Development of Mechanical Pipe Connection (MPC) Design for DEMO

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Introduction

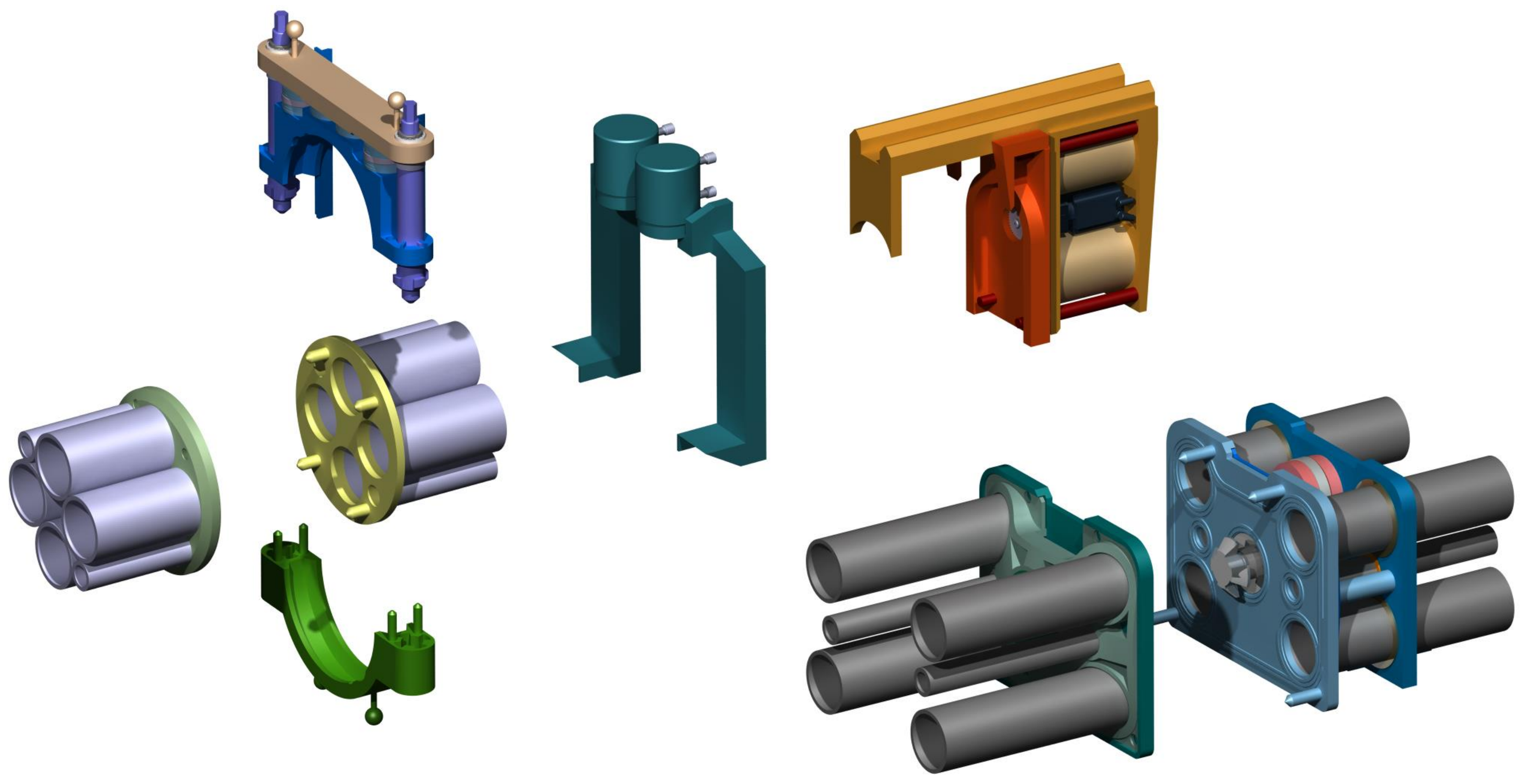
Multi-Pipe Mechanical Pipe Connection (MPC) connects of multiple size and fluids in a manifold configuration.

- reduce the overall time required to operate the mechanical pipe connection compared to multiple single-pipe connections
- The remotely operated (MPC) needs to fulfil multiple requirements
  - high operating temperature and high external forces in a vacuum surrounding
  - maintaining an acceptable level of sealing
  - additional forces and stresses due the interaction between pipe flowing (e.g. simultaneous high and low temperature fluid pipes on the same manifold) through the manifold flange.

Design process is carried out to find the optimum form and size

The resulting design will then be analysed using numerical methods to assess the capability of the MPC designs.

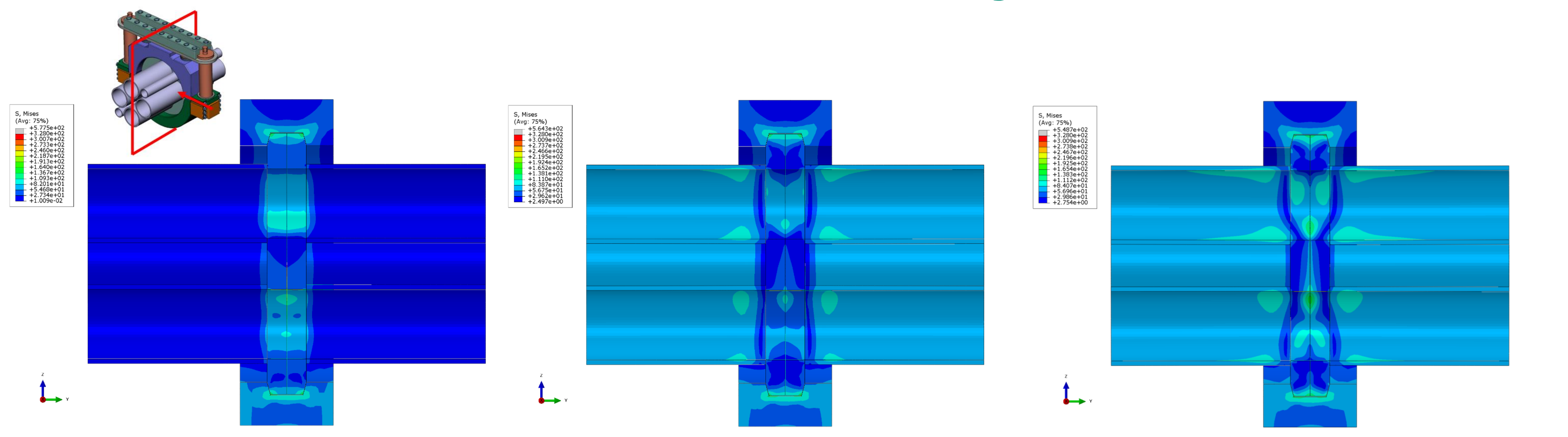
MPC Design Concepts



Hub & Clamp Design

Compact Flange design

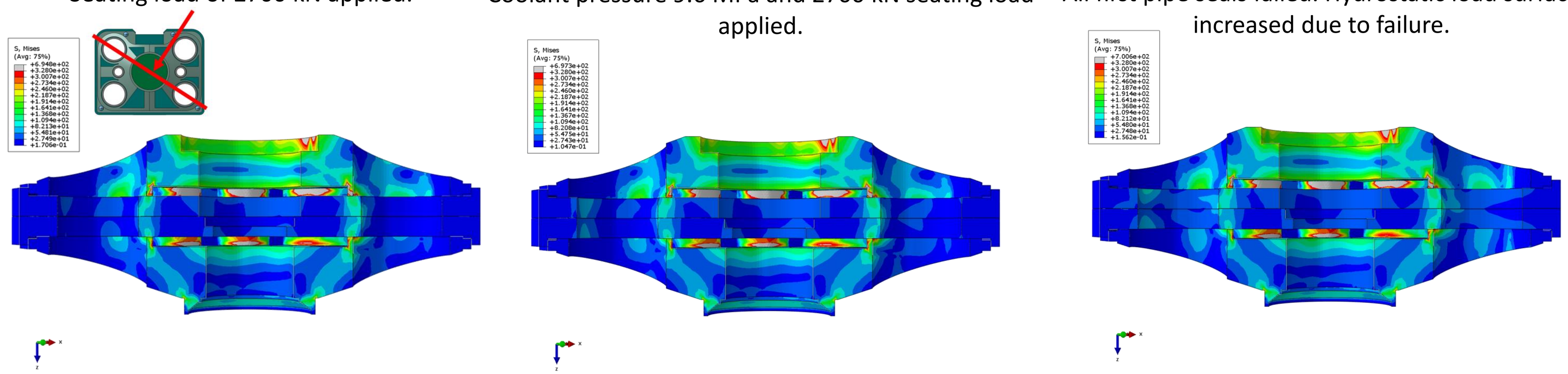
Finite Element Analysis



Seating load of 2700 kN applied.

Coolant pressure 9.6 MPa and 2700 kN seating load applied.

All first pipe seals failed. Hydrostatic load surface increased due to failure.



Seating load of 3300 kN applied.

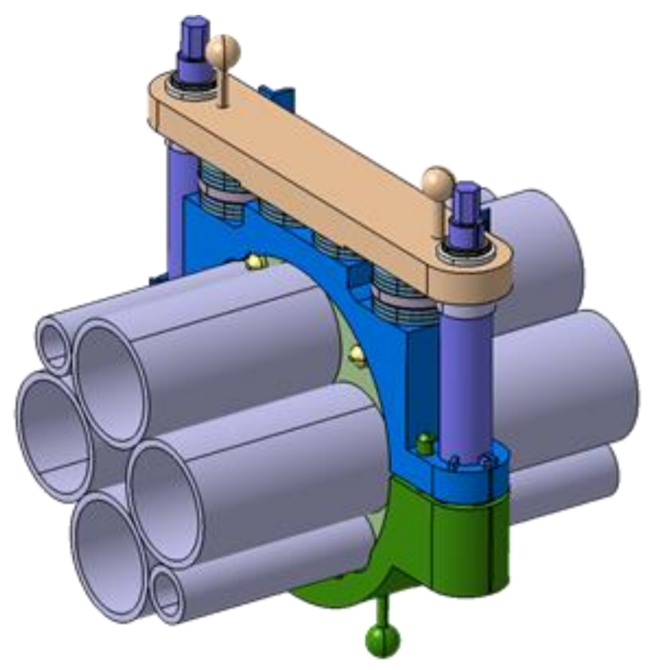
Coolant pressure 9.6 MPa and 3300 kN seating load applied.

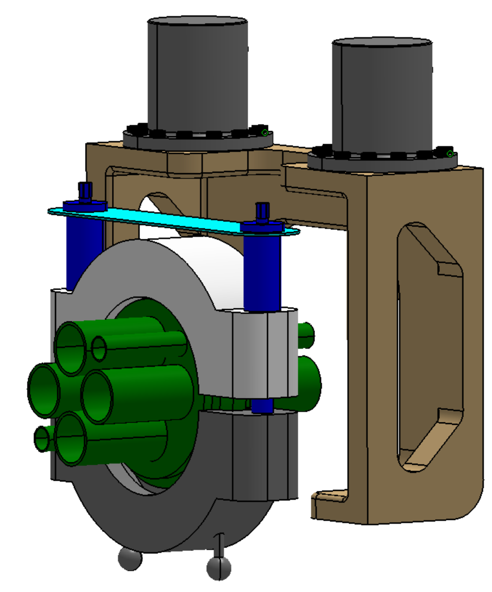
All first pipe seals failed. Hydrostatic load surface increased due to failure.

Hub & clamp concept studies show that the design is feasible and the clamping mechanism can withstand the operation pressure and all first seal failure. The flange bending behaviour has to be optimized in order to meet the leak rate requirements.

The FEA simulations for compact flange concept show that the design does not meet the requirements. Redesign work is required and is ongoing. Flange bending has not been investigated, as the design fails under sealing load.

Improvement

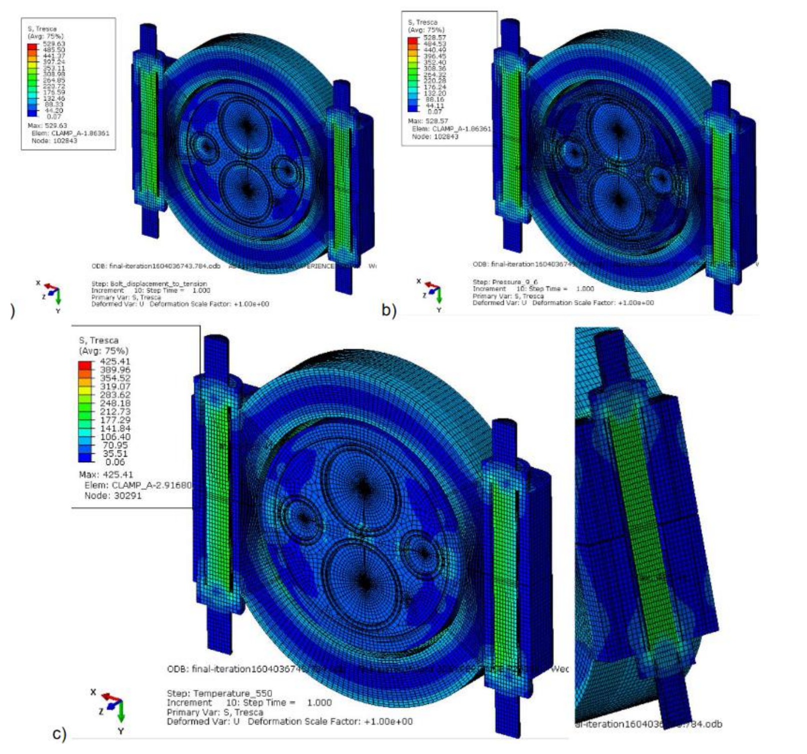




From the earlier finite element, clamp&hub concept is taken further due to the more robust nature of the design, with minimal modification, can be made to fit the DEMO requirement.

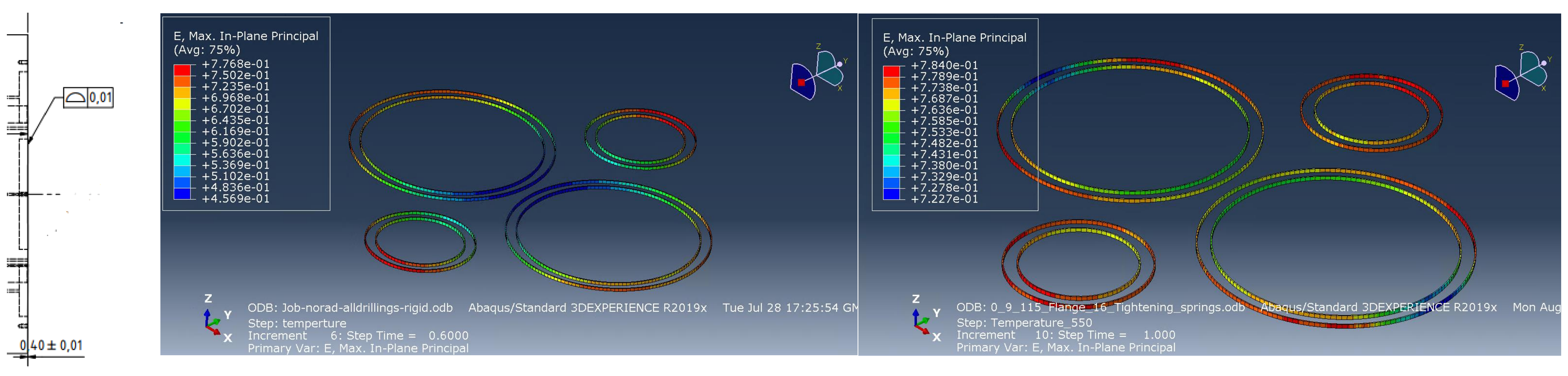
Main modification:

- Increase the flange diameter, thickness, and clamp size
- Increase the distance between each pipes
- Move the springs from the clamp distribution to concentric with the fastening bolt
- Introduction of a concaved flanged surface on one flange side



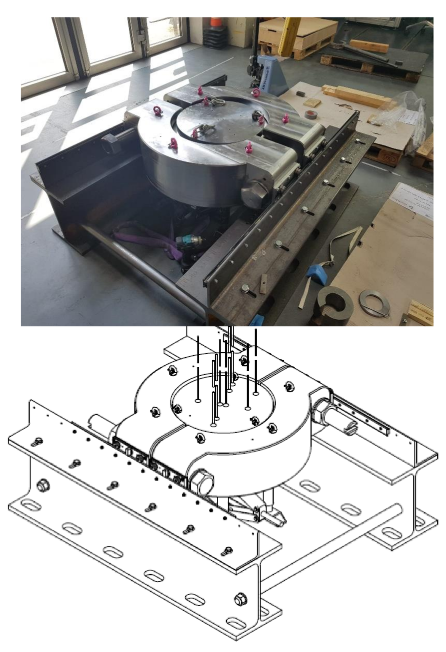
With the improved design, all of the components complies with the safety factor of 2 to the rated EUROFER-97 tensile strength at 550°C during the 1) tightening procedure, 2) pressurised condition and 3) temperature increase from room temperature to 550°C.

The introduction of a thicker flange (from a thickness of 75 mm to 115 mm and a concave surface on one of the flange, a more uniform distribution of force and deformation is achieved with the delta of seal deformation range reduced from 3.2mm to 0.6mm. This means that the seals will less likely to leak due to lack of sealing force.



Concave flange design and the corresponding FEA for 1) compression of seals with flat flange 2) seal compression with concave flange

Proof of Principle Testing



The improved design is then tested in the ongoing proof of principal testing procedure to compare the real life results with the numerical analysis.

There are some major simplification such as using P-91 steel instead of EUROFER-97 and removal of springs and bayonet connection in favour of bolted connection. The removal of spring connection is due to the insufficient data on the behaviour of disc springs under high load and high temperature, which would require a further development plan.

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