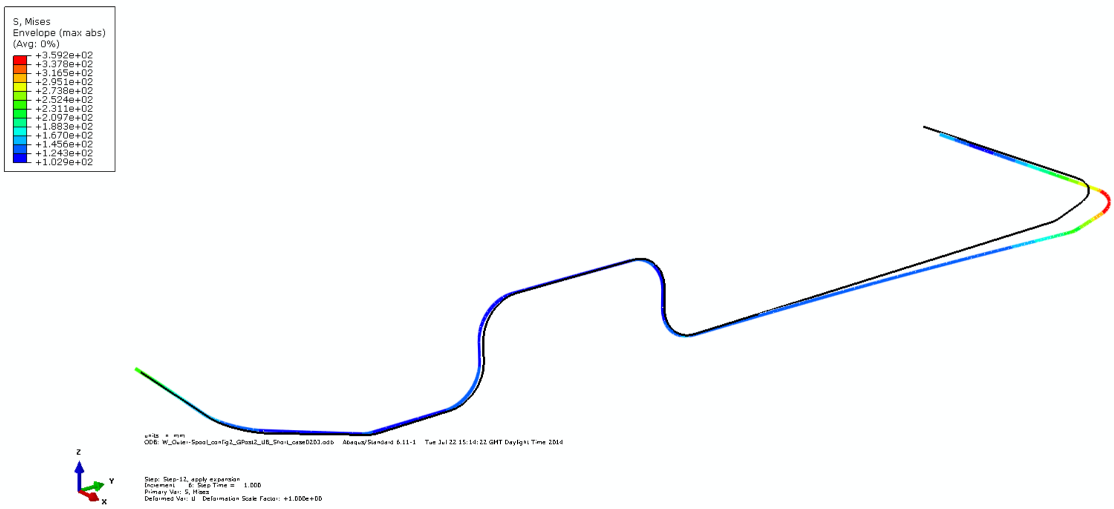

Figure 13: Outer spool – Configuration 2 – Envelope of Von-Mises Stress (MPa)

Figures 11 to 13 show examples of Abaqus' results

Two series of analyses for each spool is carried out assuming lower bound friction between spool and seabed and upper bound values. In using lower bound friction values, two ends of the spool are raised vertically up by the total vertical tolerance value and in using upper bound friction values, two ends of the spool are pressed down by the total vertical tolerance. This is because assuming lower bound friction and pressing down two ends of spool does not produce critical results, and also, assuming upper bound friction and raising two ends of the spool is not critical as well.

Within the connector itself the carrier pipe is free to rotate torsionally during the initial laydown of the connector, only after tie-in is complete is the torsional movement restricted. So there is no need to consider this degree of freedom in the initial load cases.

Considering the above assumption the number of degrees of freedom to be applied in the analysis reduces from 6 to 4 at each end so the total number of critical load cases reduces to $(2^4)^2$=256 load cases for each of lower bound and upper bound friction factors.

5. Concluding Remark

Seismic analysis of rigid spools was presented. Another check must be performed to ensure that the interface loads at the connector ends are compatible with the limiting conditions of the connectors. It is shown that to identify feasible geometries for spools that are fit for purpose according to Design by Analyses method of ASME Viii, Division 2, Part Five [3].

Results for a few of several hundred cases analyzed are presented in this paper. The following observations were made.

- It is reminded that the first step of the cluster spool design is to check spools end reactions against their allowable limit given by subsea connectors
- The shortest size of the Inner spool is the most critical spool in terms of end reactions.
- The reported case is a 12in ID pipe. If the thickness of the ID increases then a practical geometry may not exist, except if the tolerances are tightened or the capacity of the connector is increased. In such a situation flexible pipe might be necessary.
- The larger spool size has enough flexibility to pass the minimum requirement of 5 out of 7 records pass for ELE and ALE.
- As the length increase so does the margin to pass 6 out of 7 seismic records.
- Fatigue life calculations are not reported here, but as assessed using SN were satisfactory.
- Vortex indicated Vibration (VIV) screening checked (not reported here) no potential for VIV was detected.
- FLIP/FIV screening checked (not reported here) and passed, so there is no issue for FLIP/FIV.
- It was shown that suitable geometries can be found that pass the unity checks relating to the loads limit at the PMA for all spools and all conditions of operation and seismic events.
- all translational reactions (i.e. Resultant of FL, FT, and FV) were below allowable resultant of translational loads given by the connector vendor for different conditions,

- torsional reaction (ML) was compared against its corresponding value given by the vendor and resultant bending moment (i.e. Resultant of MT and MV) is compared with their allowable resultant bending moment provided by the vendor.

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Abbreviation/ Acronym	**Description**
A	Absolute
BPT	Ball Penetrometer Test
CD	Chart Datum
CDT	Cool Down Time
CPT	Cone Penetrometer Test
CRA	Corrosion Resistant Alloy
CMS	Corrosion Monitoring Spool
DEH	Direct Electrical Heating
ECA	Engineering Critically Assessment
FIV	Flow-Induced Vibration
FLIP	Flow-Induced Pulsation
FE	Finite Elements
FTA	Flowline Termination Assembly
ID	Inside Diameter
LB	Lower Bound
MEG	Mono Ethylene Glycol
PMA	Production Manifold Assembly
OD	Outside Diameter
SIWHP	Shut-in Wellhead Pressure
SMLS	Seamless
TBC	To be confirmed
UB	Upper Bound
VIV	Vortex-Induced Vibrations