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Better material utilization through improved ECA analysis

Standardized Engineering Critical Assessment (ECA) analysis is usually very conservative. There is a potential for better material utilization and cost savings through improved ECA analysis.

Acceptance criteria

For all load carrying structures where cracks can be present, it is important to establish defect acceptance criteria. The severity of cracks depends on location, size, loading, and material properties. Most cracks in structures are weld defects and it is therefore common to perform NDT examinations of the welds. Acceptance criteria for defects can be established from ECA analyses. Standardized ECA analyses, however, may be overly conservative due to simplifications based on lower bound assumptions with regards to fracture toughness. The level of conservatism is also unknown in this case.

It is important to use accurate ECA analyses to establish acceptance criteria with known safety factors to ensure that a construction has a specified safety level. Acceptance of cracks that are too deep may lead to hazardous failures. Too much conservatism in the ECA analysis on the other hand can lead to:

- Unnecessary weld repairs
- Unnecessary strict inspections demands
- Unnecessary post treatment of the welds
- Welding methods, materials, and designs that are good enough, can be disqualified based on overly conservative assessments.

There are many factors that contribute to the conservatism in ECA analyses. Two of the main factors are related to fracture toughness and plastic collapse, respectively.

Fracture toughness

It is now commonly accepted that the fracture toughness is strongly geometry dependent. The conservatism in ECA analyses can be significantly reduced if the correct fracture toughness for the structure is used.

Much effort has been undertaken to design a fracture mechanics specimen that gives the correct fracture toughness for pipes. The result is the Single Edge Notch Tension (SENT) specimen. Figure 1 shows an example of the possible gain in fracture toughness when going from a SENB to a SENT specimen.

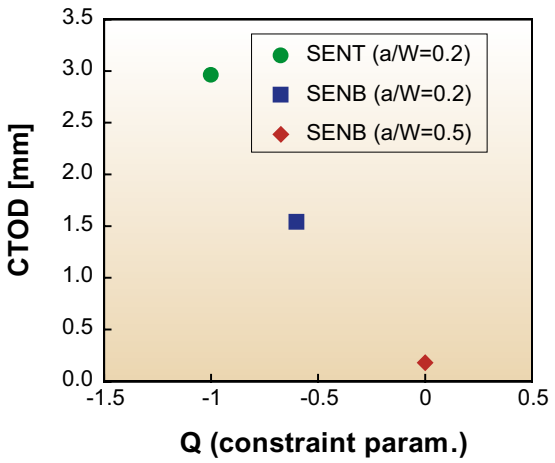

Figure 1. Differences in fracture toughness (CTOD) for three different fracture mechanics specimens with different geometry constraint (690 MPa steel).

Plastic Collapse

In ECA analyses, the average of the yield strength and the tensile strength is used as a plastic collapse limit. This is a very conservative plastic collapse criterion. For modern steels with high fracture toughness, plastic collapse is often the limiting failure mechanism in ECA analyses.

Qualification of offshore pipelines with ECA is an example where the conservatism in the plastic collapse limit has been a problem. Smaller offshore pipelines (‹14" typically) is often installed by reeling, see figure 2. During reeling the pipe can be strained up to 3% and at this strain, the stress can be higher than the plastic collapse limit. This means that even with flawless welds, the plastic collapse limit is exceeded. This is obviously conservative since the tensile strength of a modern pipeline steel is typically at 10% strain.

The development of the SENT specimen for fracture mechanics testing of pipes, has opened for a new method for finding the plastic collapse limit. SENT specimens are loaded in tension, and the maximum net section stress can be measured directly from the specimens. This net section stress can be used as the plastic collapse limit in the ECA analyses.

Figure 2. During reeling of pipelines the pipe wall can be strained up to 3%.

Further work

For pipelines the constraint concept is quite well established. However, for more brittle structures there is also a great potential in applying constraint correction of the fracture toughness. In order to fully utilize this, a better understanding of the scatter in fracture toughness is needed.

Much of this will be addressed in the SINTEF initiative Arctic Materials.

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