Next Generation HPGQ Simulation

SYNERGY CENTER
ECM DEVELOPMENT LAB

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VACUUM FURNACES

OVERVIEW

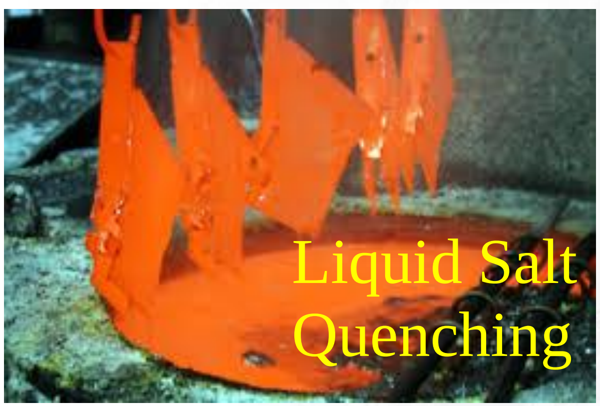
1. Why do a simulation that integrates parts and load design into a gas quench?
   1. History of quenching
   2. How are parts evaluated today ?
   3. Which parameters have the biggest impact in heat treatment ?
2. Integration of simulation software
3. Data
4. Next step
5. Conclusion

Heat treat + History of quenching

Older

Newer

AVL FIRE SOFTWARE



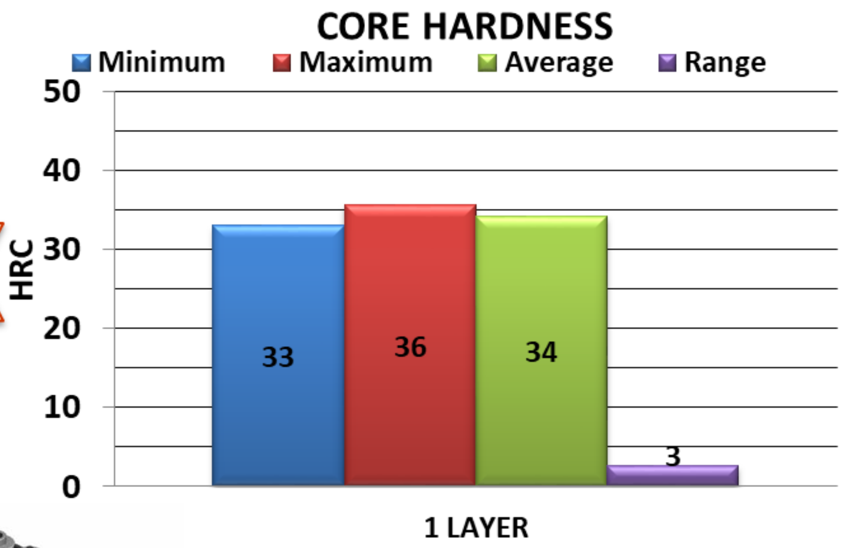
Current HPGQ development steps

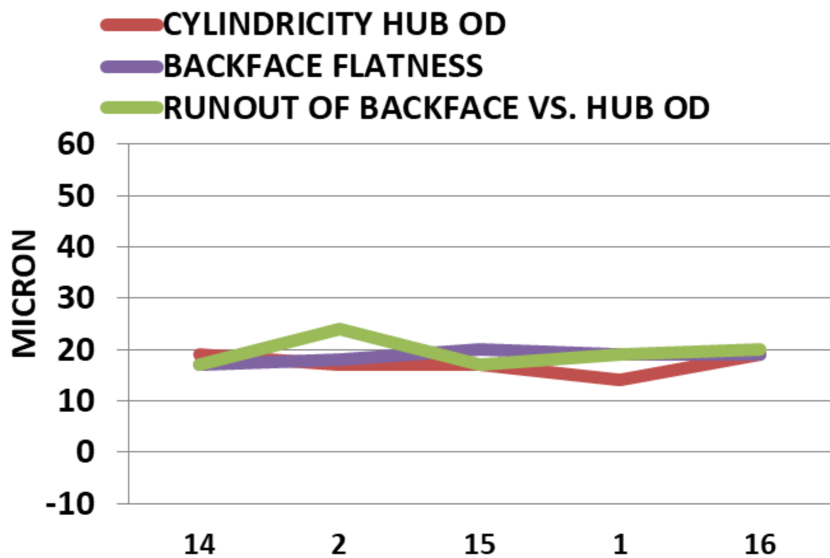
- Identify metallurgical needs
- Configure a test load for heat treat with thermal ballast + green part mix
- Execute a quench
- Examine parts for conformity to specifications

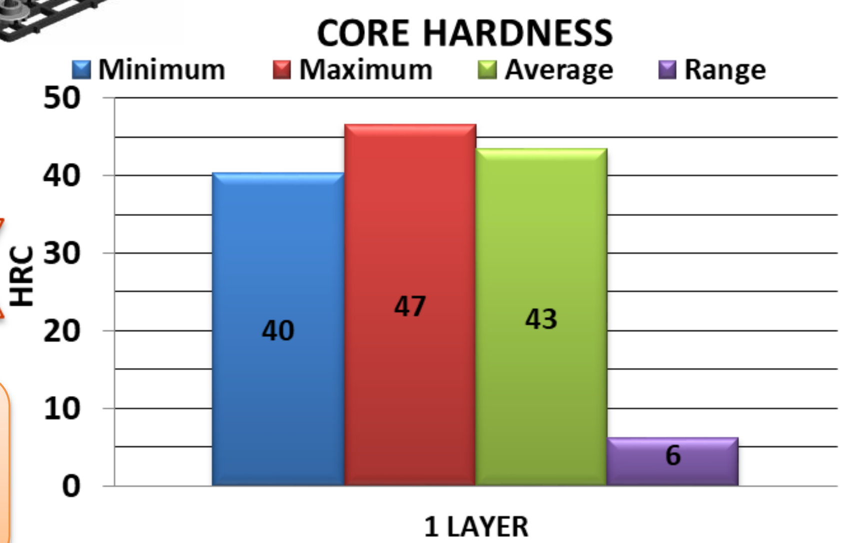
HARDNESS / DISTORTION : NANO LOAD

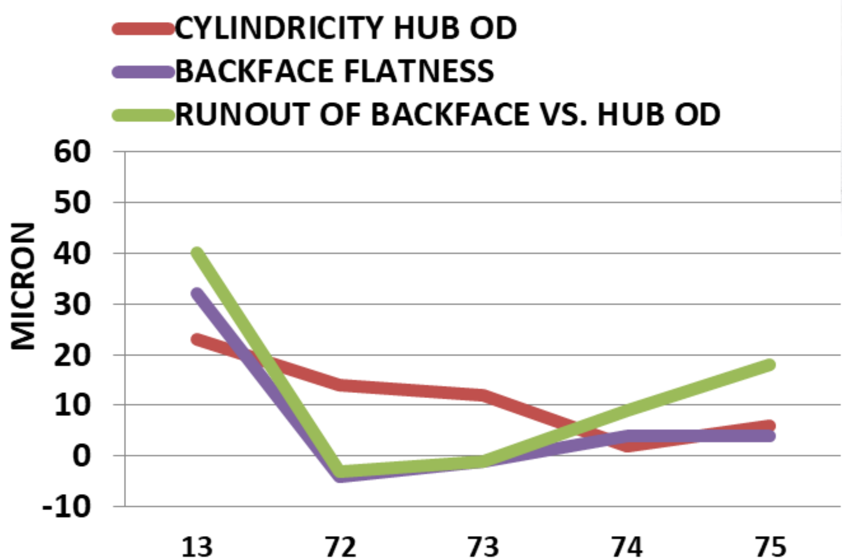
3000 RPM

10 BAR







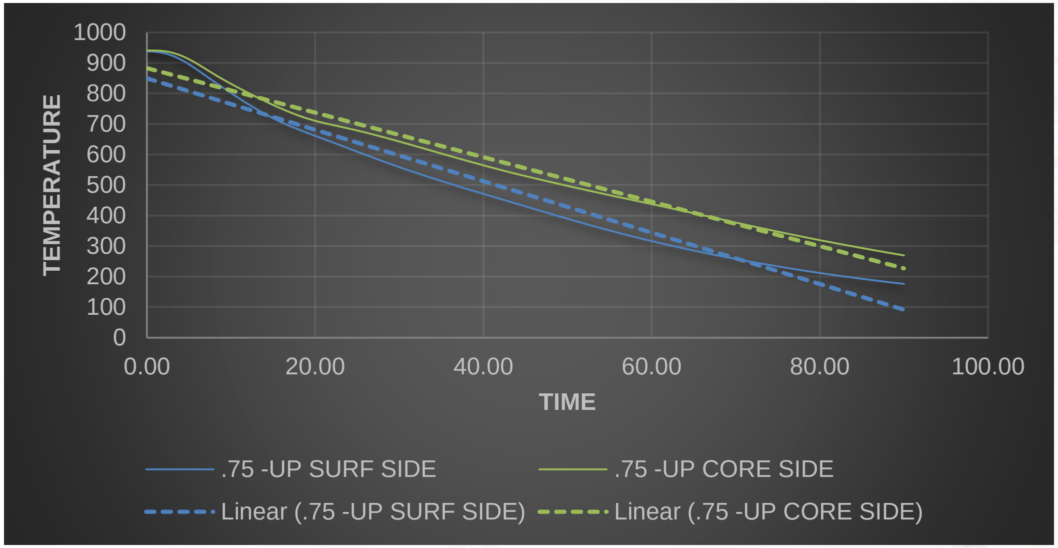


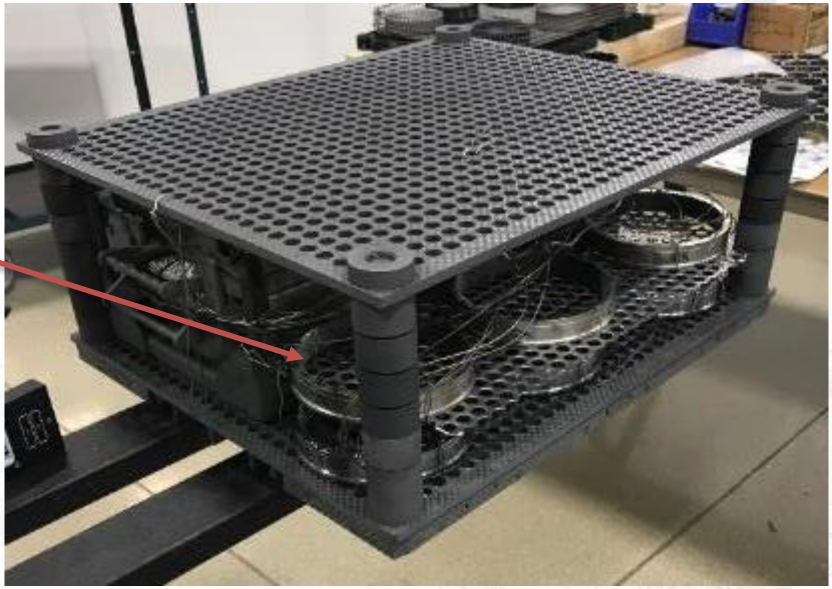
20 BAR

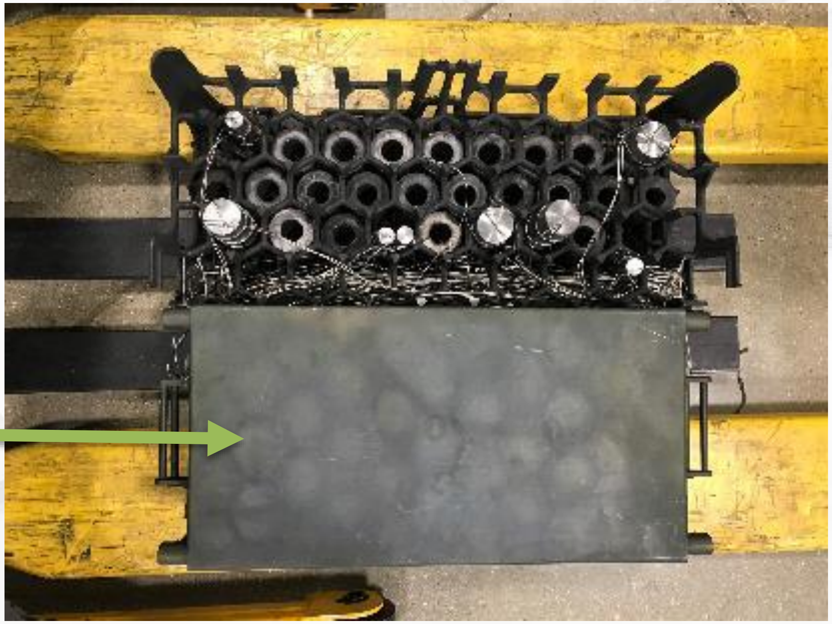
3600 RPM

Current HPGQ development steps cont.

Multiple TC Locations per part







Not a “real” load due to thermal barrier

WHICH PARAMETERS ARE IMPORTANT FOR THE HEAT TREATMENT RESULTS ?

FAST COOLING SPEED → **HIGH PRESSURE *OR/AND* HIGH RPM** → **HEAT TREAT RESULTS** → **HIGHER CORE HARDNESS**, **NOT UNIFORMED DISTORTION**

SLOW COOLING SPEED → **LOW PRESSURE *OR/AND* LOW RPM** → **HEAT TREAT RESULTS** → **LOW CORE HARDNESS**, **LOW DISTORTION**

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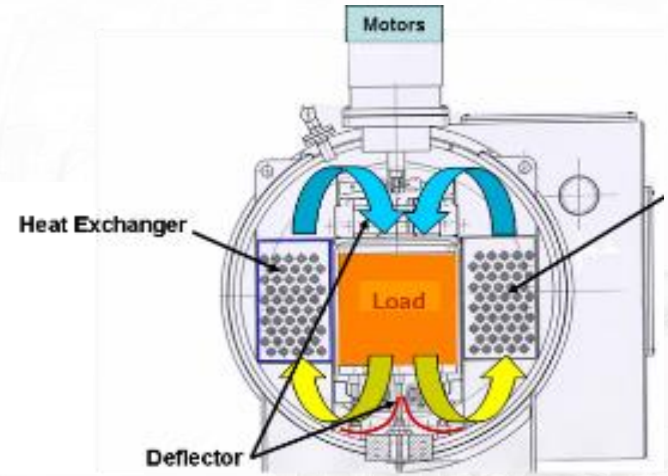
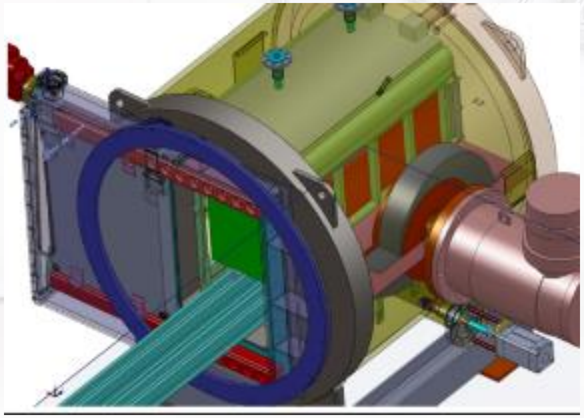
ECM TECHNOLOGIES

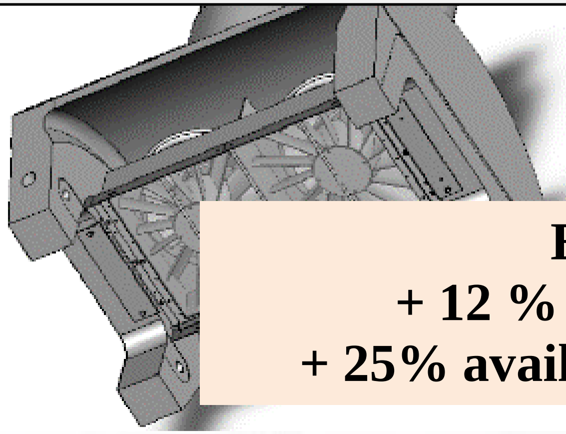
Constant Evolution of Horizontal ICBP		
1992 ICBP VERTICAL	Gas Quench Single Flow 1 TURBINE	Helicoid turbines
1998 ICBP HORIZONTAL	Gas Quench Single Flow 2 TURBINES	Helicoid turbines
2004 Single Flow	2 FIMA Turbines, Motor Power 130 kW (N2)	Helicoid turbines
2012 Single Flow	2 ENSAM Turbines Motor Power 160 kW	Helicoid turbines
2010 : REVERSE	2 TURBINES Gas Quench Reverse Flows	Centrifugal turbine
2012 : REVERSE	Centrifugal Turbines for Helium, Motor Power 130 kW	Centrifugal turbine
2015 : REVERSE	Centrifugal Turbines, Motor Power 250 kW (N2) : Highest Powered Gas Quench in Production today	Centrifugal turbine
2015 : NANO Furnace	1 TURBINE Motor Power 130 kW : small load design to integrate production line part to part : 600 x 500 x 250 mm	Helicoid turbines

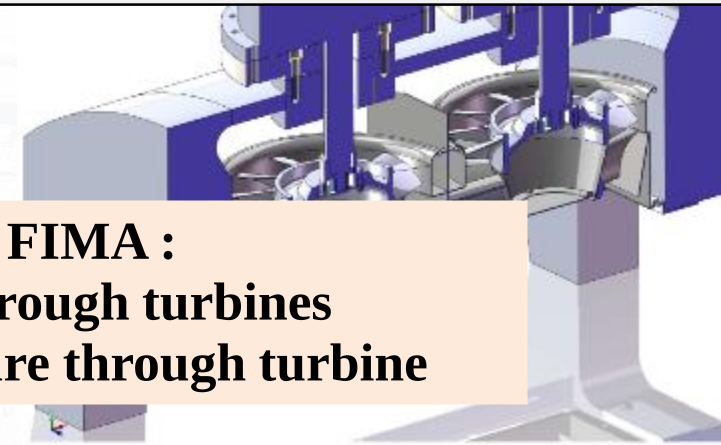




EVOLUTION OF ELEMENT OF GAS QUENCH CELL

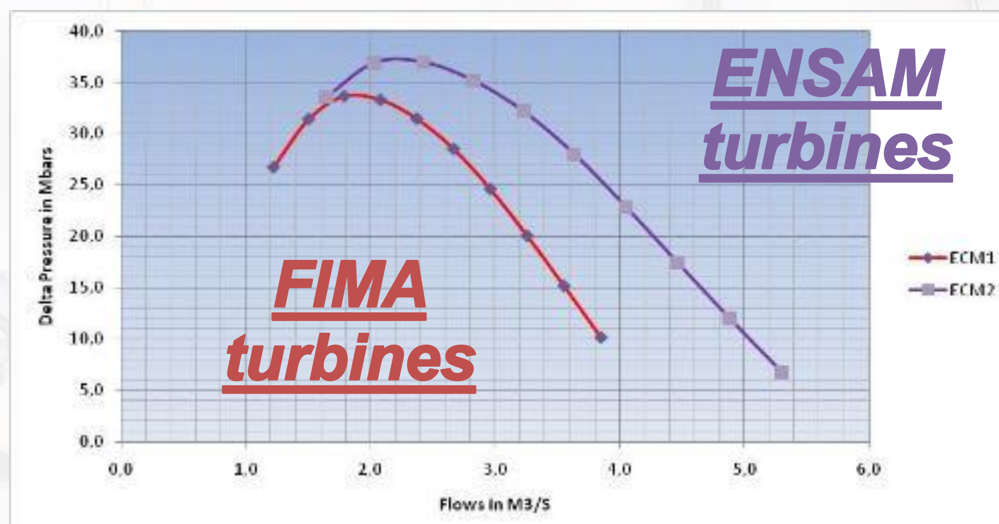
FIMA	ENSAM



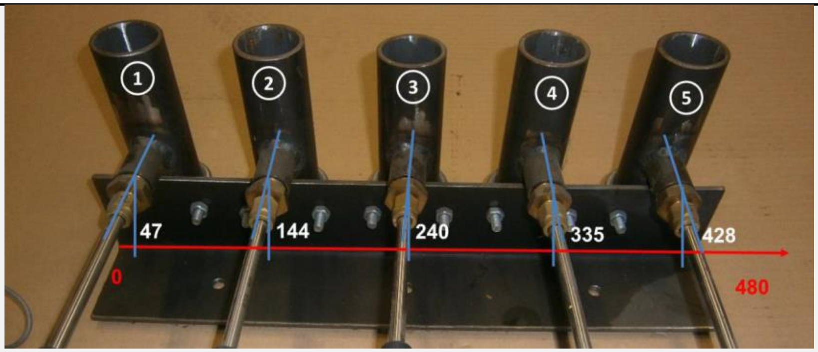


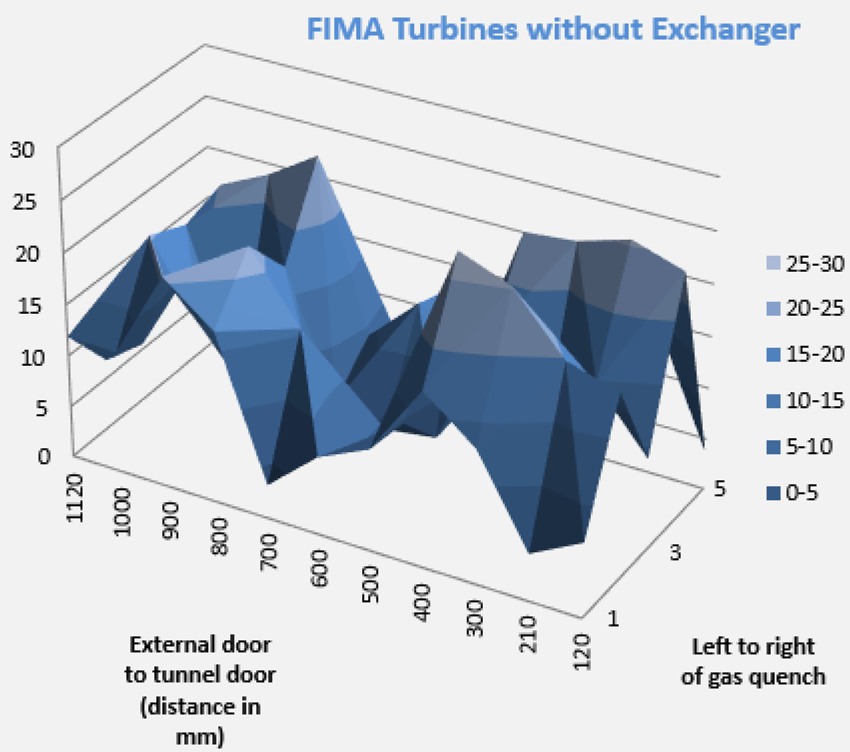
ENSAM vs. FIMA :
+ 12 % gas flow through turbines
+ 25% available pressure through turbine

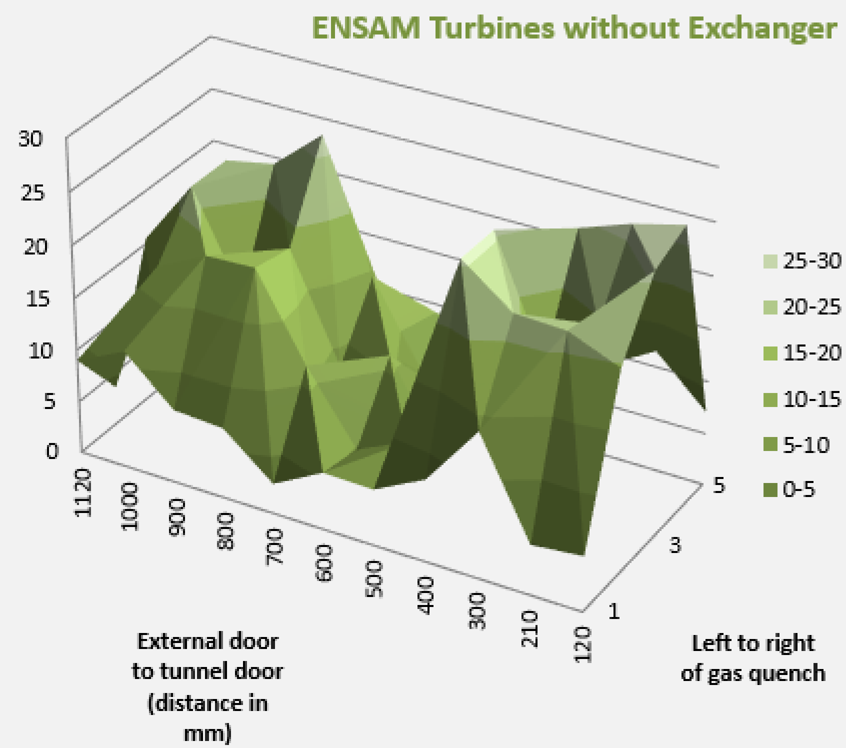
Partnership with customers and aerospace institute :
- 3D modeling of gas quench
- Simulation of velocity through chamber



VELOCITY MESUREMENT



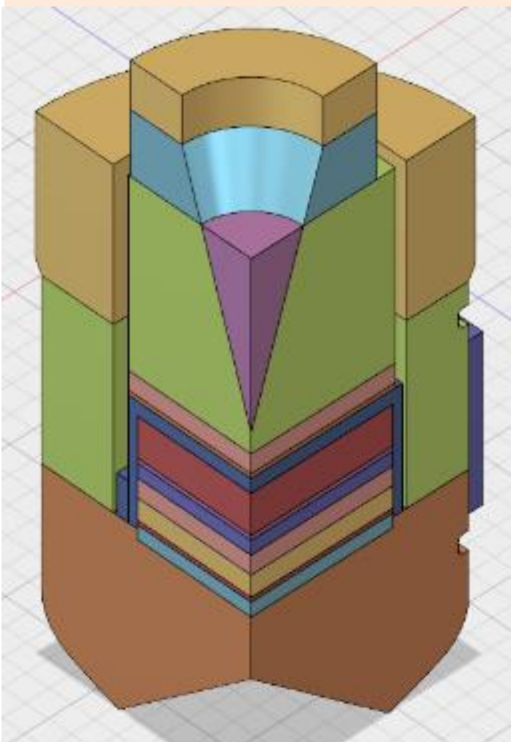


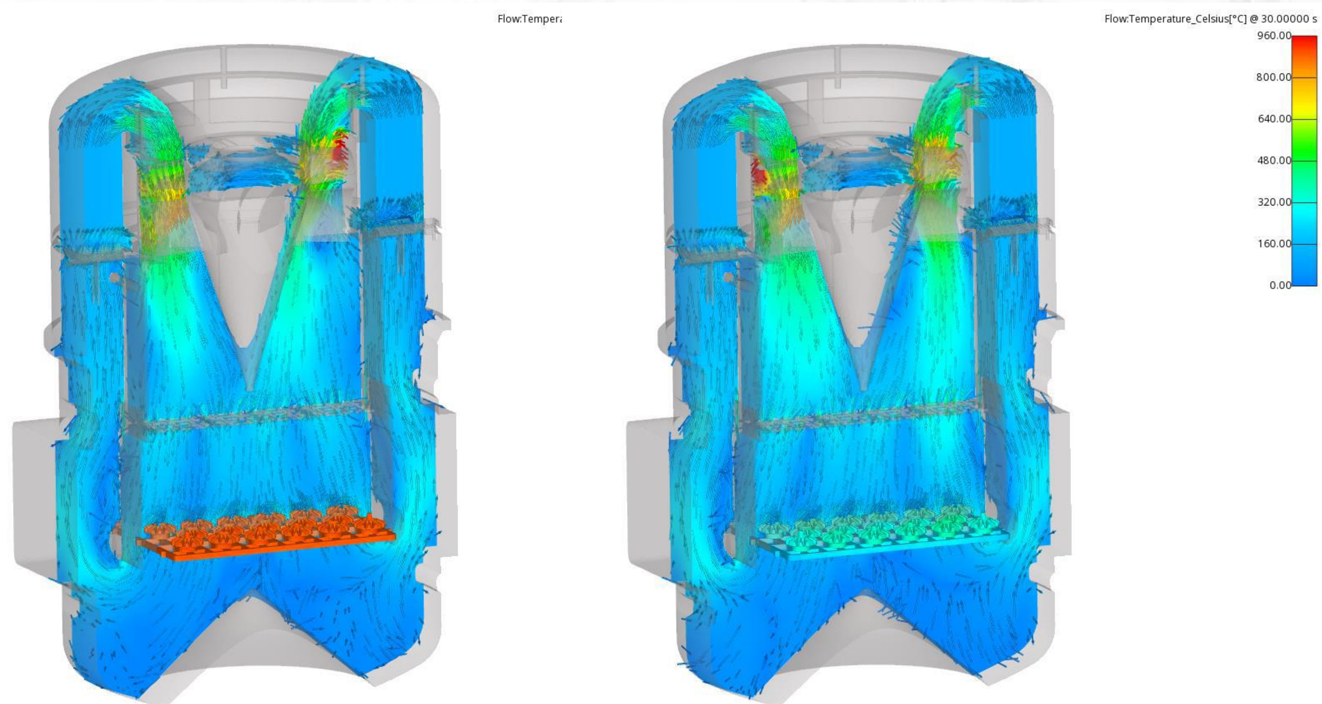


NANO GAS QUENCH CELL : INTEGRATION

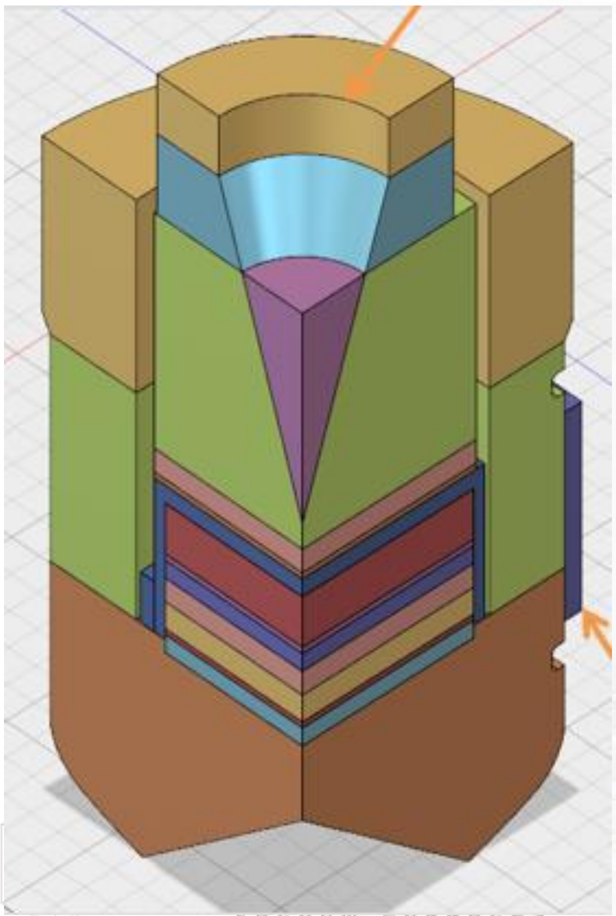
- 1 STEP FURTHER : <u>AVL SOFTWARE</u> ADDITION

= INTEGRATION OF LOAD & PART DESIGNS

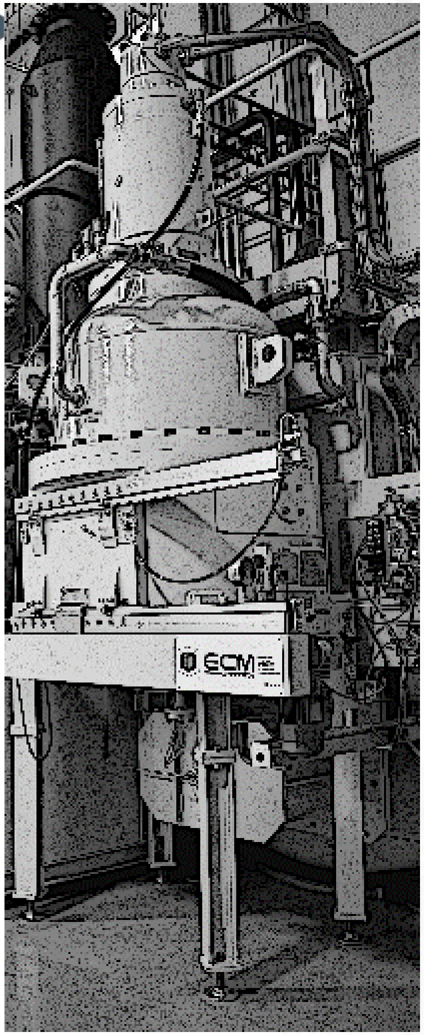




Goals in this study



- Understand impacts of part orientation on Quench Effectiveness
- Verify CFD efficacy in metallurgical testing
- Test many configurations rapidly (when compared to traditional methods)



Known Data points of quench cell

Parameter	Value
Calculated heat of exchanger in quench cell	197 kW
Pressure drop across heat exchanger	0.2bar @ 20 bar pressure
Thermal conductivity of gears	46.6 W/mK
Thermal conductivity of HT fixtures	79.2 W/mK
Initial temperature of parts/fixtures to be quenched	930°C

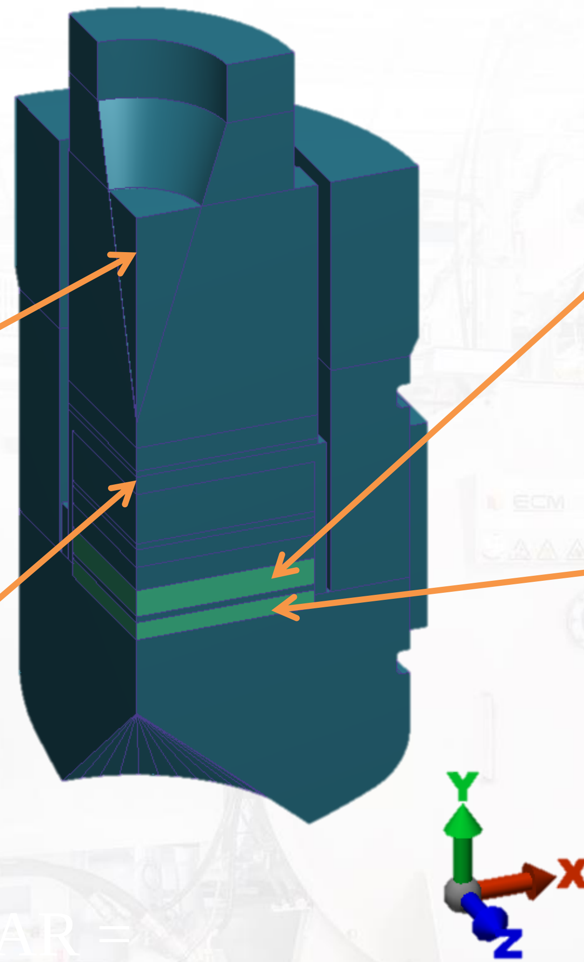
Materials in Nano Quench Development

Default material:
10 bar pressurized N_2

Other materials are distributed resistance characterized either by their FAR or the induced pressure drop

Either N_2 or part suppressed (cone)

Either N_2 or homogenization grid inducing a pressure drop of roughly 20 mbar

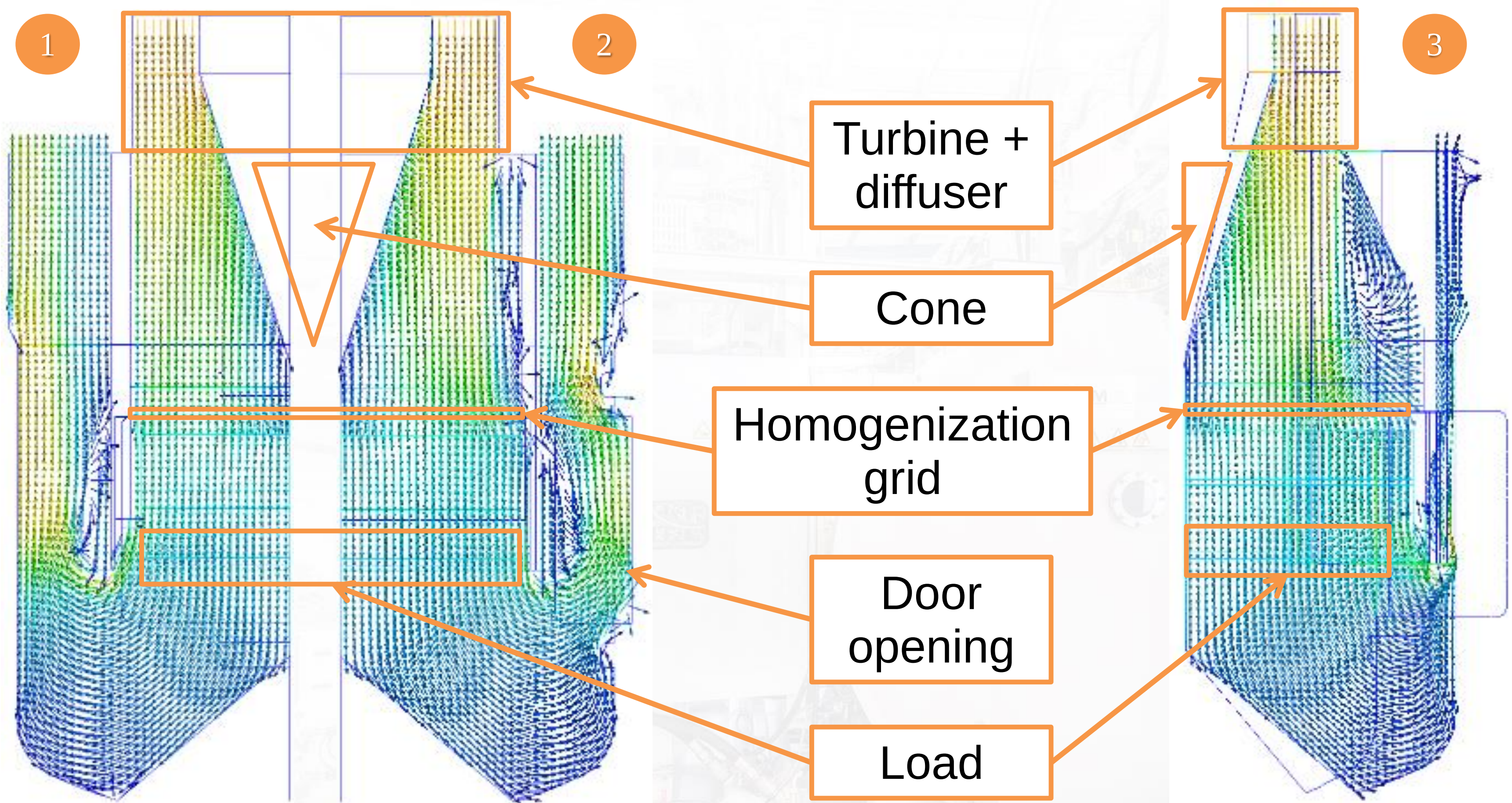


Load (1 level)
FARx = 0.75
FARy = 0.75
FARz = 0.75

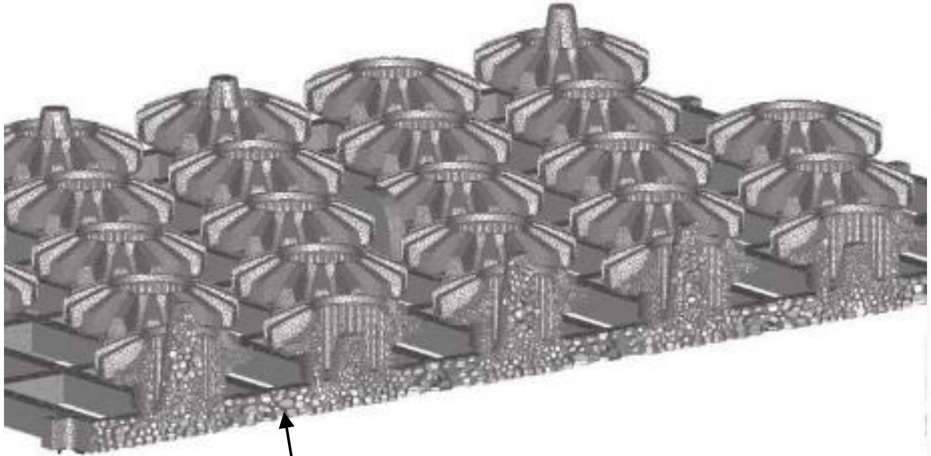
Load support (grid)
FARx = 0.05
FARy = 0.9
FARz = 0.05

Final Cell Design: grid + cone

Flow



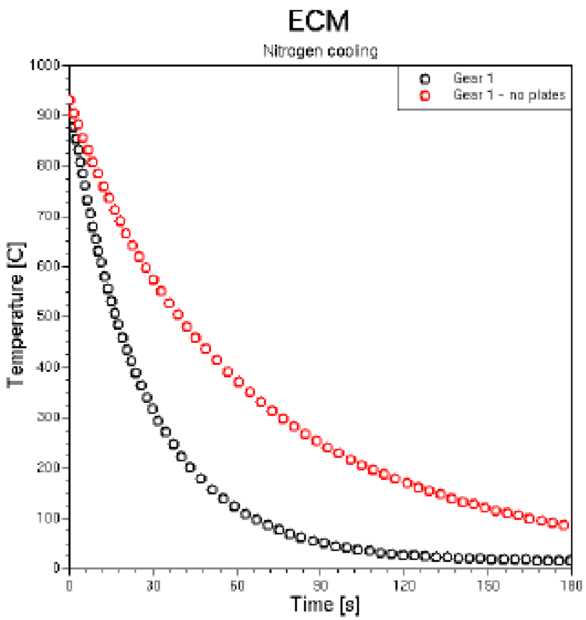
Simulation Test Parameters

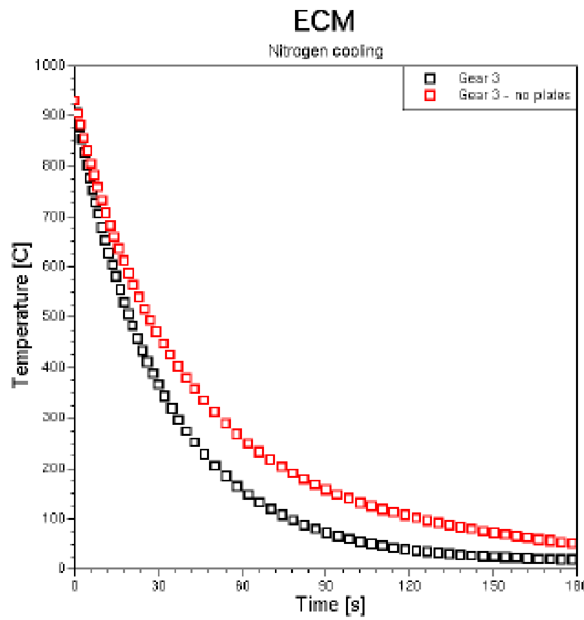


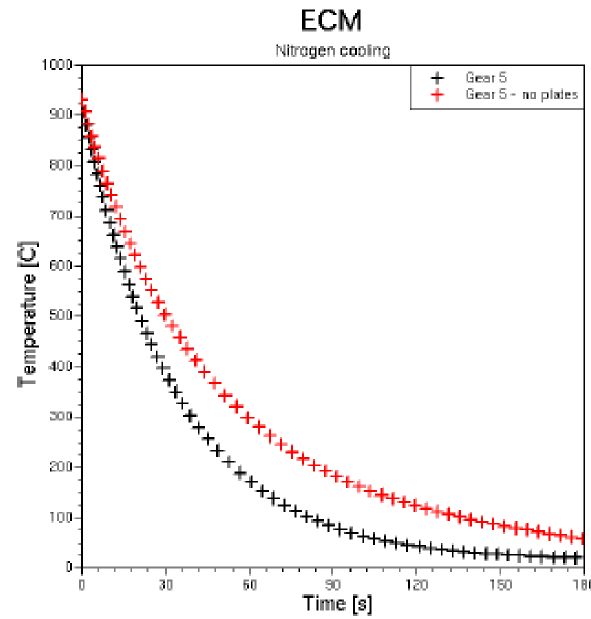
Individual element

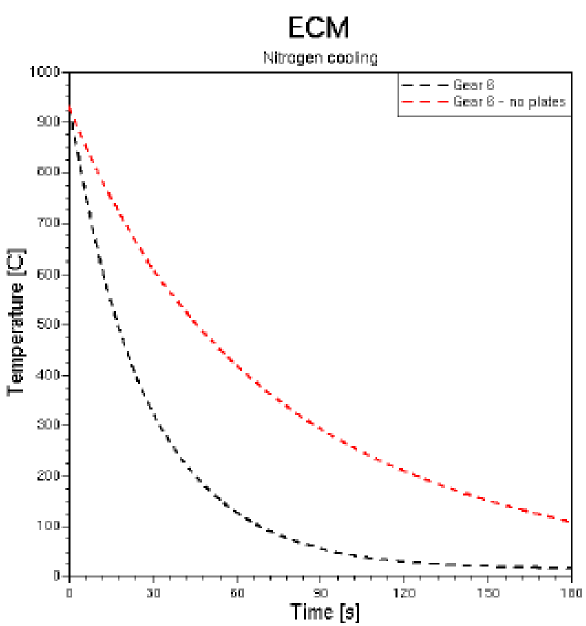
Parameter	Value
Cell Type	Polyhedral
Total number of Mesh Elements	8.3 Million [largely concentrated in parts]
Simulation time on 100 CPU set up	86 hours
Cluster Nodes	Intel Xeon CPU E5-2680 v3
Simulation time	0 – 180 seconds
Coolant Medium	Nitrogen [N_2]
Pressure of coolant medium	20 bar [290.07 psi]
Initial Temperature of quench medium	30°C
Number of DOE gears simulated	28

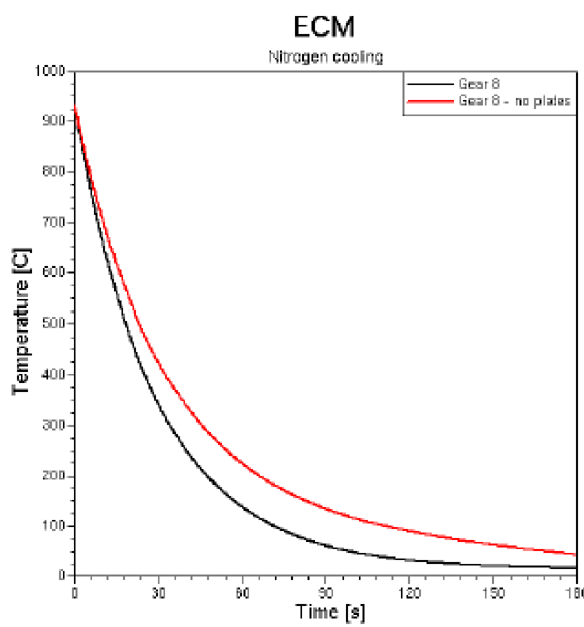
Results Summary of first run





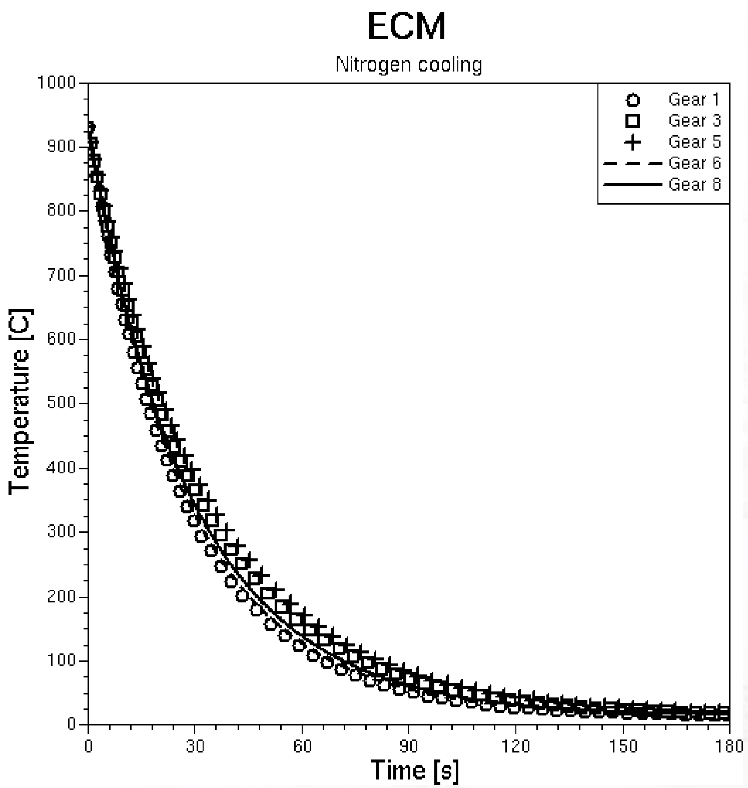






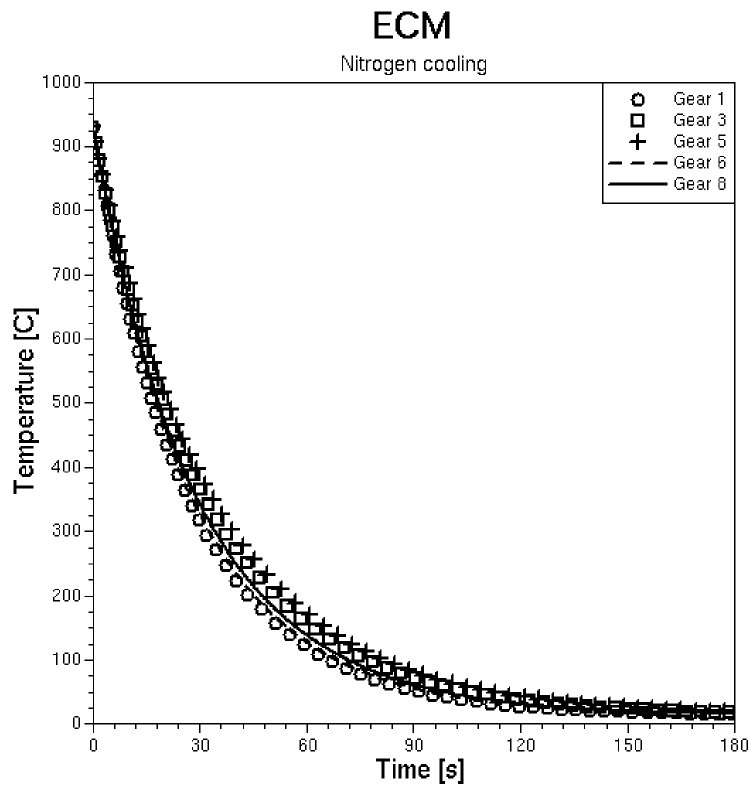
Nitrogen cooling process – with and without cooling box

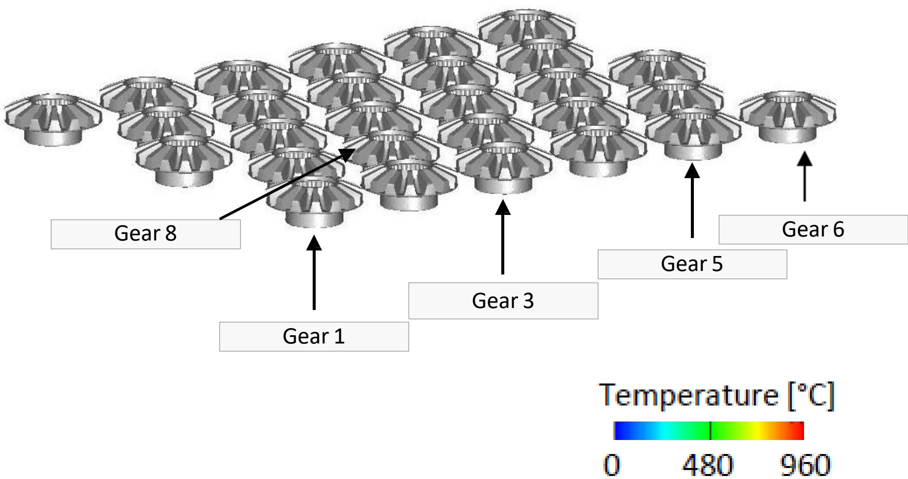
Results Summary of Second Run



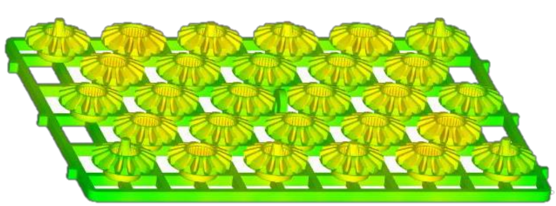
Time for load to cross Ac3	2.8 seconds
Max ΔT part/part	70°C
Max ΔT part/fixtures	210°C
Time for load to cross Ms	24.5 seconds

NITROGEN COOLING PROCESS
COOLING HISTORY PLOT – GEARS

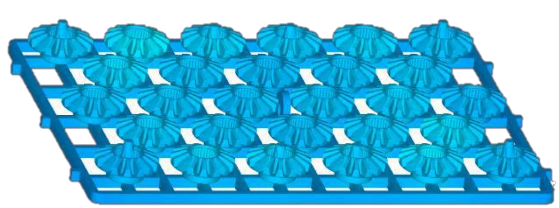




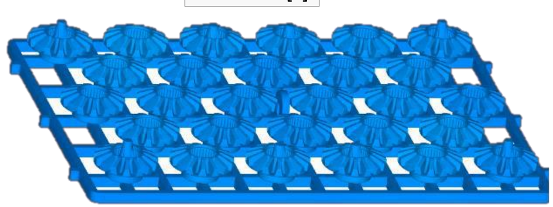
Time: 10 [s]



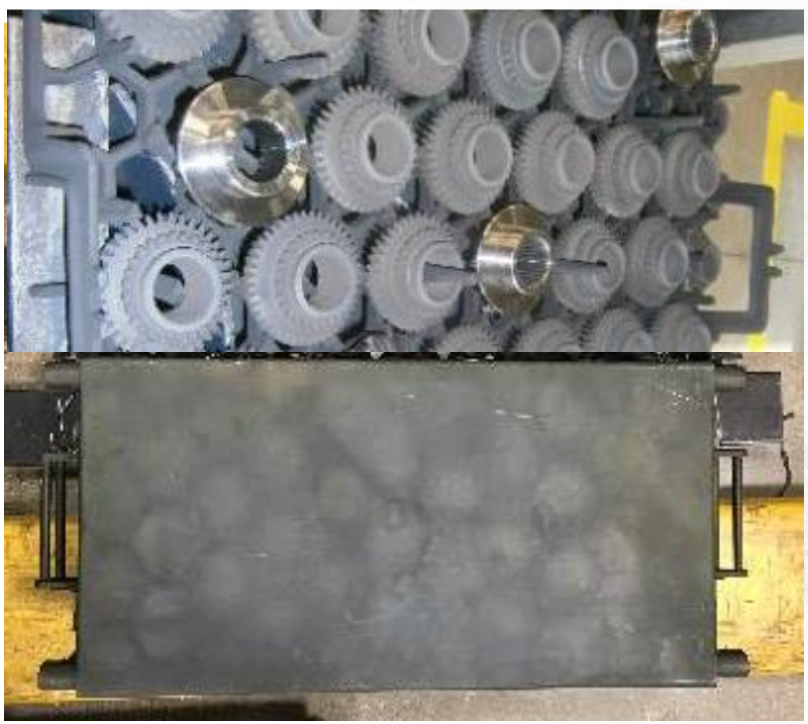
Time: 50 [s]



Time:100[s]



- Additional simulations with thermal barrier + alternate part orientations
- Physical load to replicate second simulation
- Direct comparison of results



In house simulation goals

- Rapid iterations of customer parts and orientations
- Complex modeling of changes to gas quench cell geometry
- Multiple common material comparisons with a thermal barrier/data recorder

conclusions

Simulating parts in a gas quenching environment saves skilled work time.

Additionally:

- It allows for rapid iteration of load designs to test for quench impact
- It saves money in the form of parts and labor
- It allows for testing and development with theoretical parts/fixtures. Metallurgy time travel!

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Questions?

Thank you for attending.