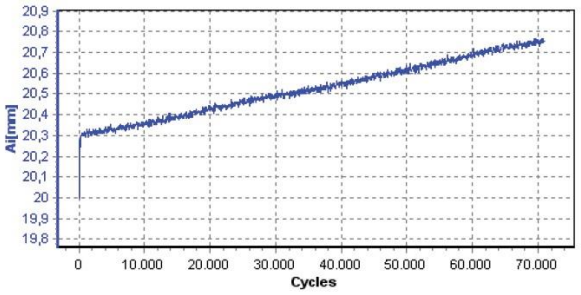
Pre-cracking Software Module, K_{Ic} test

Introduction

During the last years, researches on fatigue crack propagation and fracture toughness have become more significant, for metallic materials, polymers or composites as well.

This software module for Fatigue Strength Testing Machines allows the creation of a fissure or initial crack (pre-cracking) by the application of load cycles on standard test specimens, provided with a crack starter notch.

The crack propagation is measured using an axial extensometer specially designed for this purpose.

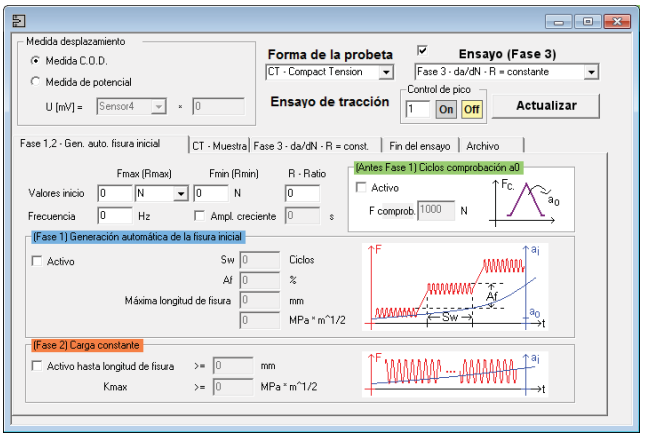


Application

The software allows the creation of precracked specimens with a controlled size before performing the static test to determinate the fracture toughness.

The full test has up to three stages.

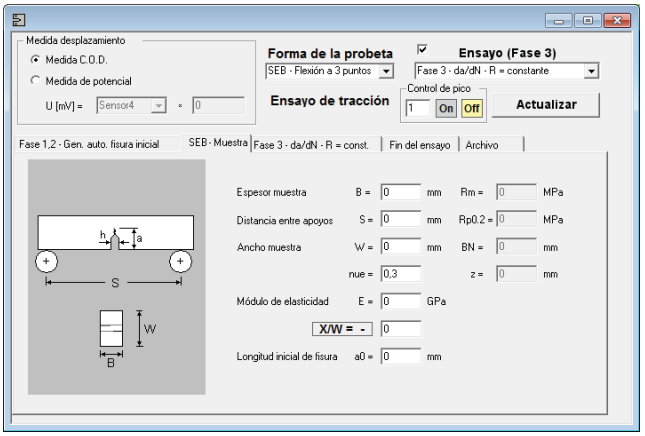
- Stage 1: Crack formation.
- Stage 2: Observation of the crack growth.
- Stage 3: K_{Ic} test.



Performing the first two stages is optional. If there is already a cracked specimen through fatigue, it is possible to go directly to the third stage.

Specimen type.
Three types of specimen geometry can be selected:

- CT. Compact Tension.
- CTs. Stepped Notch Compact Tension
- SEB. Standard Bend.



The user has a selection menu to enter the type and size of specimens.

Fatigue crack measurement method.
The fatigue crack growth can be determined using a displacement gage (extensometer), located on the crack starter notch mouth: direct measure of COD (Crack Opening Displacement).

Crack growth can be calculated according to the test method using the extensometer measure, the specimen dimensions and instantaneous measurement of the crack opening.

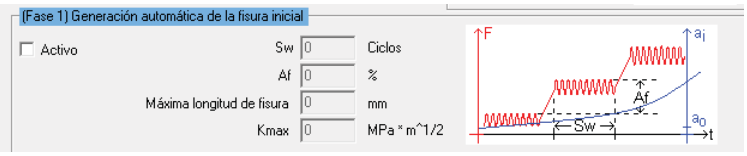
Optionally it is possible to determine the crack size with an electric potential difference procedure.

Stage 1: Automatic generation of the initial crack applying series of load cycles.

On the test specimen, charge cycles are performed at a defined load value, increasing the load on each series of cycles. The shape of the cyclic wave is sinusoidal type.

The initial values are:

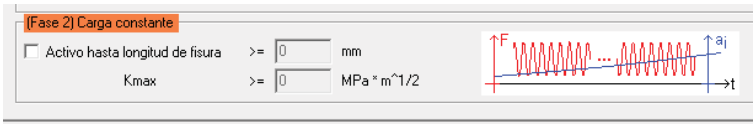
- Initial load value (f)
- Number of cycles (Sw)
- Load increase factor (percentage). (Af)
- Maximum crack length.
- Maximum stress intensity factor (Kmax)



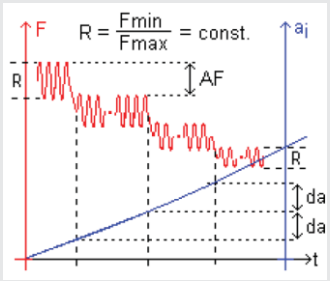
The program continuously calculates the values of a_i (crack length) and K_i (stress intensity factor).
If the predefined number of cycles **Sw** is reached, the program starts a new series of cycles, applying a load increment **Af** according to a predefined percentage.
When the a_i value is greater than the predefined maximum or when the calculated K_i value exceeds the maximum K_{max}, We move to the next stage.

Stage 2: Observation of the crack growth with constant load.

The program performs a series of cycles on the precracked specimen and keeps watching the behavior of the crack with more detail, calculating a_i and K_i.

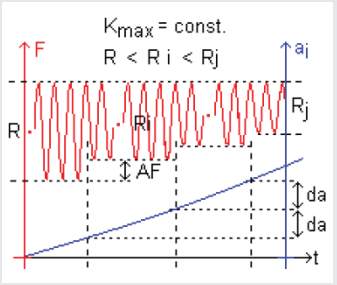


When the ai value exceeds a predefined maximum or when the calculated value of Ki exceeds the maximum value Kmax, we move to the final precracking stage. This final stage can be performed in three different ways.

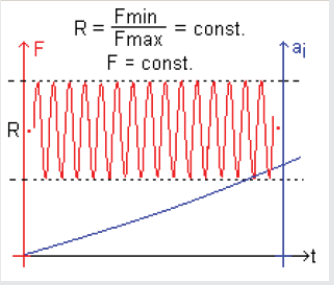


da/dN (R constant)
for R = F_{min}/F_{max}

Perform decreasing cycle load series, in which **F_{max}** and **F_{min}** are decreasing proportionally as they are multiplied by the same factor **Af**.



da/dN (K_{max} constant)
Perform cycle load series keeping constant **F_{max}** and decreasing the **F_{min}** value.



da/dN (F constant)

Perform only one cycle load serie.

All initial values for **F_{max}** and **F_{min}** remain constant.

3 Fracture Toughness determination K_{Ic} test

Prior to the determination of **Klc** it is necessary to determine **KQ** corresponding to the critical value of the stress intensity factor at point **FQ**.

KQ is obtained from:

- Load force (**PQ**)
- Specimen dimensions
- Nominal crack length (**a**).

The test consists in a precracked specimen subjected to an increasing force until break.

The values required for the calculation are determined as follows:

- Tangent line slope of the load-line displacement curve is determined.
- A secant line is drawn with a slope of 95% the previous value and adjusted in the coordinate origin. The intersection between this line and the curve is F_d (see figure on the right)
- F_Q is defined as the highest force that precedes **Fd**. Depending on the type of curve there are three possibilities to determine **FQ**

Curva type I. **Fmax** and **FQ** are equal

Curva type II. Fmax is over **Fd'** but there is another maximum point before **Fd'**, so **Fq** will be that point.

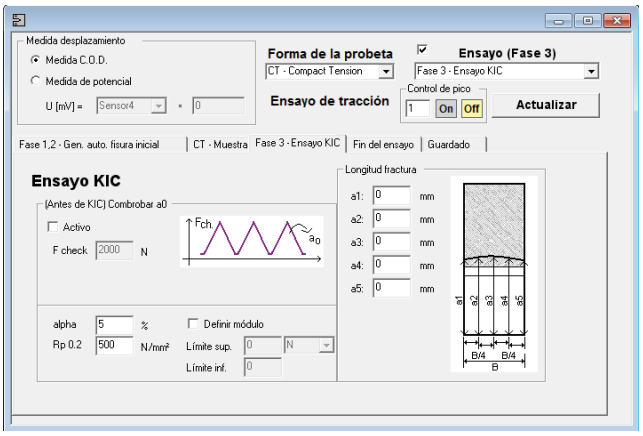
Curva type III. Fmax is over **Fd'** and there is no other maximum point before, so **FQ** and **Fd'** are equal.

The program automatically calculates the value of **Fd** but it is possible to make manual adjustments with the function: **define modulus**.

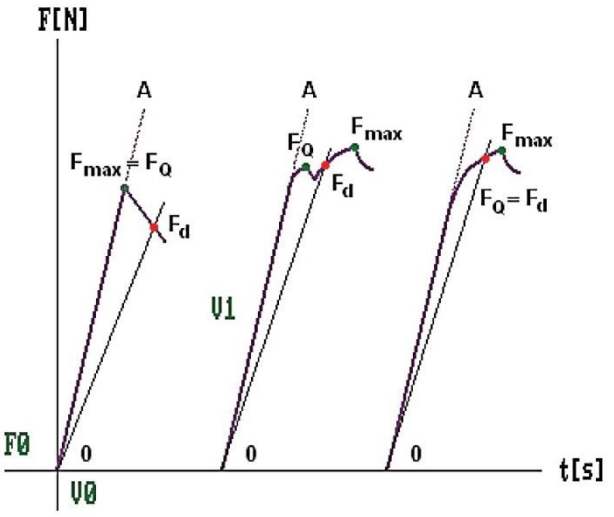
When the specimen reaches fracture, the test results are automatically calculated (see table on the right).

If the crack length is known, you can calculate the stress-intensity factor **K**.

All calculations are performed following the approximations and indications of the test method *ASTM E399 Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness KIc of Metallic Materials*



K_{Ic} test



Fd according each curve type

Symbol	Parameter	Unit
Fmax	Maximun force	N
A	Modulus: slope for the drawn line over a range of F_{max} / 5 Linear regression: y= **A**x + **n**	N/mm
n	See previous expression	mm
dLh	Elongation at maximum load	mm
F_d	Intersection point between the secant line and graph, with a slope of 5% less than the slope of the tangent OA to the initial part of the record.	N
F_Q	Is the highest force that precedes F_d	N
K_Q	Stress intensity factor calculated with F_Q	MPa $m^{1/2}$

Results table

NOTE:
In order for a result of KQ as KLC to be considered valid according to standard test method ASTM E399, is necessary to carry out a numerical verification related to the crack length and the thickness of the specimen
For more information, see the test method ASTM E399