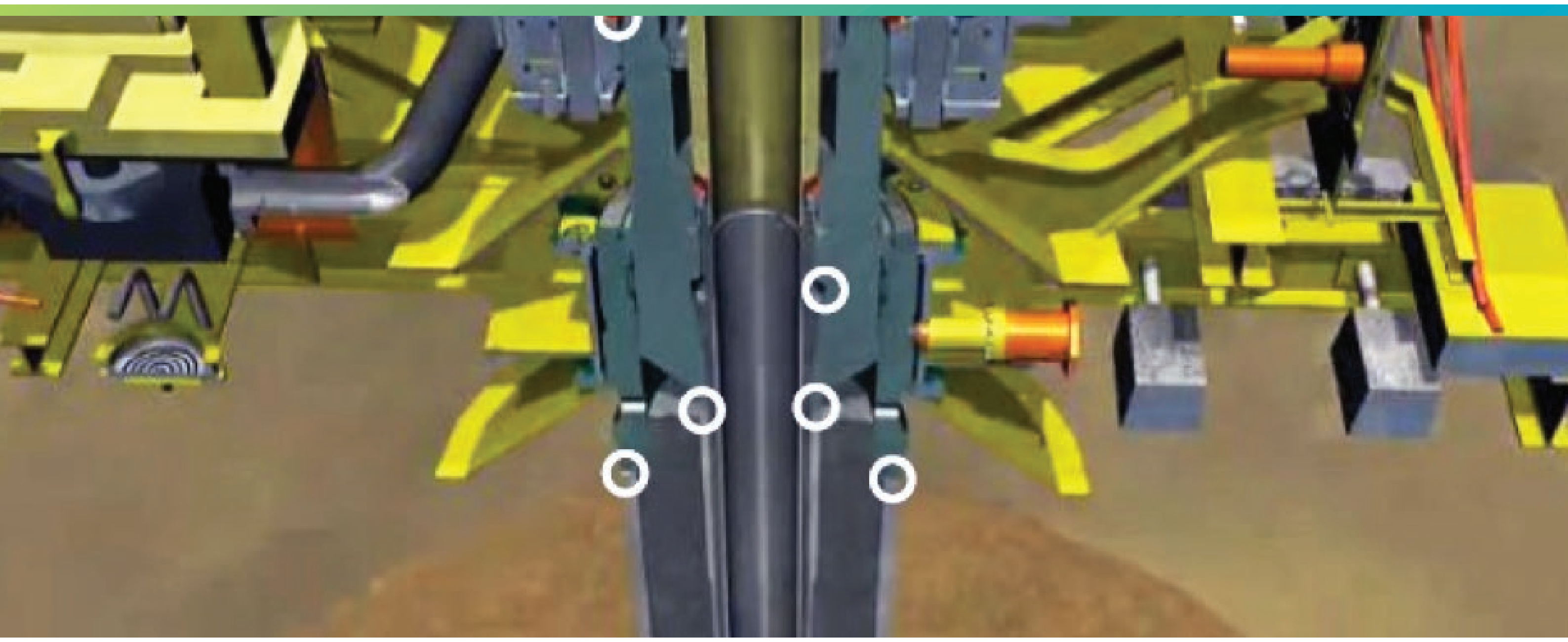
Case study

4Subsea AS

Extending the life of subsea drilling equipment



Introduction

Subsea drilling is conducted through a string of steel pipe called a rigid riser that runs from the oil rig to the blowout preventer (BOP). The primary purpose of the BOP is to cut off the flow of oil in the event of an emergency during drilling.

The BOP may be connected to the subsea well directly, which consists of a string of vertical pipe running into the seabed down to the reservoir. The part of the well above (2-5 m) the seabed is called the wellhead system. This is the interface to the equipment to be connected to the subsea well. Alternatively, the BOP may be connected to a valve tree, which in turn is connected to the subsea well. The valve tree is used to control the flow of oil, and is usually called a Christmas tree.

As the oil rig moves with waves and currents it pulls the rigid riser along, transferring loads to the equipment on the seabed. The cyclic loading from the wave motion can lead to fatigue damage. The most critical areas from a fatigue standpoint are usually welds between pipes and stress concentration points, such as notches or connections between the different components.

Challenge

The traditional approach to estimate fatigue life for underwater applications is based on the nominal stress at a given location. The calculated stress is related to test results through S-N curves, which give a required amount of stress cycles to cause fatigue failure. The results from a fatigue test are plotted as stress (S) versus number of cycles to failure (N), which gives the S-N curve. However, fatigue testing is expensive and time consuming so it is usually possible only in certain cases.

Sometimes fatigue test results are extrapolated to other geometries but this often leads to inaccuracies. For example, when S-N results are applied to a part with a higher wall thickness than the test specimens, or a higher stress concentration factor, the results will usually be too conservative. Overly conservative fatigue results can have a huge economic impact. As an example, drilling through the wellhead equipment may be allowed for only 200 days. Being able to more accurately estimate the fatigue life may make it possible to drill for another 100 days or more, which could dramatically increase the amount of oil and gas that can be produced by the well.

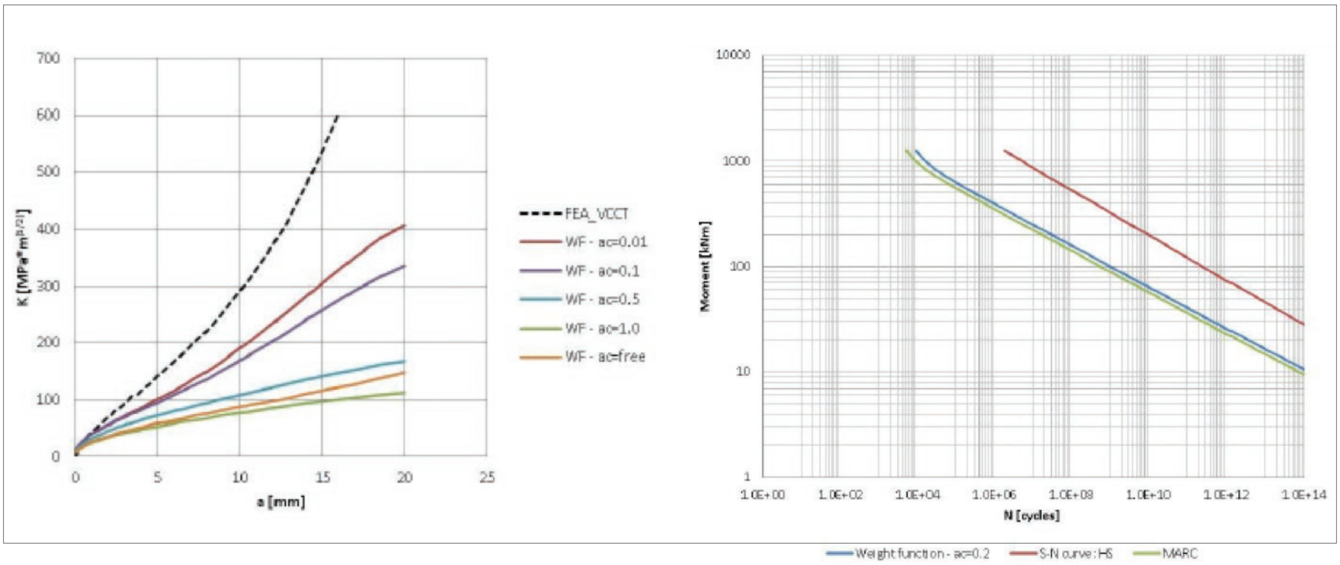
Solution/validation

4Subsea AS has used crack growth calculations to overcome these challenges. To calculate the crack driving force, a weighting function was used. This method uses the stress determined by finite element analysis (FEA) and it has been proven for a range of applications. However, it is considered more physically accurate to be able to simulate the growing crack through a finite element model. MSC Software's Marc FEA software supports this approach through use of the Virtual Crack Closure Technique (VCCT). Therefore, 4Subsea compared results from both methods in order to validate the crack growth results. In turn, these results were compared with the results found from S-N method.

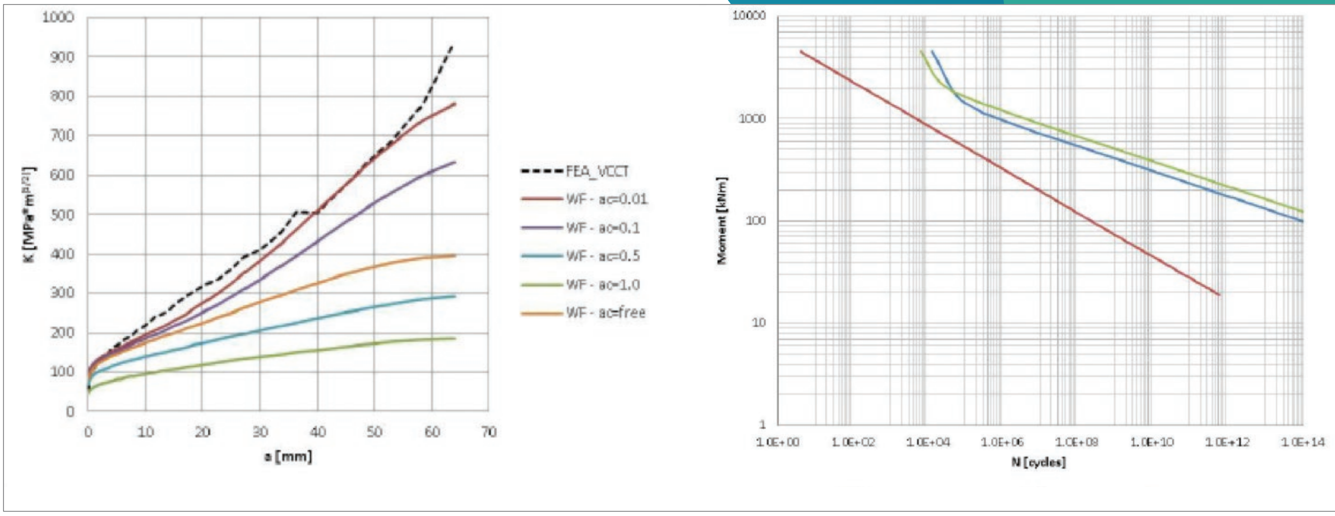
For the VCCT fatigue crack growth approach, a given crack growth increment was chosen. The crack was then incrementally grown to its final size. During each crack growth increment remeshing was applied to account for the updated crack geometry. After each increment the energy release rate range and crack growth direction was estimated. This approach thus gives a curve of crack driving force versus crack depth, which in turn can be used for the fatigue calculation with Paris' law. The benefit of the VCCT method is that it automatically updates the direction of the crack as it grows through the finite element mesh. In addition, due to the presence of the actual crack the stiffness change and stress redistribution is properly accounted for, as opposed to when using the weighting function method.

Two typical geometries found on subsea structures were recently analyzed to compare the VCCT and the weight function methods, based on linear elastic theory, with the S-N approach. The first geometry is a simple cylinder with a 25 mm wall thickness and a 500 mm ID. This is representative of specimens that are tested to generate S-N curves. In the case of this simple geometry, the VCCT and weight function methods give more conservative results than the S-N curve. This can be explained by the fact that the part geometry closely matches the specimen used for S-N testing and the crack growth methods assume the presence of a crack. In

Key highlights:
Product: Marc
Industry: Energy
Greater understanding of crack growth
More accurate prediction on part lifecycle
Increased uptime of drilling rig



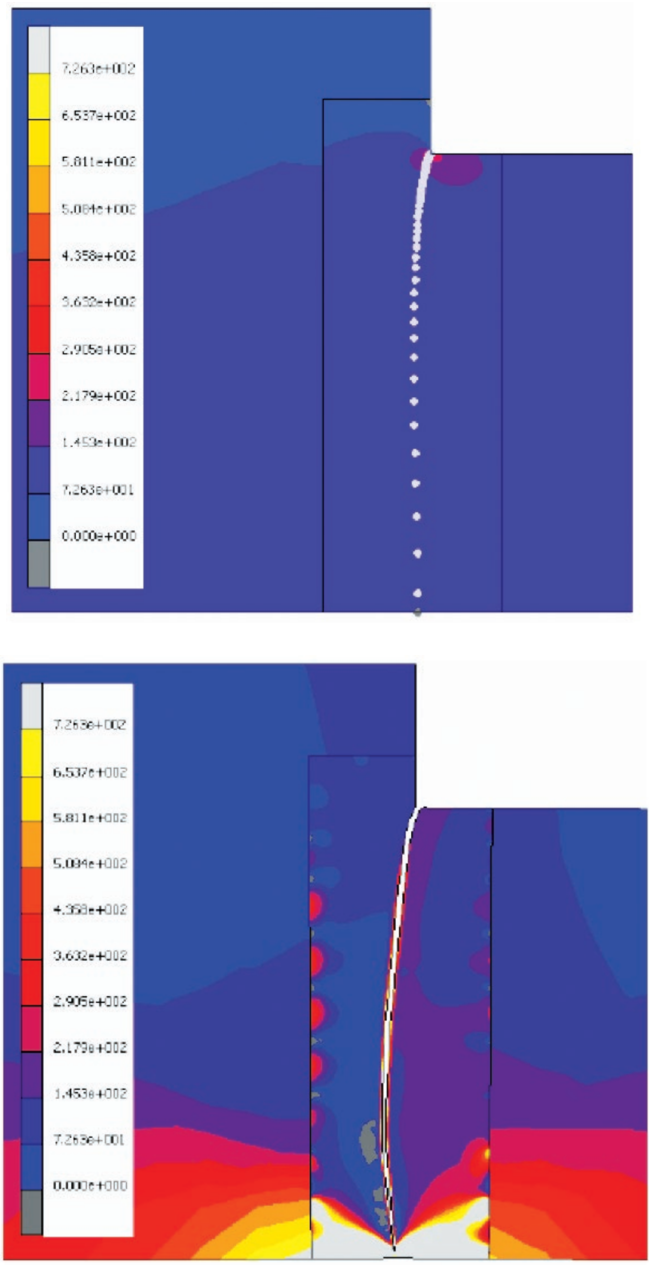
The plot on the left side shows the crack driving force on the y axis and the crack depth on the x axis for the VCCT and weight function approaches. The plot on the right shows the VCCT and weight function fatigue results compared with the S-N result.



Crack growth approach, with weighing function and VCCT method, shows longer life for cylinder with notch. In the curve on the right, both crack growth and S-N results are plotted in an S-N diagram.

general, the fatigue life of a component is best represented by test results, due to the conservatism inherent in the crack growth approach.

The second geometry is a cylinder with 0.1 mm notch, 80 mm wall thickness and 500 mm ID. With this geometry, the S-N curve shows a much lower fatigue life than both the weight function method and the VCCT. The explanation is that the crack starts at the notch, but soon grows out of the area of intense stress into an area of much lower stress, in turn slowing its rate of growth considerably. The crack growth approaches takes this slower rate of growth into account, while the S-N method assumes the stress is high throughout the wall thickness. In this typical geometry, with dimensions not untypical for an oilfield application, the VCCT method provides more accurate and less conservative results.



Predicted crack growth paths for notched cylinder, where the crack growths from the outer diameter.

Results

The crack growth method, as documented in British Standard (BS) 7910, is accepted by regulatory authorities for certification of offshore structures. 4Subsea has used both the weighting function and VCCT method in order to produce more accurate results than can be achieved with the traditional S-N method. The result in some cases is that the life of subsea equipment can be extended considerably. In a few cases, oil companies have gained financial benefits by increasing the extractable amount of oil from a well without any additional capital investment.

About 4Subsea AS

4Subsea AS is an independent engineering company operating in the subsea technology and renewable energy fields. Rather than addressing routine bulk engineering, the company focuses on solving its customers' most demanding problems. 4Subsea's core competencies include flexible riser technology, well intervention and drilling, and engineering software solutions. Established in 2007, the company has grown to 50 employees and has offices in Asker and Bergen, Norway.

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