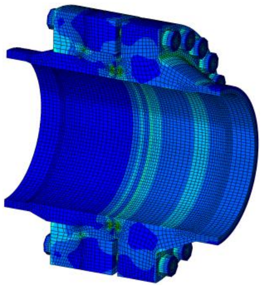
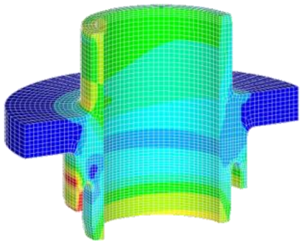
Design By Analysis for





Pipeline and Subsea Components

Subsea Component Design

Advanced analysis is a requirement for most oil and gas projects. With increasing computational power of computers, **Nonlinear Finite Element Method** (**NFEM**) has replaced the traditional linear elastic method.

Z-Subsea has successfully delivered Advanced Finite Element Analysis projects since its establishment. Its personnel have worldwide recognition in this area with strong track record on various international, ultra-deep water, and High Pressure-High Temperature (**HPHT**) pipeline component design projects.

Z-Subsea personnel are well established in advanced numerical modeling with many published technical papers in the field.

Design by Analysis (DBA)

Z-Subsea employs **Nonlinear Finite Element Method** (**NFEM**) and **Design by Analysis** (**DBA**) approach to design subsea components such as:

- **Pipe-in-Pipe bulkheads**
- **Pipeline flanges**
- **Pipeline Wye Piece (Y-piece)**
- **Pipeline Tee**
- **Pipeline Reducer**

Design by Analysis using Nonlinear Finite Element Method is an **LRFD** method which can replace the traditional stress linearization and categorization. For components with a complex geometry/loading, the stress categorization process may produce ambiguous result. In contrast, the **DBA** using **NFEM** is applicable to any component with sufficiently ductile material under any given loading.

Commonly used standards for offshore component design are:

- **ASME VIII Division 2**
- **BS EN-13445**
- **PD5500**

The design criteria for **DBA** are generally based on solution convergence, level of strain, and other failure modes such as accumulated plasticity or buckling. This makes the method more efficient than the traditional linear elastic methods.

Design by Analysis Considerations

The Design by Analysis and **NFEM** for component design should be used with complete awareness of the concept of this design method and what consideration each part of the design requires. The application and location of boundary conditions, loadings, and thermal effects are particularly of importance as it can affect the accuracy of the FE model and analysis results during a nonlinear analysis.

a) Elastic-Plastic small Deformation Analysis

One part of the DBA design method requires elastic-perfect plastic material with small deformation theory. Special care needs to be applied while conducting this part of analysis to avoid excessive plastic deformation despite achievement of solution convergence.

b) Elastic-Plastic Large Deformation Analysis

Another part of the **DBA** method requires elastic-plastic material with true stress-strain curve and large deformation theory. The true stress-strain curve is usually provided by the code based on the forging material. This part of analysis is more complicated and requires considering the implications of geometric nonlinearity to avoid erroneous and un-conservative design.

c) Elastic-Plastic Cyclic Analysis and Ratcheting

In this part of a **DBA** method, usually elastic-perfect plastic material with geometric nonlinearity and large deformation theory is required. The load and resistance factors will not be used in this part of analysis. A number of loading/unloading cycles will be applied to the component to ensure plastic shake down. It is usually a requirement of all the **DBA** codes to demonstrate that the plastic deformation stabilizes after a limited number of loading/unloading.

The plastic deformation in a component is usually localized. Therefore, using shape optimization, it must shake down after a few operational cycles.

Similar to section (b) above, care should be practiced for large deformation effects to avoid un-conservative results.

d) **Other Code Check Requirements for DBA**

There are other code checks which might need to be considered in the **DBA,** e.g. buckling check for slender components, and fatigue for components under considerable number of loading cycles.

A successful design shall pass all the applicable code requirements with given load and resistance factors.

e) **Load Safety Factors**

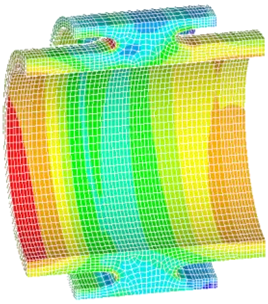
The load factors used in the **DBA** should be chosen carefully to avoid under-design as well as over-design. Some loading conditions might not be explicitly stated in some of the codes (such as installation loading), in which case suitable load factors should be extracted from the code.

From Global to Local FE Model

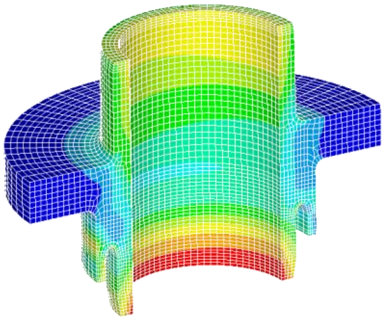
Analysis of the global **FE** model of a system during various loading conditions (Installation, hydrotest, operation, seismic, global buckling, etc.) provides the forces and bending moments acting on a given component in the system. These loads are then used in **DBA** method to perform various code checks using nonlinear **FEA**. Thermal stress analysis is necessary both at global level and local **FE** model to include thermal induced stresses and thermal material de-rating.

Pipeline and Component Code Break

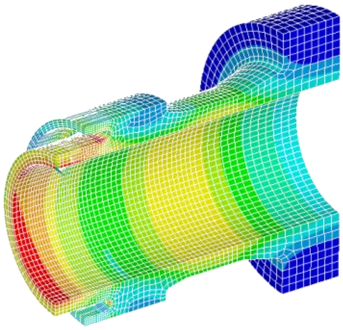
The code break between the component and pipeline is at weld location. However, based on **DNV-OS-F101** it should be demonstrated that the presence of component does not affect the stress in the pipe. If the component introduces concentration of stress/strain in the pipe and disturbs the pipe stress distribution, solutions such as increasing the length of the straight section of forging, or alternatively using pipeline pup piece should be used to remove this effect.



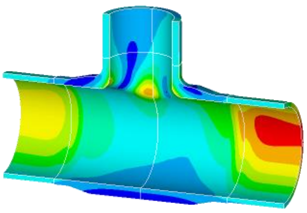
PIP In-Line Bulkhead



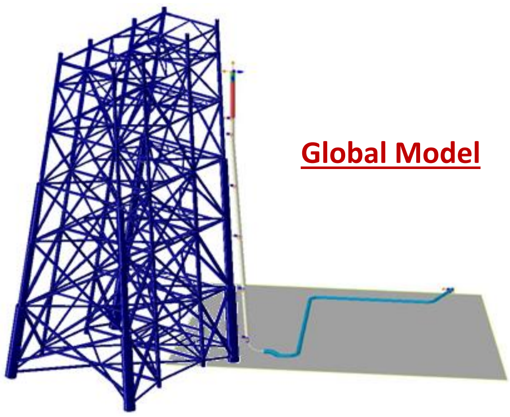
PIP Riser Hang-off Flange



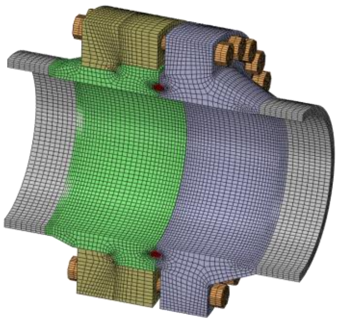
PIP Flange Bulkhead

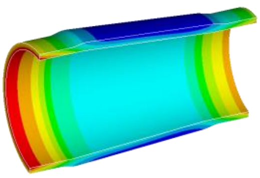


Pipeline Tee

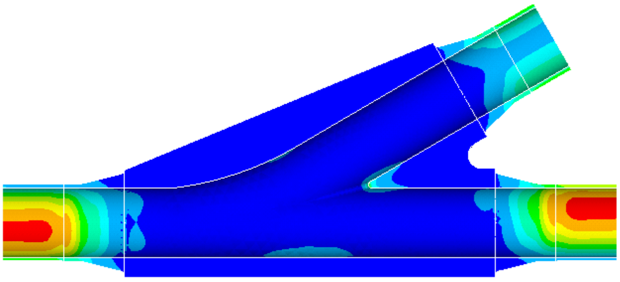


Global Model

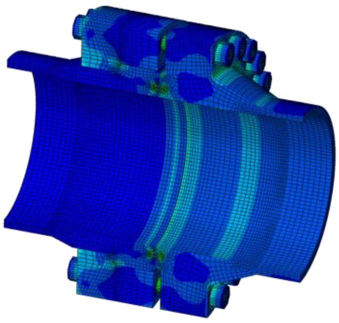




Pipeline Reducer



Wye Piece



Pipeline Flange

Z-Subsea Experience on Design by Analysis of Subsea Components