# B. INTRODUCTION TO FATIGUE ASSESSMENT PROCEDURES



F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UC UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*INTRODUCTION*

Fatigue assessments involve comparison of the actions which the component or structure will be required to sustain during its design life with its resistance to fatigue.

Obviously, the resistance must be sufficient to resist the actions without failure occurring. The form and source of the resistance data depend on the type of assessment being performed.

# FATIGUE ASSESSMENT PROCEDURES

*INTRODUCTION*

There are two main methods for assessing the fatigue life of structures or components:

- S-N curves
- The fracture mechanics approach, whereby fatigue crack growth data are used in conjunction with the stress intensity factor variation due to the spectrum of applied loading to calculate the progress of a known flaw.

The first is intended for application at the design stage and the second one is not generally used for design but for assessing known or assumed flaws. Thus, it would be applicable in an assessment of residual fatigue life.


F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*DESIGN OF NEW STRUCTURES OR COMPONENTS*

Fatigue resistance data for design are usually expressed in terms of S-N curves, relating nominal applied cyclic stress range S and the corresponding number of cycles N needed to cause failure.

The simplest situation is one in which the designer would ensure that the number of applied load fluctuations, n, in the design life that resulted in stress range S did not exceed N.

In the more general case there is a spectrum of applied loads and the cumulative damage due to individual load cycles need to be determined. The usual method is to apply Miner´s rule.

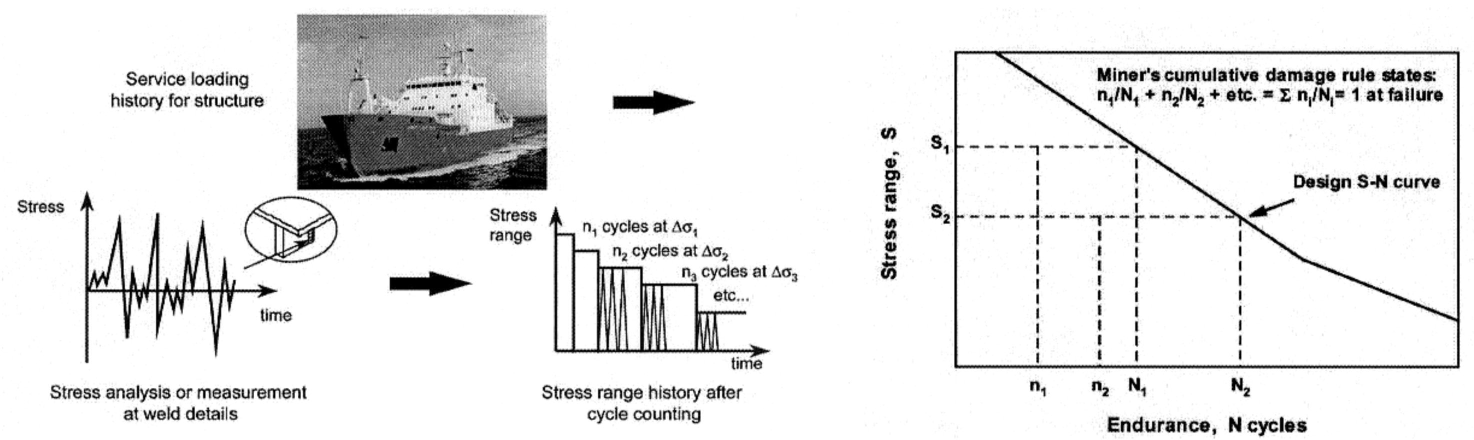

F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*DESIGN OF NEW STRUCTURES OR COMPONENTS*

This involves:

- identification of the loading history
- conversion from loads to stresses
- extraction of recognisable stress cycles from the stress spectrum (cycle counting) to provide input to Miner´s rule




**Miner´s rule for estimating fatigue lives under variable amplitude loading and analysis of fatigue loading for cumulative damage calculations**


F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

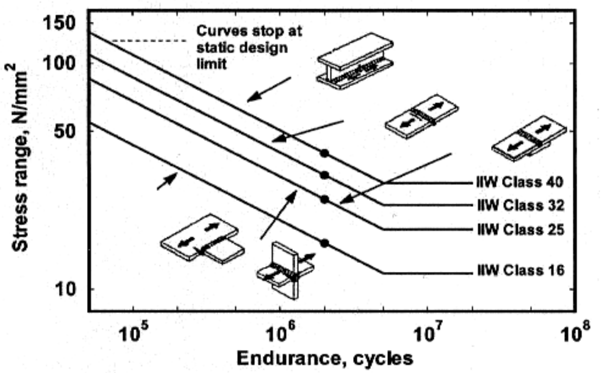
*DESIGN OF NEW STRUCTURES OR COMPONENTS*

The S-N curves used in fatigue design depend on the procedure being used. The most common approach is to use S-N curves obtained from fatigue tests.

Example: welded structures

S-N curves from fatigue tests on specimens containing the weld detail of interest are used. The design curve is usually some statistical lower bound to published experimental data (i.e, mean – 2·standard deviations of logN).

Since S-N curves refer to particular weld details, there is no need for the user to attempt to quantify the local stress concentration effect of the weld detail itself.




**Examples of design S-N curves for welded joints (from IIW recommendarions)**


F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*REMAINING LIFE OF EXISTING STRUCTURES*

Three approaches can be distinguished for the fatigue assessment of existing structures which have experienced some service:

- Fatigue design assessment
- Fatigue design reviews
- Fracture mechanics approach

The approach used will depend on the circumstances:

- Whether or not the structure was designed for fatigue loading
- The time in service
- What measures will be taken to assess its current condition with respect to potential fatigue damage already introduced during previous service.


F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*REMAINING LIFE OF EXISTING STRUCTURES*

FATIGUE DESIGN ASSESSMENT

This method follows the procedure outlined previously for original design.

If the structure was designed for fatigue loading, the same action can be assumed after any modification to allow for changes such as reduced severity of the stress history from reinforcement or a change in operating conditions. If repairs are introduced, a safety factor could be introduced.

Miner´s rule is used to calculate the fatigue damage introduced before and after the time of the assessment, on the basis that:

$$\left(\sum \frac{n}{N}\right)_{\text{before}} + \left(\sum \frac{n}{N}\right)_{\text{after}} \angle \quad 1$$


F. GUTIÉRREZ-SOLANA
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J.A. ALVAREZ
R. LACALLE
UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*REMAINING LIFE OF EXISTING STRUCTURES*

FATIGUE DESIGN REVIEW

Its aim is to improve the accuracy of the original design process to provide a better estimate of the proportions of fatigue life used and remaining at the time of assessment.

When assessing an existing structure, there may be scope for improving the accuracy of some of the assumptions made during the original design process.

Then the Miner´s rule should be applied.


F. GUTIÉRREZ-SOLANA
S. CICERO
J.A. ALVAREZ
R. LACALLE
UC UNIVERSIDAD DE CANTABRIA

# FATIGUE ASSESSMENT PROCEDURES

*REMAINING LIFE OF EXISTING STRUCTURES*

FRACTURE MECHANICS APPROACH

This method addresses circumstances in which it has been found (or it must be assumed) that flaws have been introduced during the service life endured so far.

The fracture mechanics assessment uses the same actions as those determined for design calculations. However, fatigue resistance is represented by fatigue crack growth rate data for the material under consideration, expressed in terms of the fracture mechanics stress intensity factor parameter ΔK:

$$\Delta K = Y \cdot S \cdot (\pi \cdot a)^{1/2}$$

$$Y = Y(\text{geometry, loading})$$


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R. LACALLE
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*REMAINING LIFE OF EXISTING STRUCTURES*

FRACTURE MECHANICS APPROACH

A relationship between ΔK and crack growth rate is established through different equations. One of the most widely used is the Paris law:

$$\frac{da}{dN} = C \cdot (\Delta K)^n$$

For a flaw size $a_0$ and a critical fatigue crack size of $a_f$, the remining life N under stress range S is obtained by integrating the Paris law:

$$\int_{a_0}^{a_f} \frac{da}{\left(Y \cdot S \cdot \sqrt{\pi \cdot a}\right)^n} = C \cdot N$$



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FRACTURE MECHANICS APPROACH

For variable amplitude loading the integration will be performed for each individual cycle or block of equal stress cycles, to give:

$$\int_{a_0}^{a_1} \frac{da}{\left(Y \cdot S_1 \cdot \sqrt{\pi \cdot a}\right)^n} + \int_{a_1}^{a_2} \frac{da}{\left(Y \cdot S_2 \cdot \sqrt{\pi \cdot a}\right)^n} + \ldots = C \cdot N$$

$$\sum_i \int_{a_{i-1}}^{a_i} \frac{da}{\left(Y \cdot S_i \cdot \sqrt{\pi \cdot a}\right)^n} = C \cdot N$$


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UC UNIVERSIDAD DE CANTABRIA

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UNIVERSIDAD DE CANTABRIA