

ENGINEERING AND SCIENCE SHOWCASE

23 June 2024

Build your Competitive capabilities in Manufacturing through University Cooperation

Focus on Metals

Nawaz Mahomed

Mechanical and Mechatronic Engineering

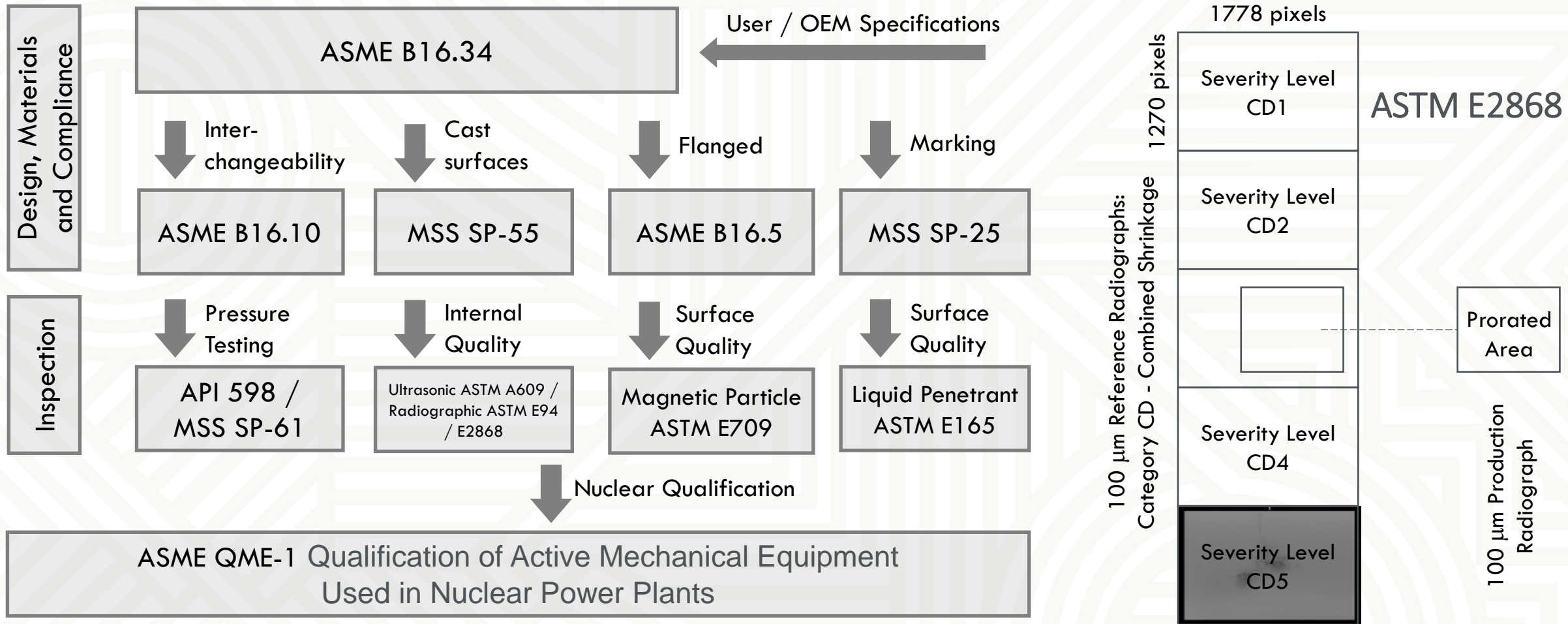


Target

- Component level suppliers (Tier 2) into subsystems (Tier 1) supply chains: Component design and analysis, design for manufacture, prototype inspection standards compliance procedures.
- OEMs for developing localisation specifications for components: Component specifications, supplier prototype quality inspections and classification against standards, Innovation (improvement in functionality, based on improved / optimised materials, optimisation of production processes (such as heat treatment)).
- Opportunities for SA companies to enter global supply chains due to the competitive pricing of steel. Local steel supplies (Middleburg Steel, Columbus Stainless, etc.) willing to support local beneficiation.



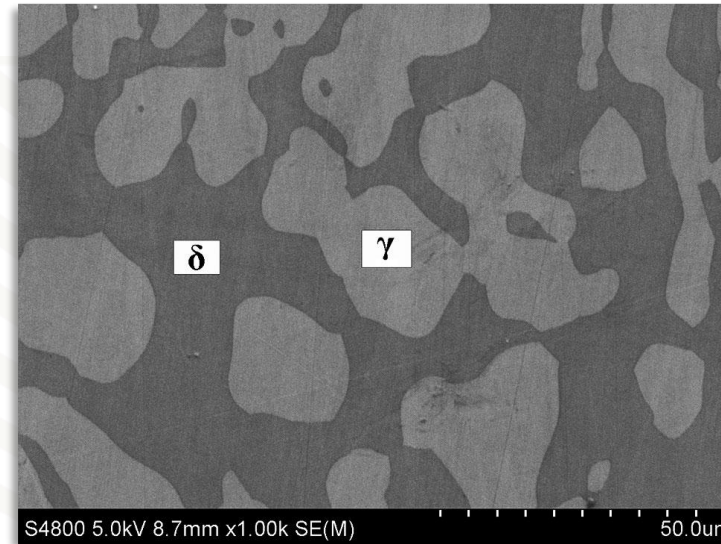
Compliance / Certification / Inspection (An example)



Qualification of Raw Materials (Compliance)

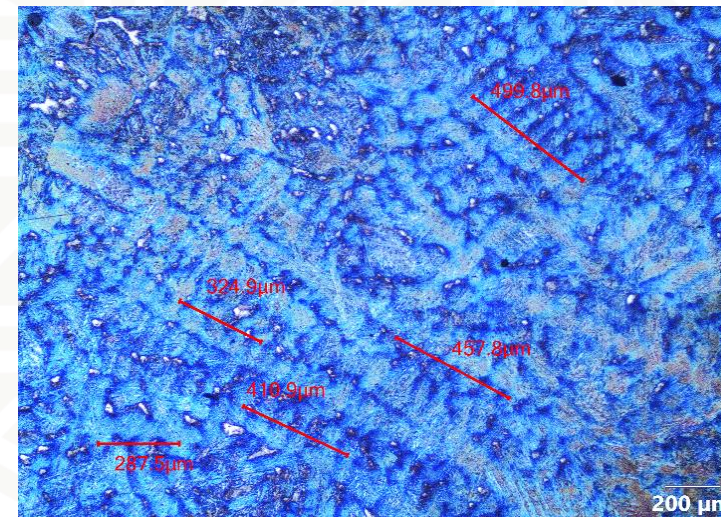
Microstructural Investigations

- Scanning Electron Microscopy (SEM) for high resolution investigation, down to 1 nanometer.
- Phase fractions using image analysis.
- Optical Microscopy for medium resolution investigation (2mm x 2mm = 2048 x 1920 pixels).



Duplex Stainless Steel (Fe-Cr-Ni alloy)

- 50% Ferrite (α); 50% Austenite (γ) microstructure
- Nuclear industry (spent nuclear fuel canisters)



35NCD6 (European Grade 34CrNiMo6 / AISI 4340) steel

- Hyper-peritectic steel
- Heavy duty (high-value) automotive castings and forgings.

Qualification of Raw Materials

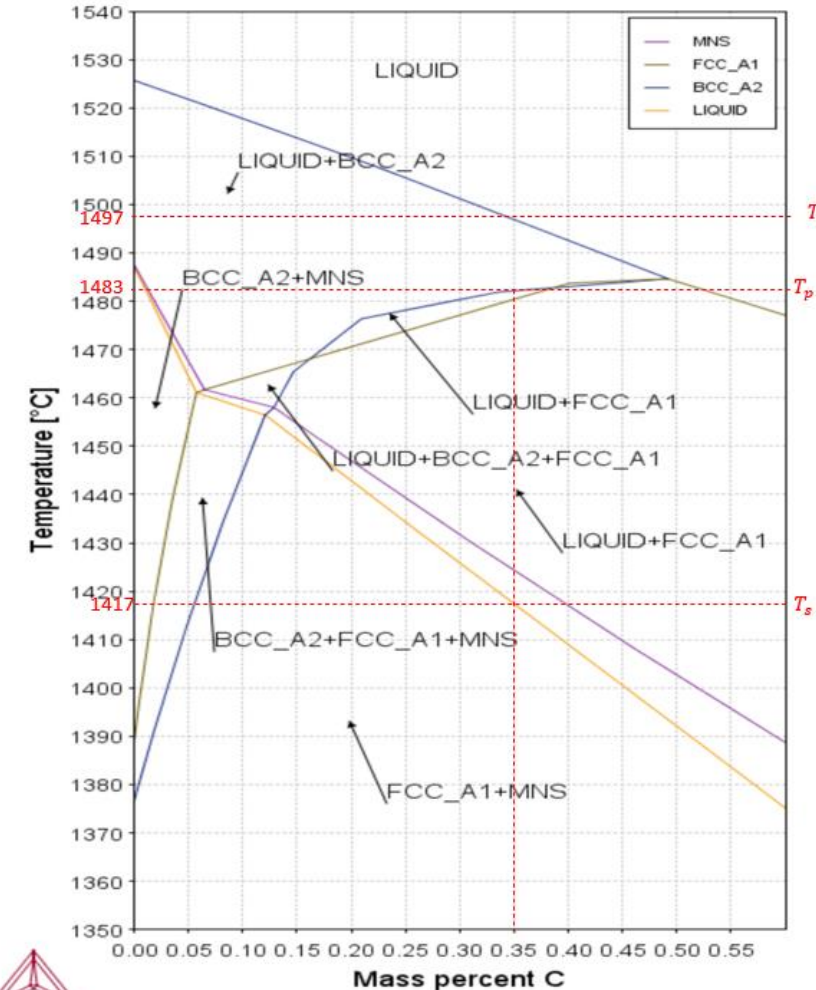
Compositional Analysis

- Electron Dispersive Spectroscopy (EDS).

Chemical composition of 35NCD6 (European Grade 34CrNiMo6 / AISI 4340) steel

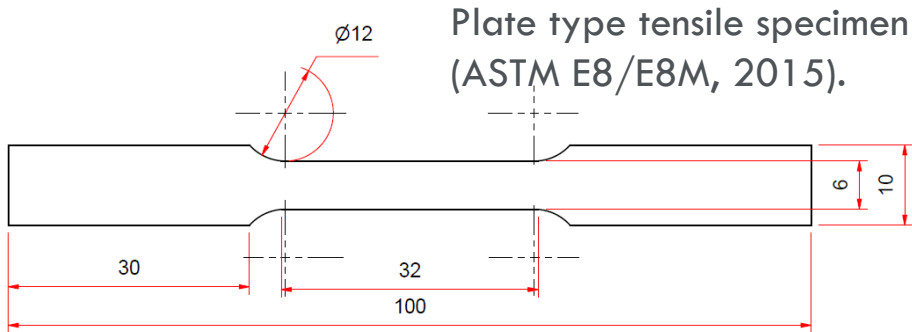
Element	C	Ni	Cr	Si	S	P	Mn	Mo	Fe
Range (wt.%)	0.30-38	1.3-1.7	1.3-1.7	0.1-0.40	0.035 max	0.025 max	0.5-0.80	0.15-0.30	Balance
Measured (wt.%)	0.30	< 1.0	2.5 ± 0.15						
Thermal matching of phase diagram (wt.%)	0.30	0.6	2.7						

- Hyper-Peritectic Steels (Carbon less than 0.53%) – preferred for steel castings – lower internal porosity.

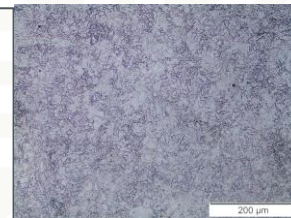
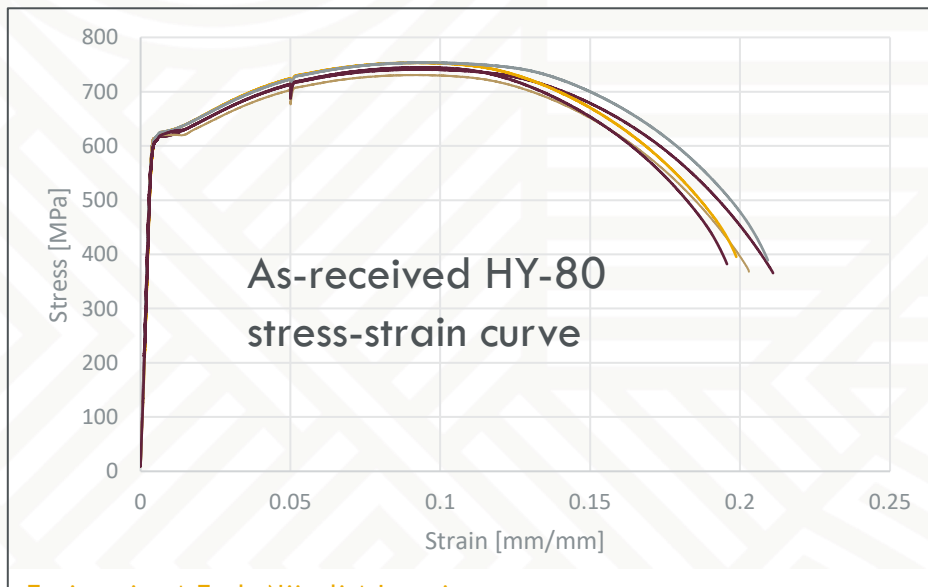


Qualification of Raw Materials

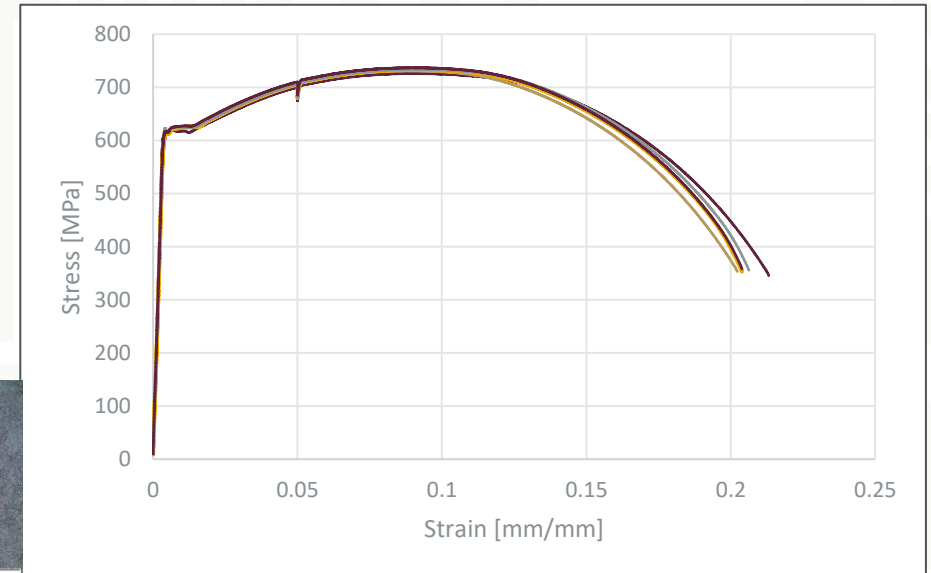
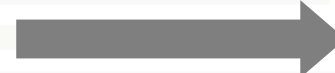
Tensile and Hardness Testing



Tensile Property	Measured as-received	Measured heat-treated
Yield strength	615 ± 4 Mpa	612 ± 2 MPa
Ultimate tensile strength	744 ± 11 Mpa	731 ± 5 MPa
Elongation at fracture	20.6 ± 0.5 %	20.6 ± 0.4 %

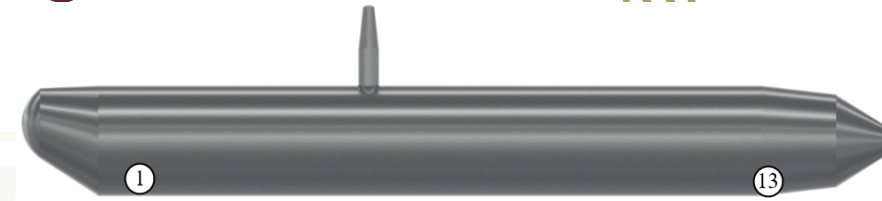


Heat treated



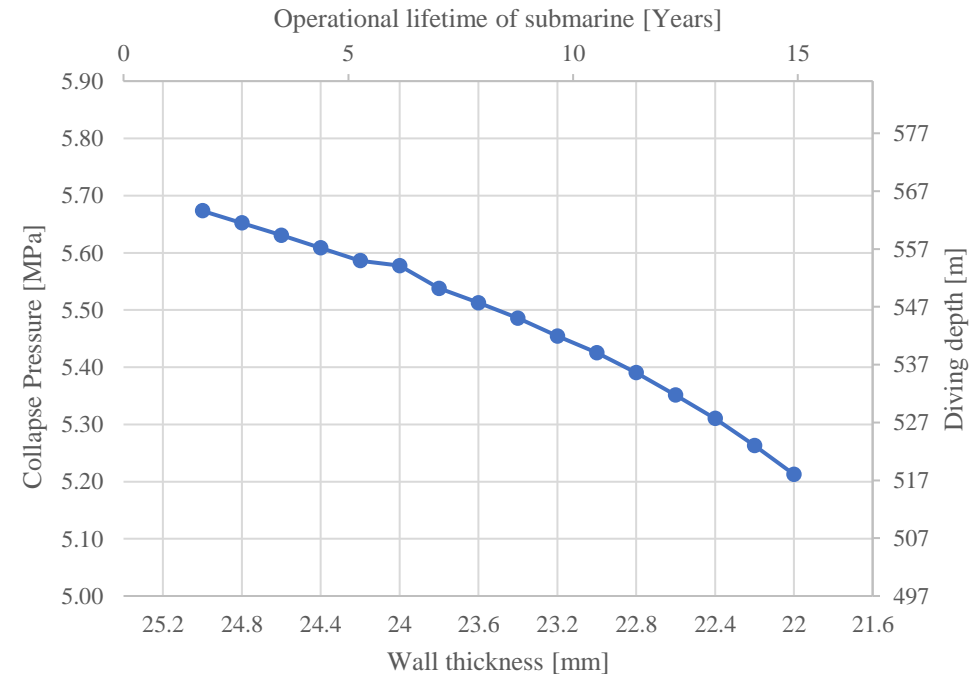
Qualification of Raw Materials: Gauge Measurements

In-situ gauge thickness measurements of submarine hull.

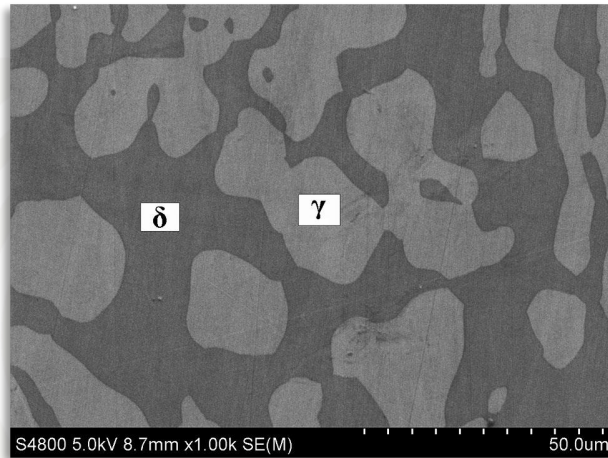


Position	1	3	5	7	9	11	13
Measurement [mm]	24.81	23.67	23.43	23.69	23.79	24.05	22.99
	24.72	23.68	23.40	23.94	24.00	-	-
Position	2	4	6	8	10	12	
Measurement [mm]	23.76	24.34	24.02	23.82	23.41	23.92	
	23.62	24.32	23.82	-	23.38	23.94	

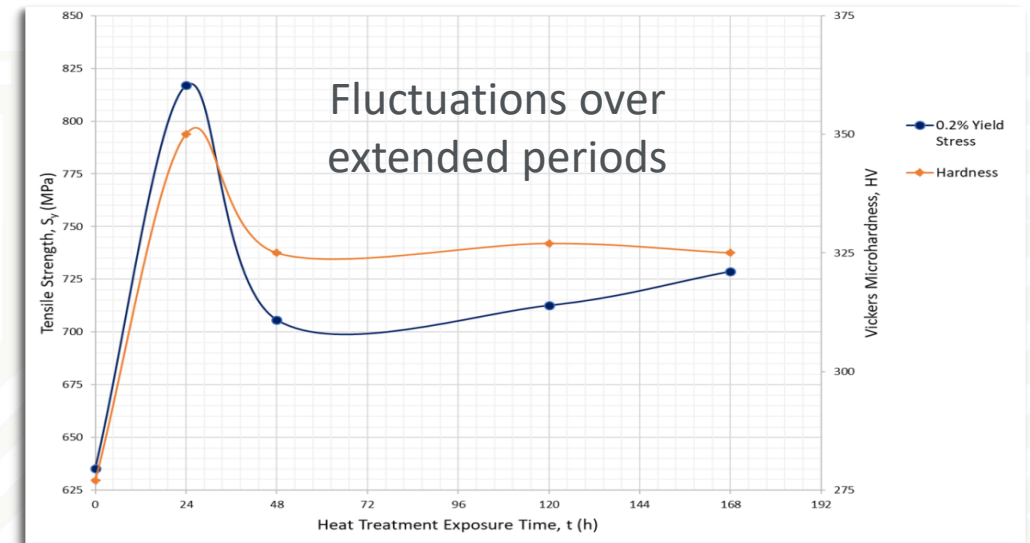
Effect of Corrosion Thinning of Submarine Hull on Depth of Operation.



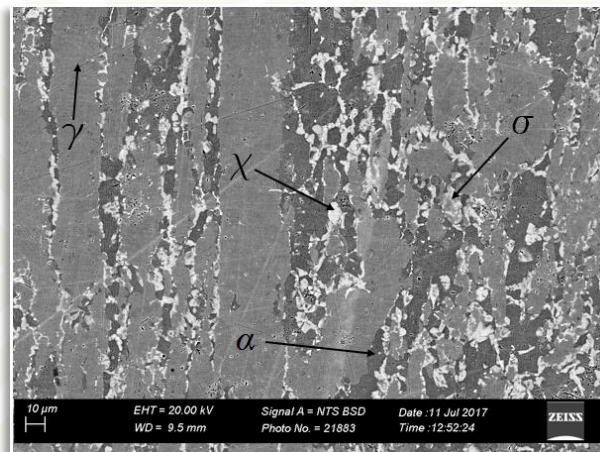
High-Temperature Exposure



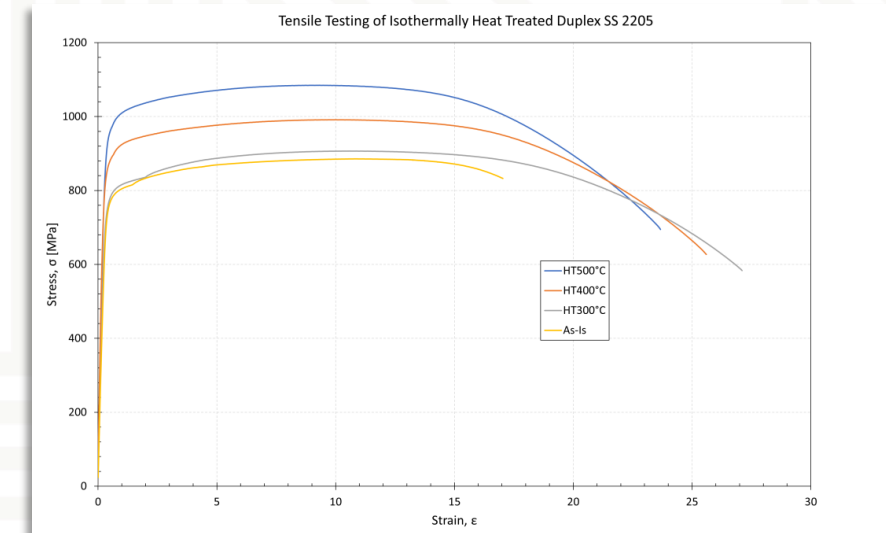
Spent Nuclear
Fuel Cannisters at
Koeberg



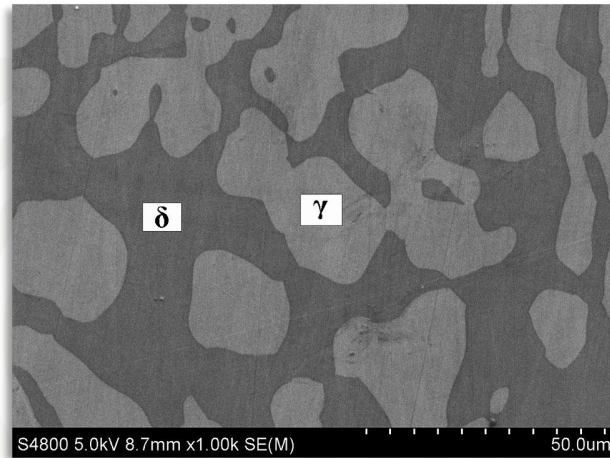
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Precipitation of undesirable
phases (Carbides ($M_{23}C_6$), Nitrides
(Cr_2N), Intermetallics (χ , σ))




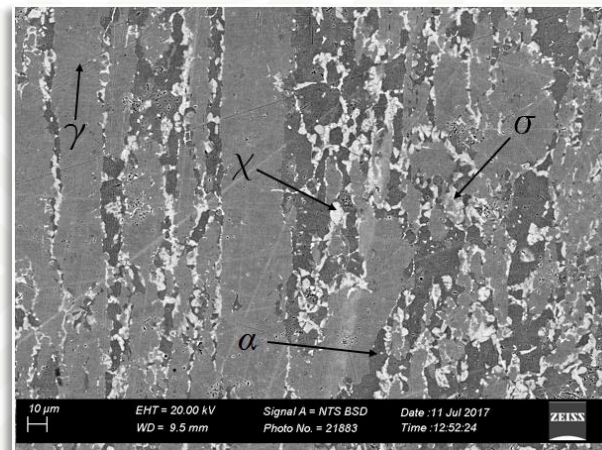
Embrittlement: increase
Strength; decrease Ductility



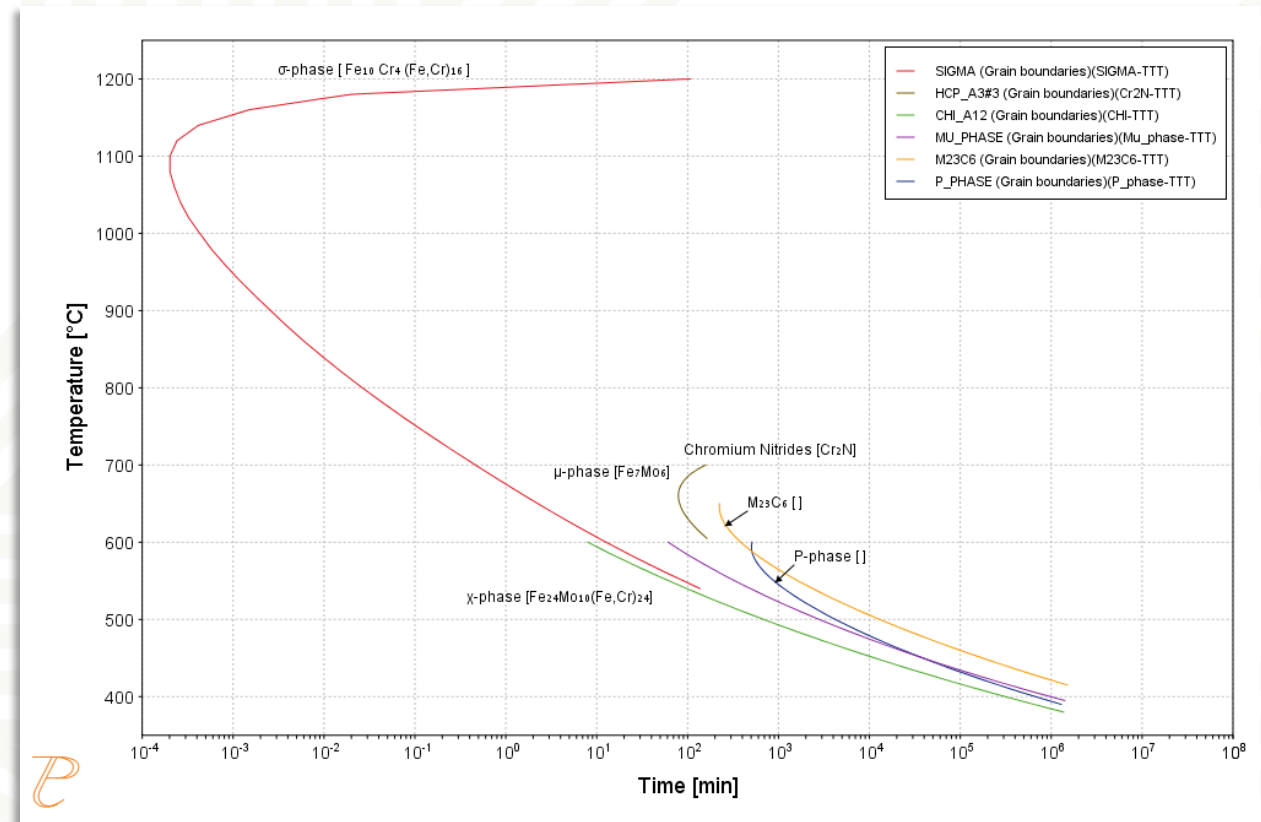
High-Temperature Exposure




Precipitation of undesirable phases (Carbides ($M_{23}C_6$), Nitrides (Cr_2N), Intermetallics (χ, σ))

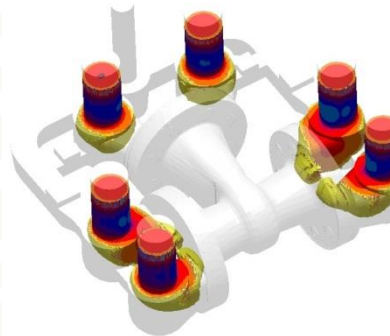
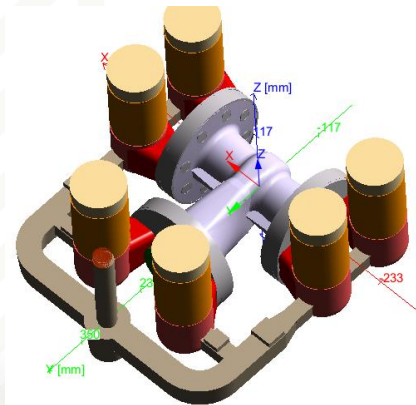


COMSOL Software to predict precipitation of undesirable secondary phases [precipitates]: Carbides ($M_{23}C_6$), Nitrides (Cr_2N), Intermetallics (χ, σ)



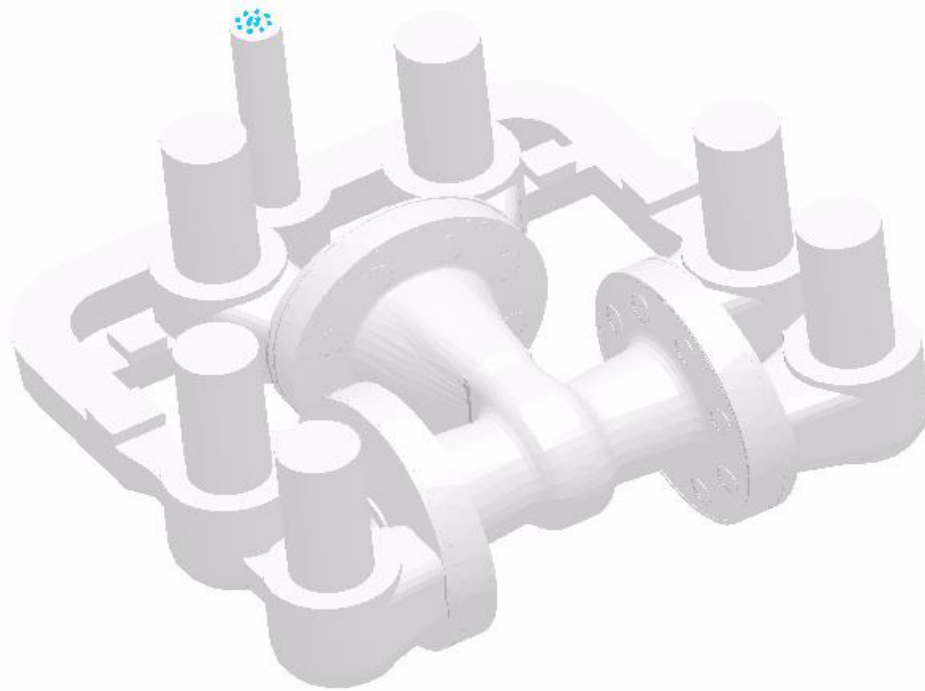
Design-Through Manufacture: Nuclear Spec Gate Valve

- Design of Classes 300 and 2500 Gate Valves (ASME B16.34 standard)
- Casting simulation for design and process optimisation
- Prototype production of patternless casting moulds
- Casting of valve body (first successful trial)
- Quality Inspection (ASTM standards)

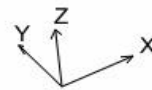
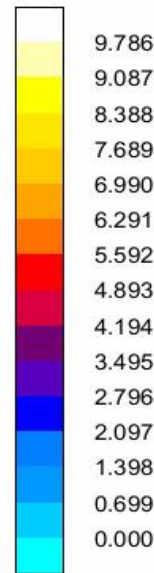


Product Development: Process Optimisation

FLOW TRACE

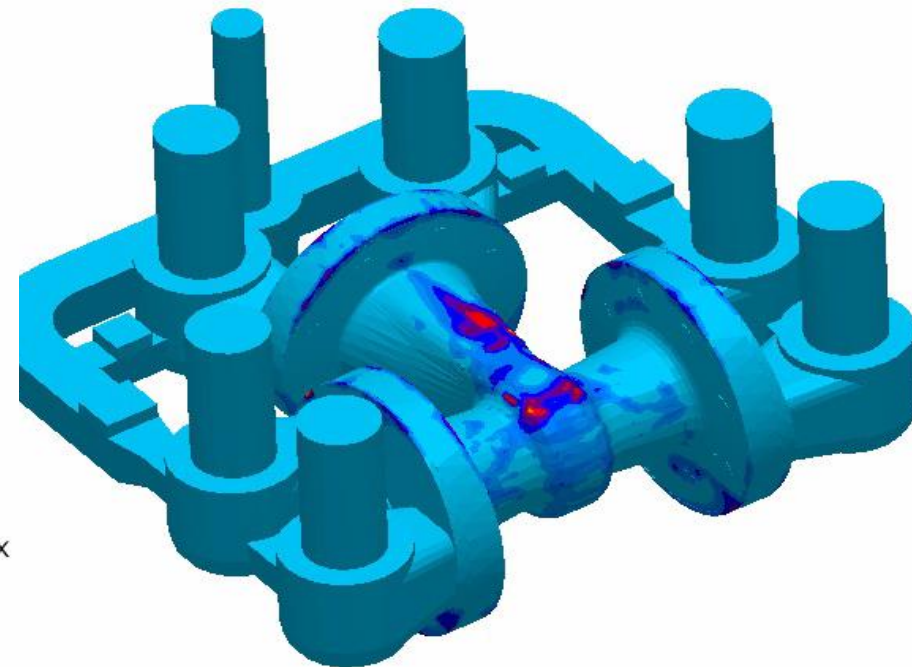


Age
s

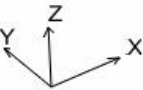
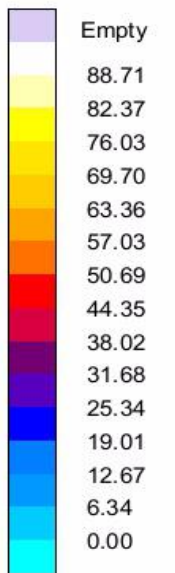




SOLID FRACTION



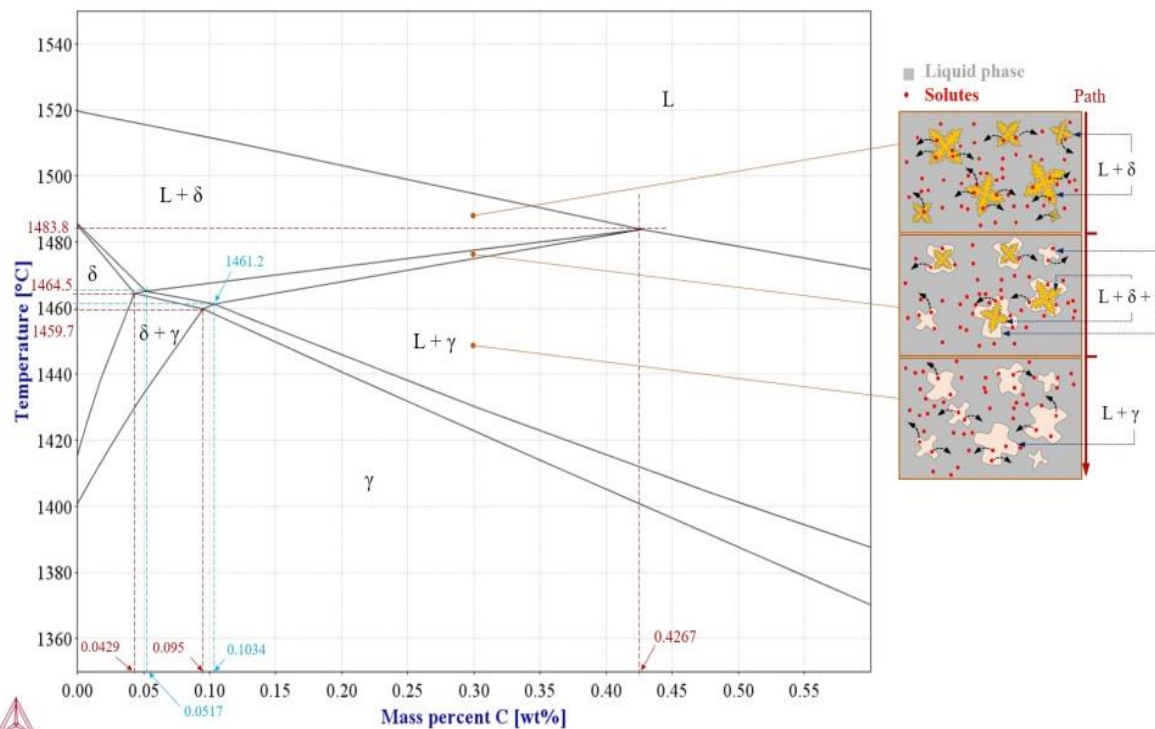
Fraction Solid
%



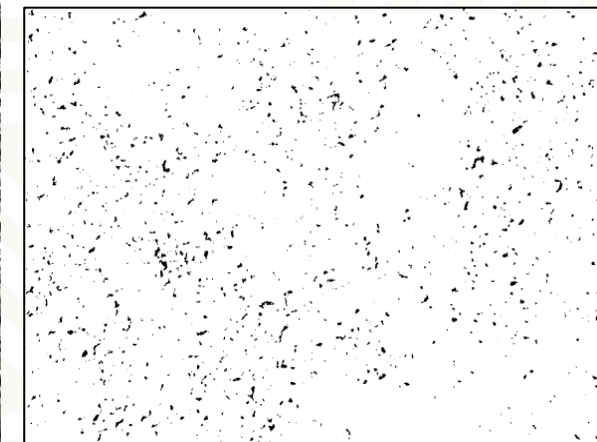
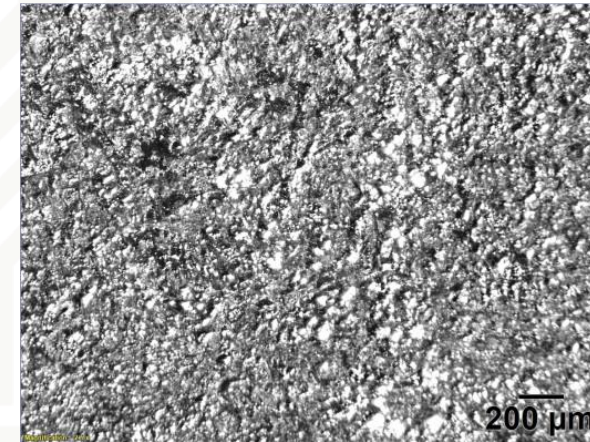


Material Integrity: Pre and Post-Cast Analysis

Thermo-Calc for phase transition analysis
A216 WCB (Peritectic) steel (freezing range
from $T_l = 1495^\circ\text{C}$ to $T_s = 1430^\circ\text{C}$)

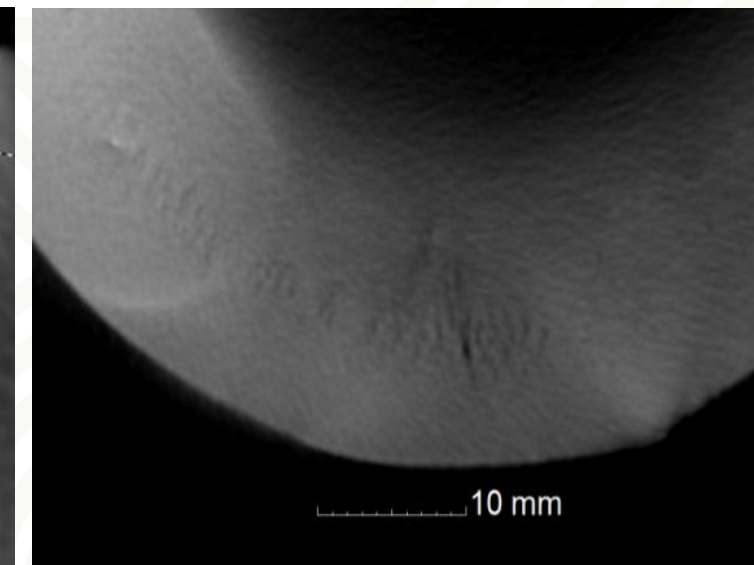
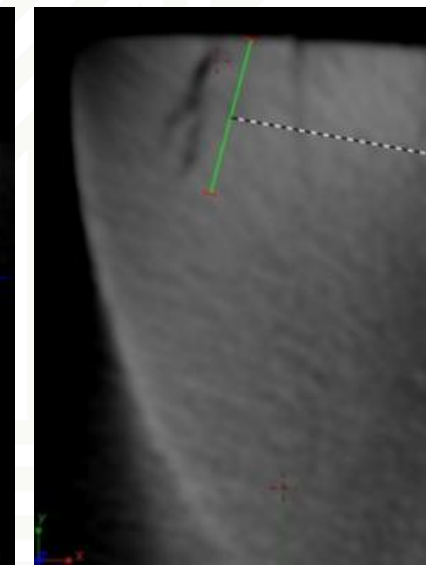
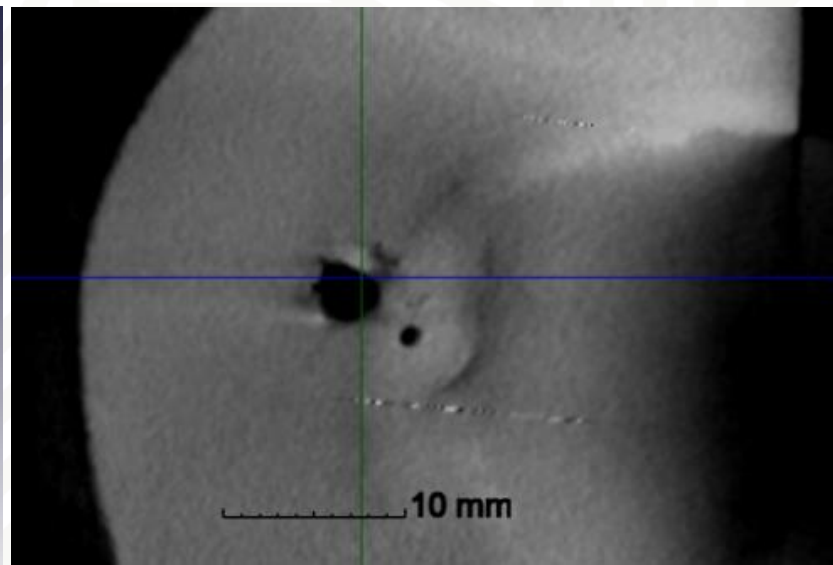
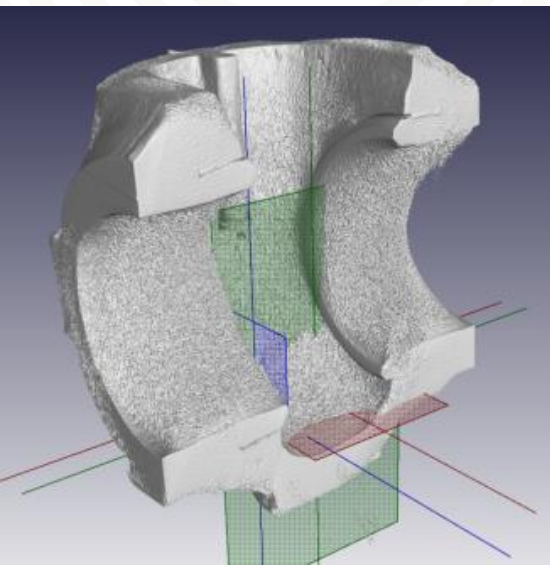


Optical Microscopy of an A216 WCB cast steel sample (left) and the contrasted image showing the micro-shrinkage porosity (right).



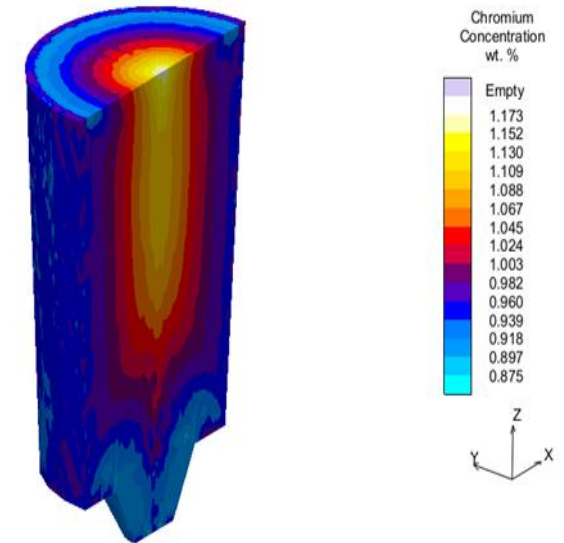
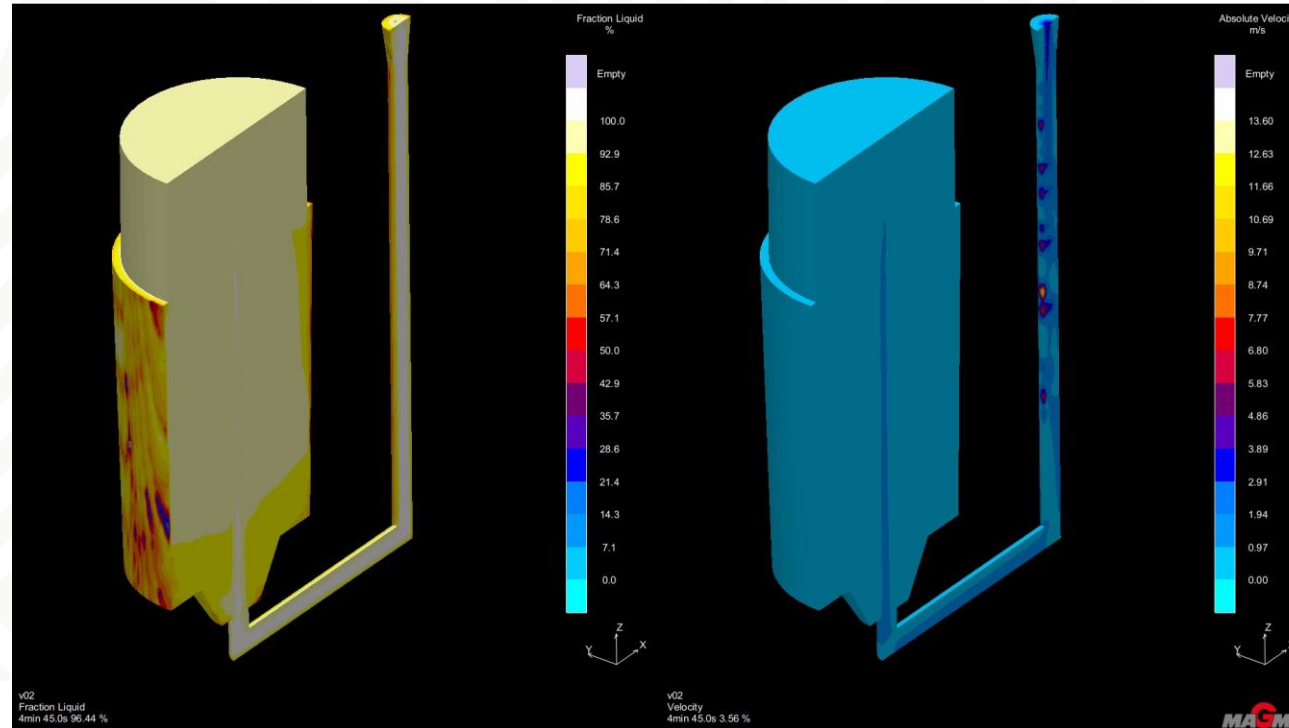
Post-Cast Inspection: CT Scanning

- Formation of macro shrinkage pores due to hotspot (left) and hot tearing / cold cracking (centre).
- layered macro shrinkage porosity due to a hotspot (Right)



Industry Project: Macrosegregation in Large Rotor Casting

- 250 ton ingot casting for power generation rotor
- Severe segregation experienced, leading to unpredictable performance
- Aim: Investigate the effect of various casting parameters on the degree of segregation.



Industry Project: Characterisation of steel plate for the fabrication of pipe fittings for water distribution

- Failure of large, locally fabricated pipe fittings for bulk water distribution networks.
- Crack initiation and propagation near welded flange.
- Material grade was changed from international standard to local grade.



In Conclusion

AIM: To promote cooperation with Tier 1 and 2 suppliers through collaboration Projects on Product Design, Design Analysis in accordance with Standards (ASME, DIN, etc.), Materials Selection, Materials Testing and Qualification, Prototype Test & Evaluation (Destructive and non-destructive).

PROJECT TYPES:

- Short term (300 hour) final-year student projects
- Longer-term Masters projects aimed at R&D and Innovation

BENEFITS:

- Mutually beneficial in giving students an opportunity to work on real industrial projects
- Access to University test and design facilities
- Close liaison between company and university personnel – technology transfer.
- Confidentially within contractual agreements in the case of commercial assignments.

Thank you
Enkosi
Dankie



Photo by Stefan Els