NPTEL course offered by IIT Madras

Risk and Reliability of Offshore structures

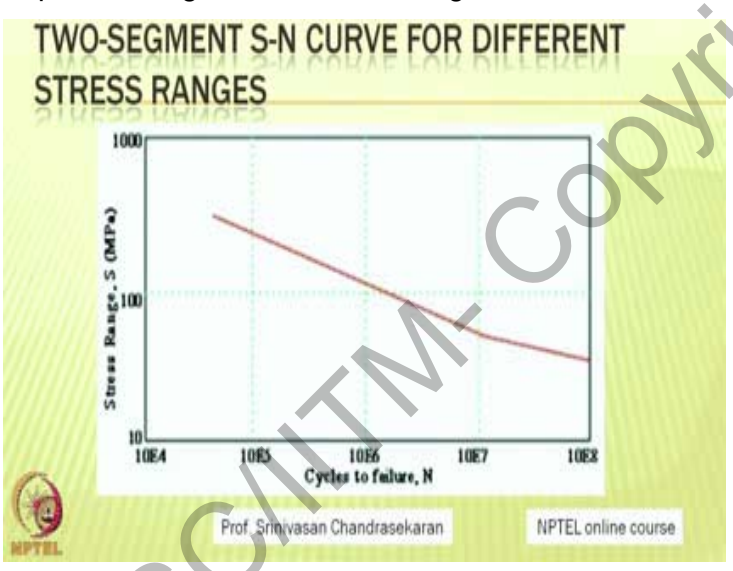
Tutorial 9: Fatigue Reliability

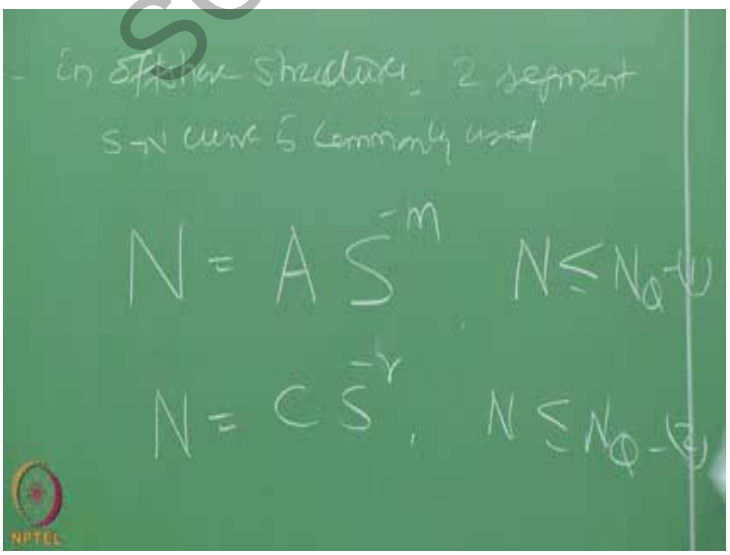
Answer all questions **Total marks: 25**

1. Explain the basis for fatigue damage assessment?

   An estimate of probability of failure by considering the probability of exceedance of a specific value, when compared to the threshold limit of that specific value is the basis for fatigue reliability. An indirect fatigue assessment can also be performed by limiting the predicted stress range within the permissible stress range. Fatigue damage is stated in terms of the stress ranges which are essentially produced by the cyclic loads

2. Explain the significance of two-segment S-N curve and Endurance limit





Traditional S-N curves are used in the design of offshore structures. If you have a case where for N exceeds or equals N_Q, this signifies endurance limit. This implies that a member can endure for all stress ranges S lesser than or equal to S_Q, indicating no fatigue damage in this range. In early years, in the design of offshore structures conservative approach was used by ignoring this endurance limit.

3. List a few factors that make S-N curve conservative

Few factors that make S-N curve conservative are as follows:

1. Relaxation of residual stress is not introduced.
2. External stress, being partly compressive as the result of which cracks will have closure effects. These factors would make the actual crack growth lesser than that is estimated.

So, the implications or the consequences could be that the actual crack growth is lesser than that implied by the stress range used in S-N curve. This makes it very conservative. On the other hand, it is important to note that S-N curves deal with constant amplitude but environmental loads that act on offshore structures have variable amplitudes. Solution to this problem is that a thickness correction factor is used along with the S-N data, when applied to offshore structures.

3. State the limitations of fatigue assessment of offshore structures

One of the serious limitations that exist in fatigue assessment of offshore structures is the assessment under combined effect of material degradation and stress cycles. In estimating a cumulative damage index, even if the sum is closer to about 50%, it is considered to be a damage scenario because combinations are very extreme. Secondly, cumulative damage approach does not consider the load-sequence effect. If load-sequence effects are included, then cumulative damage of failure assessment should be modified to 2.5 (instead of unity). Other factors that affect the damage assessment are namely: 'TIG dressing', which is used to improve the fatigue strength over a gas welded specimens in particular.

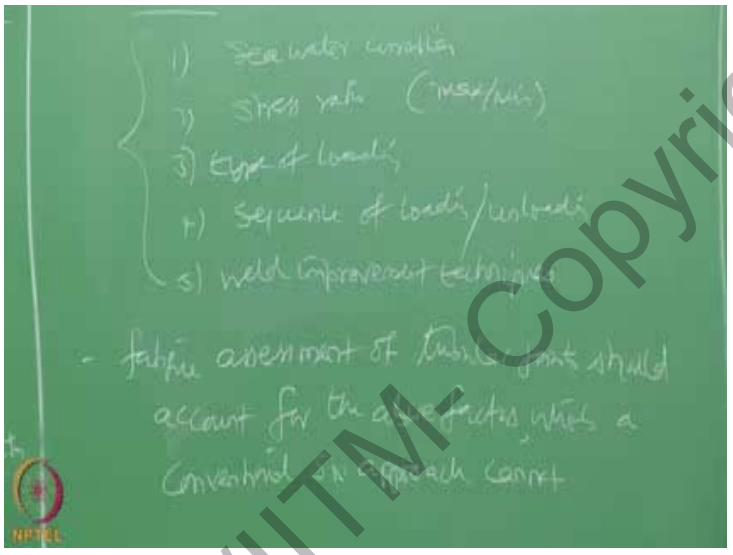
4. List the important factors that are considered in fatigue assessment of tubular joints

Following factors are important:

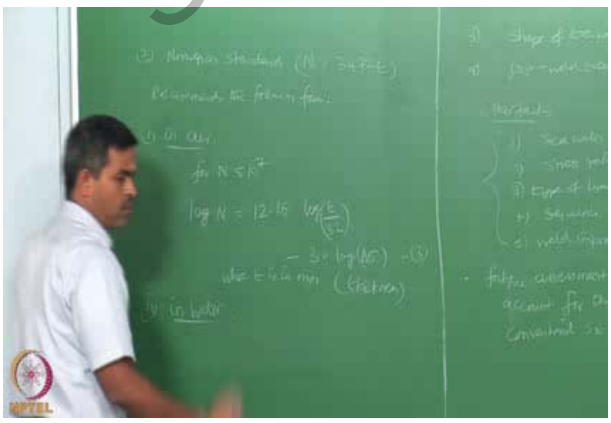
1. Standard definition of fatigue failure of tubular joints employed in the test itself is a subject of question. Stress concentration factors and load carrying capacity estimates, predicted by conventional equations vary significantly with that of the actual capacity of tubular joints under failed conditions under experimental investigations

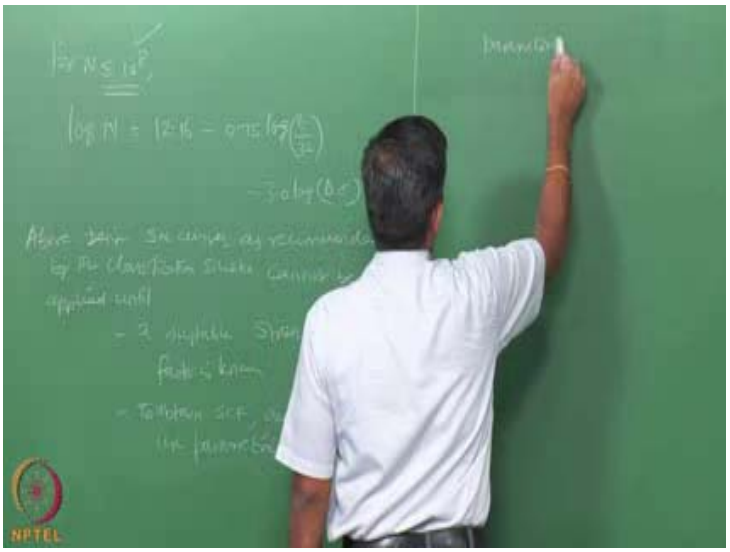
2. Size of the tubular joints play a very important role and that should be pre-decided as a size has a very significant effect on the fatigue strength. For example, tests show that larger joints have lower fatigue strength.
3. Shape of the toe weld, which is also important in estimating the fatigue behaviour of welded joints.
4. Post-weld treatment can significantly affect the results of a fatigue assessment of tubular joints.
5. Sea water corrosion, sequence of load etc can also influence fatigue assessment of tubular joints.

   Since there are no equations or parameters, which can significantly include these effect on fatigue assessment, fatigue assessment of tubular joints should account for the above factors which a conventional S-N approach cannot.



6. Discuss various design S-N curves recommended by classical societies and their discrepancies

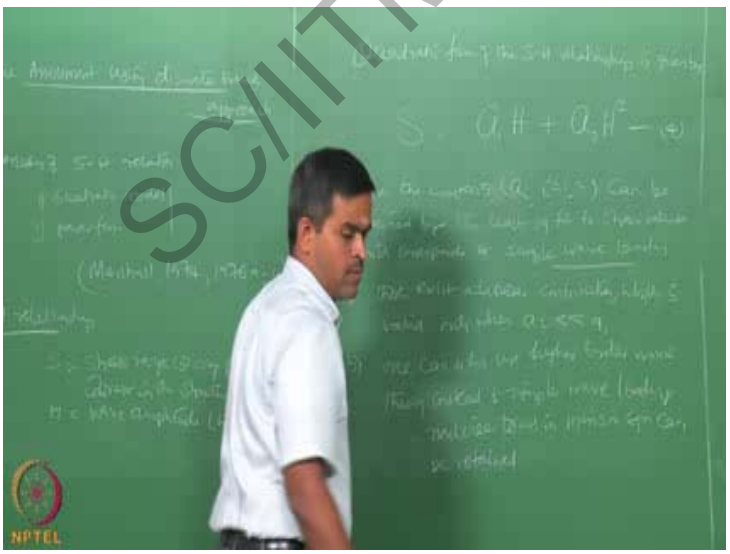




To avoid the discrepancies, one need to use parametric equations that are developed for typical joint configurations of tubular joints. These parametric equations are generally developed for typical joint configurations using experimental and numerical modelling using finite element method. So, even assessing the fatigue failure itself leads to implicit uncertainties.

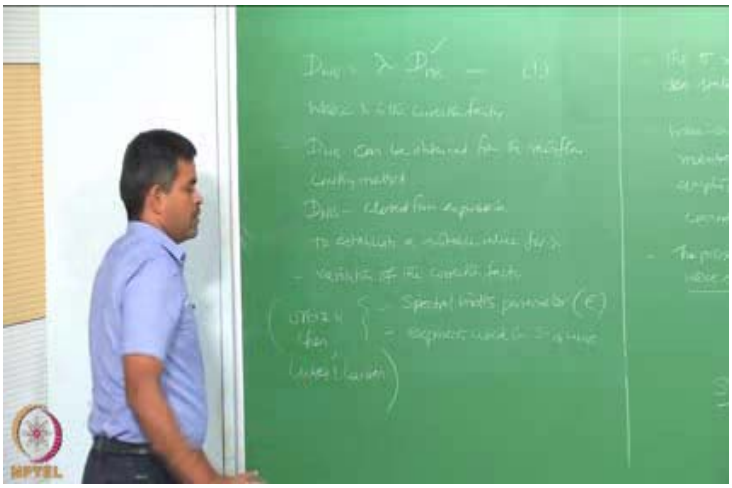
7. Explain S-H approach for fatigue assessment

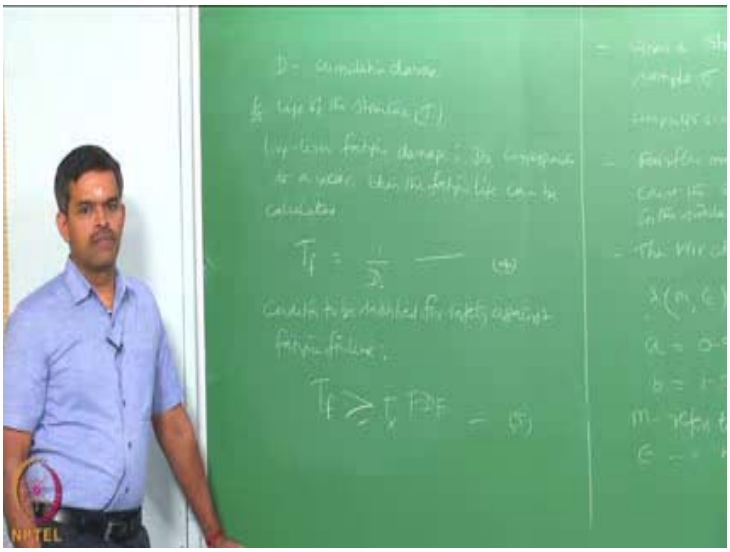
To enable faster fatigue calculations using discrete wave approach, researchers have suggested two versions of S-H relationship, where S stands for stress concentration or the stress range and H stands for the wave height.

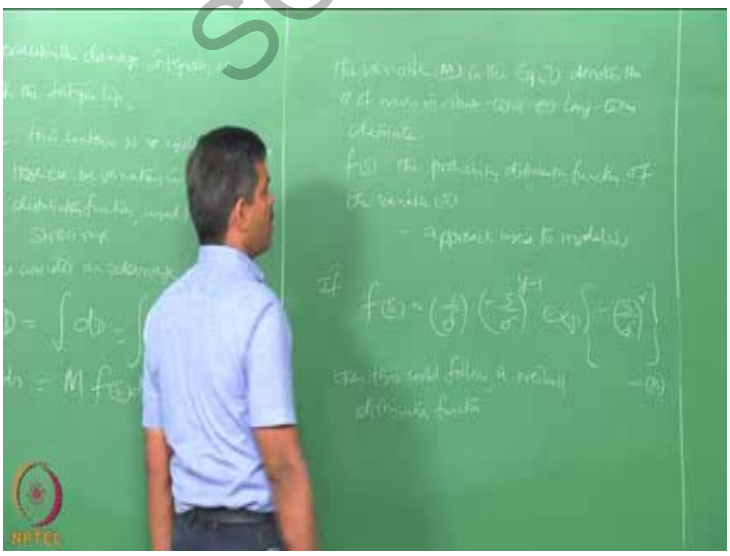


8. Explain Short-term fatigue damage

Fatigue reliability is one of the direct applications of finding probability of failure of a given system under cyclic loads. Power spectral density function of wave elevation for low and moderate sea states cannot be strictly assumed to be a narrow band but for extreme sea states this can work. Stress response due to broad-band sea states will continue to remain as broad-band particularly when the dynamic response is not dominated by large amplification factors in any given natural modes of vibration. Therefore, wave-induced stresses in offshore structural members, in the absence of large dynamic amplifications will continue to remain as broad-banded and cannot be ignored in fatigue calculations. There are significant humps near the wave spectral peaks, which are really the concern in using the2-segment S N curve. For such cases, close-form expression for stress cycles and the fatigue damage, which are derived for the spectral analysis will not be very accurate (Wirching and Light, 1980). Therefore, a general approach to a broad-band correction is to assume a suitable counting algorithm. One should estimate the stress cycles in the time history of stresses generated by the time domain analysis and then use this estimate of stress range history to obtain the damage. Instead of assuming the stress history as a narrow band process, a typical counting using rain flow counting method is popular in offshore fatigue assessments.







9. What are the major concerns of failure assessment of tubular joints?

Tubular joints essentially are connections made or welded at the interface between the tubular members. There are various factors, which will influence their behaviour. It may arise due to weld deposit in the heat-affected zone at the joint and adjacent. In case of unstiffened joints, which means that joint does not have any specific reinforcement, stiffeners are provided using rings. Rings are welded inside the chord at the intersection to make a ring-stiffened joint. It is important to note that braces produce a high-membrane stresses in the chord shell. This may result in a non-uniform stress distribution, which is a major concern at the intersection. In summary, there is a high possibility of non-uniform stress distribution and a high stress concentration at the connections.

10. Explain SCF