Innovation and Excellence in Engineering

Case Studies

Cygnas Solutions Ltd

INTRODUCTION

Who are we?

Optimising New Design using AI & Simulation
Extending the Life of Ageing Assets

Innovation and **Excellence** in Engineering is in our DNA. We create **efficient solutions** to our client's problems; **collaborating** with our customers and enabling the **successful delivery** of their projects and products in budget and on time.

- **Aberdeen & London** based, run by Engineers with **Energy Sector Experience**
- Passionate about **Digitizing Engineering Operations**
- Authorised Business Partners with **Hexagon, ZWSOFT** and **Asystom**
- Clients include Aramco, Wood Al-Heijlan, Baker Hughes and Xodus

THE CYGNAS ADVANTAGE

What we bring …

- Extensive experience across the Energy Industry
- Passion for Innovation with a wealth of Engineering Know-how
- Experienced in Fitness for Service: Asset Integrity, RBI & RAMS
- Advanced Engineering Analysis: FEA, Flow Assurance, Thermal and CFD Analysis, Pressure Vessel Design and Consulting Services

H ONESTY

I NNOVATION

V ALUE FOCUSED

E NGINEERING INSIGHT

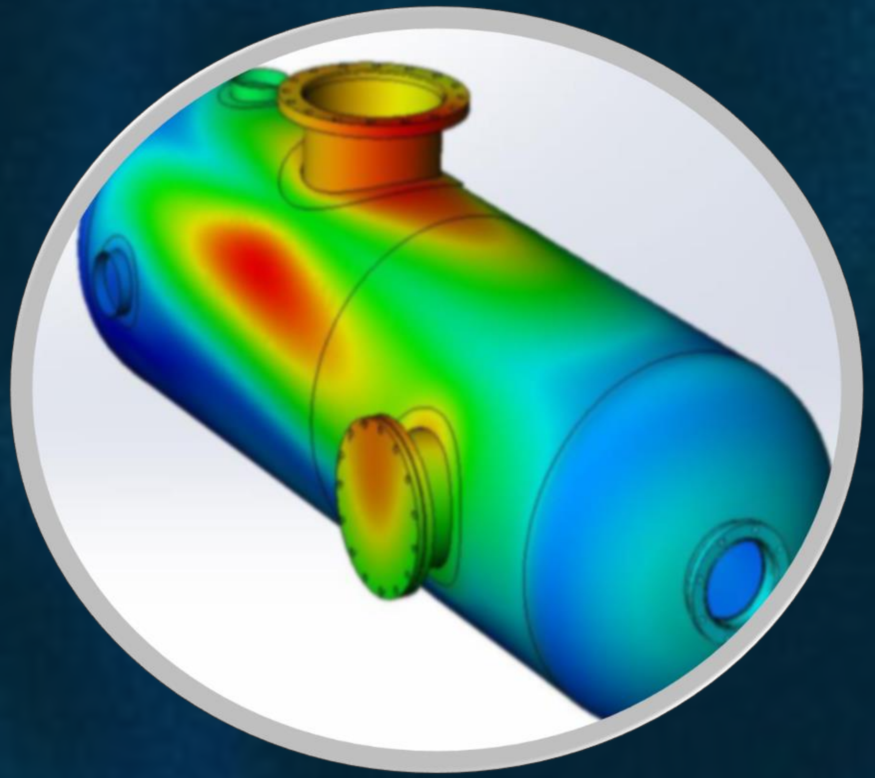
OUR SERVICES

What we do…

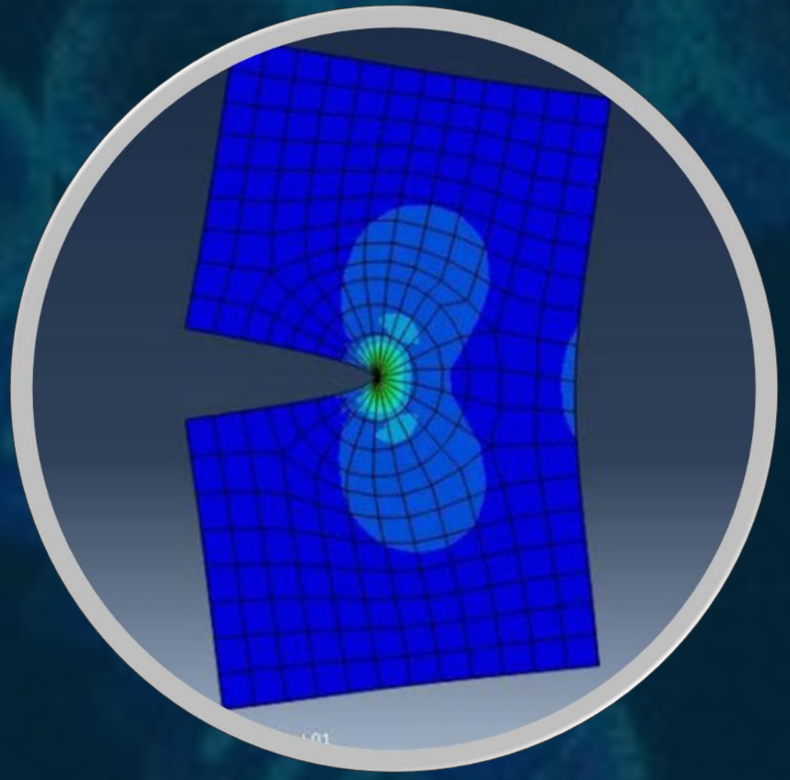
OIL & GAS

HYDROGEN

PROJECT MANAGEMENT



PROCESS EQUIPMENT

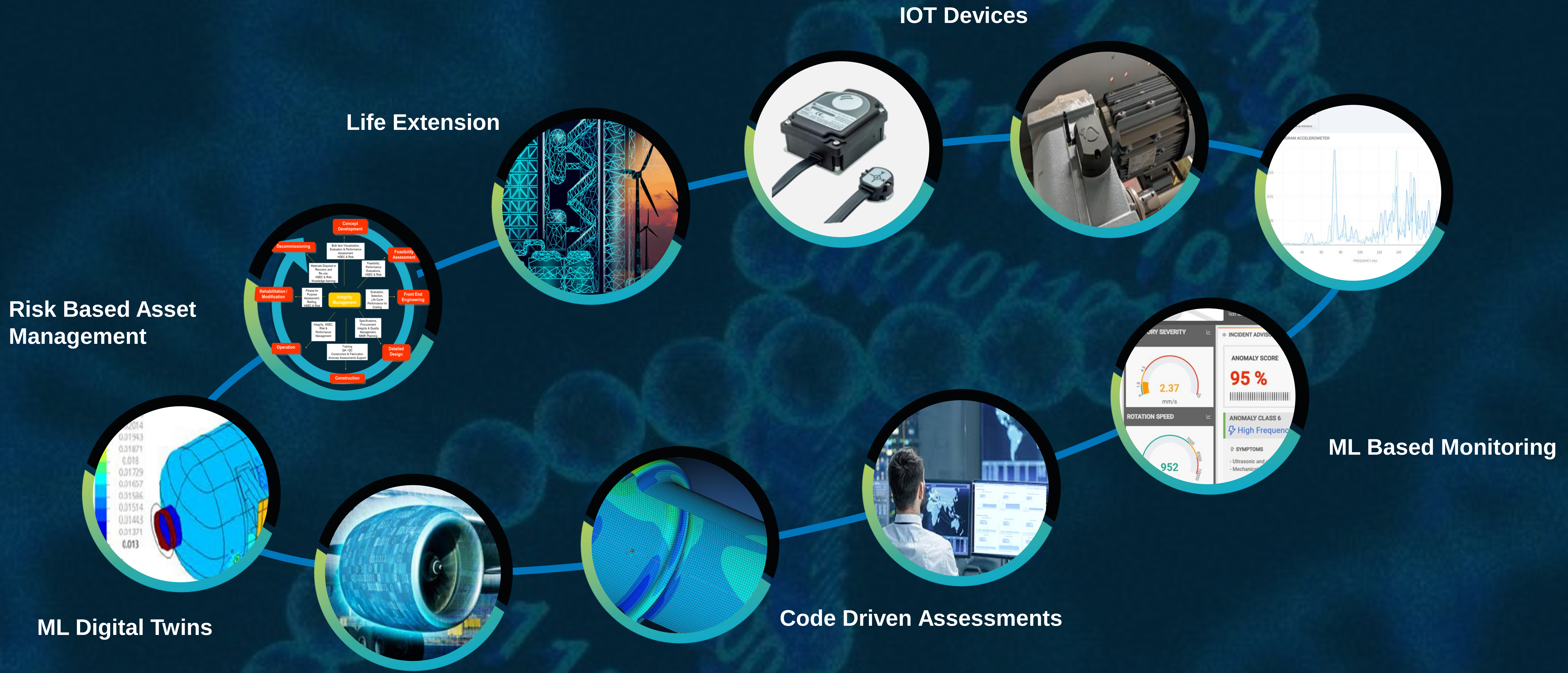


SIMULATION

SOFTWARE

DELIVERING ON INDUSTRY 4.0

Key Technologies and Domain Expertise



ADVANCED INTEGRITY SERVICES

CYGNAS

- **Design Verification & Validation** (reduced design cycle, cost of development, improved reliability)
- **Compliance** with a recognised design by analysis codes including IRC submissions for exemption to certification bodies
- **Life Extension, Failure Investigations & System Performance Improvement** for operations including AR & IOT
- Fully **Integrated Digital Twins** for Key Assets

Design by Analysis

- Verification and Optimisation of design
- Improved functionality
- Lower weight & cost (manufacture and running)
- Identification of “hot spots” during design

Life Extension

- High cycle fatigue (direct cyclic and use of ASME Code)
- Low cycle fatigue (damage and crack growth)
- Assessment of components with flaws for continued service
- Fatigue analyses and design life of the assembly

Code Compliance

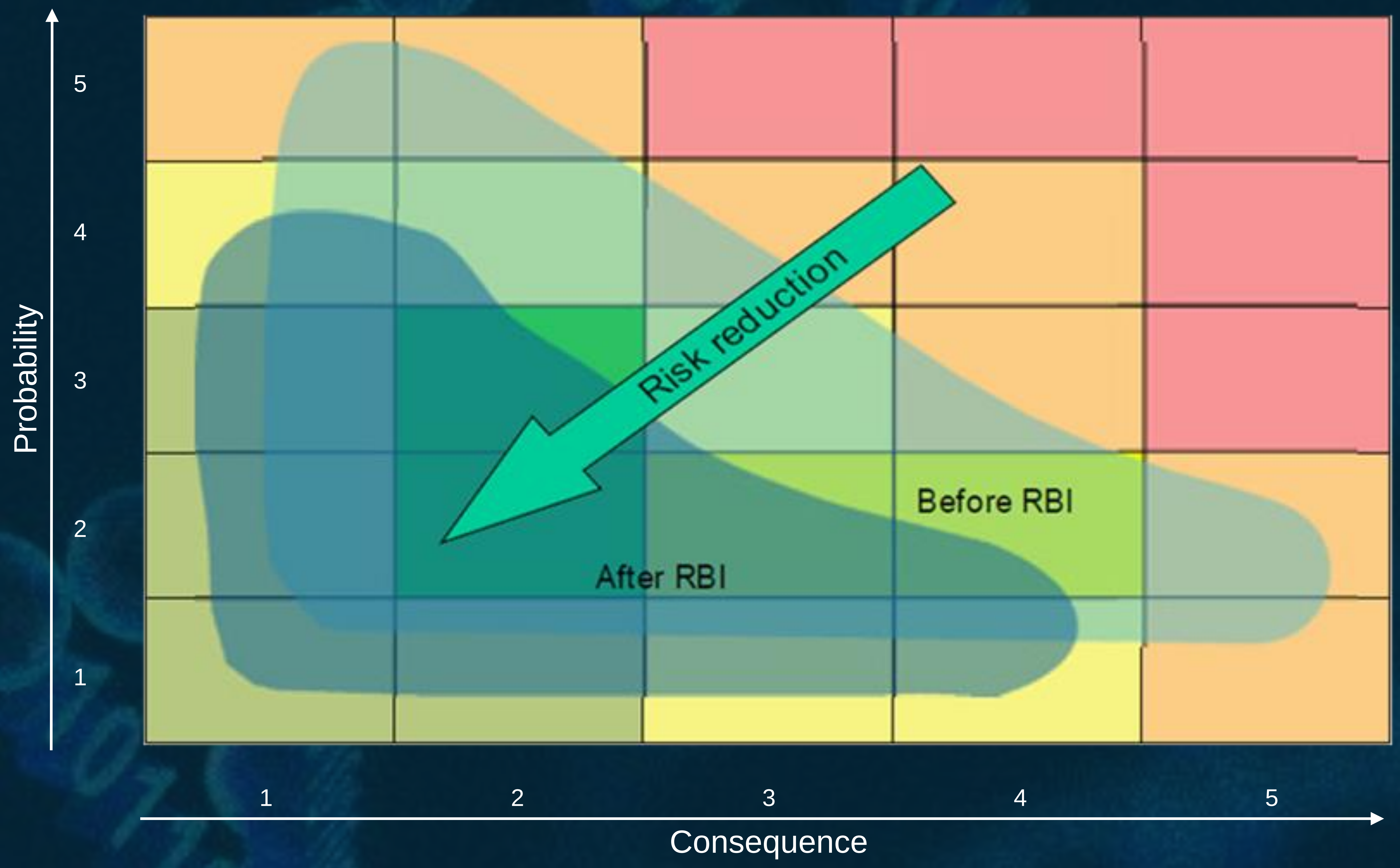
- ASME Boiler and Pressure Vessel code, Section VIII, Div.2
- ASME Boiler and Pressure Vessel code, Section XI
- BS 7910 Fitness for Service standard, ASME/API 579 FFS-1 Fitness for Service code
- Other Industry codes as required (ASME B31, DNVGL, ISO, API, Company specific etc

BENEFITS OF RBI

Effective understanding of Asset integrity relies on understanding the Probability of Failure (POF) and the Consequence of Failure (COF).

When implemented with a sound understanding of the principles, the benefits Risk Based Integrity (RBI) are:

- Improved Risk Management
- Reduction in critical and severe failures
- Promotes Cultural Change
- Optimisation of Costs and Resources devoted to Inspection and therefore improved uptime and Revenue



Non-Metallic Engineering Support

THE NMM EXPERTS

Trusted by the largest Companies in the World

- With extensive experience in identifying and implementing innovative non-metallic materials for offshore applications, Cygnas has proven capability in selecting materials that meet stringent industry standards and company standard.

- Our comprehensive approach spans initial concept though to final application, ensuring all aspects of NMM implementation are expertly managed.

- Our experience includes; detailed assessments from design parameters, cost comparisons between conventional and NMM, and extensive practical experience in piping, mechanical, electrical, and offshore structures.

- Cygnas are trusted by Industry heavy-weights like Saudi Aramco, SABIC, Shell, BP, Exxon Mobil, and Total Energies, underscoring our drive to deliver high-quality, compliant, and efficient non-metallic solutions for the industry.

NON-METALLICS: PROJECT EXPERIENCE

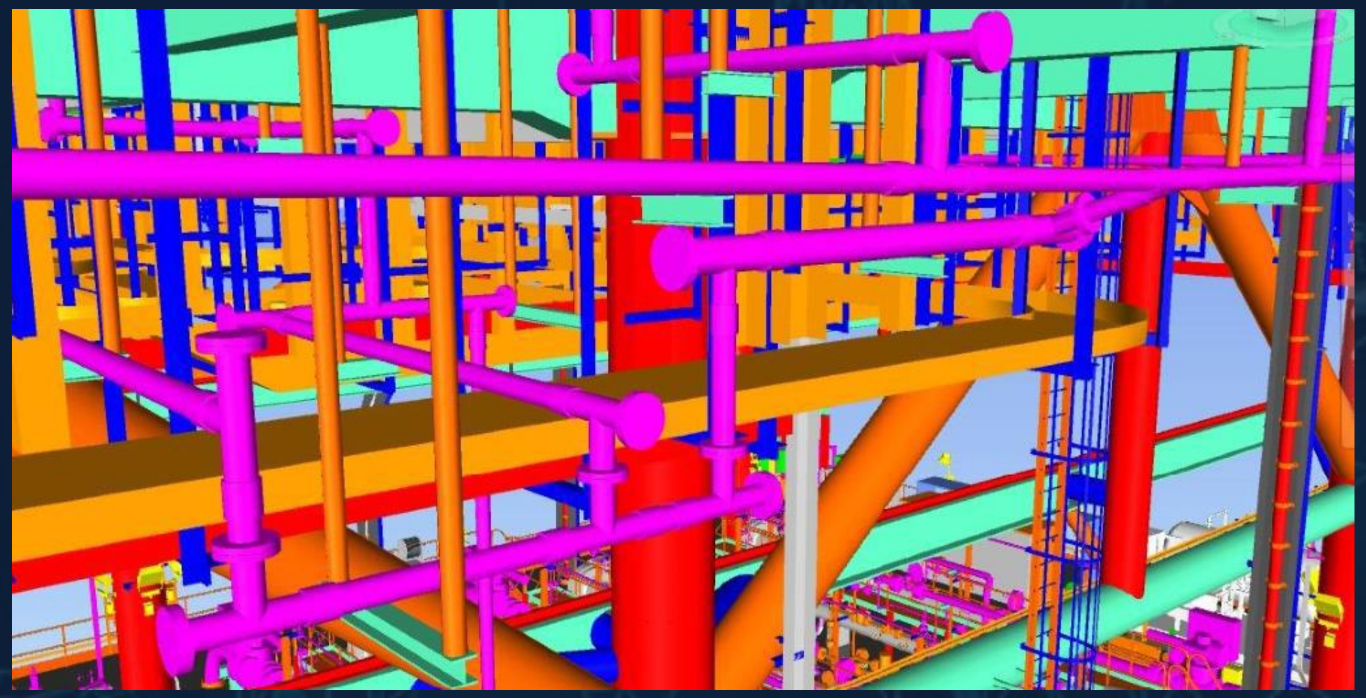
- Worked with Saudi Aramco, SABIC, Shell, BP, Exxon Mobil, Total Energies etc on the application of Non-Metallics over the past decade, across more than 20 different international projects.

- Provided Non-Metallic solutions by identifying and evaluating Non-Metallic Applications in Offshore Platforms (Wellhead, Water/Foam Injection, Auxiliary Platforms, Tie In Platforms and Accommodation Platforms).

- Performed calculations for application of Non-Metallics in offshore Platforms.

- Prepared scope for Non-Metallic vendors for Tests and Trial runs.

- Provided safety reviews of the Vendor Items/Products for Operation and Maintenance for Non-Metallic Applications in Offshore Platforms.



3D model of RTR piping and supports in PDS

Case Studies

MULTI-SYSTEM OFFSHORE NMM STUDY

Background

The aim of the Non-Metallic Material (NMM) Study was to identify the feature or component of the platform (jacket & deck) where NMM could be used in place of conventional materials and thus maximize the use of NMM with due consideration given to cost reduction, based on a favourable cost-benefit results as per Client’s requirements.

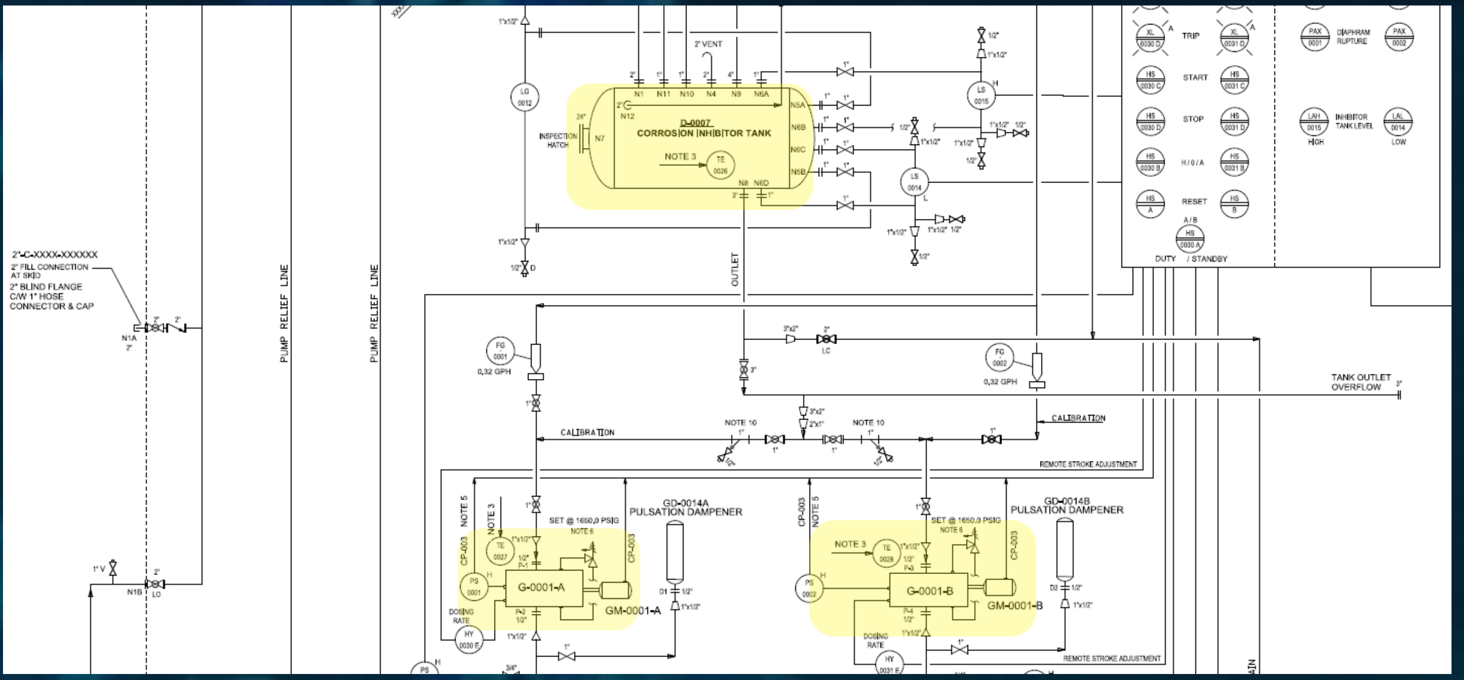
To execute the study, Cygnas was required to; Identify features or components of the platform where NMM could be used, Develop budgetary cost data for the complete lifecycle, Identify techno-economic challenges associated with wide deployment & propose alternate solutions & Evaluate other disruptive technologies that can enable the safe & cost-effective substitute for conventional materials with NMM.

Challenges

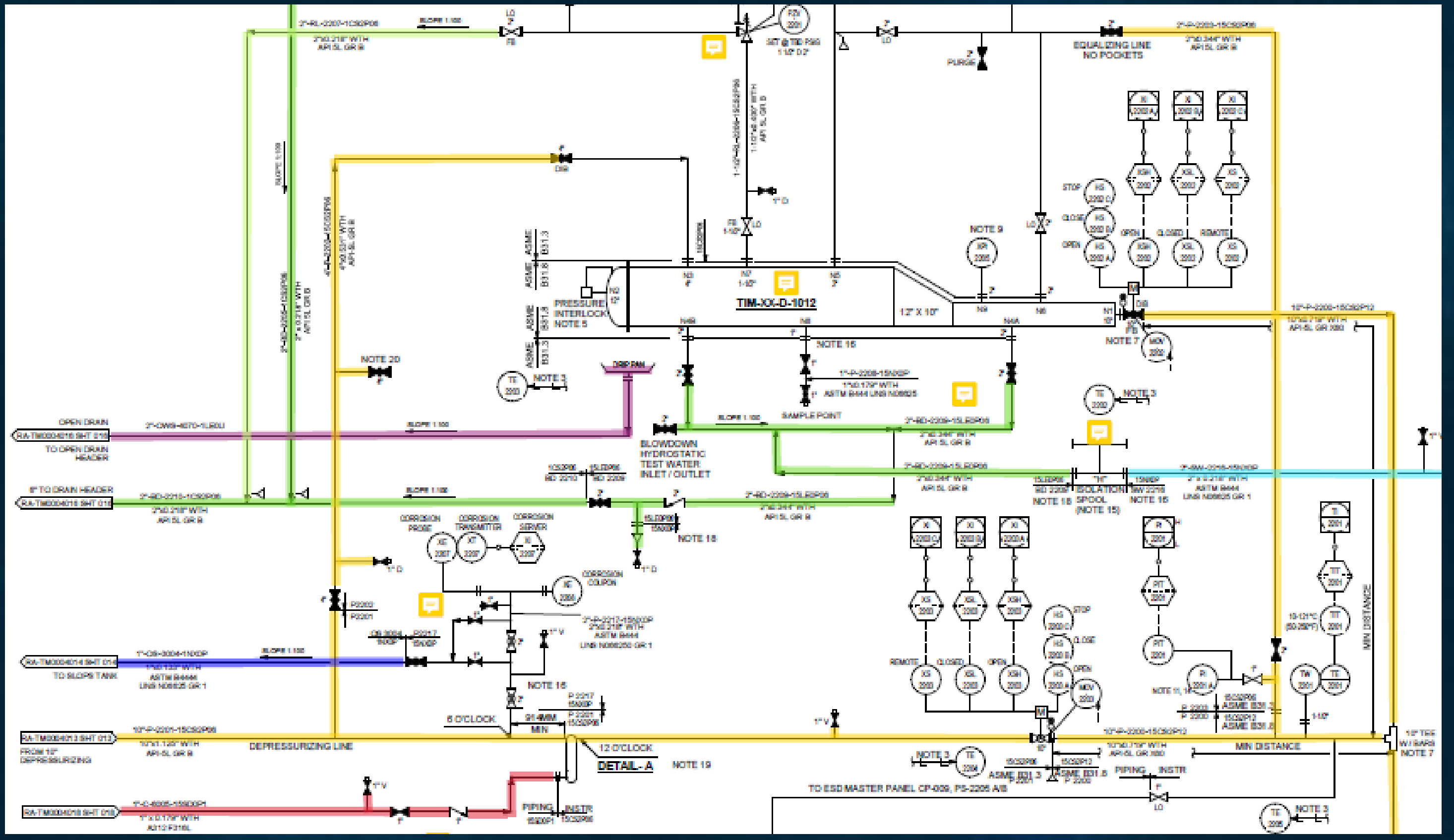
- The in-depth review of Offshore Platforms for all disciplines including; Mechanical, Structural, Electrical and Process
- Identify gaps in Client’s standards via a detailed review of all associated International and Company Standards
- Identify existing solutions covered by International standards but not currently deployed by Client
- Propose innovative solutions (TRL 6/7) that can meet Client needs
- Propose *feasible* and *cost-effective* solutions based upon a detailed review of *technical risks* associated with NMM MOC

Outcomes

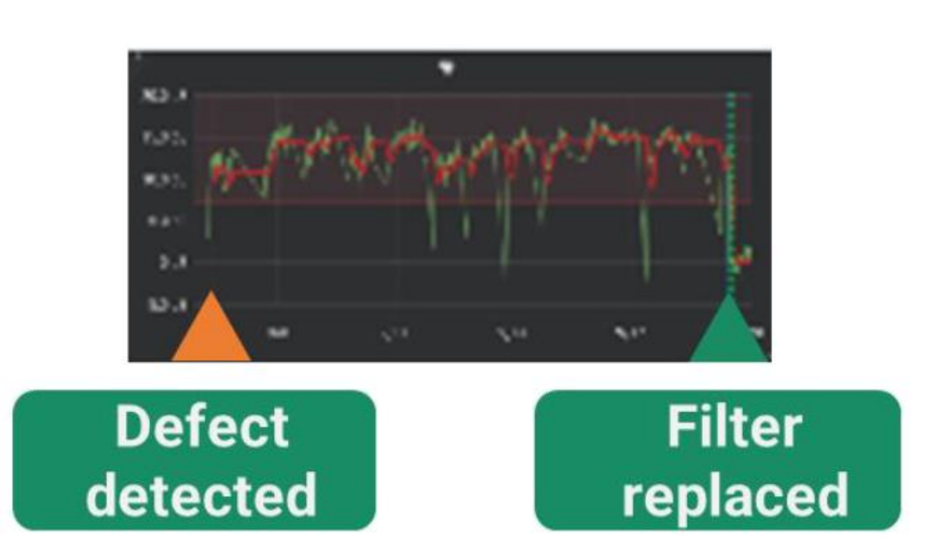
- Weight savings of up to 44% and cost saving of up to 43% by system were identified through NMM replacement
- Factors for the successful deployment of NMM for Oil and Gas applications were identified and reported
- Commissioning & Operational risk associated with NMM systems were identified and mitigations recommended
- An updated approach to the design of systems for NMM specifically which would allow improved system design and adoption in environments where vibration is of concern



Pipe Size		Inside Diameter		Pressures by NOV Designation and Piping Size								
				2410	2412	2414	2416	2420	2425	2432	2440	2450
In	mm	In	mm	psi	psi	psi	psi	psi	psi	psi	psi	psi
2	50	2.09	53.20	724.50	724.50	724.50	724.50	724.50	724.50	724.50	877.45	1027.64
3	80	3.22	81.80	477.16	477.16	477.16	477.16	477.16	579.70	630.50	781.11	977.80
4	100	4.14	105.20	373.38	373.38	373.38	413.89	454.21	534.28	613.60	770.05	923.63
6	150	6.20	159.00	278.56	305.93	333.21	360.41	414.54	495.11	601.37	758.29	912.33
8	200	8.22	208.80	252.50	273.22	314.50	355.58	396.47	477.67	578.08	736.32	891.64
10	250	10.35	261.90	234.21	250.70	299.98	332.68	381.50	462.25	574.03	715.62	870.20
12	300	12.35	313.70	210.59	252.10	293.41	334.53	375.45	456.72	563.88	722.13	877.45
14	350	13.56	344.40	204.65	242.50	280.17	330.15	367.45	453.85	563.67	707.92	884.82
16	400	15.50	393.70	201.46	245.60	278.56	322.31	365.84	452.24	559.02	664.49	871.53
18	450	17.08	433.80	193.07	243.17	283.05	322.74	362.25	450.49	557.11	709.85	n/a
20	500	18.98	482.10	192.04	237.15	273.07	317.75	362.21	450.44	555.12	701.25	n/a
24	600	22.76	578.60	190.67	228.30	280.72	317.97	362.46	443.42	552.61	696.04	n/a
28	700	17.56	700.00	285.11	352.55	419.46	485.85	542.35	672.74	837.48	n/a	n/a
30	750	29.53	750.00	182.31	507.83	269.17	309.41	349.47	434.67	541.39	n/a	n/a



MIXER CONDITION MONITORING

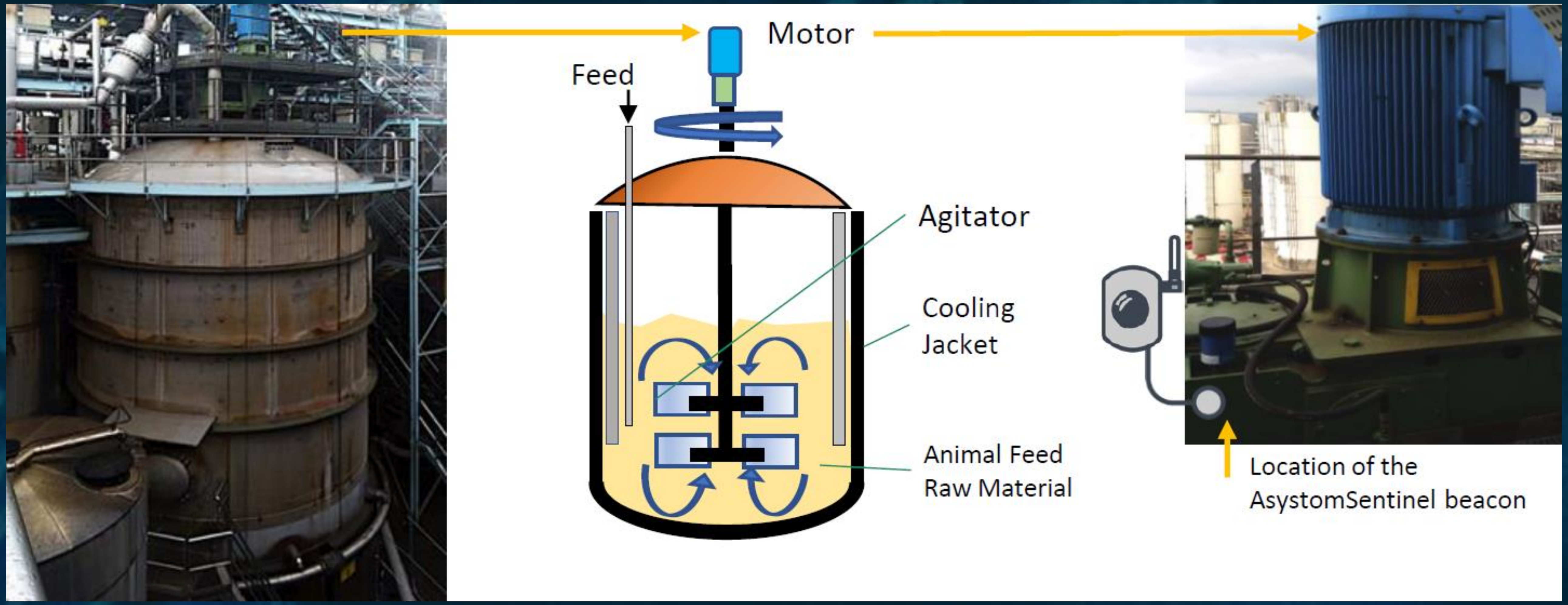


Background

- The clients, a leading Japanese company for animal nutrition, were having difficulties having any visibility on the health of the agitator and its gearbox, which are key to the fermentation process and to a continuous operation.
- The site produces 120,000 tons of amino acids per year, so it is essential for the client to ensure the equipment's availability to maintain production output.

Challenges

- Visibility of equipment health
- Improve availability of equipment
- Avoid Black swan events



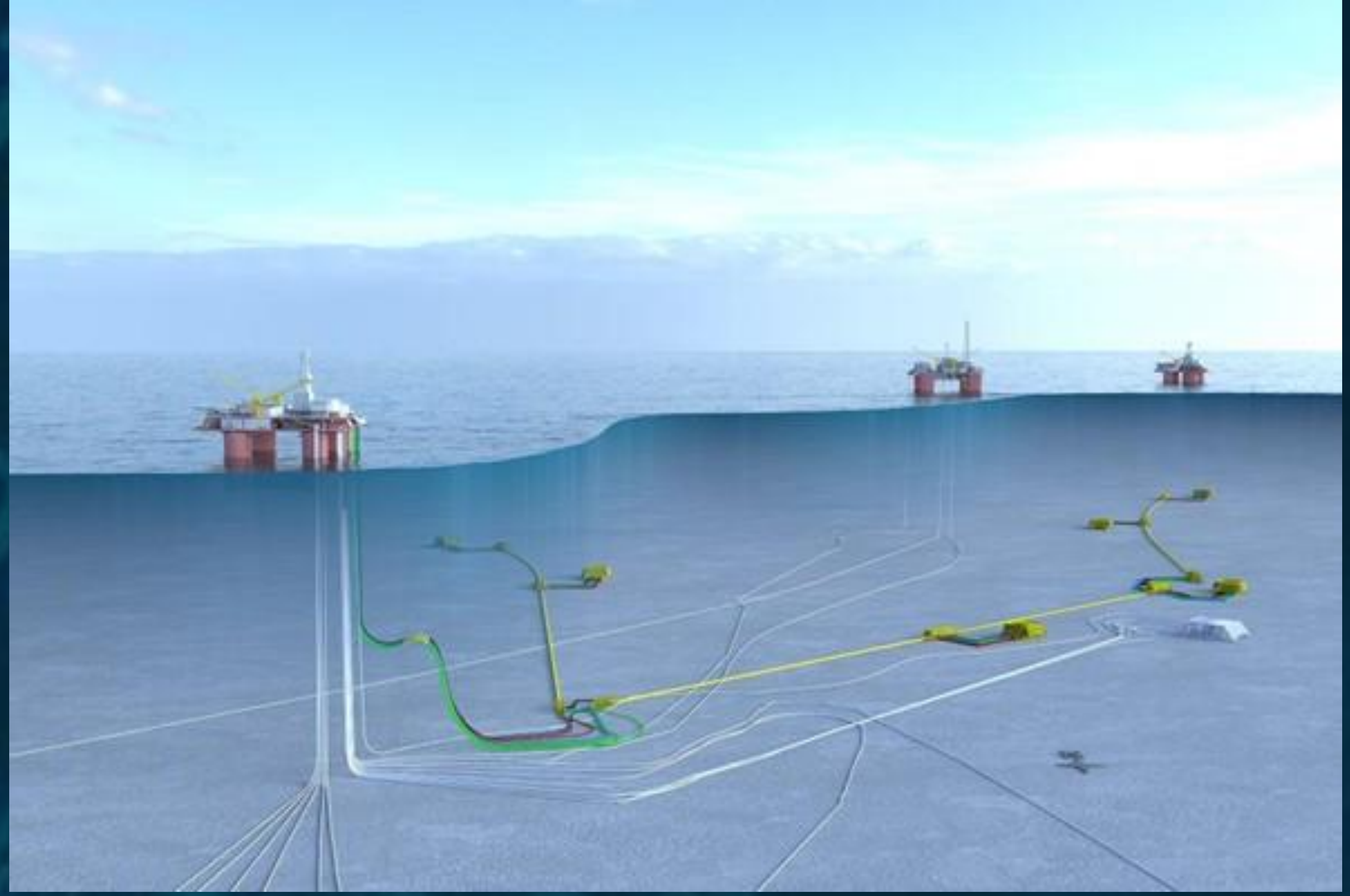
Outcomes

- No gearbox replacement needed
- 50 m^3 raw material SAVED
- No crane rental needed for potential repair

"The on-line solution allows us to monitor a set of equipment over time without human intervention. The ergonomics of the dashboard are flexible and pleasant. The configuration of the alarm thresholds is vast, and allows many possibilities. It is a different approach to conventional vibration analysis, very pertinent"

REPURPOSING OF BUNDLES

CYGNAS



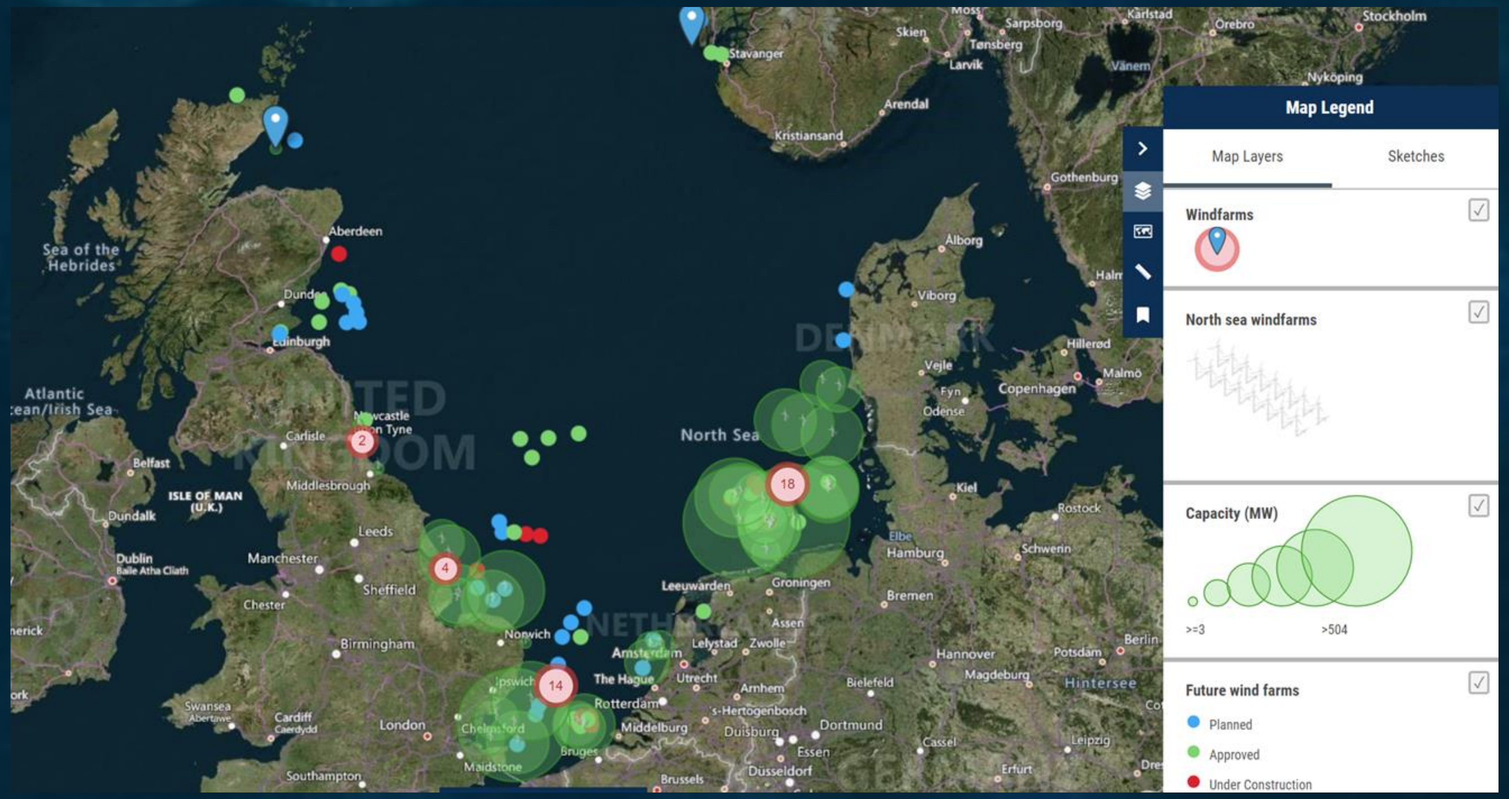
Background

The first bundle was installed in the North Sea in 1980 and since then more than 70 bundles have been installed. A lot of these bundles are now nearing the end of their life and would need to be decommissioned or repurposed. Currently most Bundles are cleaned and left on the seabed or would need to be either rock dumped or pilled to the seedbed. An example of leaving the bundle on the seafloor is the Leadon Bundle.
Repurposing bundles have been looked at and at the moment there are proposals including relocation to reuse bundles in other locations. Cygnas was approached by the National Subsea Centre to look at innovative ways to repurpose bundles.

Challenges

Bundles are large generally and have towheads at the ends which requires the pipe sections to be cut from the towheads to decommission the bundles. Its also difficult to lift the pieces out for which they need to be cut in to smaller sections which is seen as uneconomical by most operators.

Their location is offshore subsea which makes it challenging to access the bundles.



Outcomes

- Cygnas was able to devise a novel strategy of utilising bundles for storing hydrogen that can be generated by offshore windfarms in the vicinity
- A tool was developed to shorlist potential bundles that can be economical and generate revenue using hydrogen storage subsea.

RELIABILITY IMPROVEMENT – RUBBER CHEMICAL PLANT

Background

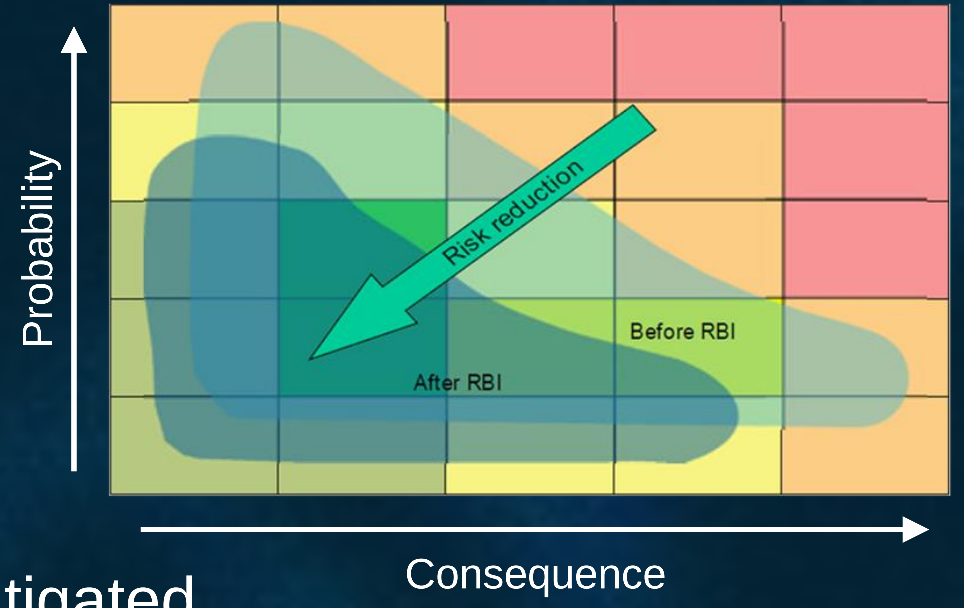
- The process of manufacturing a product consists of a condensation reaction of acetone with aniline in a glass-lined reactor with HCL as catalyst. The HCl is neutralised using caustic soda (NaOH). The condensation reaction is followed by polymerisation to form the product.

Challenges

- Severe frequent breakdowns of various equipment.
- Black swan events (catastrophic failure of H2 reformer tubes and leakage of hazardous liquid from Agitator glands)

Outcomes

- The RAMS study identified the bad actor’s equipment causing majority of the failures:
  - H2 reformer tube was found to be cracked causing catastrophic disruption due to thermal ageing of the reformer tube bellows.
  - Weld joints were defective – welding process incorrect and the weld joints were not properly stress relieved in the previous repair.
  - lubrication, preventive overhauling of the equipment was inadequate
- Corrective actions taken:
  - Resolution location-specific issues (vibration/heat etc), Lubrication schedule etc
  - A variable frequency Condition monitoring regime (age and criticality focussed)
  - Appropriate welding process selected and stress reliving with the replaceable spare reformer tubes and bellows
  - Service changeover schedule modified (prevent simultaneous wear-out of redundant equipment)
  - A FRACAS programme was deployed to monitor the modified assets and the teething trouble were root analysed and mitigated

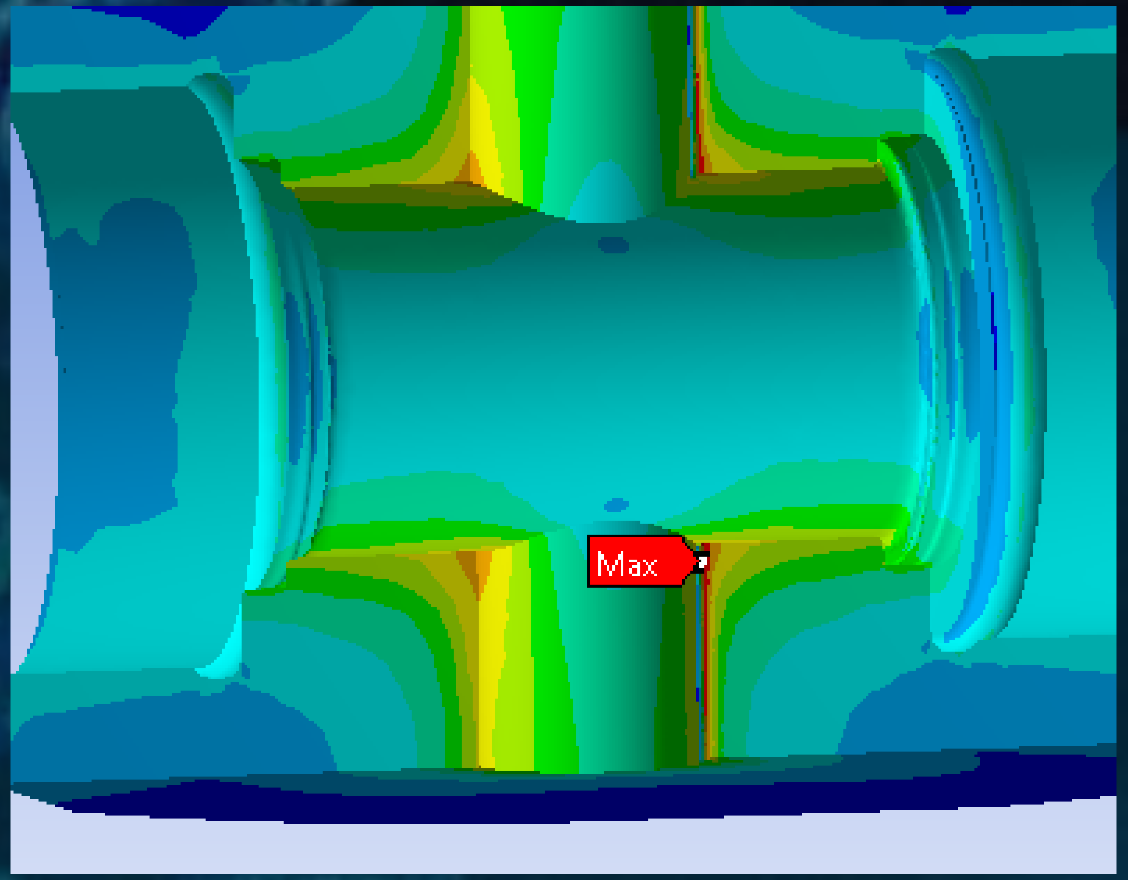


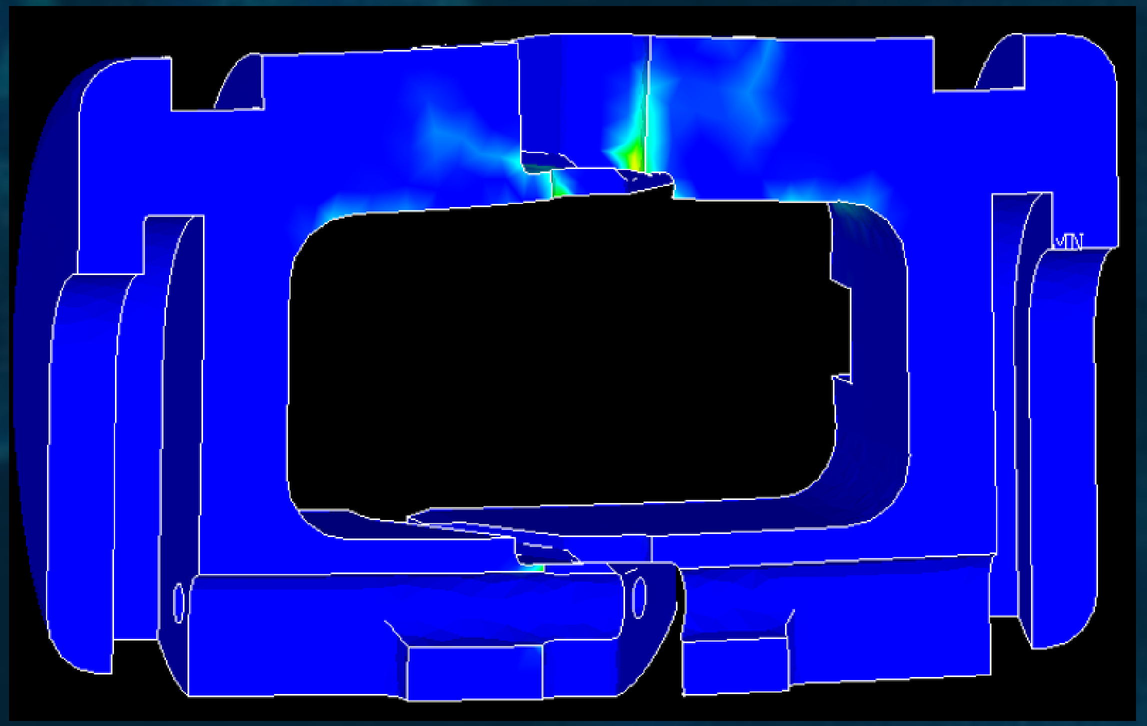
HPHT BOP ANALYSIS

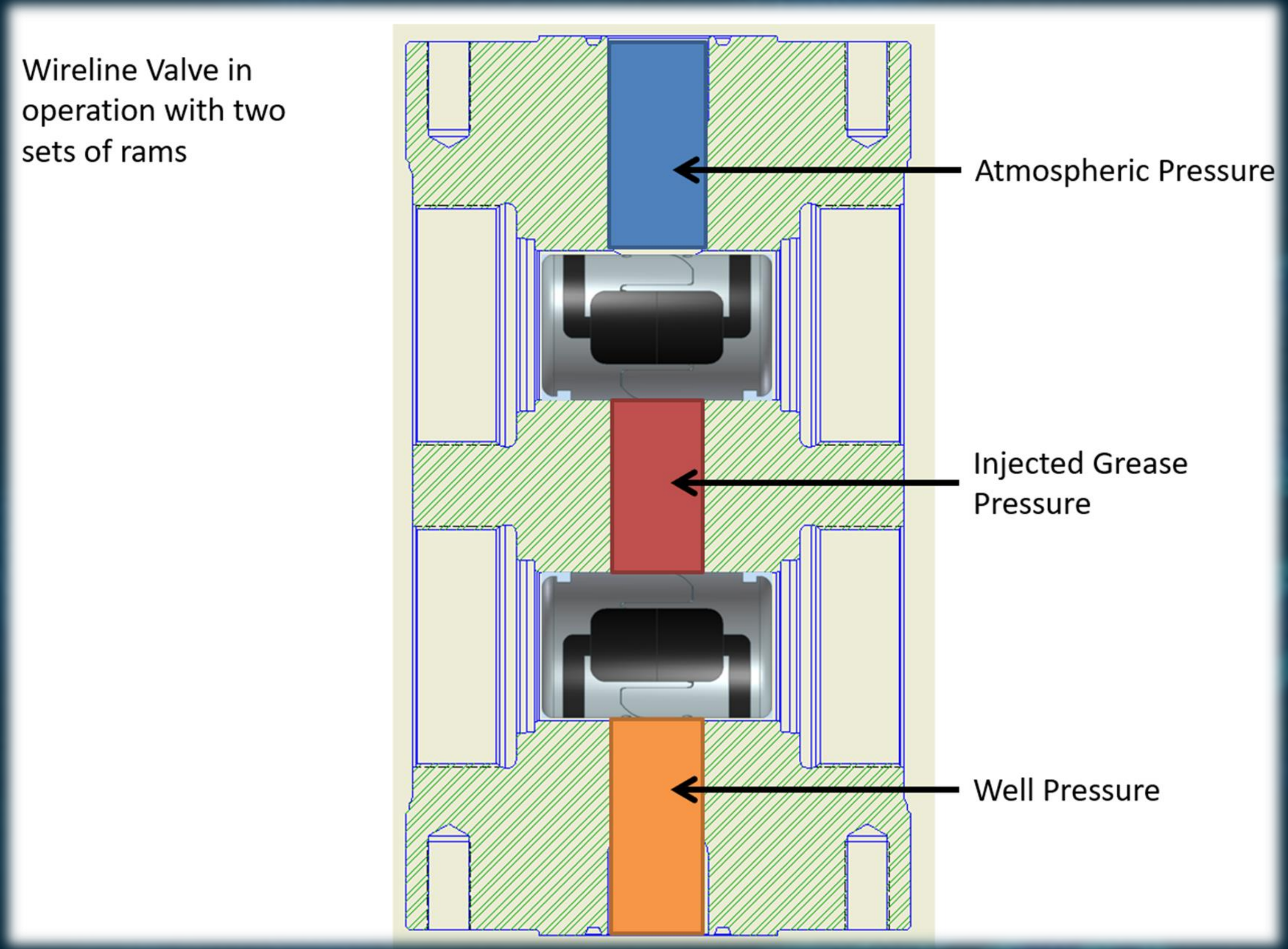
FEA Simulation of a high pressure and high temperature (HPHT) BOP and Wireline valves assessing sealing function of rams as well as robustness of mechanical design.

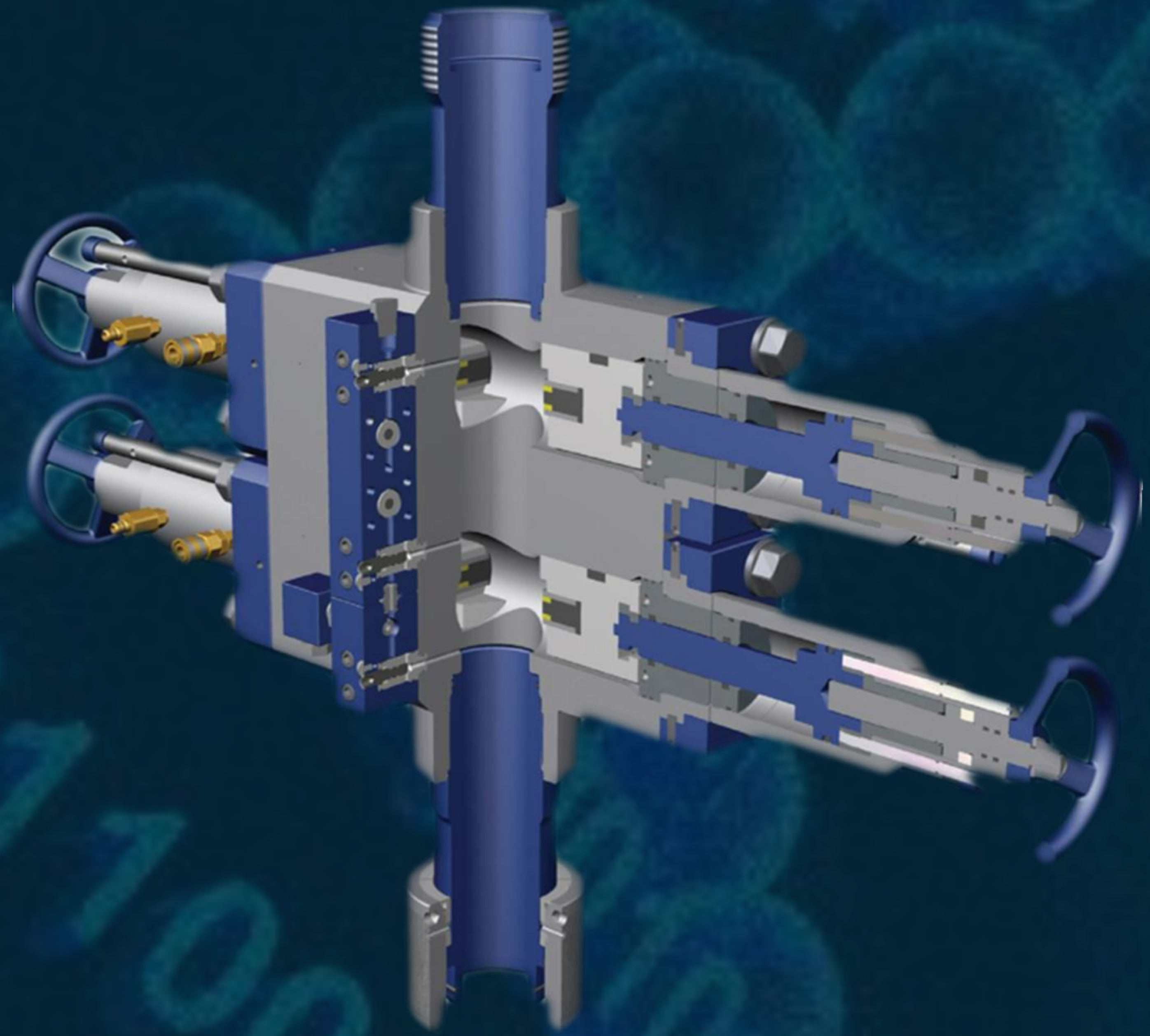
The model considered nonlinear effects such as elastomeric seals, plasticity, large displacements and contact. Local damage was evaluated as per ASME section VIII Div 2 design by Analysis rules.

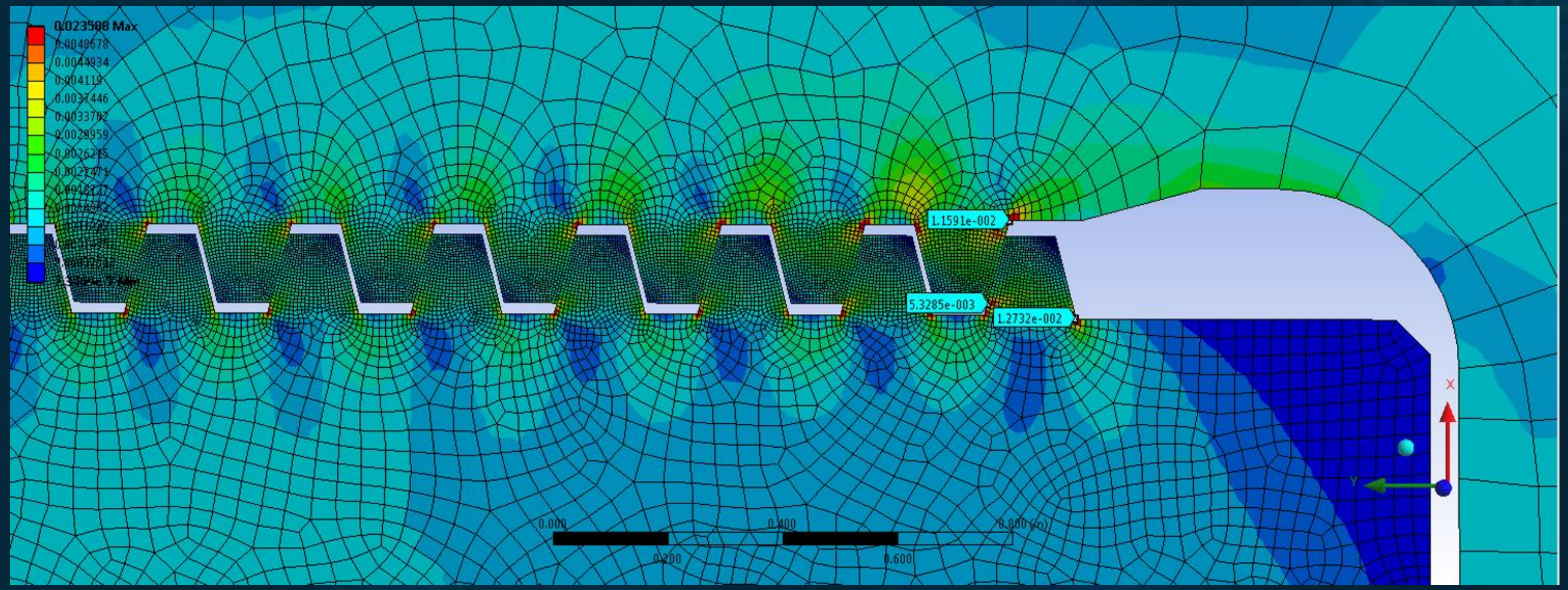
Thread plasticity and failure load was assessed including stress at the root and contact pressure of the threads to properly assess fatigue and the risk of thread galling.







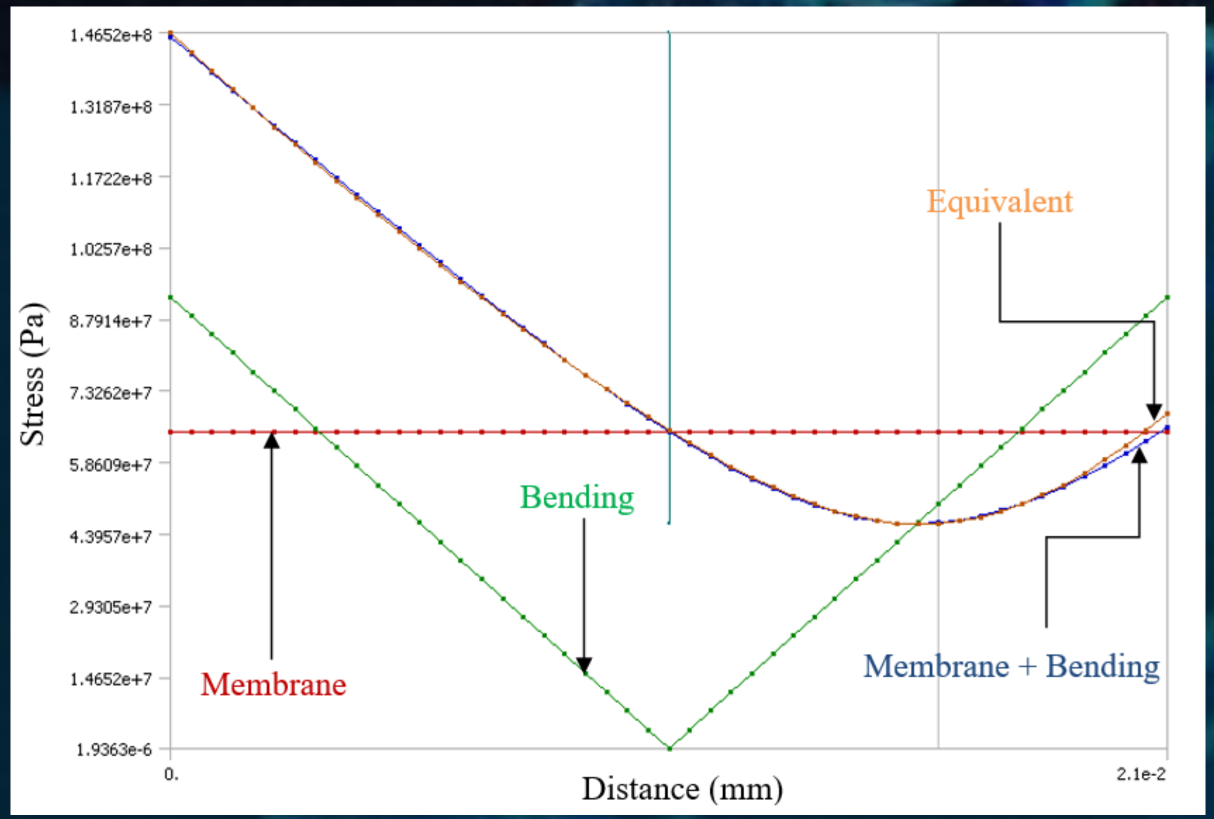


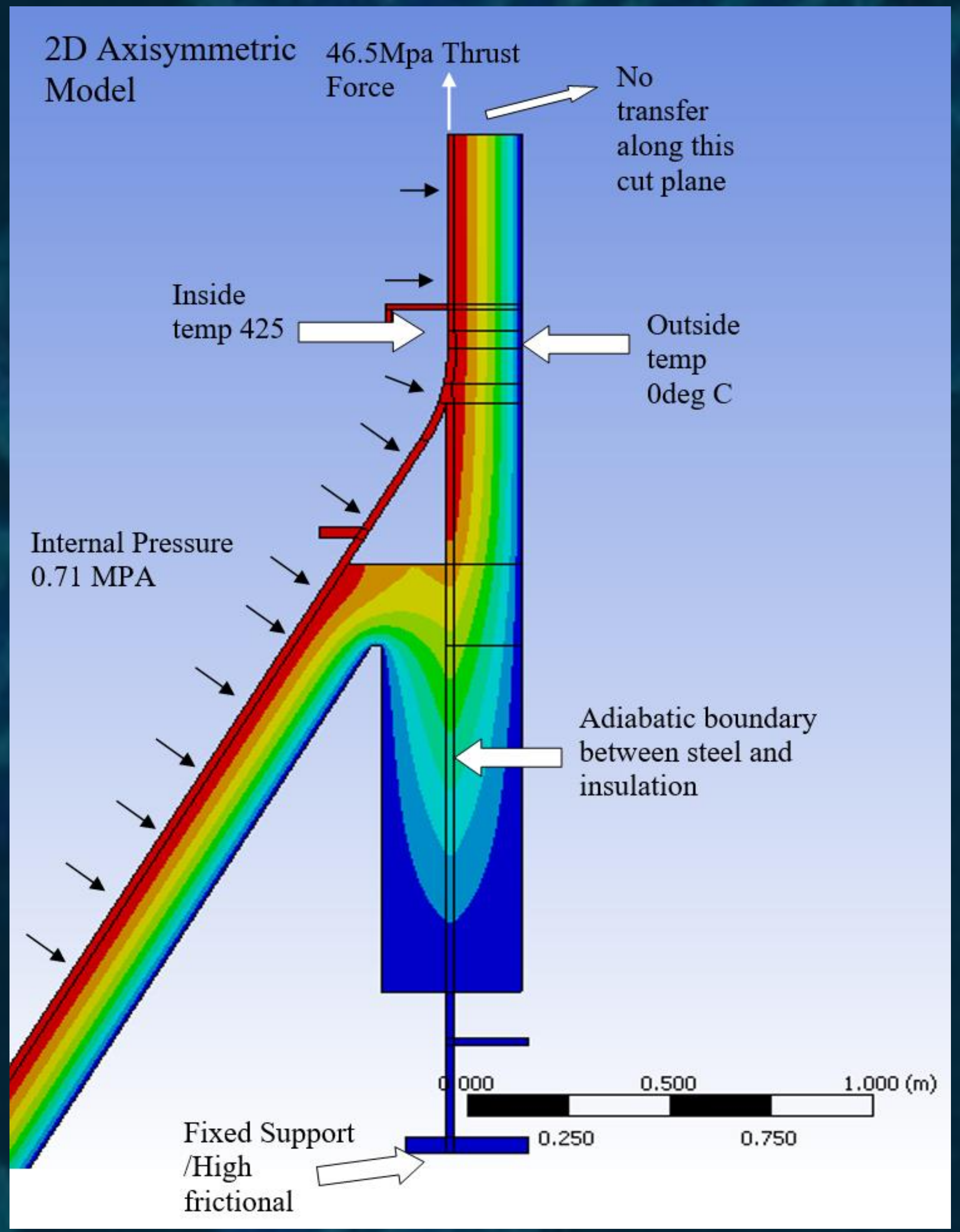


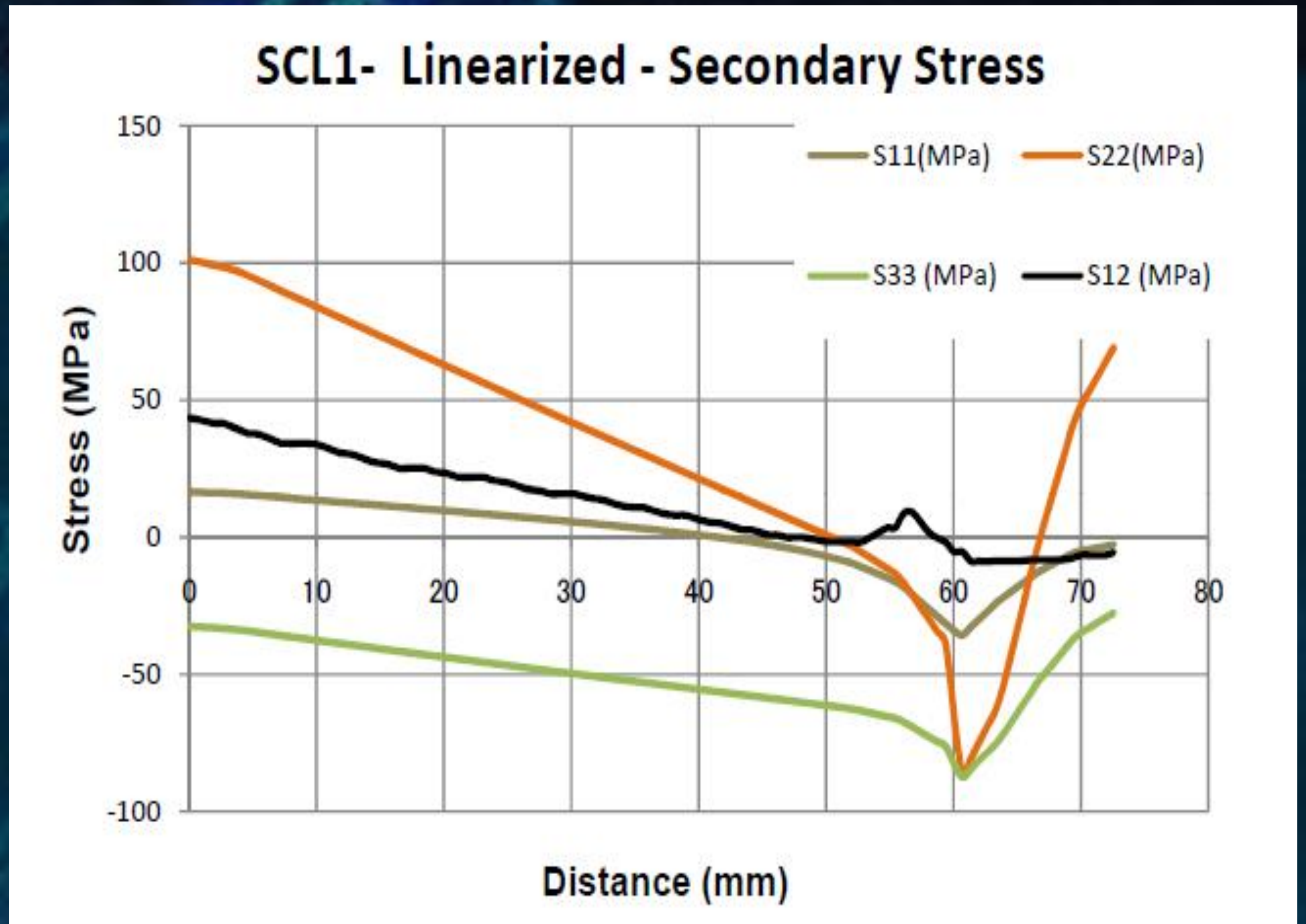
HOTBOX ANALYSIS

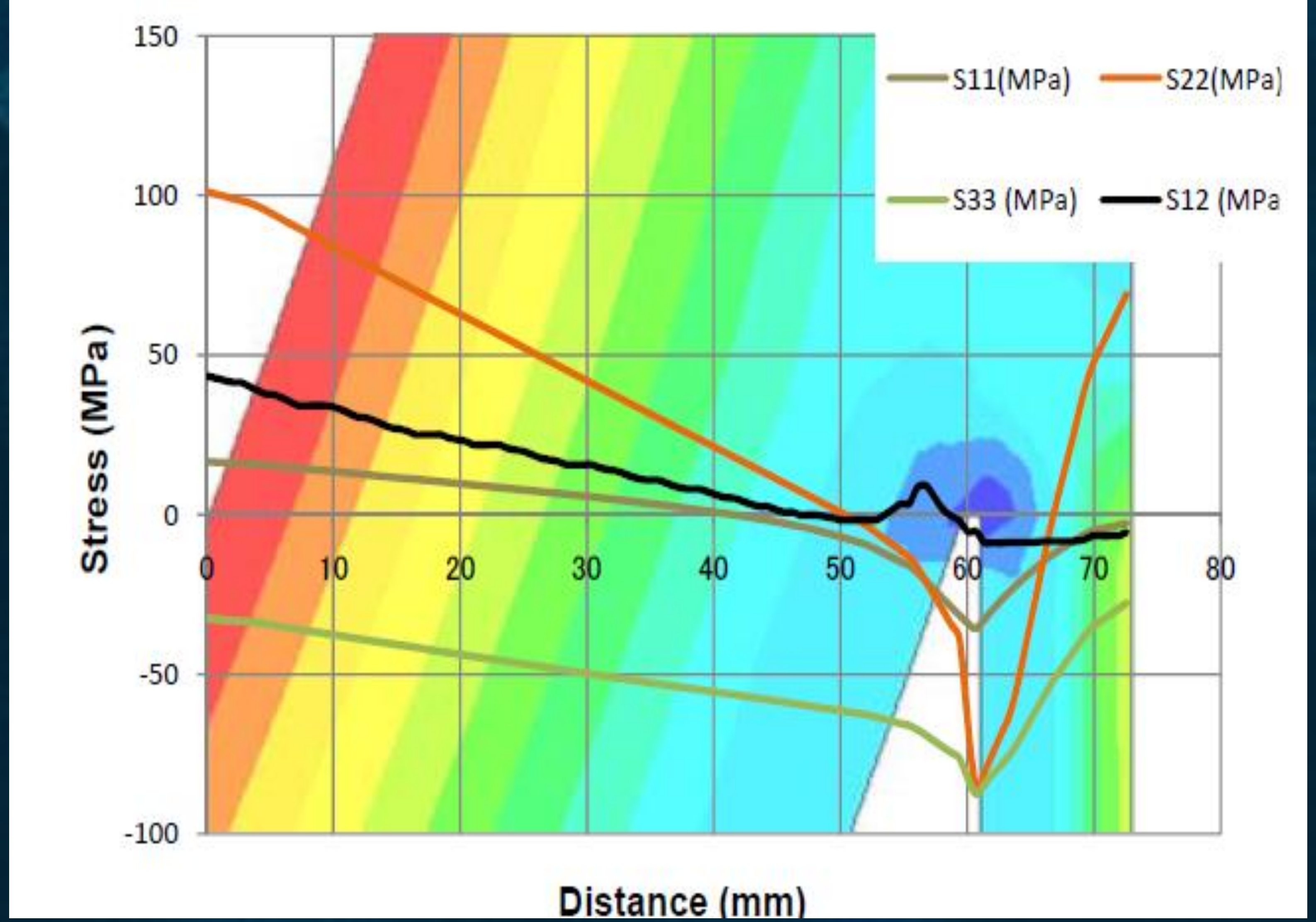
The Hotbox Analysis considers thermal effects due to high temperature fluid in the vessel. Conduction, convection and thermal radiation were all considered in order to establish the correct temperature distribution in the y-joint. The model also considered nonlinear effects such as plasticity, large displacements and contact.

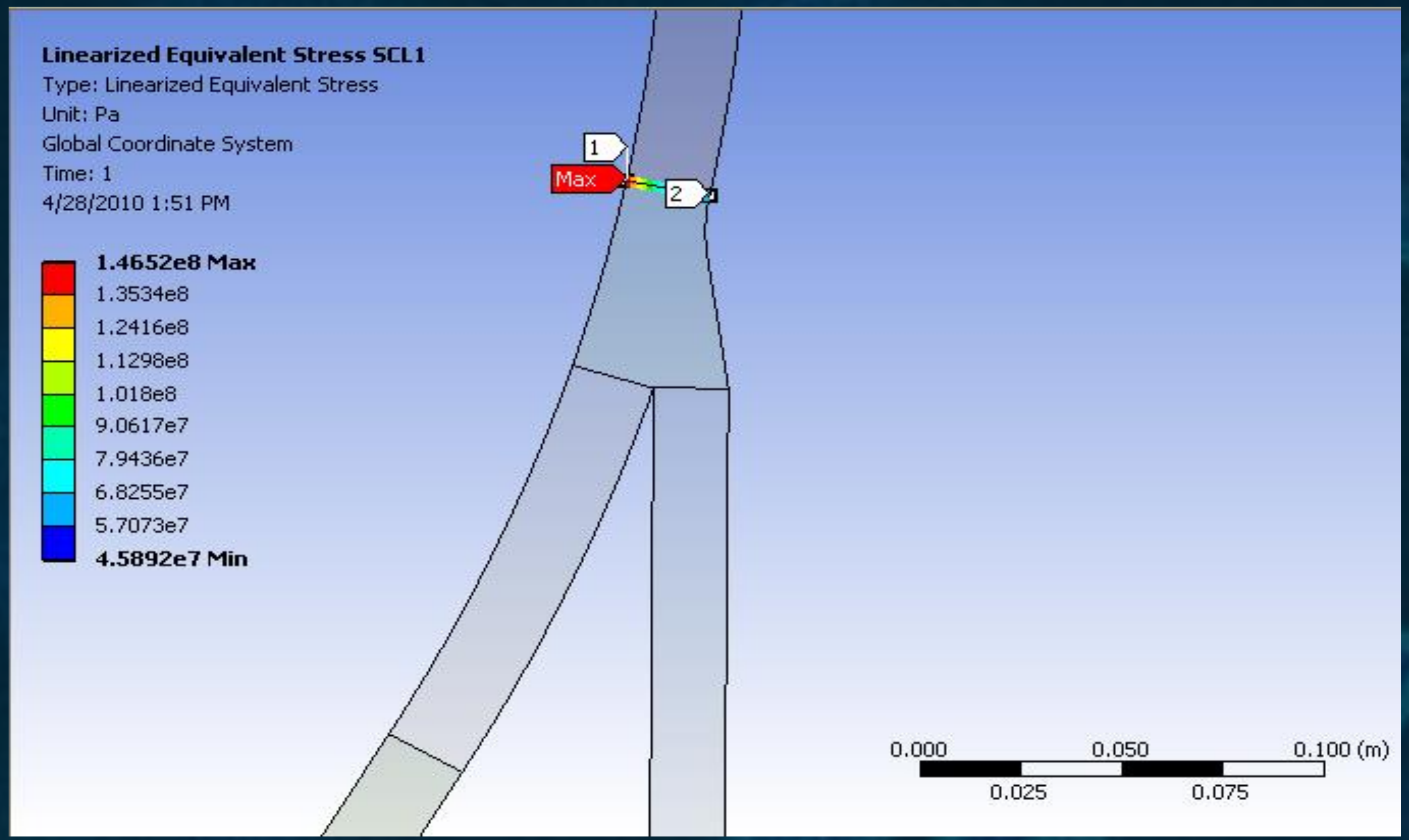
Local damage and fatigue was evaluated as per ASME section VIII Div 2 design by Analysis rules.



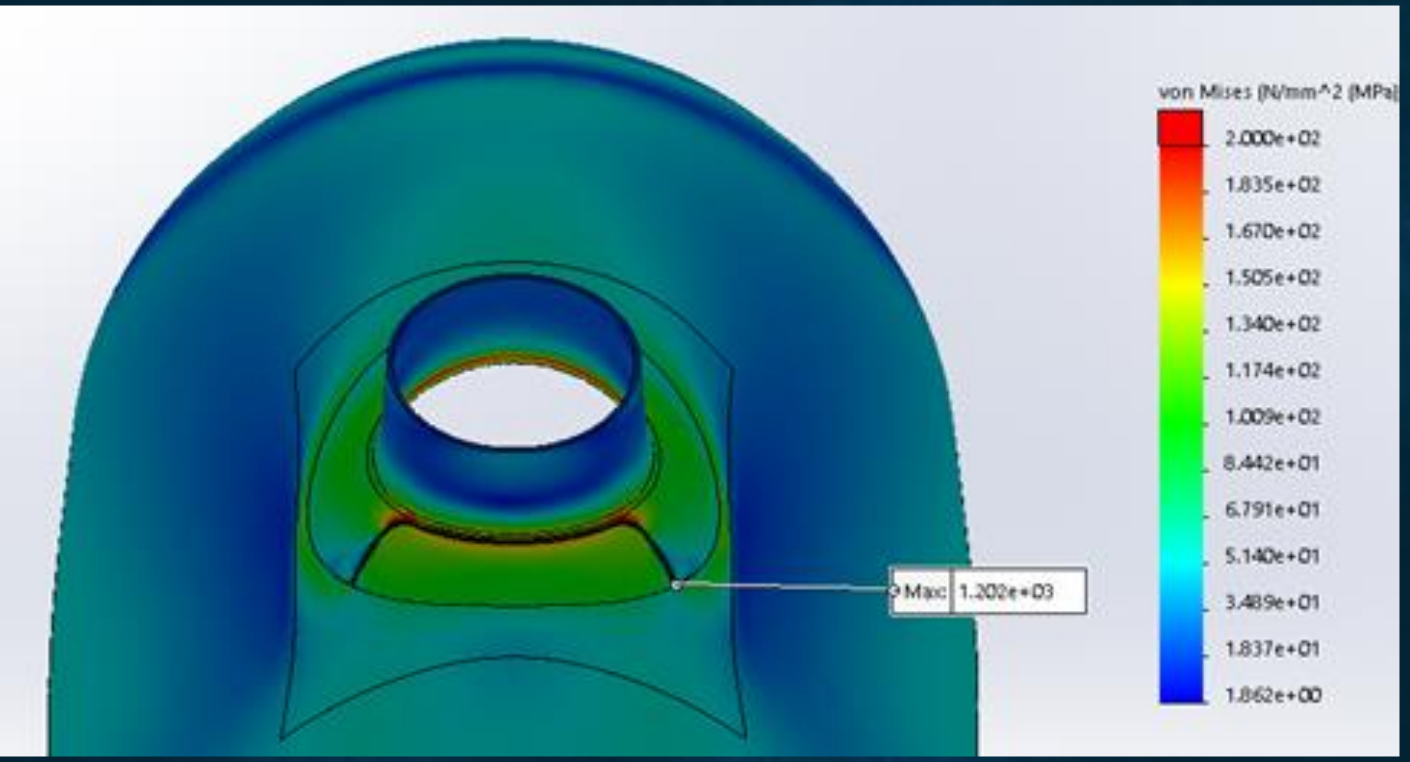






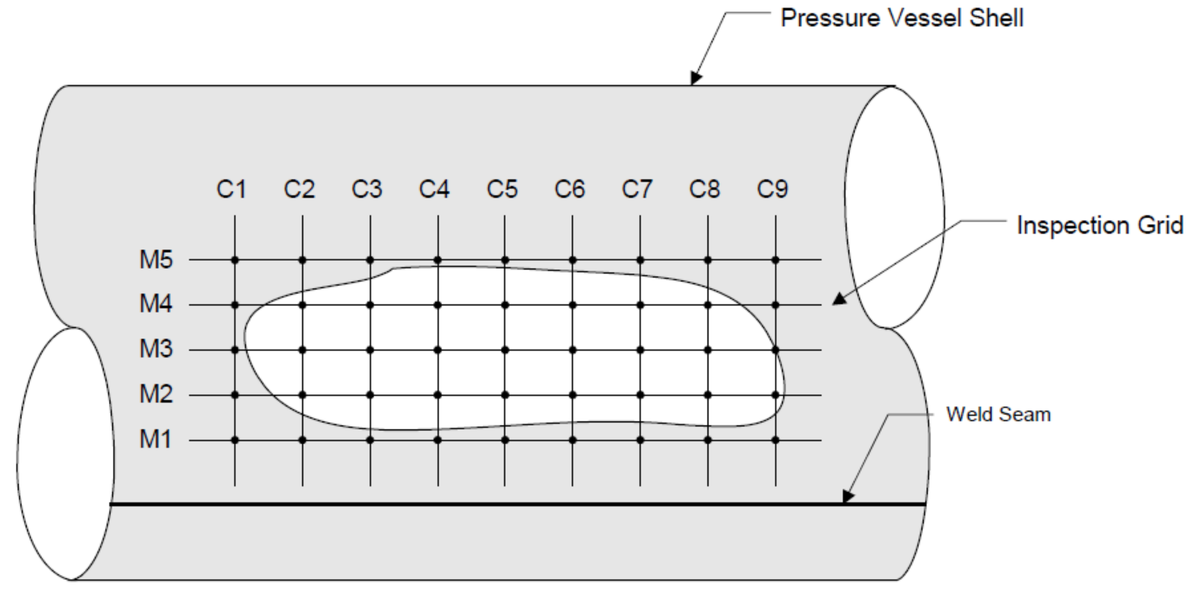


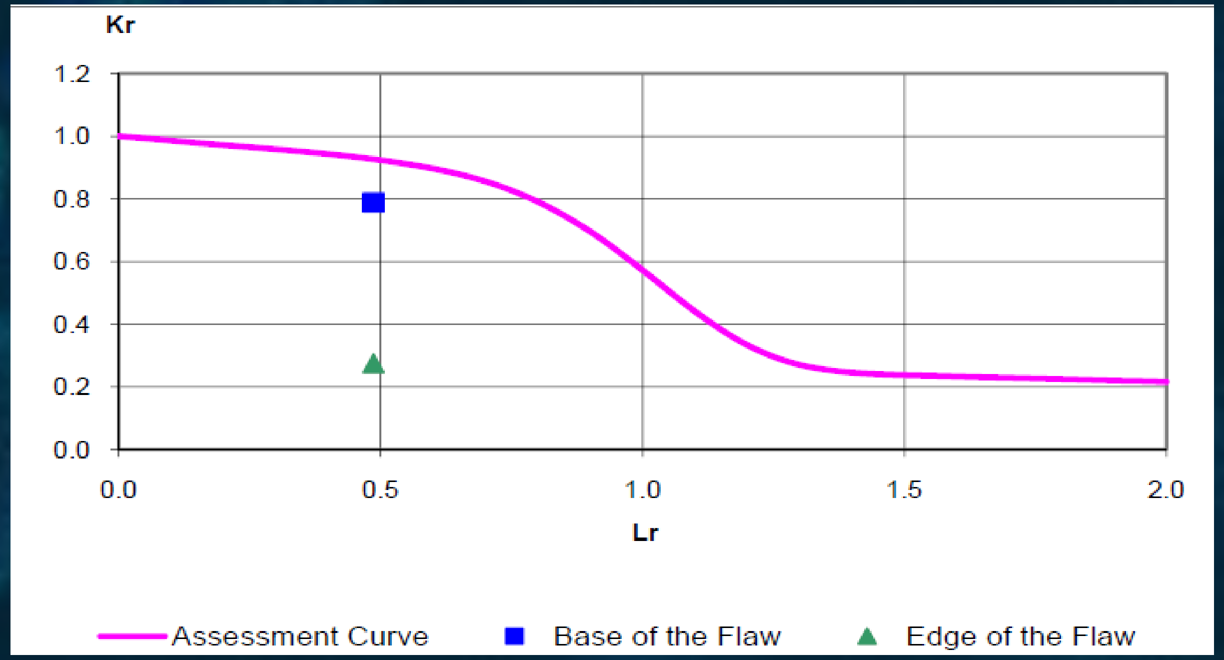
FITNESS FOR SERVICE ANALYSIS



Background

- Separator nozzle N1 was suffering from crevice corrosion due to moisture ingress via the weep hole in the reinforcement pad.
- Preliminary code calculations were not fully conclusive as to the fitness for service of this item and therefore a Level 3 assessment using a linear elastic Finite Element Analysis (FEA) model was built.



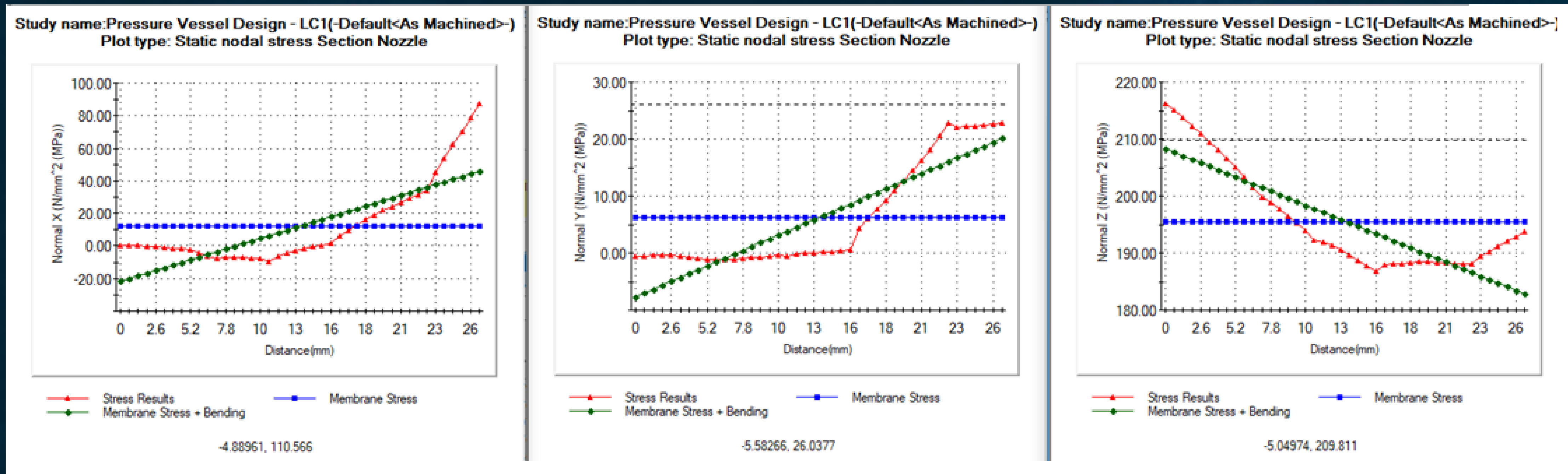


Challenges

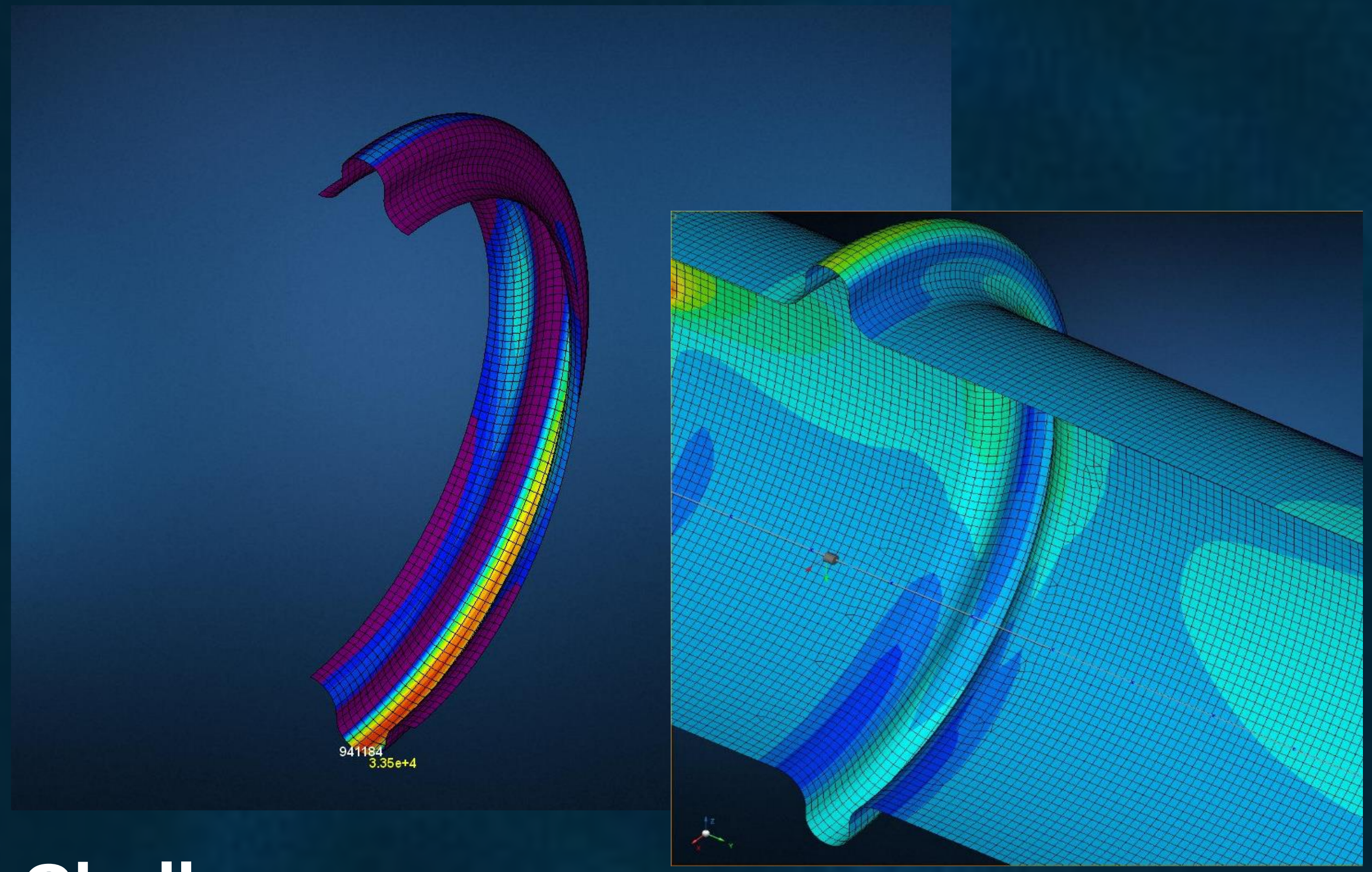
- Bespoke geometry of the cut-out in the nozzle pad had to be modelled.
- Low cycle fatigue evaluation required using fracture mechanics approach.

Outcomes

- The maximum stress utilisation was evaluated to be 91.8% and is based on the current estimated remaining wall thickness (RWT) of 9.6mm with no future corrosion allowance (FCA) included.
- The nozzle was verified against the loads provided by operator and found to be fit for service in the current state.
- The fracture mechanics assessment revealed on the FAD that the equipment was safe.



BELLOWS REQUALIFICATION



Background

- Client wished to use existing Heat Exchangers at elevated temperature conditions. The single involute bellows originally designed to EJMA 6th Ed. Code (2002) for 3.0 MPa and 343.0 °C for operational conditions of 2.9 MPa & 270.0 °C (Shell side) and 2.8 MPa & 276.0 °C (Tube side).
- Operational temperature and pressure were found to peak at 2.86 MPa & 289.0 °C (Shell side) and 2.92 MPa & 280.0 °C for Heat Exchanger A, and 2.86 MPa & 179.0 °C (Shell side) and 3.0 MPa & 170.0 °C for Heat Exchanger B

Challenges

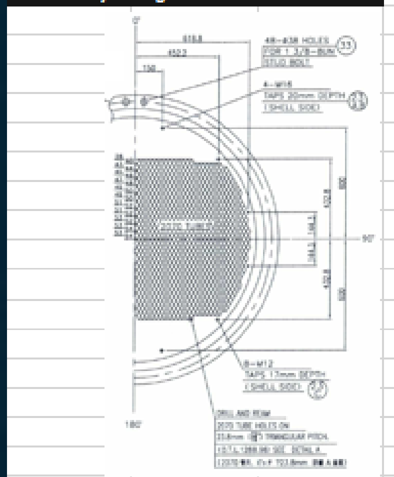
- The original EJMA calculations showed that the Squirm pressure limit was already lower than the design pressure at the original operating temperatures
- The axial expansion of the bellows as predicted by FEA, was also greater than the values used in the original calculations

Outcomes

- The von Mises stresses for both Heat Exchangers pass code requirements for the secondary membrane plus bending stress (plastic collapse) in accordance with ASME BPVC VIII Div 2. as well as the fatigue checks.
- Re-certification and Life-Extension for the in-service Bellows was achieved

Single Tube		
ID	14.830	mm
wt	2.110	mm
length	2881.000	mm
X-section	112.291	mm^2
J	8180.855	mm^4
Ixx/Iyy	4090.427	mm^4
E	2.070E+05	N/mm^2
v	0.300	
Kxx	8068.129	N/mm
Pitch	23.813	mm

NOTE: Only change the values in Yellow



Row	No tubes	J mm^4	Ixx mm^4	Iyy mm^4	Net X-sect mm^2	Kxx N/mm
21	26	640891029.492	547662828.485	93228201.006	2919.571	209771.348
20	40	1103781359.766	764240334.169	339541025.597	4491.648	322725.151
19	43	1163292458.408	741473568.324	421818890.084	4828.522	346929.537
18	44	1132912671.494	680972333.718	451940337.776	4940.813	354997.666
17	45	1104697768.612	621235175.830	483462592.783	5053.104	363065.795
16	46	1078966115.061	562548623.427	516417491.634	5165.395	371133.923
15	47	1056036076.139	505199205.279	550836870.859	5277.687	379202.052
14	48	1036226017.144	449473450.155	586752566.989	5389.978	387270.181
13	49	1019854303.377	395657886.824	624196416.553	5502.269	395338.310
12	50	1007239300.135	344039044.054	663200256.081	5614.560	403406.439
11	49	907535025.967	283338609.414	624196416.553	5502.269	395338.310
10	50	902178751.538	238978495.457	663200256.081	5614.560	403406.439
9	51	901279591.291	197483669.188	703795922.103	5726.851	411474.567
8	52	1694829197.620	159140659.378	1535688538.243	5839.143	419542.696
7	51	823343766.150	119547844.047	703795922.103	5726.851	411474.567
6	52	1625298216.367	89609678.124	1535688538.243	5839.143	419542.696
5	53	853381975.535	63491895.787	789890079.748	5951.434	427610.825
4	52	785959942.663	39944691.514	746015251.149	5839.143	419542.696
3	53	812885909.530	22995829.782	789890079.748	5951.434	427610.825
2	54	845988163.193	10535918.762	835452244.431	6063.725	435678.954
1	53	792637876.527	2747796.779	789890079.748	5951.434	427610.825
0	54	1718181735.731	220883.082	1717960852.649	6063.725	435678.954
Full Bundle	2070	44296612767.750	13680855960.078	30615756807.672	232442.790	16701026.557

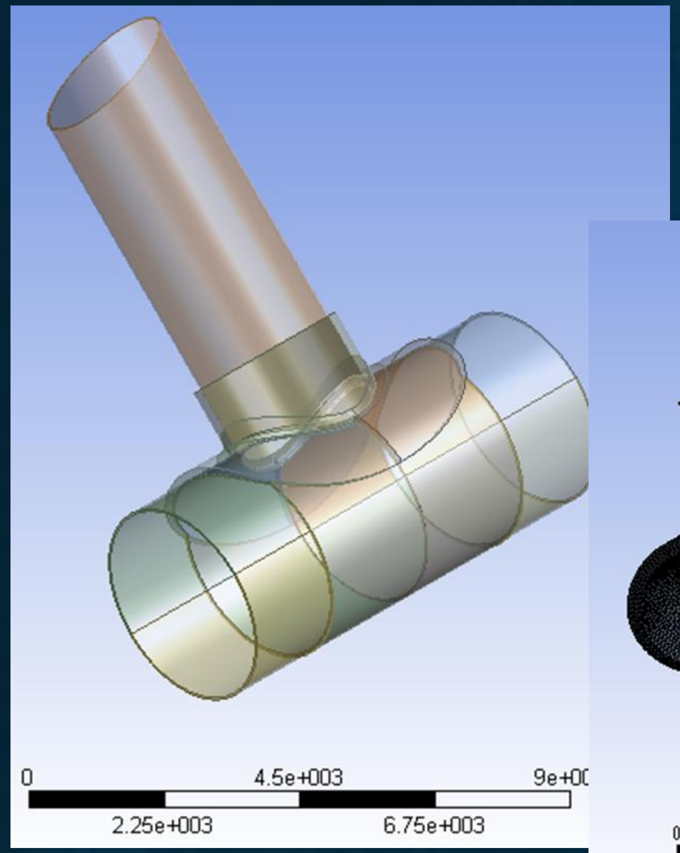
Composite Tube		
b	1031.571	mm
d	624.385	mm
wt	76.968	mm
length	2881.000	mm
X-section	231214.958	mm^2
J	43926224935.194	mm^4
Ixx	13310468127.522	mm^4
Iyy	30615756807.672	mm^4
E	2.070E+05	N/mm^2
Kxx	16612806.776	N/mm

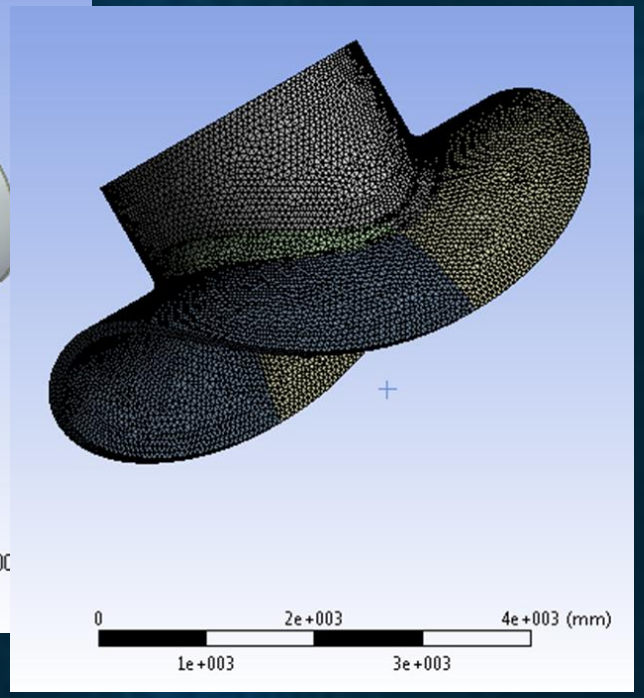
Layout Space		
1/2H	433.0668285	mm
Cent. 1/2W	631.03125	mm
Top 1/2W	309.5625	mm

CoG Location for C-channel		
x	189.1715186	mm
Offset	326.6139421	mm

Comp Tube m	10839.158	kg

FAILURE OF FRP SEAWATER LINE





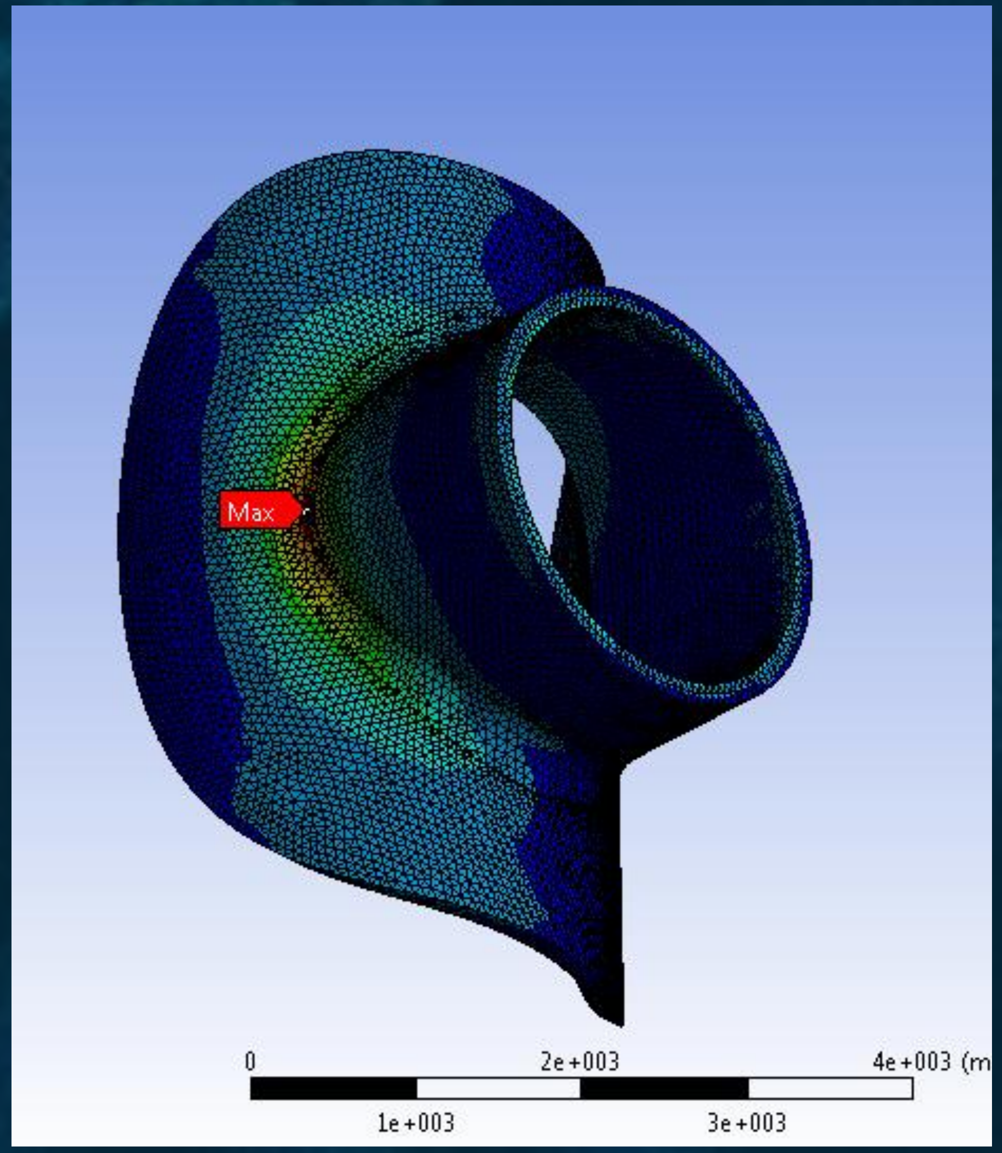
Background

Client had experienced a failure in on the their FRP seawater lines. It was suspected that downstream re-routing of a cooling water line had resulted in a negative impact on the branch with the main header. This failure had shutdown the facility.

The FRP lines were made in sections and assembled in-situ. According to manufacturer's data, the material properties of the spool-sections were transverse isotropic.

Challenges

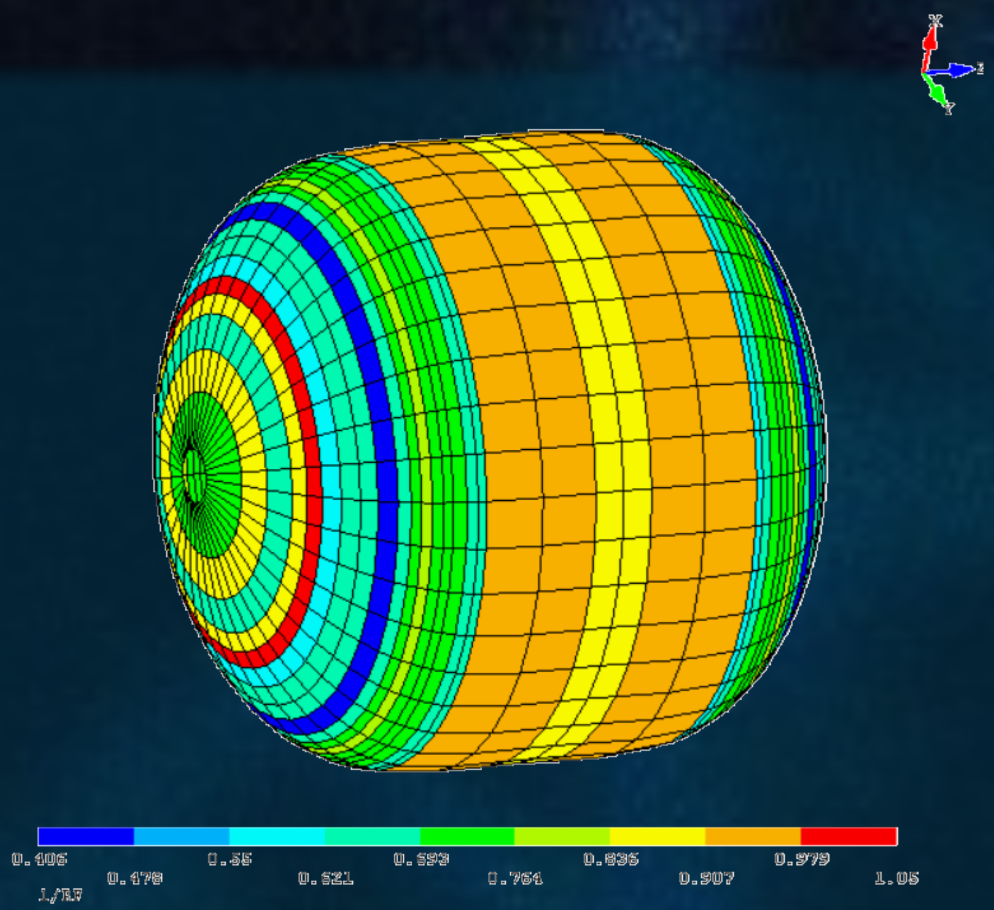
- Rapid turnaround on solution was required.
- Data on manual lay-up sections was missing, according to manufacturer lay-up sections were effectively isotropic.
- Stress limits highly conservative as per Standards (10% UTS).
- Correct treatment on a layer-by-layer basis requires application of the Tsai-Wu failure criterion. In agreement with the Client for the bulk modelling of FRP the Tresca Criterion was applied, as interlaminate failure was not an observed failure mechanism for the Manufacturer.



Outcomes

- Analysis confirmed that re-routing had caused loading scenarios where stresses at the re-enforcement pad would significantly exceed the agreed failure criterion, resulting in the observed failure.

CFRP VESSEL DEVELOPMENT



Failure Index: Worst Case Ply

Background

The Client wanted to develop a liner-less type-V pressure vessel using wound carbon-fibre composite layup. To achieve this, we needed to:

- Simulate the behaviour of the vessel at the laminate
- Validation of the simulation results and material model against real life test data

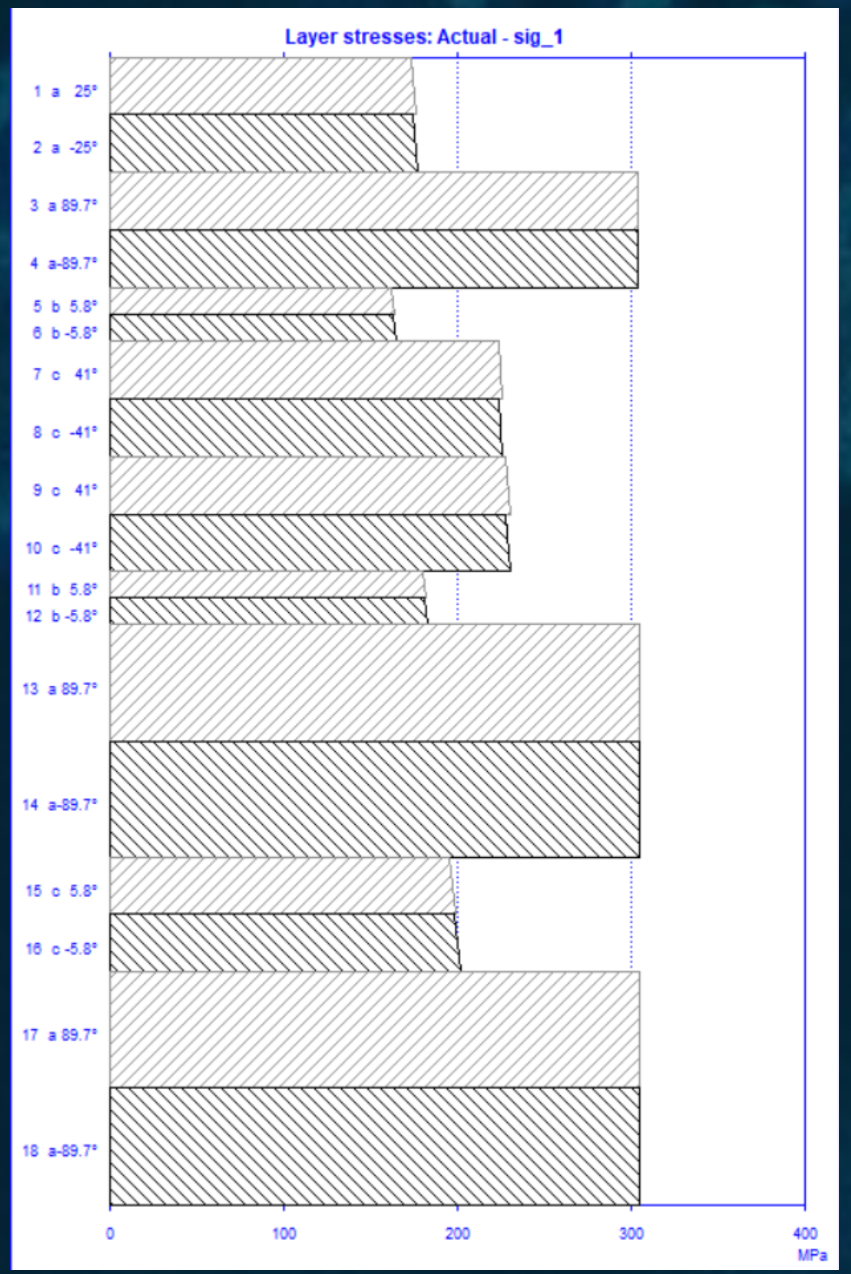
The would enable the Client to predict failure pressure and mechanism of failure (leak, burst or fibre damage).

Challenges

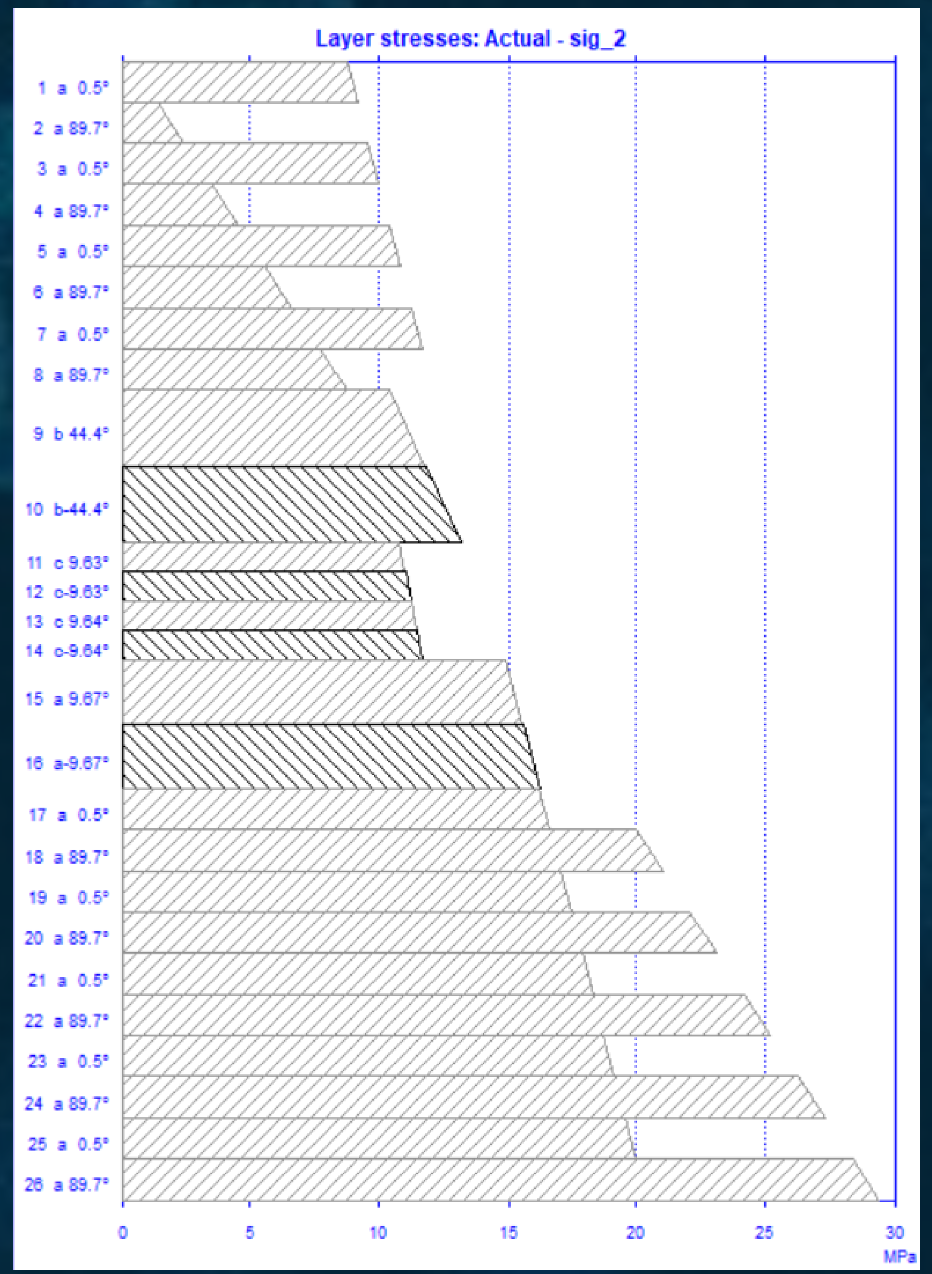
- The vessel was liner-less therefore transverse stresses become critical; any damage within the matrix can lead to leakage paths for the gas.
- Low temperature application with high thermal gradients require layup to be balanced in terms of thermal expansion and elasticity; high gradients that can lead to damage to the composite structure.
- The thickness of the dome varies across longitudinally.

Outcomes

- Weak areas along the longitudinal direction were identified.
- Excessive transverse stress in the dome (preferred mode of failure).
- Predicted that no leak would occur but rather some local damage validated in test.

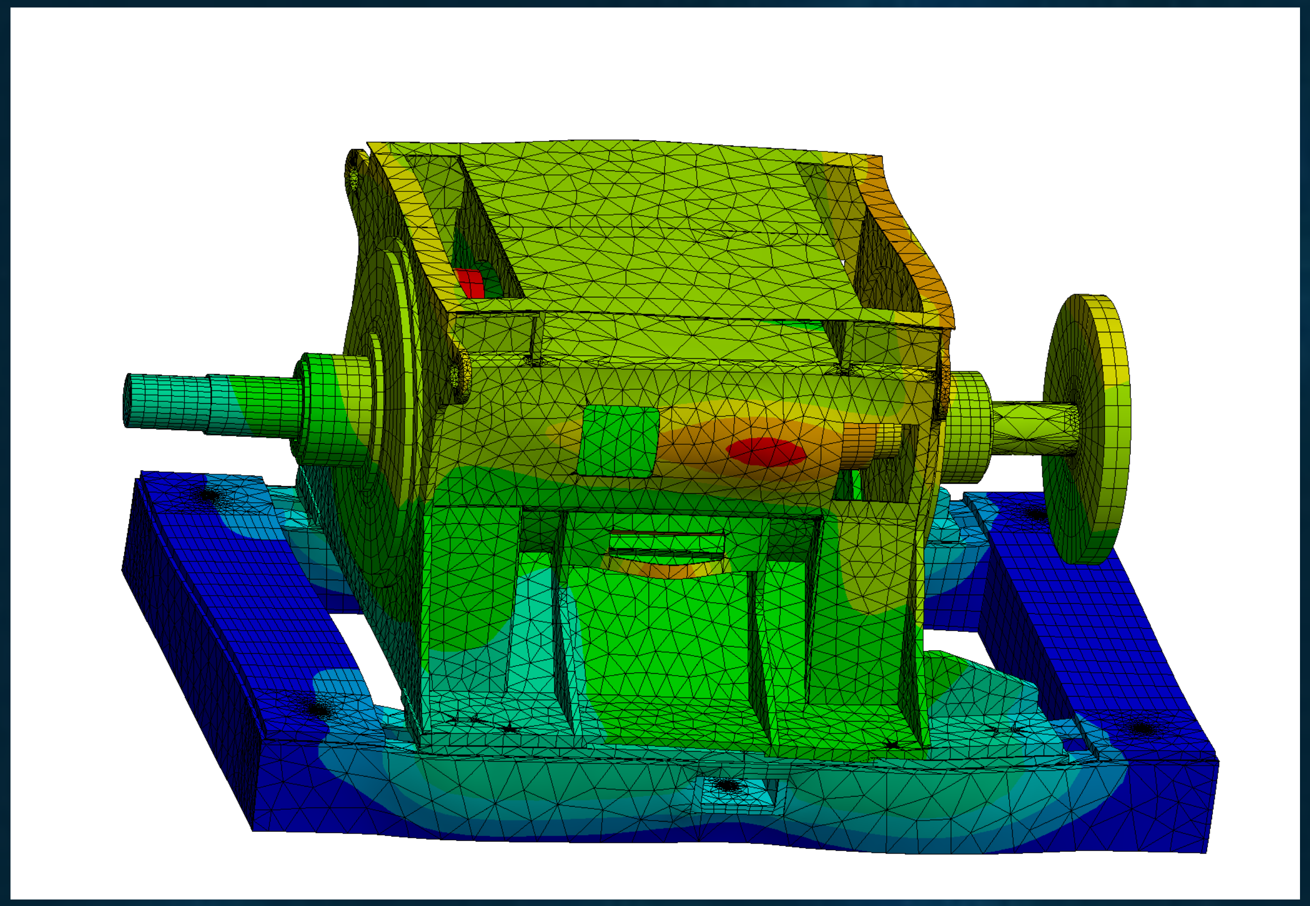


Fibre Stress at element



Transverse Stress at dome element

MOTOR VIBRATION ANALYSIS

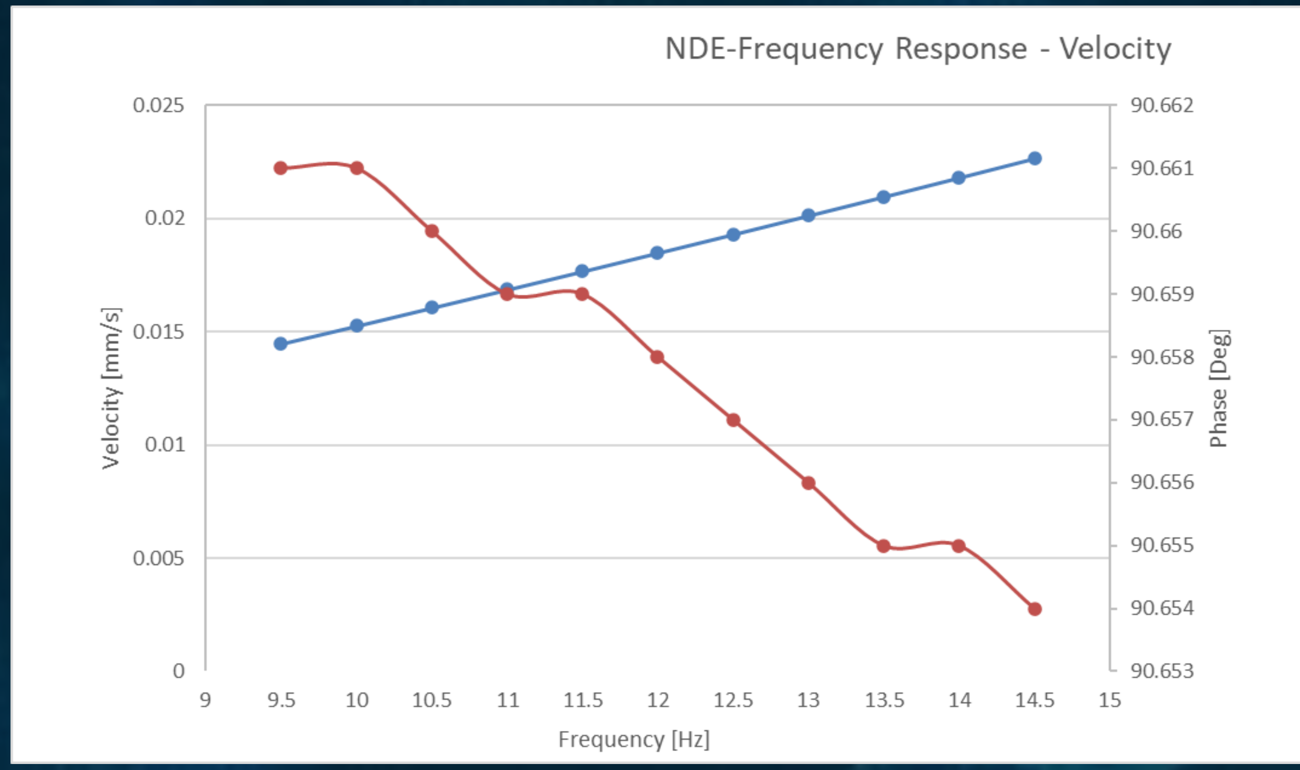


Background

- Client required structural dynamic analysis of the motor base plate with a lighter weight (approx 4T less) electric motor installed. The integrity and code compliance of the motor and the baseplate was required.

Solution

- Complete Motor model including the baseplate and connections was modelled and optimised for simulation.
- A Modal analysis was carried out to identify the natural frequencies of the motor assembly followed by a harmonic analysis to verify if the velocity amplitude is within the limits specified by the ISO-10816-3_2009 standard as requested by the client.



Outcomes

- The Modal analysis followed by Harmonic simulation has shown that the Motor Base with the new motor assembly is below the allowable velocity amplitude as per the governing guidelines.
- The stiff design of the motor assembly and the large difference between the rotor primary frequency and the first natural frequency of the baseplate was the reason for low RMS velocity.

PERFORMANCE BENEFITS OF THERMOWELL HELIX

CYGNAS

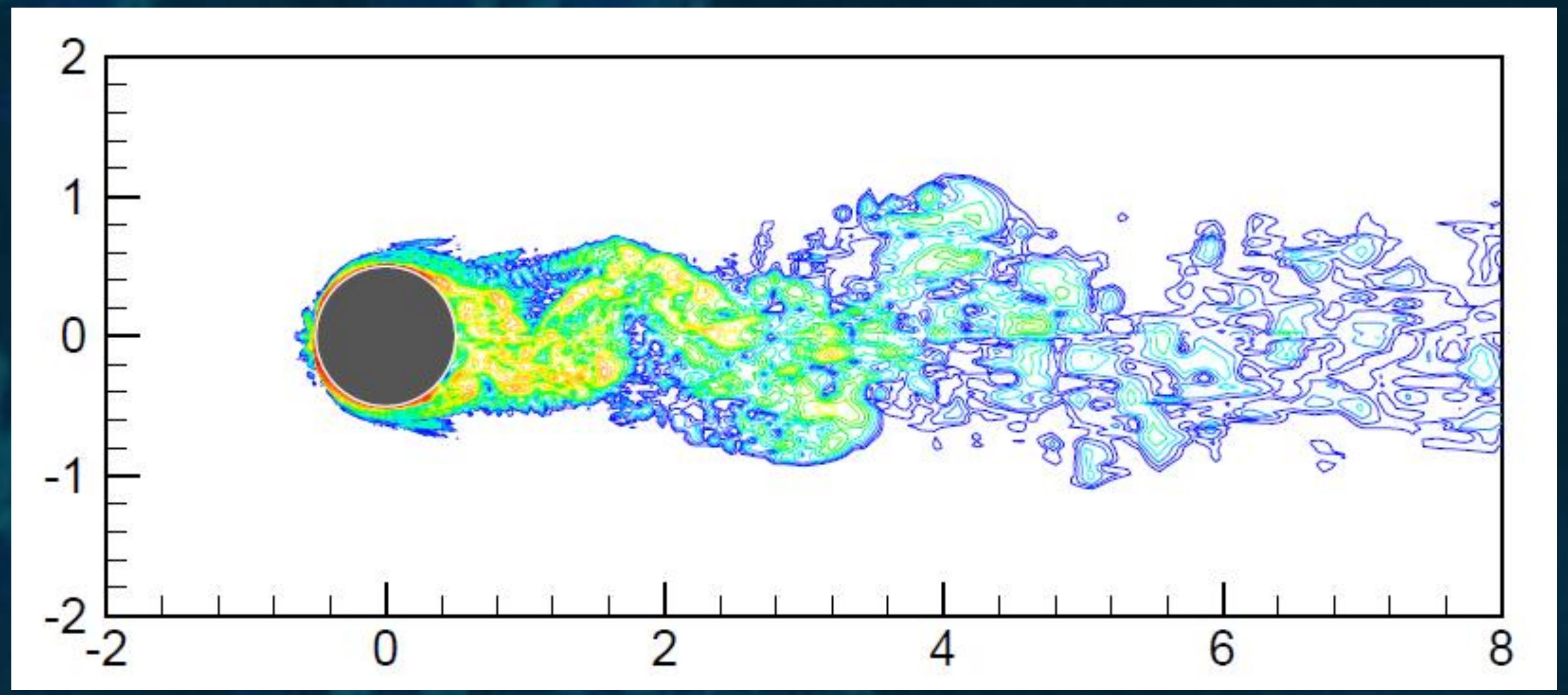
Background

The national petrochemical company in Brazil considered a major replacement program of thermowells inside pipes and vessels. Any significant change in the selected type of thermowells would inevitably lead to changes in the maintenance schedule and the related equipment outage periods.

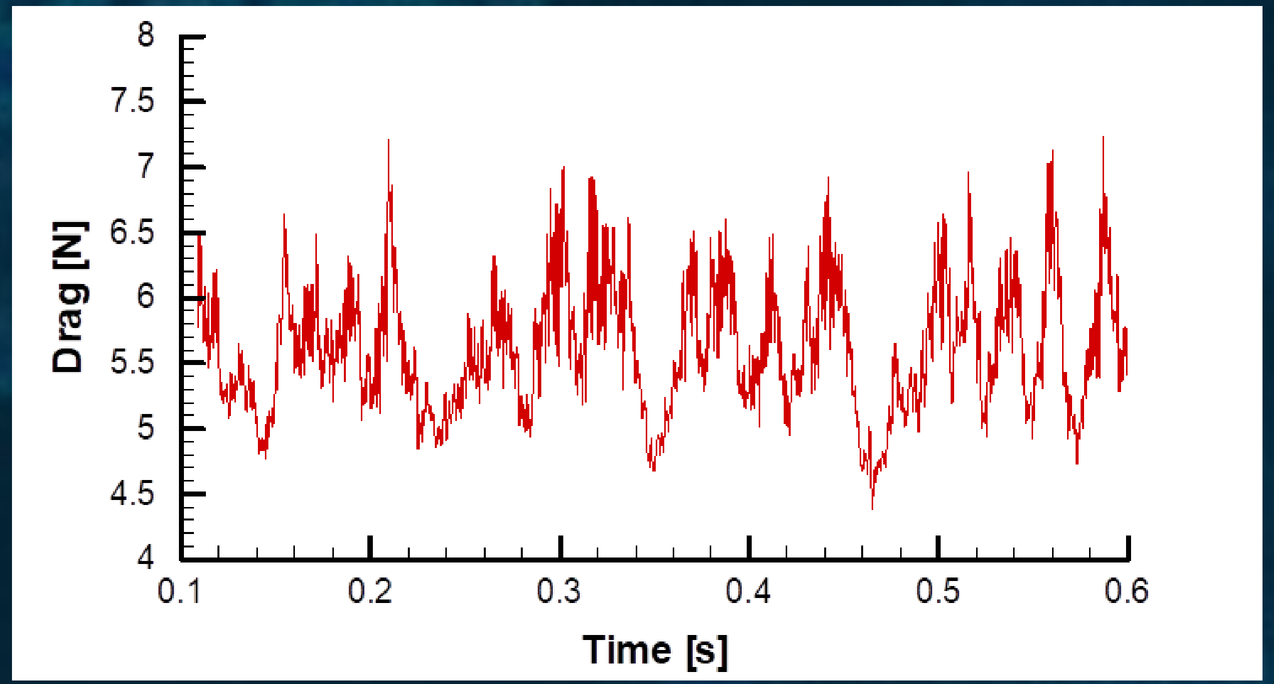
For that reason, the company intended to explore benefits of a helix thermowell design in comparison to the smooth, cylindrical type. Members of Cygnas were approached to quantify performance benefits in terms of oscillatory pressure loading and the resulting fatigue lifetime. A valuable feedback was also provided to the EPC contractor and to the equipment vendor.

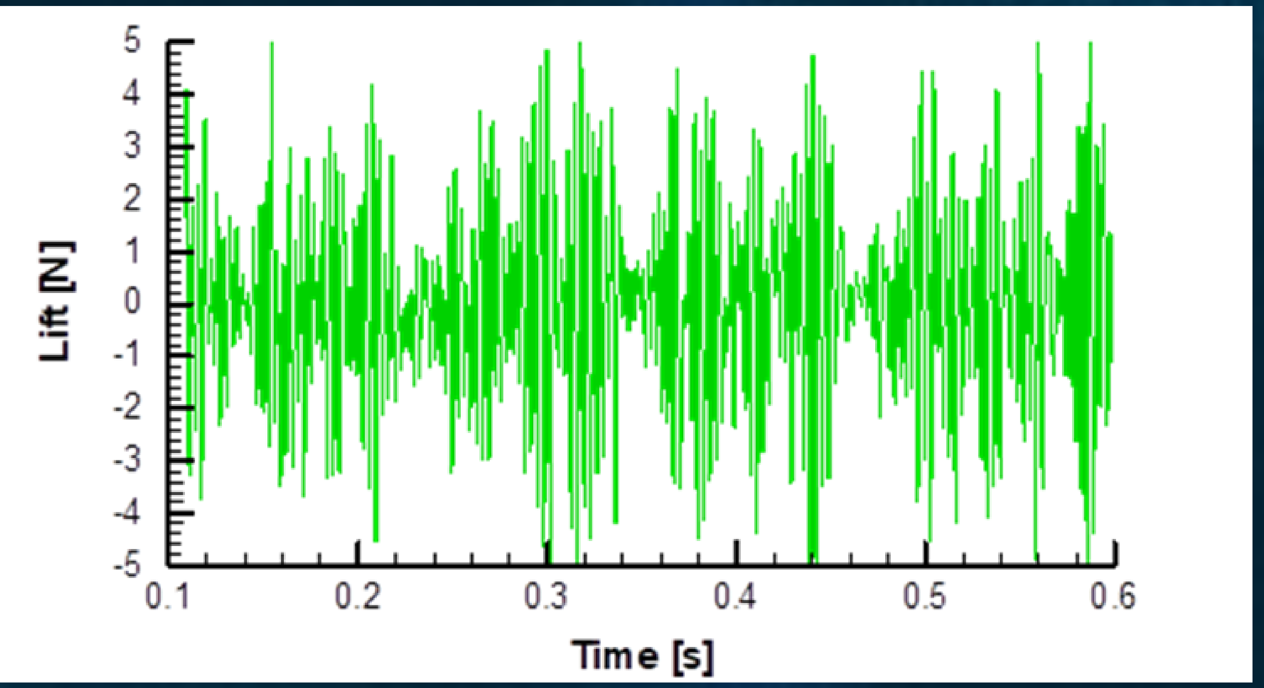
Challenges

- Cylindrical objects subjected to cross-flow induce vortex-induced vibrations (VIV) which may severely limit fatigue lifetime of the structure
- Simulation analysis requires transient CFD simulations followed by FE analysis and fatigue assessment
- These simulations are demanding (selection of turbulence model, timestep and grid resolution, spectral conversion) and time consuming
- Precise definition of installation conditions is necessary as they affects the dynamic performance of the structure
- One of main operational criteria is the avoidance of the system harmonics (which must be determined as well)



vortex shedding from a stem segment





drag and lift force time-variation

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