Detailed fatigue assessment according to EN 13445-3 Clause 18 and AD 2000 S 2

How to perform fatigue analysis with the detailed approach proposed in EN 13445 Clause 18 and AD 2000 S 2.
Online version: https://nextgen.sant-ambrogio.it/KB894184
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With NextGen it is possible to perform a detailed fatigue calculation for projects according to the EN 13445 and AD 2000 standards.

It is important to underline that in order to perform a detailed fatigue analysis it is essential to have data deriving from a finite element analysis (FEA). This calculation must be performed with a specific software, different from NextGen. Sant'Ambrogio does not offer this type of program nor can it support its choice and use.

> *For the simplified fatigue analysis, described in the chapters EN 13445 Clause 17 and AD 20000 S 1 there is a dedicated article. The simplified fatigue analysis does not require a supporting FEA.*

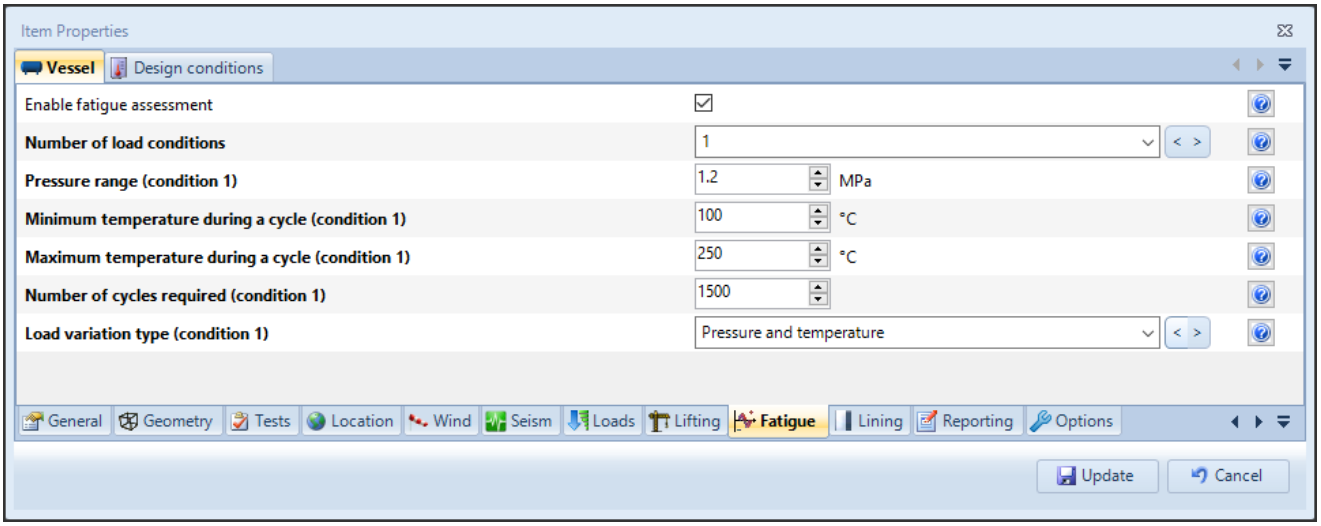
The calculation is essentially divided into two parts:

- The definition at *Item* level of the calculation conditions and the number of cycles required
- The definition of one or more analyses relating to specific points of the equipment

In this article, examples relating to EN 13445 are shown, but the same considerations apply to AD 2000. See the respective chapters of the standards for more information regarding the calculation implementations.

Definition of the item properties

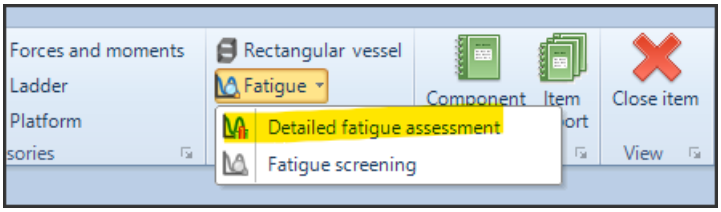
The general definition of the calculation takes place in the properties of the *Item* (File > Item properties > Fatigue). The data must be filled in as follows, enabling the calculation using the appropriate checkbox:



> *Warning: setting these properties alone does not produce any checks. In the absence of the following steps, no fatigue analysis will be performed.*

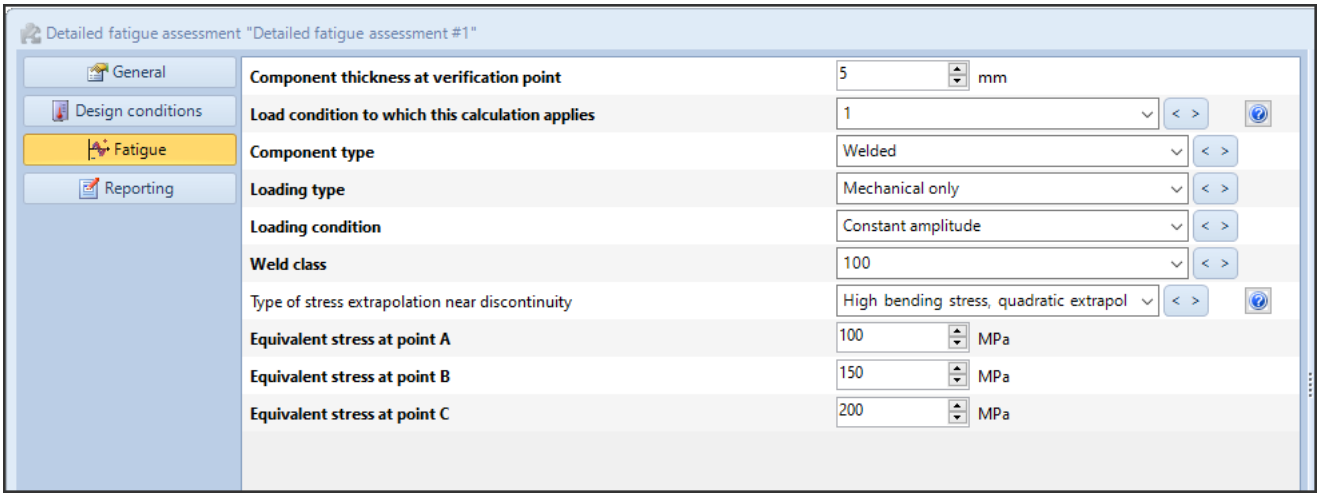
Detailed fatigue analysis definition

From the ribbon, select the item related to *Detailed fatigue assessment*:

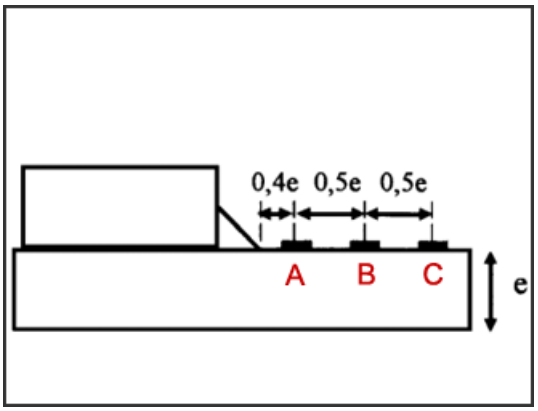


This item will be added in *Desktop view* mode, since it does not have a 3D representation.

The data compilation occurs as for a normal component. After defining the name and material, in the *Fatigue* section the characteristics of the analysis must be defined.



There are different options for choosing the stress extrapolation method. The required values must be taken from the FEA. The program supports the user by indicating at what distance the stress values should be read from the finite element analysis:



> *The detailed fatigue analysis is a more complex matter than the calculation by formulae of the components available in NextGen. Please refer to the respective standards for further information.*

As with a normal 3D component, the detailed fatigue analysis has its own calculation report:

Detailed fatigue assessment - Detailed fatigue assessment #1

According to: EN 13445 Ed. 2021 Issue 1 (2021-04), Clause 18

Design data

Component type: Welded
Loading type: Mechanical only
Loading condition: Constant amplitude

Weld class		=	100
Type of stress extrapolation near discontinuity: High bending stress, quadratic extrapolation			
Equivalent stress at point A	σA	=	100.00 MPa
Equivalent stress at point B	σB	=	150.00 MPa
Equivalent stress at point C	σC	=	200.00 MPa
Nominal thickness	en	=	5.00 mm
Parameter xA	xA=0.4·e	=	2.00 mm
Parameter xB	xB=0.9·e	=	4.50 mm
Parameter xC	xC=1.4·e	=	7.00 mm
Parameter a	a=σA·xB²-σB·xA²	=	1 425 N
Parameter b	b=σA·xC²-σC·xA²	=	4 100 N
Parameter c	c=xA·xB²-xB·xA²	=	22.5 mm³
Parameter d	d=xA·xC²-xC·xA²	=	70.0 mm³
Parameter e	e=xB²-xA²	=	16.2 mm²
Parameter f	f=xC²-xA²	=	45.0 mm²
Equivalent structural stress range	Δσeq(FEA)=(a/c-b/d)/(e/c-f/d)	=	60.00 MPa
Material: P265GH (EN 10028-2) - Plate (t ≤ 16.00 mm) - No.: 1.0425			
0.2% yield strength at design temperature	Rp0.2/T	=	188.00 MPa
Tensile strength	Rm	=	0 MPa
Load condition 1, load details			
Design pressure	P	=	1.50 MPa
Pressure range	ΔP	=	1.20 MPa
Minimum operating temperature during cycle	Tmin	=	100.00 °C
Maximum operating temperature during cycle	Tmax	=	250.00 °C
Assumed mean cycle temperature	T*=0.75·Tmax+0.25·Tmin	=	212.50 °C
Number of required fatigue cycles	Nreq	=	1 500
Tensile strength	Rm/20	=	410.00 MPa
Yield strength	Rp/T*	=	200.75 MPa
Mechanical loading correction factor in elasto-plastic conditions	ke	=	1.00000
Thermal loading correction factor in elasto-plastic conditions	kv	=	1.00000
Equivalent structural stress range	Δσeq=Δσeq(FEA)·ke·kv	=	60.00 MPa
Temperature correction factor	$f_{T^*} = 1,03 - 1,5 \cdot 10^{-4} \cdot T^* - 1,5 \cdot 10^{-6} \cdot T^{*2}$	=	0.93039
Thickness correction factor	few	=	1.00000
Overall correction factor	fw=few·fT*	=	0.93039

In the summary in the calculation report of the entire device, the detailed analyses are combined with the simplified ones, indicating any errors in red:

Fatigue assessment summary

Loading condition

1: ΔP=1.20 MPa - Tmin=100.00 °C - Tmax=250.00 °C - Required cycles=1500

Number of equivalent full pressure cycles neq=Σ ni·(ΔPi/P)³ = 768

neq ≤ 500: Ko

Simplified fatigue assessment according to: EN13445-3 Clause 17

Load condition, component, detail	Required cycles	Allowable cycles	Damage index
1, 2 - Main shell, Longitudinal butt weld	1500	1423	1.054
1, 2 - Main shell, Circumferential butt weld	1500	3941	0.381

Detailed fatigue assessment according to: EN13445-3 Clause 18

Load condition, component	Required cycles	Allowable cycles	Damage index
1, 4 - Detailed fatigue assessment #1	1500	Unlimited	0.000

Allowable number of cycles: 1423 (limited by Load condition 1, 2 - Main shell, Longitudinal butt weld)