Computer Methods of Analysis of Offshore Structures Prof. Srinivasan Chandrasekaran Department of Ocean Engineering Indian Institute of Technology, Madras

> Module - 03 Lecture - 06 Fatigue Damage 1 (Part - 1)

(Refer Slide Time: 00:17)



Friends, let us continue with the discussion on module 3, where we are discussing about the stochastic process.

## (Refer Slide Time: 00:57)

|           | · · · · · ·   |
|-----------|---|
| nto Tillo | [V]odule 3  |
|           | Lecture 6: Fatigue damage                               |
|           | Fabigue damage!   |
|           | If any material ( exectially metallic) is subjected to  |
|           | harmonic stress cycles, of a constant amplitude, larger |
|           | than a threshold value (depends on the material)        |
|           | then, there is a convection between the                 |
| *         | Shren experienced by material                           |
| NPTEL     | -77 ( 0 -   |

In lecture 6, today we will talk about Fatigue damage estimates which is one of the important methodology of estimating failure phenomenon in complaint offshore structures. Now, let us try to understand what do we mean by fatigue if any material essentially it is metallic is subjected to harmonic stress cycles of a constant amplitude which is larger than a threshold value the threshold value actually depends on the material because every material has a threshold value of acceptance of stress value.

So, if any material is subjected to harmonic stress cycles of a constant amplitude, which is larger than a threshold value then, there is a connection between the stress experienced by the material and the number of cycles which is required to fracture the material. So, a relationship is between the stress experienced by the material and the number of cycles required to fracture the material.

## (Refer Slide Time: 02:05)

| ile (dit View Insert Actions Tools Help<br><u>↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ </u> | Fatique damage 1 (Part - 1)                              | Prof. Srinivasan Chandrasekaran |
|--|--|---------------------------------|
|  |  |                                 |
| Re   | lationship is between                                    |                                 |
|  | Shew (5) coopenienced by mate                            | nal                             |
|  | and<br>Number of yells (N) repuired to o<br>the material | fracture                        |
|  | S-N relationship   |                                 |
| Th<br>(*)  | $s$ is expressed as: $NS^m = K -$                        | — (1)                           |
| NPTEL  | ,  | 2/2                             |

We call this relationship as S-N relationship this is expressed as N S to the power m is k I call this is equation number 1.

(Refer Slide Time: 02:59)

| File Edit View Ins | sert Actions Tools Help Faligue damage 1 (Part – 1) |                    |
|--------------------|---|--------------------|
| 1-1-9              | ? • 9 - 2 × 3 B I I ■ ■ ■ ■ ■ ■ ■ ■ ■ □ □ □ □ ♥     |                    |
|                    |   | ^                  |
|                    |   |                    |
|                    |   |                    |
|                    | took to the character                               |                    |
|                    | to estimate the fairbul damage,                     |                    |
|                    |   |                    |
|                    | a comma nypothesis applic                           | 20 (9              |
|                    |   |                    |
|                    | PALMGREN- MINER'S                                   | RULF               |
|                    |   |                    |
|                    | "For a load history of duration T with              | different stress   |
|                    |   |                    |
|                    | amplitudes it is assumed that the                   | accumulated damage |
|                    |   |                    |
|                    | in gives by D(T)                                    |                    |
|                    |   |                    |
|                    | m(r) - 5 Ni   |                    |
|                    |   |                    |
| NPTEL              | 4 'F  | · · · · ·          |
|                    | 1   | 4/4                |
|                    |   | 4 😵                |

So, in this case N denotes the number of cycles to fracture the material, S denotes the stress range that is very interesting it is not a single value at which the material fracture, but there is a range m and k are actually material constants. Usually, m varies anywhere from 3 to 5 for marine steel, we will talk about this slightly later in more detail. We

estimate the fatigue damage a common hypothesis applied in the literature is Palmgren -Miner's Rule.

(Refer Slide Time: 04:42)

Where Nj = Number of cycles in the timeshistory amounted with the stress range (S:) ig The shew rape lies is the bard-widts of  $\left(S_{j} - \frac{A_{j}}{2}\right)$  to  $\left(S_{j} + \frac{A_{j}}{2}\right)$ for a suitable discetion legets As  $N_j = K S_j^m$ is the Number of shew cycles to facture with ()5 2

What is this rule state? This rule states that for a load history of duration t with different stress amplitudes, it is assumed that the accumulated damage is given by D T which is summation of n j to capital N J is summation equation 2, Where the n j is number of cycles in the time history associated with the stress range S j, that is the stress range lies in the bandwidth of S j minus delta s by 2 to S j plus delta s by 2 for a suitable discretion length delta s, capital N J is actually equal to K S j minus m which is the number of stress cycles to fracture with stress range S j, fracture is assumed to occur when the following condition is satisfied.

## (Refer Slide Time: 05:50)

| ile Edit View Insert Actions Tools Help<br><u>↓ • </u> ↓ •<br><i>●</i> •<br><i>●</i> •<br><i>●</i> •<br><i>■</i> ■<br>■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ | Fatigue damage 1 (Part - 1)                       | Prof. Srinivasan Chandrasekaran |
|---|---|---------------------------------|
|   |   |                                 |
| Fractio   | e is assumed to occur 1                           | when the following              |
| Cond  | itia is Satisfied:                                |                                 |
|   | $\tilde{D}(\tau) = \int (w)$                      | iiby)                           |
| frompting<br>()   | Nj bad cycles consume a p                         | sart of life time of            |
|   | the material                                      |                                 |
| (*)<br>NPTEL (2) ACCU   | (This is expressed a<br>unulated dange y Uneo B(1 | , accumulated damage            |
|   |   | 6                               |

It says that, it should be equal to unity the above hypothesis an assumption it says that that n j load cycles consumes a part of the 'lifetime' of the material. This is expressed as accumulated damage which is D T, the second assumption it says that the accumulated damage in this model is linear.

(Refer Slide Time: 06:42)

Olt XIt denses a stationary, narrow-bandled process which represents the Van-Mises shears in a section of a member which is lightly damped. 

Let us say that the X of t is a response time history which denotes as stationary, narrow banded process which represents the Van - Mises stresses in a section of a member which is lightly damped.

## (Refer Slide Time: 07:45)

| Let i      | 1(a) denote Number of shess yields with amplitude |  |
|------------|---|--|
|            | botween The range (a) and (ext de)                |  |
|            | (ie) S= 2 a, which is a part of the process       |  |
|            | X (J) durning the bine T.                         |  |
| Hence,     | Nov da is also                                    |  |
| ~          | /   |  |
| *)<br>PTEL |   |  |

So, to start with we assume that X of T is a 0 mean process in that case, let N bar of a denote the number of stress cycles with amplitude between the range a and a plus d a that is S is going to be now equal to 2 a which is a part of the process X of T during the time T. Therefore, friends we now understand that N bar a d a is also a random variable.

(Refer Slide Time: 09:02)

The accumulated damage,  $\tilde{D}(t) = \int \frac{\tilde{N}(e)}{Ne} de$  (3) where Na = K (20) which also become a random variable. The Expected value is given by:  $\mathcal{D}(\tau) = \mathbb{E}\left[ \tilde{\mathcal{I}}(\tau) \right]$  $= \int \frac{E[\tilde{N}(k)]dk}{Nk}$ (4)()

The accumulated damage, as given by the existing hypothesis is followed by the same equation call equation number 3, where N a is K stress range to the power of this load, which also becomes a random variable the expected value is given by D of t the expected

value of this which is further said as integral 0 to infinity expected value of N tilde a d a by N a which I say as equation 4.