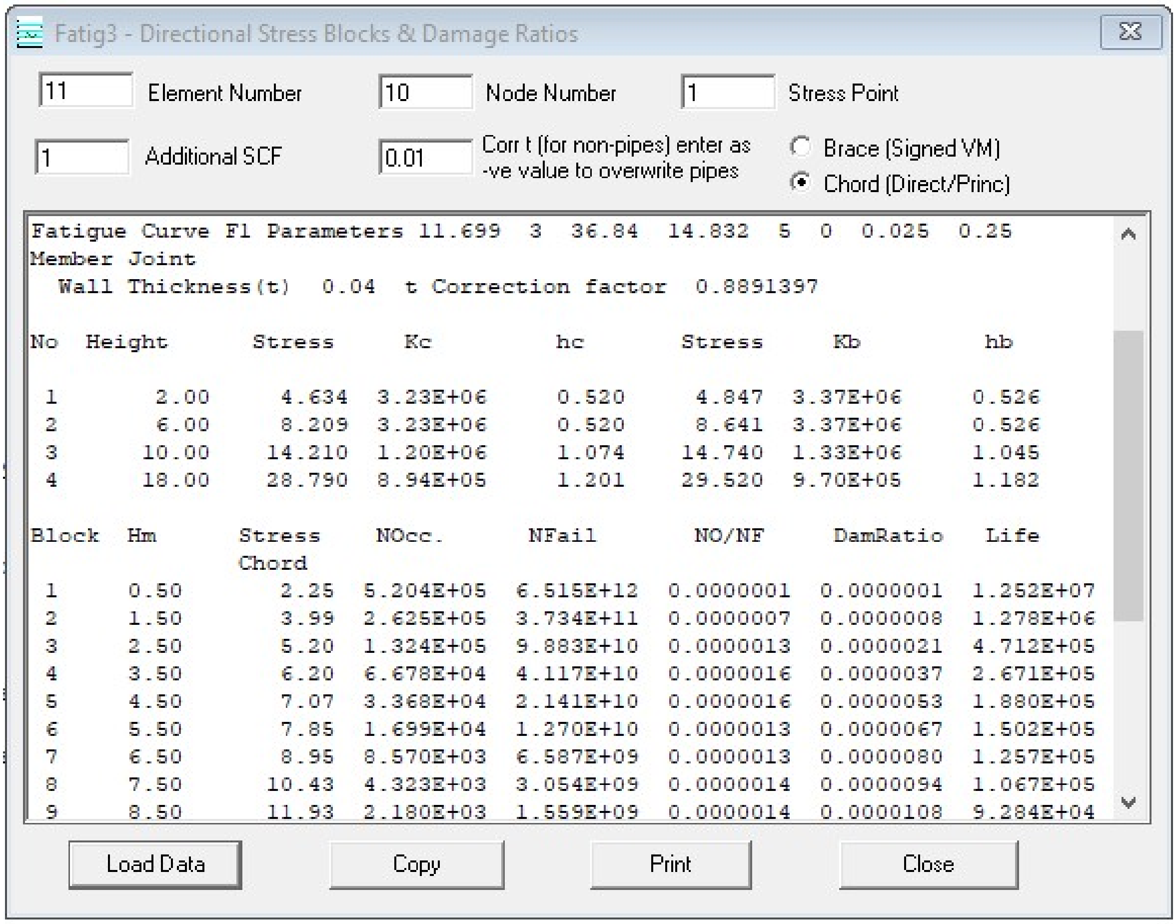
The following illustrates how the FATIG 3 batch command can be used to start this data veiwer.

Typical standard FATIG3 batch commands are shown below.

```
REM ******************* DIRECTION  1
FATIG3 1/1/1/1/T/B/
REM ******************* DIRECTION  2
FATIG3 5/2/2/1/T/B/
REM ******************* DIRECTION  3
FATIG3 9/3/3/1/T/B/
REM ******************* DIRECTION  4
FATIG3 13/4/4/1/T/B/
```

If these lines are copied and the B replaced with an I then each command line can be use to start FATIG3 for a given direction. The following illusrates this. Note that the 'stop' command inserted to ensure only one instance of the program started at a time.

```
FATIG4 1/4/10000/70/1/
stop
REM ******************* DIRECTION  1
FATIG3 1/1/1/1/T/I/
stop
REM ******************* DIRECTION  2
FATIG3 5/2/2/1/T/I/
stop
REM ******************* DIRECTION  3
FATIG3 9/3/3/1/T/I/
stop
REM ******************* DIRECTION  4
FATIG3 13/4/4/1/T/I/
stop
```


Fatig3 - Directional Stress Blocks & Damage Ratios
11 Element Number
10 Node Number
1 Stress Point
1 Additional SCF
0.01 Corr t (for non-pipes) enter as -ve value to overwrite pipes
Brace (Signed VM)
Chord (Direct/Princ)
Fatigue Curve F1 Parameters 11.699 3 36.84 14.832 5 0 0.025 0.25
Member Joint
Wall Thickness(t) 0.04 t Correction factor 0.8891397
No Height Stress Kc hc Stress Kb hb
1 2.00 4.634 3.23E+06 0.520 4.847 3.37E+06 0.526
2 6.00 8.209 3.23E+06 0.520 8.641 3.37E+06 0.526
3 10.00 14.210 1.20E+06 1.074 14.740 1.33E+06 1.045
4 18.00 28.790 8.94E+05 1.201 29.520 9.70E+05 1.182
Block Hm Stress Chord NOcc. NFail NO/NF DamRatio Life
1 0.50 2.25 5.204E+05 6.515E+12 0.0000001 0.0000001 1.252E+07
2 1.50 3.99 2.625E+05 3.734E+11 0.0000007 0.0000008 1.278E+06
3 2.50 5.20 1.324E+05 9.883E+10 0.0000013 0.0000021 4.712E+05
4 3.50 6.20 6.678E+04 4.117E+10 0.0000016 0.0000037 2.671E+05
5 4.50 7.07 3.368E+04 2.141E+10 0.0000016 0.0000053 1.880E+05
6 5.50 7.85 1.699E+04 1.270E+10 0.0000013 0.0000067 1.502E+05
7 6.50 8.95 8.570E+03 6.587E+09 0.0000013 0.0000080 1.257E+05
8 7.50 10.43 4.323E+03 3.054E+09 0.0000014 0.0000094 1.067E+05
9 8.50 11.93 2.180E+03 1.559E+09 0.0000014 0.0000108 9.284E+04
Load Data
Copy
Print
Close

-o-

4.6 FATIG 4

This module sums the damage ratio at all stress points for all wave directions and produces the result data in both text and graphical life plot data.

FATIG3 processes the fatigue data for all stress points using the current fatigue parameters. When selective assessments are undertaken it is this module that selects what is to be output.

-o-

4.6.1 Program Input

The inputs to this program modules are:

1) **Command Line Switches**

2) .D"d" files - Damage Ratio Files for each wave direction

3) .~"d" files - Wave Block Data

-o-

4.6.2 Program Output

The output for the fatigue analysis will be output as Tubular Joint Design Results using the following categories.

Summary Output - Minimum fatigue life at joint, output text

Stress Output - Fatigue life at all joint stress points, output text

Section 4.8 described in more detail how the results may be accessed.

-o-

4.6.3 Command Line Switches

FATIG4 C1/C2/C3/C4/C5/C6/C7/C8/

C1 First DM file number ("d")

C2 Final DM file number ("d")

C3 Fatigue life limit (years) for .JF output text files

C4 RC - Output Results Case Number

C5 Fatigue Category

1 for Tubular Joints

2 for DS Member Joints (Solid elements Principle Stress & Signed Tresca or Signed VM)

C6 Group SET to be read.

C7 Restrict output to Group defined in SET C6

C8 Restriction Applies to 0 - Elements 1 - Nodes

C9 Description for output

If C7 is preceded by a - the output will be sorted into groups up to the group attribute limit defined by C7

-o-

4.7 FATIG3S

This module is used to evaluate fatigue damage from conventional FS2000 result cases. FATIG1 or FATIG1S and FATIG2 would be used to create the stress range file from 2 or more result cases. Note that at least two cases are required to be processed. Therefore if only one loading range is analysed a null case with no loading must also be processed.

The module will read a single stress range file (.Y file) and produces a damage ratio file based on a defined SN curve and optional global SCF.

The output will be:

- A damage ratio data for processing by FATIG4
- An output text file showing fatigue lives for this specific case

It will create damage data that can be combined with other damage data using the FATIG4 module. This feature can be used to added other type of fatigue damage to the damage resulting from that evaluated for wave loading. This feature enables:

- Damage from initial loading to be included e.g. transportation
- Damage from simultaneous loading e.g. wind turbine loading

-o-

4.7.1 Program Input

The inputs to this program modules are:

1)	**Command Line Switches**	
2)	.Y file -	Stress range File Number
3)	SCF	Global SCF
4)	SN Curve	Curve from SNCURVES.DAT
5)	Wall thickness	Used for non tubular joints
6)	Stress Cycles	Number of Stress Cycles in Return Period
7)	Return Period	Return Period (Usually in years)

-o-

4.7.2 Program Output

Damage Result for Combination with other damage results (for processing by FATIG4)

1) .D"d" files - Damage ratios at all stress points by direction
2) .~"d" - *Fatigue Blocks*

Fatigue Results for Specific Case

The output for the fatigue analysis will be output as Tubular Joint Design Results using the following categories

Summary Output - Minimum fatigue life at joint, output text
Stress Output - Fatigue life at all joint stress points, output text
Life plots - Damage ratio plot file

The result case number (RC) to which the output is assigned is defined by C7 in the Command Line Switches.

Life plots are obtained by using the tubular joint design UR plot facility. By default this will plot the damage ratio but if the **Life** option is active the life in years will be plotted. Note: The Lower UR plot limit is interpreted as a damage ratio, therefore lower the value if long lives are to be plotted.

The tubular joint Sorted Unity Ratio (UR) can be used to sort the fatigue life output into an ascending order list.

Typical Summary Output

Global SCF = 1
Tubular Joints
Actual Cycles = 5.000E+07

Return Period = 20

*** Fatigue Performance Data ***

Elem	Node	Stress Ranges	Failure Cycles	Fatigue Curve	Damage Ratio	Life Years
21	11	31	1.410E+08	T	0.355	56.40
22	21	30	1.753E+08	T	0.285	70.10
22	51	11	2.342E+10	T	0.002	9368.85
23	51	11	2.220E+10	T	0.002	8880.56
23	12	19	1.527E+09	T	0.033	610.81
24	22	20	1.360E+09	T	0.037	544.16

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4.7.3 Command Line Switches

FATIG3S C1/C2/C3/C4/C5/C6/C7/C8/C9/C10/

C1 Stress Range File.Y"w" file.

C2 Additiional Global SCF

C3 SN Curve

C4 Wall thickness for SN Curve Correction - used for non-pipe joints (optional - default is SN curve reference thickness used for non-pipe elements)

C5 Actual Stress Cycles

C6 Return Period (Years)

C7 RC - Output Results Case Number and damage file ID for FATIG4

C8 Group SET to be read

C9 Restrict output to Group defined by SET C8

C10 Sub Case Description

If C4 is preceded by a - i.e. negative it will overwrite any model defined t for Member Joints including pipes (not applied to Tubular Joints).

If C7 is preceded by a - i.e. negative only the FATIG4 damage data file will be created.

If C9 is preceded by a - i.e. negative the output will be sorted into groups up to the group attribute limit defined by C8

C8 to C10 are optional and not required in C7 is negative.

The example below shows a typical example of combining damage from wave induced fatigue with that from wind turbine loading expressed in terms of an equivalent load and number of cycles.

Wave Loading

```
REM ***********************************GLOBAL ASSESSMENTS
REM ******************* DIRECTION  1
FATIG3 1/1/1/1/T/B/
FATIG3 51/11/1/1.0/F2/B/
REM ******************* DIRECTION  2
FATIG3 5/2/2/1/T/B/
FATIG3 55/12/2/1.0/F2/B/
REM ******************* DIRECTION  3
FATIG3 9/3/3/1/T/B/
FATIG3 59/13/3/1.0/F2/B/
REM ******************* DIRECTION  4
FATIG3 13/4/4/1/T/B/
FATIG3 63/14/4/1.0/F2/B/
REM *******************COMBINE ALL DIRECTIONS
FATIG4 1/4/10000/100/1/
FATIG4 11/14/10000/101/2/
```

Turbine Loading

```
REM ********* Turbine Fatigue Direction 1
FATIG3S 20/1/T/0/5E7/20/5/
FATIG3S 70/1/F2/0/5E7/20/15/
REM ********* Turbine Fatigue Direction 2
FATIG3S 21/1/T/0/5E7/20/6/
FATIG3S 71/1/F2/0/5E7/20/16/
REM ********* Turbine Fatigue Direction 3
FATIG3S 22/1/T/0/5E7/20/7/
FATIG3S 72/1/F2/0/5E7/20/17/
```

```
REM ********* Turbine Fatigue Direction 4
FATIG3S 23/1/T/0/5E7/20/8/
FATIG3S 73/1/F2/0/5E7/20/18/
REM ********* Turbine Fatigue Damage - All Directions
FATIG4 5/8/10000/102/1/
FATIG4 15/18/10000/103/2/
```

Combine Wave & Turbine

```
REM ********* Combined Wave And Turbine Fatigue Damage - All Directions
FATIG4 1/8/10000/104/1/
FATIG4 11/18/10000/105/2/
```

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4.8 Output Results

The text output from the fatigue analysis will be output as Tubular Joint Design Results using the following categories.

- Summary Output - Minimum fatigue life at joint, output text
- Stress Output - Fatigue life at all joint stress points, output text
- Individual UR - Damage Ratios sorted by unity ratio (Life=1/UR) - Requires UR sort utility to be run.

Fatigue lives can also be plotted using the UR (Unity Ratio) plot command. The plot show the lowest fatigue life at each end of the element.

The result case number (RC) to which the output is assigned is defined by C4 in the Command Line Switches.

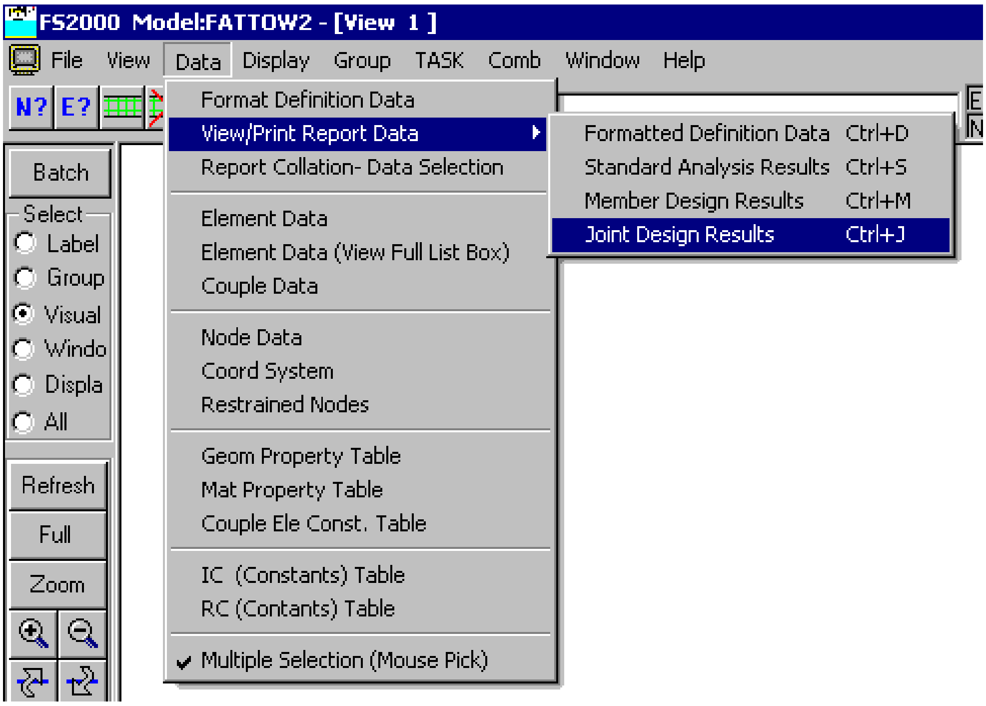
8 Stress points are used for CHS sesction and CHS joints and members

4 Stress points are used for beam elements

3 Stress point are used for shell elements top, mid and bottom surfaces.

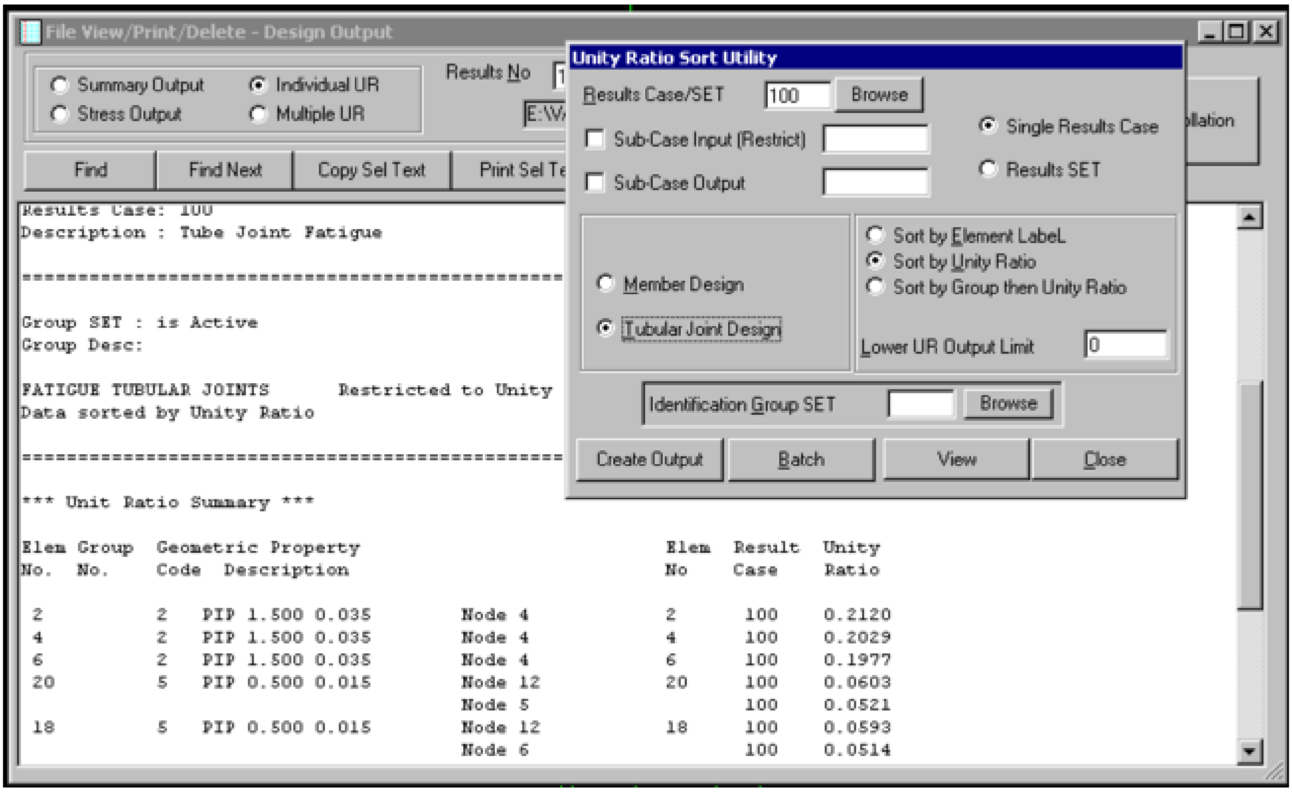
Viewing Text Results

The FS2000 menu commands shown below can be used to view the fatigue results. Selecting the Summary Output



Individual UR

The tubular joint Sorted Unity Ratio (UR) can be used to sort the fatigue life output into an ascending order list based on damage ratio.

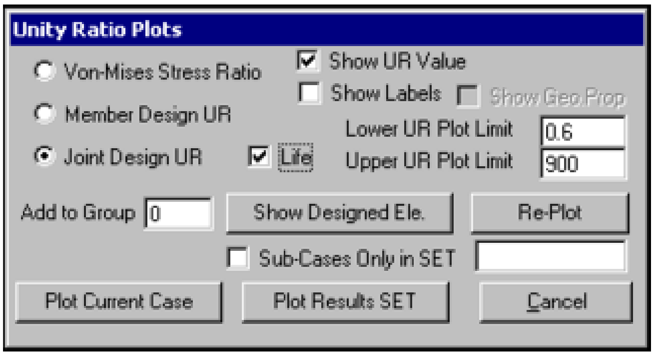


Plotting Fatigue Lives

Fatigue life plots are obtained by using the tubular joint design UR plot facility. This will plot the lowest fatigue life at each end of the element.

By default this will plot the damage ratio but if the **Life** option is active the life in years will be plotted. Note: The Lower UR plot limit is interpreted as a damage ratio, therefore lower the value if longer lives are to be plotted. Setting this to 0.01 would show all lives below 100 years.

Ensure that the **Life** option is active.



-o-

4.9 Using Non Global Parameters - Selective Assessments

When the Batch File Creation Utility (see Section 5) is used the set up the fatigue batch file, the fatigue prediction for all stress ranges will be based on the global default values. It is likely that non-default parameter will be required at different locations on the structure, this is achieved by undertaking selective assessments.

The parameters that often required to be changed are:

- Local SCF.
- SN Curve.
- Wall thickness for SN-Curve thickness correction.

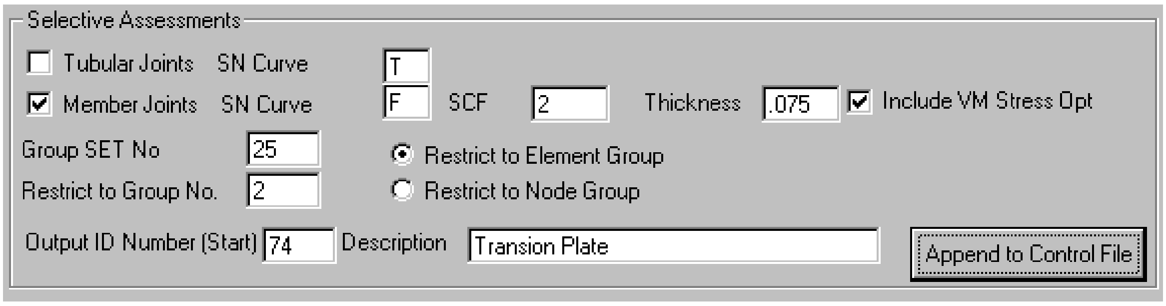
Each selective assessment can be assigned to an additional Results Case.

These additional command lines are added to the bottom (after the Analysis Phase) of the fatigue batch to form an additional assessment phase. Alternatively, they could be included in a separate batch used only for selective assessments.

The following show an example of the command to achieve this. A review of the module command line switches will indicate the resulting output.

```
----------------------------------------------------------------------------------------------------
----
REM  SCF=2: F Curve  t=0.075: SET 25: Group 2: Result Case 74 & 75
----------------------------------------------------------------------------------------------------
----
REM ******************* DIRECTION  1
FATIG3 51/11/1/2/F/B/0.075/
REM ******************* DIRECTION  2
FATIG3 55/12/2/2/F/B/0.075/
REM ******************* DIRECTION  3
FATIG3 59/13/3/2/F/B/0.075/
REM ******************* DIRECTION  4
FATIG3 63/14/4/2/F/B/0.075/
REM *******************COMBINE ALL DIRECTIONS
FATIG4 11/14/10000/74/2/25/2/0/Transition Plate/
FATIG4 11/14/10000/75/3/25/2/0/Transition Plate/
------------------------------------------------------------
```

Note that the Batch File Creation Utility has the capability to append selective assessments to a batch file (see Sect 5). The settings below would would enter the above batch entries.



When a correction **Thickness** is defined it will only be applied to elements with zero values in the .EC file, it will not overwrite existing value based on the pipe wall or the defined stub thickness in the case of Tubular Joints. The only elements with zero entries will be non-pipe beam elements.

This behaviour can be changed by defined the **Thickness** as a negative value. A negative value will replace any existing value for t. An instance where this would be done is when thickened chord can welds are being assessed and chord thickness is always the nominal pipe wall (not a requirement for brace stubs).

The **Include VM Stress** option is used to evaluate fatigue damage based on the Von-Mises stress at the stress point. This can be used to scan for areas where shear stresses (torsional or direct) may be significant. Normally only direct and bending stresses are considered at member joints.

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5.0 Batch File Creation Utility

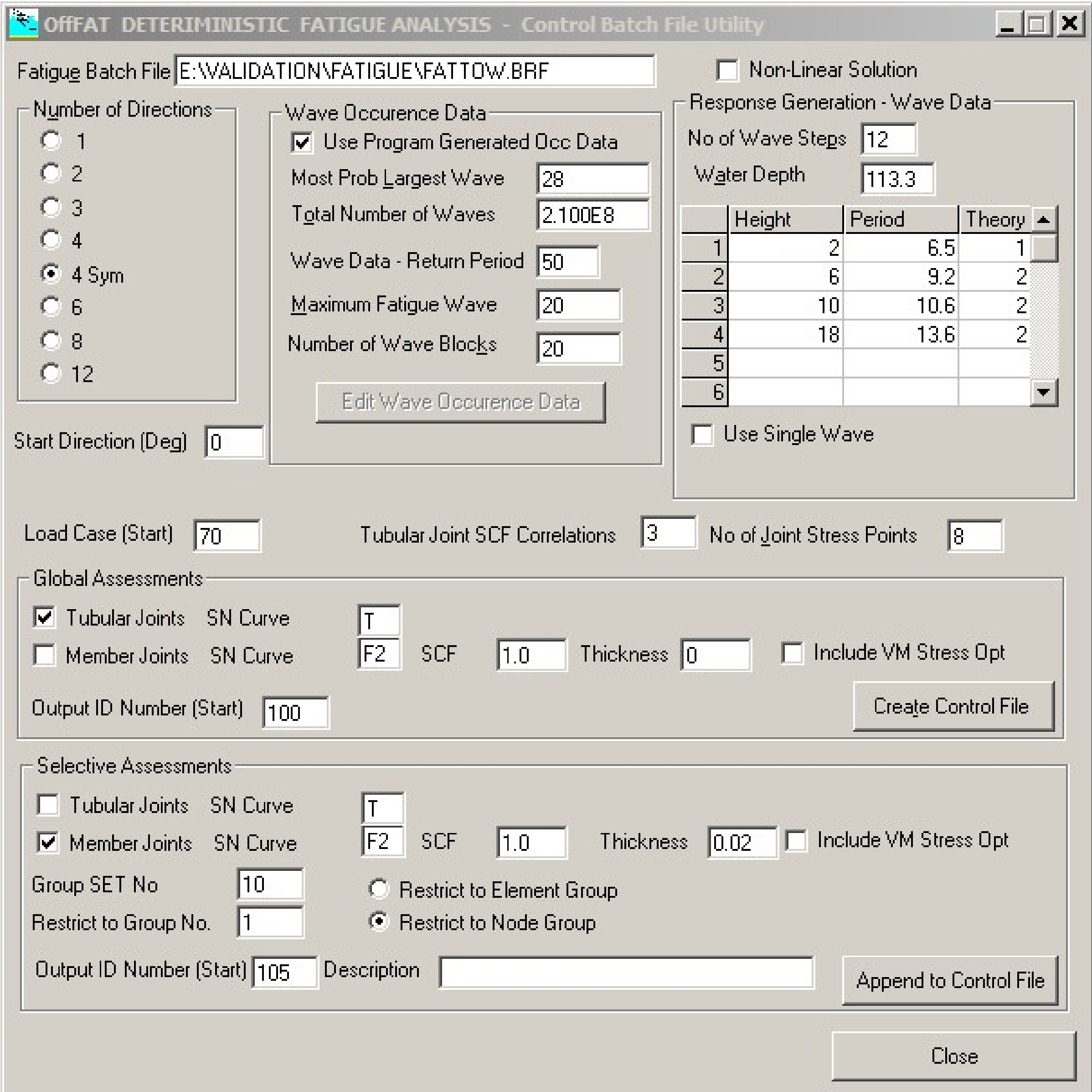
This utility program is started from the Windows Start menu by clicking the OffFat icon in the FS2000 program menu.

This utility will generate the Batch file and associated model files necessary for a fatigue analysis. It should not be used as a 'black box' for fatigue analysis, the user should have an understanding of the how the resulting Batch file undertakes the fatigue analysis.

It is essential that an appropriate Hydrodynamic Model Data File called **WAV** is saved in FS-Wave before using this utility.

The default-input data is as for Example 1 given in Appendix F. The input form below will appear when the program is activated is given below.

The set up data is saved to a data file with the extension **.DFT.** This file will always be archived.



The following describes how the above data relates the operation of the Fatigue Modules described in the Section 4.

The **Fatigue Batch File** shows and defines the recipient batch filename. It can be advantageous to change the name and create a secondary batch file for the Selective Assessments e.g. .BRFA. Using a secondary file ensures that Selective Assessment entries are not overwritten if the Create Control File option is used at a later stage.

The **Non-Linear Solution** is used to create a batch file that uses the static non-linear solution. This would be used when models incorporate non-linear elements e.g. tension, contact etc. See Section 4.2.2 for more detailed information on the implications of using this option. Note that a solution Load Case Combination (LC0) has to be created. This is used as a template.

The **Create Control** button in the **Global Assessment** frame is used to create the batch control file. This will overwrite any other previous batch file with the same name. When the batch file is created it will also create all secondary data to run a fatigue analysis based on the current model,

The **Append to Control File** in the **Selective Assessments** frame is used to identify sections in the models where specific SN curves, SCF and thickness are to be applied. It does this by appending additional Assessment Phase commands (FATIG3 & FATIG4) to the bottom of the existing command file. Node or elements groups identification identifies these sections. See Section 4.9. Using a secondary batch file file for selective assessment can make assist solution management.

Note that **Selective** assessments can be appended at any time to the main batch file or added to new batch files (Append will also create if the batch file does not exist). It is not necessary to run the whole batch file when undertaking selective assessments (FATIG3 & FATIG4). However, it is essential that the Analysis Phase (FATIG1 & FATIG2) of the batch has been run so that the stress range data is available for the assessments. Also, if Tubular or Member Joints are required to be selectively assessed that they must have also been selected for the Analysis Phase of the global selective, this ensures that appropriate stress range data exists.

Fatigue Batch File This is the file name of the Fatigue Batch Control File. It may be convenient to create a separate batch file for selective assessments which doe not contain the Analysis Phase.

Number of Directions This is used to define the number of directions to be considered. 4 Symm is applied at 45 deg increments. The module FATIG3 will be run and a FD'n' will be created for each direction. The distribution factor for the Return Period (see 4.5.4) is assumed to be equal for all directions e.g. .25 for 4 wave directions. Edit the **.DD** files if this is to be changed.

Start Direction This defines the direction of the wave relative to the model co-ordinate system. See WaveLoader Manual.

Start Load Case This may be set to any number. The number of load cases created is defined by the **Number of Wave Steps.** These are used in the Command Line of FATIG1 i.e. C2 and C3. Although a larger number of load cases are processed, the cases are repeatedly overwritten.

Number of Waves This defines the number of waves and associated characteristics that enable a wave height-stress range relationship to be obtained for each stress point. Theory : 1 is Airy, 2 is Stokes 5th, 3 Stream Function. Max number of waves is 14. Note that these waves are not used directly for fatigue life evaluation they are use to establish the wave-stress range relationship fro each stress point. This relationship is then interpolated to obtain the stress ranges corresponding to the wave blocks in the wave occurence data. In deterministic fatigue analysis there is no requirement to use that many waves. Sect 4.5.2 shows such a relationship with 4 waves. If only one wave is specified (for fast fatigue analysis) the user is require to input an exponent constant (see 4.5.6) and the wave height should be the most probable largest wave in the return period. The single wave approach is not recommended for design purposes.

Number of Wave Steps Defines the number of wave steps (load cases) used to evaluate the stress range for a given wave as it passes through the structure. 12 is the default.

Wave Depth Defines the water depth for the wave evaluation.

Wave Occurence Data The following parameters are used to define the wave exceedence data (see Sect 4.5) and the stress block to be used for fatigue damage evaluation. This data is entered into the .DD'n' file used by FATIG3.

Most Probable Largest Wave (onmi-directional)

Total Number of Waves (for all directions)

Return Period in Years

Number of Wave Blocks

Maximum Fatigue Wave

If the the **Use Program Generated Occ Data** is not active the user must define the wave occurence data (see Sect 4.5.5). Note that the **Return Period** and **Number of Wave Blocks** must still be specified. Note that the **Number of Blocks** defined here will be entered in the all the .DD(n) data files so ensure that the number of entries in the .DB(n) data files are the same for each direction. Tip add zero entries to .DB(n) make them all the same and equal to the direction with the largest number of blocks, this save editing the .DD((n) file to match..

ASSESSMENTS

Tubular Joints If checked will evaluate fatigue lives at tubular joints using the default SN curve. Joints can be referenced to specific curves.

Member Joints If checked will evaluate fatigue lives at using element nodes based on nominal stresses using the defaults SN curve.The **VM Stress** option is used to evaluate fatigue damage based on the Von-Mises stress at the stress point. This can be used to scan for areas where shear stresses (torsional or direct) may be significant. Normally only direct and bending stresses are considered at member joints. The wall thickness is used for SN Curve wall thickness correction.

The wall thickness is used for SN Curve wall thickness correction. When a correction **Thickness** is defined it will only be applied to elements with zero values in the .EC file, it will not overwrite existing value based on the pipe wall or the defined stub thickness in the case of Tubular Joints. The only elements with zero entries will be non-pipe beam elements. This behaviour can be changed by defined the **Thickness** as a negative value. A negative value will replace any existing value for t. An instance where this would be done is when thickened chord can welds are being assessed and chord thickness is always the nominal pipe wall (not a requirement for brace stubs).

Number of Stress Points Defines the number of stress point used in fatigue life evaluation of tubular joints. Max is 12. For non- tubular joints the 8 stress points are used for tubular elements and 4 stress points for beam elements.

SCF Correlations - Code 1 to 3 to identify SCFs for tubular joints (see 4.3)

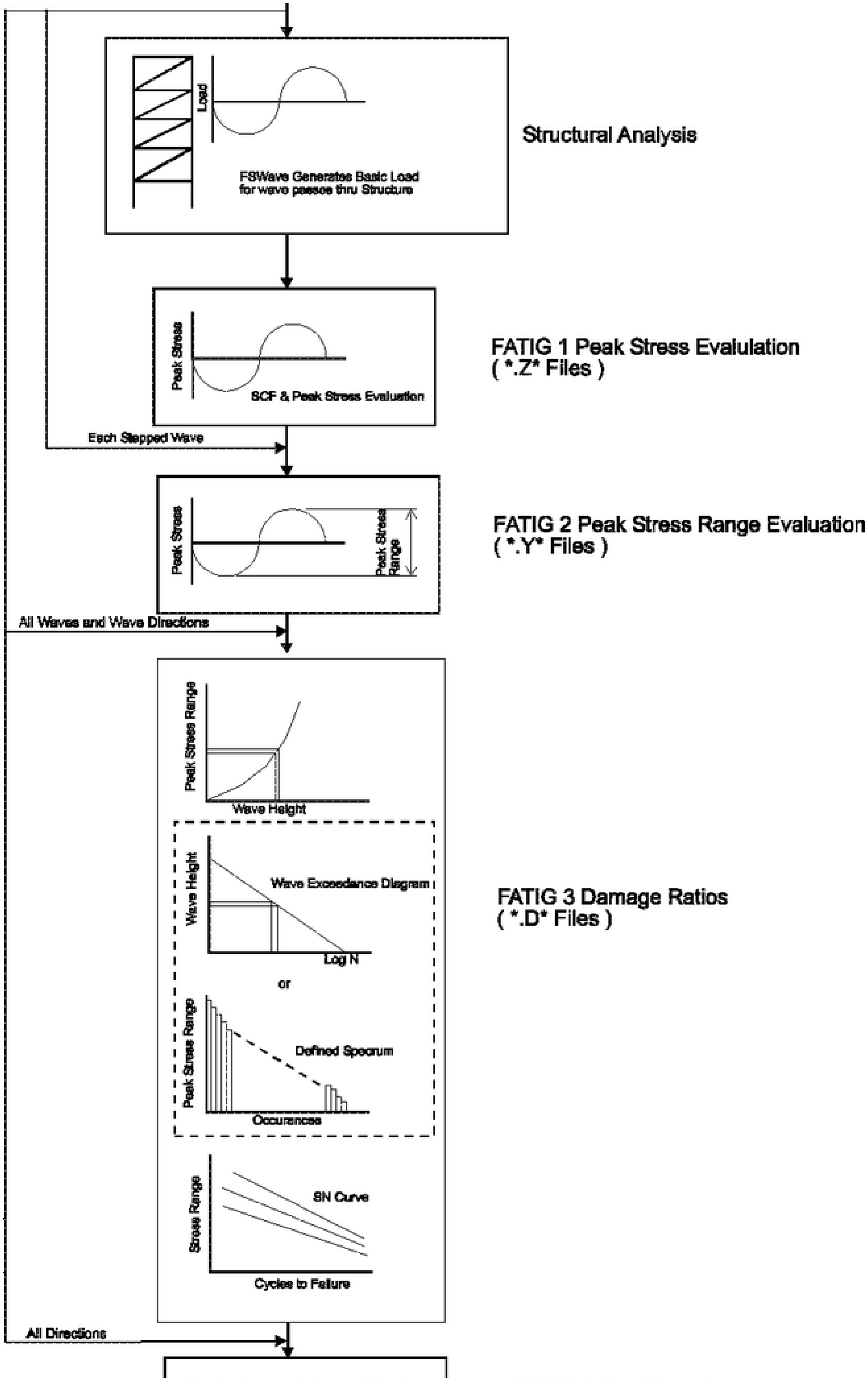
1	Design Recommended Combination
2	UEG Recommended Parametric Equations
3	HSE Recommended Parametric Equations
4	Efthymiou (DNV/API) Parametric Equations

The **Output ID Number (Start)** define the case number to which the results will be assigned (see 4.8). Two cases will be created if both tubular and member joints are active.

Selective Assessments provide a means to provide non global parameter to specific areas of the model. These areas are identified using node and element Group attributes.

-o-

APPENDIX A - Basic Fatigue Analysis Process


Load
FSWave Generates Basic Load for wave passes thru Structure
Structural Analysis
Peak Stress
SCF & Peak Stress Evaluation
FATIG 1 Peak Stress Evalulation
(*.Z* Files)
Each Stepped Wave
Peak Stress
Peak Stress Range
FATIG 2 Peak Stress Range Evaluation
(*.Y* Files)
All Waves and Wave Directions
Peak Stress Range
Wave Height
Wave Height
Wave Exceedance Diagram
Log N
or
Peak Stress Range
Defined Specrum
Occurances
FATIG 3 Damage Ratios
(*.D* Files)
Stress Range
SN Curve
Cycles to Failure
All Directions

-o-

APPENDIX B - Batch Command Line Summary

Command Line Summary

FATIG1 C1/C2/C3/C4/

C1 Number of Locations (stresspoints) at Brace End (12 max)

C2 First Results Case Number (Element force file)

C3 Final Results Case Number

C4 SCF equations (1-Design Rec: 2-UEG: 3-HSE : 4-Efthymiou)

FATIG1S C1/C2/C3/ (Non-tubular Joints)

C1 Number of Locations on Tubes (Up to 12)

C2 First Load Case Number (Element force file)

C3 Final Load Case Number

C4 Solid element stress type (1-Maximum Principle & Maximum Principle; 2- Maximum Principle & Signed Tresca ; 3-Maximum Principle & Signed VM)

FATIG2 C1/C2/C3/

C1 First .Z file

C2 Final .Z file

C3 File ID ("w" wave number) number for .Y"w" file

C4 1 for Tubular Joints 2 for Member Joints

FATIG3 C1/C2/C3/C4/C5/C6/C7/

C1 Start .Y"w" file. (w-Wave number)

C2 .D"d" damage output reference file number (related to direction)

C3 Wave Data Number (n) for .DD"n" or .DB"n" files - see 4.5.4

C4 Additional global SFC

C5 S-N Curve

C6 Interactive Switch (I for interactive)

C7 Wall thickness - used for non tubular joints (optional - default is SN curve reference thickness)

FATIG3S C1/C2/C3/C4/C5/C6/C7/C8/C9/ (Simple SN curve predictions)

C1 Stress Range File.Y"w" file.

C2 Additiional Global SCF

C3 SN Curve

C4 Wall thickness - SN Curve Correction

C5 Actual Stress Cycles

C6 Return Period

C7 RC - Output Results Case Number

C8 Group Set to be read

C9 Restrict output to Group SET defined by C8

If C7 is preceded by a - ie negative only the FATIG4 damage data file will be created.

If C9 is preceded by a - the output will be sorted into groups up to the group, attribute limit defined by C9

C10 Sub Case Description

FATIG4 C1/C2/C3/C4/C5/C6/C7/C8/C9/

C1 First D"d" file number

C2 Final D"d"file number

C3 Fatigue life limit for .JFD output text files in Years

C4 RC - Output Results Case Number

C5 Fatigue Category

1 for Tubular Joints

2 for DS Member Joints (Solid elements Principle Stress & Signed Tresca or Signed VM)

C6 Group Set to be read

C7 Restrict output to Group C7 in Group SET C6

C8 Restriction applies to 0 - Elements or 1 - Nodes

C9 Description for RC output

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APPENDIX C - Fatigue Related Files

Fatigue Programs

FATIG1.EXE

FATIG1S.EXE

FATIG2.EXE

FATIG3.EXE

FATIG3S.EXE

FATIG4.EXE

Model Independent Data Files

SNCURVE.DAT	SN Curve Definition

Model Dependent Data Files

.USNC	SN Curve Definition

Batch Utility Options File

.DFT	Data file for Batch File Creation Utiliy

Specific Fatigue Related Definition Files

.DD"n"	Fatigue Wave Data
.DB"n"	Optional Explicit Wave Exceedance Data
.ECJ	Optional User Defined SCF Data

Raw Data Output Files

.F"n"	Element Force File
.EF1	Joint Parameters and SCF data
.Z"n"	Peak Beam Stresses (overwritten for each wave)
.ZF"n"	Peak Solid Element Stresses (overwritten for each wave)
.Y"w"	Peak Stress Ranges for Wave w
.D"d"	Damage Ratios for Direction reference number d
.~"d"	Wave Block Data (Spectrum)
.EC1	Joint can and stub wall thickness for SN Curve Correction - Tubular Joints check
.EC2	Joint can and stub wall thickness for SN Curve Correction - Member Joints

Processed Output Files

Tubular Joint Summary Output	Minimum Fatigue Life at Tubular Joints
Tubular Joint Stress Output	Fatigue Lives at all Stress Points
Tubular Joint UR Graphic Plot	Damage Ratio/Fatigue Life Plot data

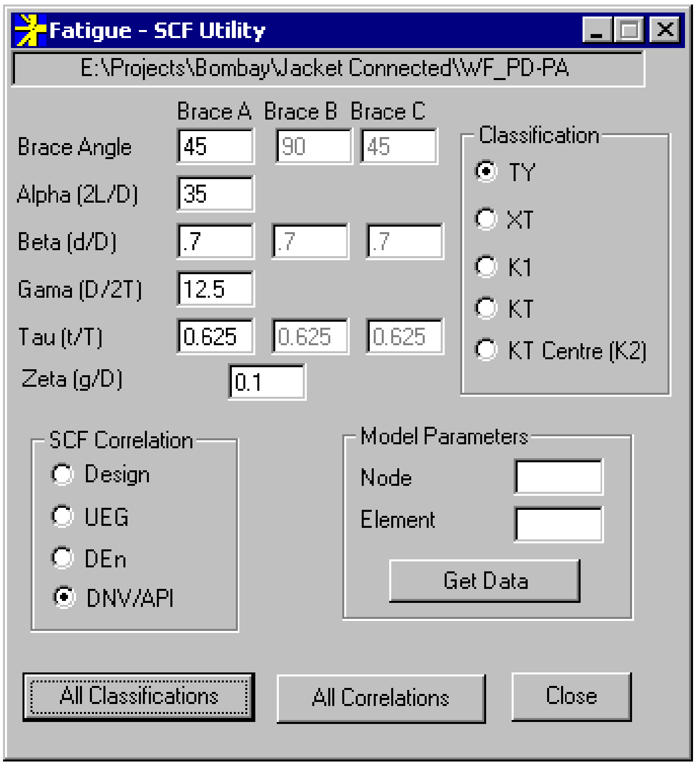
-o-

APPENDIX D - SCF Equation Utility

The SFC utiliy is started from the WINDOWS Start Menu - All Programs - FS2000

The program can be used to evalute the SCF values using the different SCF correleations and joint classifications available in OffFat.

If a fatigue analysis has been run on a model then the utility (Get Data button) can be used to obtain the classifications and parameters used by the program at a specific element node.



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APPENDIX E - Selected File Formats

Wave Data File Format (.DD"n") for FATIG3

Ho
No
Distribution Factor
Return Period
Maximum Wave Height
Number of Wave Blocks
Number of Waves (nw)
H1
to
H"nw"
h (exponent constant for single wave)

If Ho is zero explicitly define wave exceedance blocks in .DB"n"

.EF1 Files   Joint and SCF Data

```
1  14 TY,  0.050 23.107 40.000  0.800 21.429  0.714  0.033
 1.853  2.167  7.609  5.794  3.125  2.969  7.710  5.857
 2  15 TY,  0.050 23.107 40.000  0.800 21.429  0.714  0.033
 1.853  2.167  7.609  5.794  3.125  2.969  7.709  5.857
 3  16 TY,  0.050 23.107 40.000  0.800 21.429  0.714  0.033
 1.853  2.167  7.609  5.794  3.125  2.969  7.710  5.857
```

```
No Ele Class  g    θ      α      β    γ      τ     ξ
 4  2 TY,  0.050 16.574 40.000  0.600 20.833  0.833  0.020
  ACs   ABs   ACc   ABc   IPCc  IPBc  OPCs  OPBs
 1.846  2.163  7.438  5.686  2.354  2.483  4.545  3.863

 4  4 TY,  0.050 16.574 40.000  0.600 20.833  0.833  0.020
 1.846  2.163  7.438  5.686  2.354  2.483  4.545  3.863
 4  6 TY,  0.050 16.574 40.000  0.600 20.833  0.833  0.020
 1.846  2.163  7.438  5.686  2.354  2.483  4.545  3.863
 5  7 TY,  0.050 75.698 40.000  0.508 21.429  0.571  0.033
12.959  9.164  9.021  6.683  3.452  3.175  9.382  6.911
 5  9 TY,  0.050 75.698 40.000  0.508 21.429  0.571  0.033
12.959  9.164  9.021  6.683  3.452  3.175  9.382  6.911
```

ACs = Axial Chord Saddle

ABs = Axial Brace Saddle

ACc = Axial Chord Crown

ABc = Axial Brace Crown

IPCc = In Plane Chord Crown

IPBc = In Plane Brace Crown

OPCs = Out Plane Chord Saddle

OPBs = Out Plane Brace Saddle

α = 2L/D β = d/D γ = D/2T τ = t/T ξ= g/D

.Z Files - Peak Stresses (71)

8

1 14

1.944E+07 8.852E+06 -6.861E+06 -1.858E+07 -1.936E+07 -8.637E+06 7.207E+06 1.880E+07

1.479E+07 5.787E+06 -6.551E+06 -1.506E+07 -1.469E+07 -5.606E+06 6.815E+06 1.524E+07

4 2

-2.950E+06 3.716E+06 1.039E+07 9.981E+06 5.911E+06 3.729E+06 1.543E+06 -2.537E+06

-2.032E+06 3.781E+06 9.223E+06 9.107E+06 5.500E+06 2.512E+06 -1.039E+05 -2.813E+06

No Ele

4 4

8.892E+05 3.739E+06 8.99002E+06 5.940E+06 4.002E+06 8.560E+06 1.171E+07 6.359E+06 **Chord or Direct (Principle Stress)**

1.543E+06 2.882E+06 5.579E+06 4.753E+06 4.188E+06 7.516E+06 9.487E+06 5.645E+06 **Brace or VM (Signed VM)**

Pt 1 Pt 2 Pt 3 Pt 4 Pt 5 Pt 6 Pt 7 Pt'n'

4 6

8.506E+06 1.113E+07 9.791E+06 1.556E+06 -5.031E+06 -2.387E+06 4.215E+06 7.185E+06

7.790E+06 9.842E+06 8.294E+06 1.706E+06 -3.717E+06 -2.453E+06 2.412E+06 5.684E+06

5 7

-1.317E+07 -1.175E+07 -7.031E+06 -4.829E+05 2.763E+06 2.924E+06 -1.213E+06 -8.341E+06

-9.547E+06 -8.897E+06 -4.899E+06 -5.988E+05 2.188E+06 2.534E+06 -4.677E+05 -5.763E+06

5 9

-1.084E+07 -1.037E+07 -3.579E+06 5.657E+06 1.183E+07 1.121E+07 4.269E+06 -4.817E+06

-7.996E+06 -8.151E+06 -3.354E+06 3.652E+06 8.696E+06 8.756E+06 3.864E+06 -3.047E+06

.ZF Files - Peak Stresses (71) (not processed for inspection purposes only)

Stresses at Mid, Top and bottom planes. Maximum Principle Stress, signed Tresca and signed VM

```
 6    21         M-5.46E+04 7.90E+04 0.00E+00 1.02E+05 0.00E+00 0.00E+00 1.34E+05 0.00E+00-1.10E+05
2.44E+05 2.12E+05
                                                                                          1.34E+05
2.44E+05 2.12E+05
                 T-9.69E+04-3.16E+04 0.00E+00 3.97E+04 0.00E+00 0.00E+00 0.00E+00-1.28E+04-1.16E+05
1.16E+05 1.10E+05

-1.16E+05-1.16E+05-1.10E+05
                 B-1.24E+04 1.90E+05 0.00E+00 1.64E+05 0.00E+00 0.00E+00 2.82E+05 0.00E+00-1.04E+05
3.86E+05 3.46E+05
                                                                                          2.82E+05
3.86E+05 3.46E+05

 5    21         M-5.46E+04 7.90E+04 0.00E+00 1.02E+05 0.00E+00 0.00E+00 1.34E+05 0.00E+00-1.10E+05
2.44E+05 2.12E+05
                                                                                          1.34E+05
2.44E+05 2.12E+05
                 T-9.01E+04 4.27E+04 0.00E+00 1.35E+05 0.00E+00 0.00E+00 1.27E+05 0.00E+00-1.74E+05
3.01E+05 2.62E+05

-1.74E+05-3.01E+05-2.62E+05
```

```
                B-1.92E+04 1.15E+05 0.00E+00 6.88E+04 0.00E+00 0.00E+00 1.44E+05 0.00E+00-4.82E+04
1.92E+05 1.73E+05
                                                                                          1.44E+05
1.92E+05 1.73E+05
```

No Ele

```
 12   21        M-5.46E+04 7.90E+04 0.00E+00 1.02E+05 0.00E+00 0.00E+00 1.34E+05 0.00E+00-1.10E+05
2.44E+05 2.12E+05
                                                                                          1.34E+05
2.44E+05 2.12E+05
                T 3.27E+04 1.87E+05 0.00E+00 1.49E+05 0.00E+00 0.00E+00 2.77E+05 0.00E+00-5.79E+04
3.35E+05 3.10E+05
                                                                                          2.77E+05
3.35E+05 3.10E+05
                B-1.42E+05-2.89E+04 0.00E+00 5.53E+04 0.00E+00 0.00E+00 0.00E+00-6.41E+03-1.64E+05
1.64E+05 1.61E+05

-1.64E+05-1.64E+05-1.61E+05
                                                                                          Princ
Tresca    VM
 5    22        M-5.79E+04-2.58E+03 0.00E+00-9.83E+04 0.00E+00 0.00E+00 7.19E+04 0.00E+00-1.32E+05
2.04E+05 1.79E+05

-1.32E+05-2.04E+05-1.79E+05
                T-1.34E+05-1.42E+05 0.00E+00-1.05E+05 0.00E+00 0.00E+00 0.00E+00-3.33E+04-2.43E+05
2.43E+05 2.28E+05

-2.43E+05-2.43E+05-2.28E+05
                B 1.84E+04 1.37E+05 0.00E+00-9.19E+04 0.00E+00 0.00E+00 1.87E+05 0.00E+00-3.16E+04
2.19E+05 2.05E+05
                                                                                          1.87E+05
2.19E+05 2.05E+05
```

.Y Files - Peak Stress Ranges (16)

```
8
 2 5
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 2 4
 7.293E+07 4.348E+07 1.726E+08 1.832E+08 1.293E+08 1.050E+08 6.269E+07 4.051E+07
 5.319E+07 4.415E+07 1.480E+08 1.634E+08 1.193E+08 8.088E+07 3.876E+07 4.176E+07
 4 6
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
```

Ele Node

```
 4 4
 7.405E+07 1.706E+08 2.214E+08 1.180E+08 1.138E+07 2.987E+07 8.177E+07 6.730E+07  Chord
 7.479E+07 1.552E+08 1.905E+08 1.104E+08 1.734E+07 1.919E+07 4.784E+07 4.814E+07  Brace
   Pt 1      Pt 2      Pt 3      Pt 4      Pt 5      Pt 6      Pt 7      Pt'n'

 6 7
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 6 4
 1.481E+08 1.416E+08 7.002E+07 5.566E+07 1.261E+08 8.398E+07 2.491E+07 1.096E+08
 1.296E+08 1.235E+08 7.008E+07 4.454E+07 1.038E+08 7.441E+07 1.450E+07 9.011E+07
```

.D Files - Directional Damge Ratio (1)

8

.25

1

T

.03

2 5

1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14

1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14

2 4

2.000E-02 5.420E-03 3.265E-07 4.592E-03 1.954E-02 4.899E-03 5.031E-10 4.944E-03

9.015E-03 2.161E-03 1.435E-07 1.743E-03 8.646E-03 1.884E-03 2.707E-10 1.897E-03

4 6

1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14

1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14

Ele No

4 4

5.877E-05 1.667E-03 7.021E-02 4.358E-02 5.606E-03 2.236E-03 7.260E-04 4.620E-06

3.993E-06 1.164E-03 3.004E-02 2.536E-02 3.600E-03 4.183E-04 2.374E-05 8.657E-06

Pt 1 Pt 2 Pt 3 Pt 4 Pt 5 Pt 6 Pt 7 Pt'n'

6 7

1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14

1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14 1.050E-14

6 4

5.134E-03 4.092E-02 5.727E-02 1.635E-03 5.520E-05 4.480E-06 6.941E-04 2.022E-03

3.367E-03 2.492E-02 2.843E-02 1.106E-03 3.702E-06 8.714E-06 2.019E-05 3.753E-04

7 5

8.998E-05 5.471E-06 2.797E-07 1.010E-06 1.107E-06 2.099E-06 2.140E-05 1.283E-04

1.029E-05 8.579E-07 1.308E-07 3.232E-07 1.479E-07 4.743E-07 5.515E-06 2.165E-05

.JFP File - Fatigue Life at all Points all Joints

2	4	1	30.06111	61.27797
2	4	2	14.77152	25.09408
2	4	3	6.608934	12.45328
2	4	4	14.50947	24.98044
2	4	5	29.88548	61.09575
2	4	6	105.8612	327.3178
2	4	7	522.9304	15608.35
2	4	8	108.5728	334.1364

Ele	No	Pt	Chord Life (Yrs)	Brace Life (Yrs)
4	4	1	30.19527	63.63674

4	4	2	15.24685	26.76731
4	4	3	6.844337	13.11985
4	4	4	14.26231	25.49051
4	4	5	29.17067	61.10505
6	4	2	14.95504	25.97316
6	4	3	7.008136	13.45146
6	4	4	14.9386	26.24647
6	4	5	29.87107	62.6476
6	4	6	107.1263	330.026
6	4	7	524.8112	17172.01

.EC1 & .EC2 File - Element Thickness for SN Curve Thickness Correction

Ele No Chord t Brace t

```
 1  1  0.035  0.035
 1  5  0.035  0.035
 2  5  0.035  0.035
 2  4  0.1  0.035
 3  3  0.035  0.035
 3  6  0.035  0.035
 4  6  0.035  0.035
 4  4  0.1  0.035
 5  2  0.035  0.035
 5  7  0.035  0.035
 6  7  0.035  0.035
 6  4  0.1  0.035
```

-o-

APPENDIX F - Demonstration Examples

The purpose of Examples 1 and 2 are to illustrate how batch control files are set up and used. Although the OffFat utility described in Sect. 4.1 will create all the control and definition files necessary to undertake a fatigue analysis, an understanding is useful if the user requires to modify any aspect of the analysis e.g. directional distribution factors.

To run the models simple recover the model from archive (Interpret and re-save) and run the OffFat program to create the control files. Then run the model batch file.

Note that in the example shown below the directory set up is different from that created by OffFat.

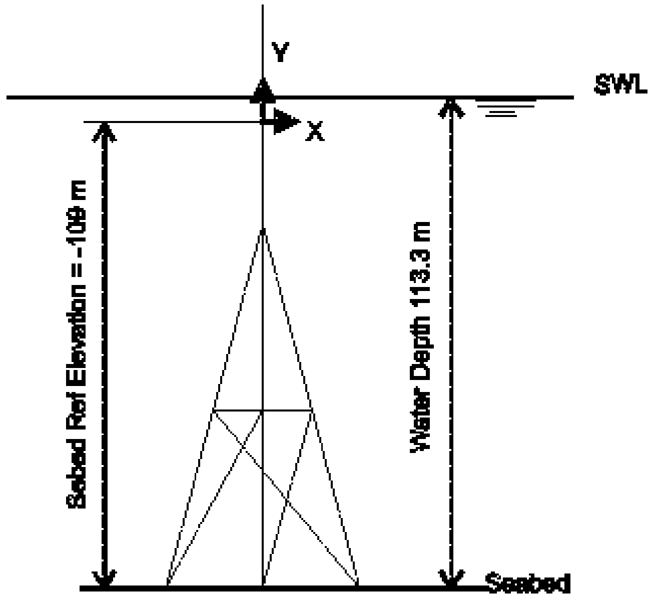
Validation Examples

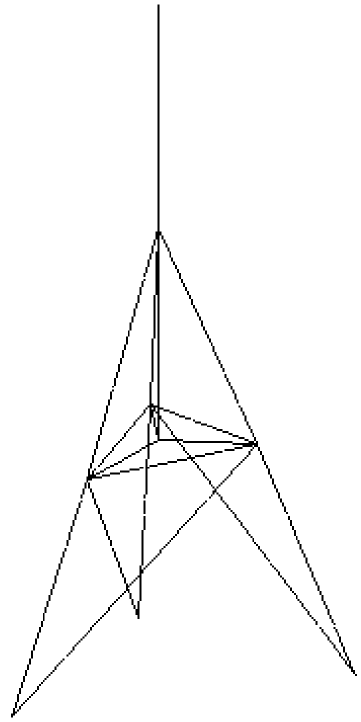
Unlike linear structural analysis it is difficult to obtain benchmark examples for such a specialised and numerically intensive process as wave induced fatigue analysis. As OffFat uses text intermediate files it is possible to trace all stages of the fatigue analysis and hence validate any result obtained.

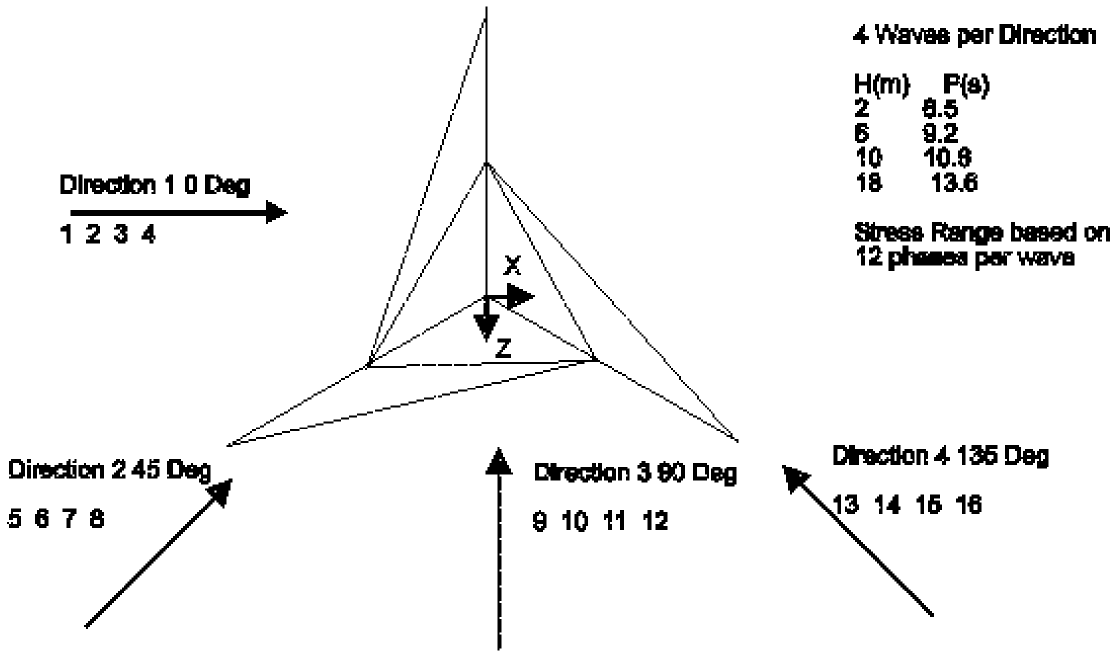
Example 3 is an example of a surface penetrating pile subjected to wave action from one direction only. The life predicted is compared with the life obtained using the simplified long term fatigue prediction method in NORSOK N004 Design of Steel Structures Annex C C.2.11.

Example 1 - Filename FATTOW

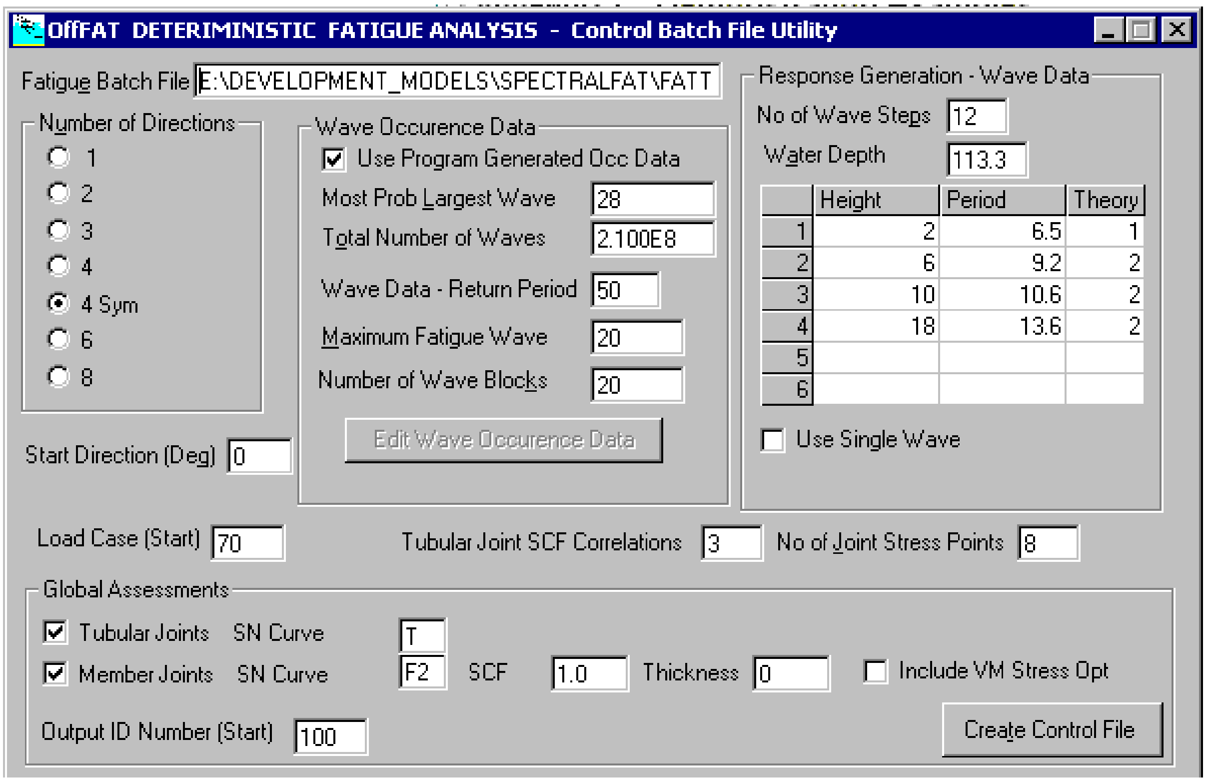
This example illustrates the fatigue analysis of a Tripod Tower.







The setting used in the OffFat input form are shown below



Hydrodynamic model data is defined for the model in the usual way using FS-Wave

Because of assumed symmetry of the structure only 4 wave directions have been considered.

For each of these directions 4 waves have been used to establish the Stress Range/Wave relationship for the structure. 2m, 6m 10m and 18m waves were used.

To establish the stress range from each wave the waves are stepped through the structure in 12 steps.

In total 4(dir) x 4(waves) x 12(steps) = 192 separate load cases are analysed.

The wave numbers and corresponding direction numbers are shown in the following table. For each wave number 12 load cases are created (L70 to L81) and overwritten by the next wave.

Wave Numbers

1	**2**	**3**	**4**	Direction 1	0
5	**6**	**7**	**8**	Direction 2	45
9	**10**	**11**	**12**	Direction 3	90
13	**14**	**15**	**16**	Direction 4	135
2m (Airy)	6m	10m	18m	Wave Height	
6.5s	9.2s	10.6s	13.6s	Wave Period	

The full batch file to control the above analysis is given later. The various additional control files are described below.

WaveLoader Batch Control Files (.BC)

A full description of the .BC file is given in the FSWave User Manual.

16 WaveLoader Batch Control Files called MODEL.BCWAVF1 to MODEL.BCWAVF16 have been created.

The control file MODEL.BCWAVF1 file and MODEL.BCWAVF15are given below. The only differences between the files are shown in **bold**. The first is the corresponding environmental file. The second is the wave period.

```
       1
E:\VALIDATION\FATIGUE\FATTOW.@F1
0,6.5,12
70


 1
E:\VALIDATION\FATIGUE\FATTOW.@F15
0,10.6,12
70
```

Environmental Files

In this example 4 environmental file are required for each wave and there are 4 wave directions. Therefore a total of 16 waves and the associated environmental files are used. The differences between the environmental files tare the wave height, wave period and wave direction. In this example the files are called MODEL.@F1 to MODEL.@F16

The environmental files corresponding to the above WaveLoader batch control (.BC) files are given below. The only differences between the files are the wave height, wave period and wave direction. These differences are shown in bold.

```
FS2000 Stuctural & Pipework Analysis
FSWave - Dynamic Fluid Loading for FS2000
Date:23/05/2004   Time:09:16:48
ENVIRONMENTAL LOAD DATA     Filename: FATTOW.@F1
**** WATER  DEPTH *****
WDEPTH, 113.3
**** WAVE DATA ****
Wave Theory
WTH, 1
Linear (Airy)
     Wave Height   Wave Period   Wave Direction
WAVE,     2,                  6.5,               0

FS2000 Stuctural & Pipework Analysis
FSWave - Dynamic Fluid Loading for FS2000
Date:23/05/2004   Time:09:16:48
ENVIRONMENTAL LOAD DATA     Filename: FATTOW.@F15
**** WATER  DEPTH *****
WDEPTH, 113.3
**** WAVE DATA ****
Wave Theory
WTH, 2
Stokes V Order
     Wave Height   Wave Period   Wave Direction
WAVE,     10,                 10.6,              135
```

Wave Data File

The wave data file called FATTOW.DD1 file for this examples is.

```
    28         Most probable largest wave
    2.1E8      Total number of waves in return period
    .25        Directional distribution factor
    50         Return period
    20         Maximum fatigue wave
    20         Number of fatigue wave blocks
    4          Number of wave per direction
    2          H1      Wave heights
    6          H2
    10         H3
    18         H4
```

Main Fatigue Batch File - Called FATTOW.BRF

The following shows the portion of the batch file for wave number 16. These commands produce the peak stresses ranges for wave 16. These line are repeated 16 times to represent the 16 wave numbers. The entries shown in bold are the only differences between the repeated portions.

```
REM ******************* DIRECTION    4
REM ******************* WAVE         4
REM ******************* WAVE NUMBER 16
MFCOPY "WAV" "WAVF16"
WAVELOAD WAVF16
LOADA C70/1/0/
OFRAME
POST6 70-81
FATIG1 8/70/81/3/0/
FATIG2 70/81/16/1/
```

At this stage all 16 .Y"w" files have been created and the final stages is the fatigue life evaluation. This is achieved by the following command lines.

```
REM ************************************GLOBAL ASSESSMENTS
REM ******************* DIRECTION  1
FATIG3 1/1/1/1/T/B/
FATIG3 51/11/1/1.0/F2/B/
REM ******************* DIRECTION  2
FATIG3 5/2/2/1/T/B/
FATIG3 55/12/2/1.0/F2/B/
REM ******************* DIRECTION  3
FATIG3 9/3/3/1/T/B/
FATIG3 59/13/3/1.0/F2/B/
REM ******************* DIRECTION  4
FATIG3 13/4/4/1/T/B/
FATIG3 63/14/4/1.0/F2/B/
REM *******************COMBINE ALL DIRECTIONS
FATIG4 1/4/10000/100/1/
FATIG4 11/14/10000/101/2/
```

FATTOW Results

```
=============================================================================
FS2000 Structural/Pipework Analyisis System  Ver 8            (c) AES Ltd

Date:13/07/2022  Time:13:24:50
=============================================================================
Model File:FATTOW                      Date Created:25/10/1995 Time:16:18:47
Analysis Desc. :Tripod Jacket Model (Fatigue Example)
Created/Checked:
Job Reference  :RMAT
=============================================================================
              O F F A T    F A T I G U E    R E S U L T S
=============================================================================

Direction Ref No 1

Return Period in Years            50
Maximum Wave Height               28
Maximum No of Waves             2.100E+08
Distribution Factor               0.25
Maximum Fatigue Wave              20
Number of Wave Blocks             20

Fatigue Spectrum Blocks

 Mean Height      Occurrences (per year)
     0.5           5.204E+05
     1.5           2.625E+05
     2.5           1.324E+05
     3.5           6.678E+04
     4.5           3.368E+04
     5.5           1.699E+04
     6.5           8.570E+03
     7.5           4.323E+03
     8.5           2.180E+03
     9.5           1.100E+03
     10.5          5.548E+02
     11.5          2.798E+02
     12.5          1.412E+02
     13.5          7.121E+01
     14.5          3.593E+01
     15.5          1.813E+01
     16.5          9.154E+00
     17.5          4.626E+00
     18.5          2.342E+00
```

```
     19.5          1.190E+00

 Total Occurrences 1.050E+06

Number of Waves per Direction     4

   Wave Height  1        2
   Wave Height  2        6
   Wave Height  3        10
   Wave Height  4        18

Average Power Index =  1.02711
:
Direction Ref No 2

Return Period in Years            50
Maximum Wave Height               28
Maximum No of Waves             2.100E+08
Distribution Factor               0.25
Maximum Fatigue Wave              20
Number of Wave Blocks             20

Fatigue Spectrum Blocks

 Mean Height      Occurrences (per year)
     0.5           5.204E+05
     1.5           2.625E+05
     2.5           1.324E+05
     3.5           6.678E+04
     4.5           3.368E+04
     5.5           1.699E+04
     6.5           8.570E+03
     7.5           4.323E+03
     8.5           2.180E+03
     9.5           1.100E+03
     10.5          5.548E+02
     11.5          2.798E+02
     12.5          1.412E+02
     13.5          7.121E+01
     14.5          3.593E+01
     15.5          1.813E+01
     16.5          9.154E+00
     17.5          4.626E+00
     18.5          2.342E+00
     19.5          1.190E+00

 Total Occurrences 1.050E+06

Number of Waves per Direction     4

   Wave Height  1        2
   Wave Height  2        6
   Wave Height  3        10
   Wave Height  4        18

Average Power Index =  1.04701
:
Direction Ref No 3

Return Period in Years            50
Maximum Wave Height               28
Maximum No of Waves             2.100E+08
Distribution Factor               0.25
Maximum Fatigue Wave              20
Number of Wave Blocks             20

Fatigue Spectrum Blocks

 Mean Height      Occurrences (per year)
     0.5           5.204E+05
     1.5           2.625E+05
     2.5           1.324E+05
     3.5           6.678E+04
     4.5           3.368E+04
     5.5           1.699E+04
     6.5           8.570E+03
     7.5           4.323E+03
     8.5           2.180E+03
     9.5           1.100E+03
     10.5          5.548E+02
```

```
     11.5          2.798E+02
     12.5          1.412E+02
     13.5          7.121E+01
     14.5          3.593E+01
     15.5          1.813E+01
     16.5          9.154E+00
     17.5          4.626E+00
     18.5          2.342E+00
     19.5          1.190E+00

 Total Occurrences 1.050E+06

Number of Waves per Direction     4

   Wave Height  1        2
   Wave Height  2        6
   Wave Height  3        10
   Wave Height  4        18

Average Power Index =  1.038117
:
:
Direction Ref No 4

Return Period in Years            50
Maximum Wave Height               28
Maximum No of Waves             2.100E+08
Distribution Factor               0.25
Maximum Fatigue Wave              20
Number of Wave Blocks             20

Fatigue Spectrum Blocks

 Mean Height      Occurrences (per year)
     0.5           5.204E+05
     1.5           2.625E+05
     2.5           1.324E+05
     3.5           6.678E+04
     4.5           3.368E+04
     5.5           1.699E+04
     6.5           8.570E+03
     7.5           4.323E+03
     8.5           2.180E+03
     9.5           1.100E+03
     10.5          5.548E+02
     11.5          2.798E+02
     12.5          1.412E+02
     13.5          7.121E+01
     14.5          3.593E+01
     15.5          1.813E+01
     16.5          9.154E+00
     17.5          4.626E+00
     18.5          2.342E+00
     19.5          1.190E+00

 Total Occurrences 1.050E+06

Number of Waves per Direction     4

   Wave Height  1        2
   Wave Height  2        6
   Wave Height  3        10
   Wave Height  4        18

Average Power Index =  1.048014
:

=============================================================================
Fatigue Output Case Number: 70
Fatigue Tubular Joints
Local SCF                       1
Global Fatigue Curve            T 12.48 3 67.09 16.13 5 0 .016 .25
Group SET                       0
Thickness for non tube joints   0
All Groups & Non Groups - Sorted by El Label

=============================================================================

*** Fatigue Lives Below  10000  Years ***
```

Ele	Node	Point	Location	Life
2	4	3	Brace	4.5556011079037
4	4	3	Brace	4.81522537061844
6	4	3	Brace	4.90908376333158
7	5	8	Chord	129.449723557019
7	6	4	Chord	99.5256204660634
8	6	8	Chord	126.478372477288
8	7	4	Chord	98.2205382079257
9	7	8	Chord	132.851794947585
9	5	4	Chord	98.4883885701304
14	7	1	Chord	1162.30413574542
15	6	1	Chord	1077.26116774951
16	5	1	Chord	1140.0428541699
18	6	6	Chord	18.1593165809237
18	12	2	Chord	14.5907699396299
19	7	6	Chord	17.6636933277367
19	12	2	Chord	14.9504762573182
20	5	6	Chord	17.0407395506957
20	12	1	Chord	15.325037000518

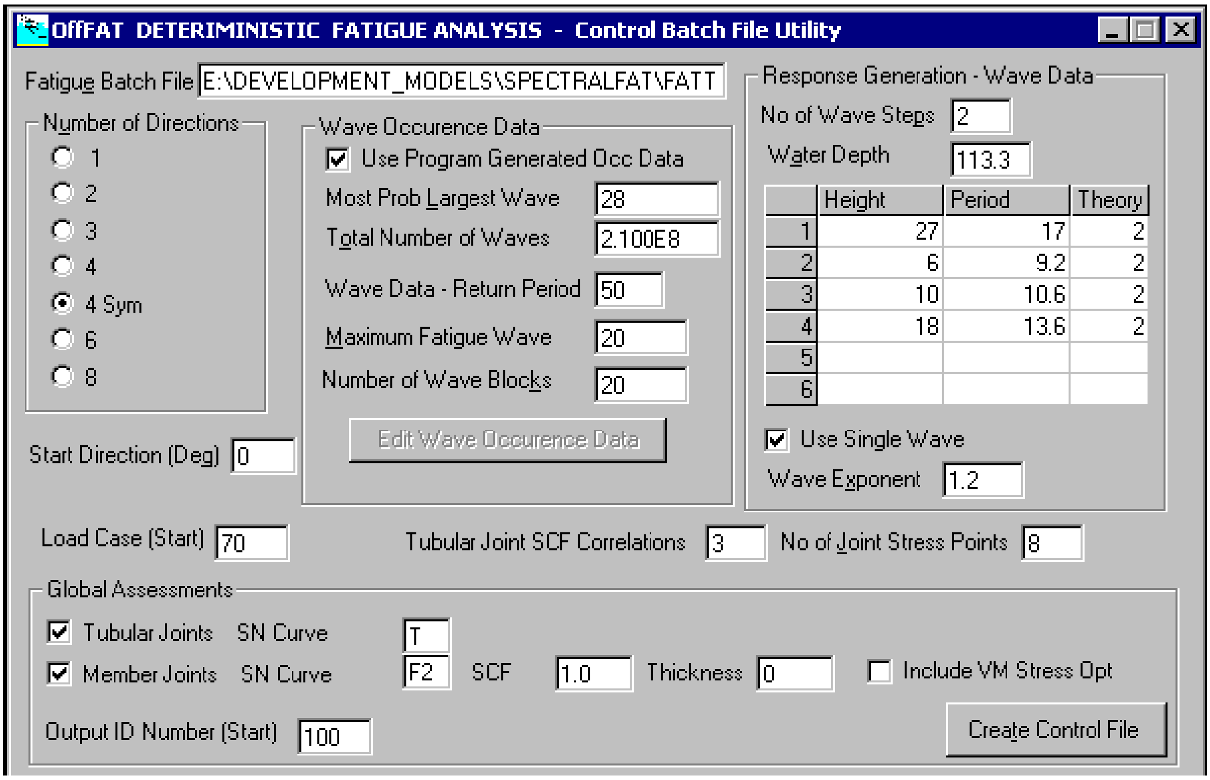
Lowest Life is 4.555601 years

Example 2 - Filename FATTOW2

This example uses the same Tripod Tower as Example 1. In the example the solution is simplified by only using the stress range from only one wave - see Sect 4.5.6.

The OffFat input form for the example is shown below.

This is the same example as above and the results have indicated that an index of less than 1.1 could be used. This example conservatively uses 1.2



Wave Data File

The wave data file FATTOW.DD1 for this example is. (DD2, DD3 & DD4 similar)

```
28          Most probable largest wave
2.1E8               Total number of waves in return period
.25         Directional distribution factor
50          Return period
20          Maximum fatigue wave
20          Number of fatigue wave blocks
1           Number of wave per direction
28          H1      Wave heights
1.4         Stress/wave height exponent
```

Main Fatigue Batch File

The batch control file called FATTOW2.BRF is given below

```
REM ******************* DIRECTION    1
REM ******************* WAVE         1
REM ******************* WAVE NUMBER 1
MFCOPY "WAV" "WAVF1"
WAVELOAD WAVF1
LOADA C70/1/1/
OFRAME
POST6 70-71
FATIG1 8/70/71/3/0/
FATIG2 70/71/1/1/
FATIG1S 8/70/71/
FATIG2 70/71/51/2/
REM ******************* DIRECTION    2
```

```
REM ******************* WAVE         1
REM ******************* WAVE NUMBER 2
MFCOPY "WAV" "WAVF2"
WAVELOAD WAVF2
LOADA C70/1/2/
OFRAME
POST6 70-71
FATIG1 8/70/71/3/0/
FATIG2 70/71/2/1/
FATIG1S 8/70/71/
FATIG2 70/71/52/2/
REM ******************* DIRECTION    3
REM ******************* WAVE         1
REM ******************* WAVE NUMBER 3
MFCOPY "WAV" "WAVF3"
WAVELOAD WAVF3
LOADA C70/1/2/
OFRAME
POST6 70-71
FATIG1 8/70/71/3/0/
FATIG2 70/71/3/1/
FATIG1S 8/70/71/
FATIG2 70/71/53/2/
REM ******************* DIRECTION    4
REM ******************* WAVE         1
REM ******************* WAVE NUMBER 4
MFCOPY "WAV" "WAVF4"
WAVELOAD WAVF4
LOADA C70/1/0/
OFRAME
POST6 70-71
FATIG1 8/70/71/3/0/
FATIG2 70/71/4/1/
FATIG1S 8/70/71/
FATIG2 70/71/54/2/
REM ***********************************GLOBAL ASSESSMENTS
REM ******************* DIRECTION  1
FATIG3 1/1/1/1/T/B/
FATIG3 51/11/1/1.0/F2/B/
REM ******************* DIRECTION  2
FATIG3 2/2/2/1/T/B/
FATIG3 52/12/2/1.0/F2/B/
REM ******************* DIRECTION  3
FATIG3 3/3/3/1/T/B/
FATIG3 53/13/3/1.0/F2/B/
REM ******************* DIRECTION  4
FATIG3 4/4/4/1/T/B/
FATIG3 54/14/4/1.0/F2/B/
REM *******************COMBINE ALL DIRECTIONS
FATIG4 1/4/10000/100/1/
FATIG4 11/14/10000/101/2/
```

FATTOW2 Results

```
Wave data same as FATTOW
Number of Waves per Direction     1
   Wave Height  1        27
Average Power Index =  1.2
=============================================================================
Fatigue Output Case Number: 70
Fatigue Tubular Joints
Local SCF                       1
Global Fatigue Curve            T 12.48 3 67.09 16.13 5 0 .016 .25
Group SET                       0
Thickness for non tube joints   0
All Groups & Non Groups - Sorted by El Label
=============================================================================
*** Fatigue Lives Below  10000  Years ***
Ele       Node  Point Location     Life
2        4        3    Brace      35.8705536062623
4        4        3    Brace      48.1023620547916
6        4        3    Brace      56.9275103107781
7        5        3    Chord      1245.8373051395
7        6        6    Chord      350.08183258696
8        6        3    Chord      1268.1984892142
```

8	7	6	Chord	464.958407918381
9	7	2	Chord	1641.3583176006
9	5	6	Chord	252.581322430677
14	7	1	Chord	105.070911727903
15	6	1	Chord	72.0340571327086
16	5	1	Chord	111.768900631558
18	6	8	Chord	180.195113844693
18	12	4	Chord	190.972132409348
19	7	8	Chord	201.067543915819
19	12	4	Chord	197.634707020626
20	5	8	Chord	183.762622637943
20	12	5	Chord	193.559913478991

Lowest Life is 35.87055 years

Example 3 - Filename OffshorePile2

This example is a single surface penetrating pile.

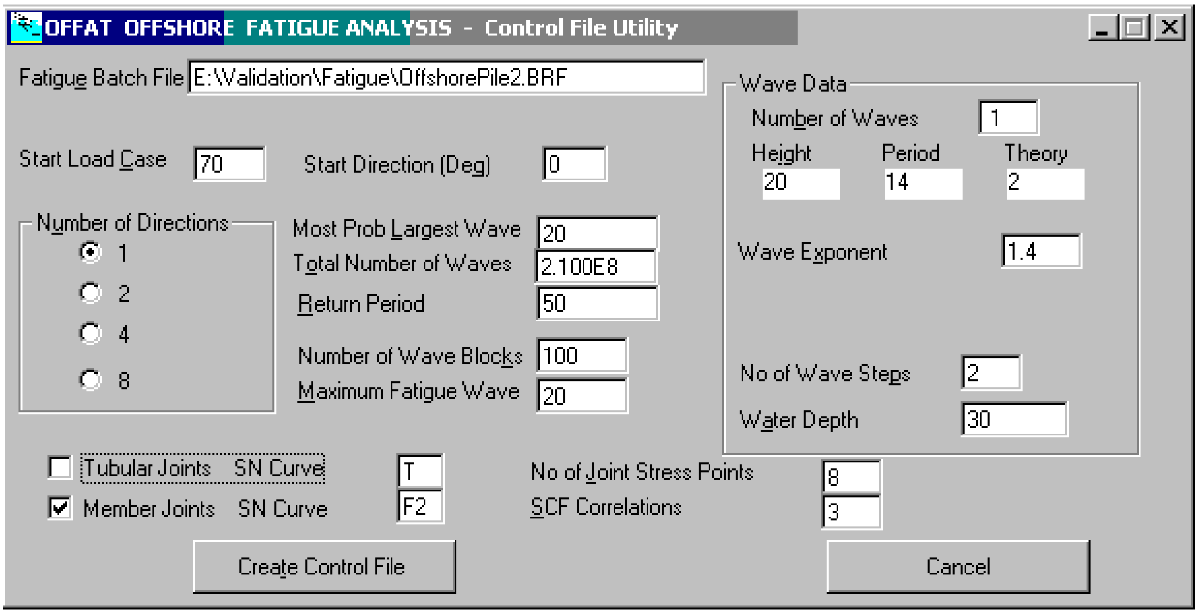
Length of pile above seabed 50m

Pile diameter 1.5m

Nominal Pile thickness 75mm (note that thickness correction is not applied in this example)

Depth of water 30m

The OffFAT input form for the example is shown below.



The Mathcad sheet at the end of this section shows the fatigue life predictions using the simplified long term fatigue prediction method in NORSOK N004 Design of Steel Structures Annex C C.2.11. This gave a predicted fatigue life of 34.4 years.

The maximum stress range in the period was obtained from the peak and trough stresses at the pile base for a H = 20m & T = 14 wave using a Stoke 5th wave. These were obtained from Result Cases 1 and 2 respectively (Run batch file OffshorePile2.BRM to get results).

OffFat Results

OffFAT evaluated a predicted fatigue life of 30.2 years. The NOSOK Mathcad predicted fatigue life of 34.4 year compares with 33.05 years using the same stress range as the Mathcad calculation.

```
=============================================================================
FS2000 Structural/Pipework Analyisis System  Ver 8            (c) AES Ltd

Date:13/07/2022  Time:11:17:11
=============================================================================
Model File:OffshorePile2              Date Created:5//24/4 Time:09:39:51

Analysis Desc. :

Created/Checked:

Job Reference  :
=============================================================================
              O F F A T    F A T I G U E    R E S U L T S
=============================================================================

Direction Ref No 21

Return Period in Years           50
```

```
Maximum Wave Height              20
Maximum No of Waves            2.100E+08
Distribution Factor              1
Maximum Fatigue Wave             20
Number of Wave Blocks            20

Fatigue Spectrum Blocks

 Mean Height      Occurrences (per year)
     0.5           2.589E+06
     1.5           9.931E+05
     2.5           3.810E+05
     3.5           1.461E+05
     4.5           5.606E+04
     5.5           2.151E+04
     6.5           8.250E+03
     7.5           3.165E+03
     8.5           1.214E+03
     9.5           4.657E+02
     10.5          1.787E+02
     11.5          6.855E+01
     12.5          2.631E+01
     13.5          1.010E+01
     14.5          3.886E+00
     15.5          1.502E+00
     16.5          5.871E-01
     17.5          2.362E-01
     18.5          1.016E-01
     19.5          4.994E-02

 Total Occurrences 4.200E+06

Number of Waves per Direction     1

   Wave Height  1        20

Average Power Index =  1.4
:

=============================================================================
Fatigue Output Case Number: 100
Fatigue DS Joints
Local SCF                       1
Global Fatigue Curve            F2 11.699 3 36.841 14.832 5 0 .016 .25
Group SET                       0
Thickness for non tube joints   0.001
All Groups & Non Groups - Sorted by El Label

=============================================================================

*** Fatigue Lives Below  10000  Years ***

Ele       Node  Point Location     Life

1        1        1    DS-Member  30.2023556066792
1        2        1    DS-Member  57.9710159416381
2        2        1    DS-Member  57.9710159416381
2        3        1    DS-Member  125.360404288239
3        3        1    DS-Member  125.360404288239
3        4        1    DS-Member  331.564995963363
4        4        1    DS-Member  331.564995963363
4        5        1    DS-Member  1164.00881482555
5        5        1    DS-Member  1164.00881482555
5        6        1    DS-Member  6305.17020581711
6        6        1    DS-Member  6305.17020581711

Lowest Life is  30.20236  years
```

The following output relating the to stress point with the lowest life was obtained using FATIG3 with C6 set to I for interactive. Using and SCF of 0.973 gave 33.05 years.

```
Model Name: OffshorePile2
Descrition:
24/5/04   09:39:51

Elment No  1    Node No  1     Point  1    Additional SCF  0.973
```

```
Fatigue Curve F2 Parameters 11.699  3  36.841  14.832  5  0  0.016  0.25
Member Joint
  Wall Thickness(t)  0.016  t Correction factor  1
   t Overwrite

No  Height      Stress     Kc         hc       Stress     Kb         hb

 1      20.00   316.906  4.78E+06     1.400   317.101  4.78E+06     1.400

Block  Hm       Stress    NOcc.      NFail       NO/NF     DamRatio   Life
                Chord
 1     0.50       1.81  2.589E+06  3.481E+13  0.0000001  0.0000001  1.345E+07
 2     1.50       8.43  9.931E+05  1.592E+10  0.0000624  0.0000625  1.601E+04
 3     2.50      17.24  3.810E+05  4.456E+08  0.0008549  0.0009173  1090.1060
 4     3.50      27.62  1.461E+05  4.227E+07  0.0034569  0.0043743   228.6091
 5     4.50      39.26  5.606E+04  8.261E+06  0.0067861  0.0111604    89.6028
 6     5.50      52.00  2.151E+04  3.556E+06  0.0060470  0.0172074    58.1147
 7     6.50      65.70  8.250E+03  1.763E+06  0.0046789  0.0218862    45.6908
 8     7.50      80.27  3.165E+03  9.667E+05  0.0032738  0.0251600    39.7456
 9     8.50      95.65  1.214E+03  5.714E+05  0.0021245  0.0272845    36.6508
 10    9.50     111.76  4.657E+02  3.582E+05  0.0013003  0.0285848    34.9837
 11   10.50     128.57  1.787E+02  2.353E+05  0.0007595  0.0293442    34.0783
 12   11.50     146.04  6.855E+01  1.605E+05  0.0004270  0.0297712    33.5895
 13   12.50     164.12  2.631E+01  1.131E+05  0.0002326  0.0300037    33.3292
 14   13.50     182.79  1.010E+01  8.187E+04  0.0001234  0.0301271    33.1927
 15   14.50     202.02  3.886E+00  6.064E+04  0.0000641  0.0301912    33.1222
 16   15.50     221.80  1.502E+00  4.583E+04  0.0000328  0.0302240    33.0863
 17   16.50     242.08  5.871E-01  3.525E+04  0.0000167  0.0302407    33.0681
 18   17.50     262.87  2.362E-01  2.753E+04  0.0000086  0.0302492    33.0587
 19   18.50     284.14  1.016E-01  2.180E+04  0.0000047  0.0302539    33.0536
 20   19.50     305.87  4.994E-02  1.747E+04  0.0000029  0.0302568    33.0505
```

Long Term Stress Distribution

Return Period $RP := 50$ Years

Total number of waves in period $n_o := 2.1 \cdot 10^8$

Maximum stress range in period $\Delta\sigma := 317.14$ N/mm2

Weibull parameter for long term stress range distribution $h := .714$

Actual thickness $t := 25 \ mm$

S-N Curve Data

SN curve slope $m_1 := 3$ $m_2 := 5$

SN curve intercept $loga_1 := 11.699$ $loga_2 := 14.832$

Thickness $t_{ref} := 25 \ mm$

$k := 0.25$

SCF & Directional Factor

$scf := 1.$ SCF

Directional Distribution Factor $dd := 1$

Fatigue Life Bilinear S-N Curves

$$a_1 := 10^{loga_1}$$

$$a_1 = 5 \times 10^{11}$$

$$S_1 := \left[\frac{(a_1)}{10^7}\right]^{\frac{1}{m_1}}$$

$$S_1 = 36.841$$

Density Weibull Function Defined as:

$$f(S,\Delta\sigma,h) := h \cdot \frac{S^{h-1}}{\frac{(\Delta\sigma \cdot scf)^h}{\left[\ln\left((n_o \cdot dd)\right)\right]}} \cdot \exp\left[-1\left[\frac{S}{\frac{(\Delta\sigma \cdot scf)}{\left[\ln\left((n_o \cdot dd)\right)\right]^{\frac{1}{h}}}}\right]^h\right]$$

Integrating Damage Below each part of the bilinear S-N curve:

$$D := \int_0^{S_1} n_o \cdot dd \cdot \frac{f(S,\Delta\sigma,h)}{10^{\left(loga_2 - m_2 \cdot \log(S \cdot scf)\right)}} dS + \int_{S_1}^{\Delta\sigma \cdot scf} n_o \cdot dd \cdot \frac{f(S,\Delta\sigma,h)}{10^{\left(loga_1 - m_1 \cdot \log(S \cdot scf)\right)}} dS$$

Damage ratio $D = 1.455$ $L := \frac{1}{D} \cdot RP$

Fatigue Life 37.37 Years

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APPENDIX G - Fracture Mechanics FATIG6 (Optional Module not part of OffFat)

Fracture Mechanics FATIG6 (Optional Module not part of OffFat)

This module reads the .Y files and a definition file called <ModelName>.UFR. It does what FATIG3 and FATIG4 does for tubular joints using SN curves but used instead uses a crack growth model.

Input Data Command Line C1/C2/C3/

C1	Number of Directions
C2	Group SET (Braces restricted to all non zero groups)
C3	Limit (Life Limit for output)

FRACT.DAT File Format

	a
	c
	B
	L
	W
	M
	CMat
*	Threshold
*	Deslife
	Repeat
*	BMR
	BMRC
	BMRB
	SSCF

* Not used

Output Data

.K80	Text File
.680	UR File

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