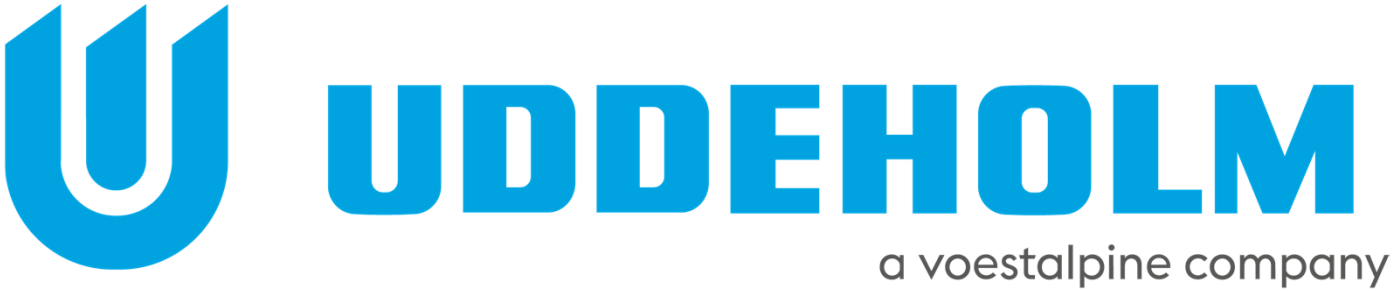
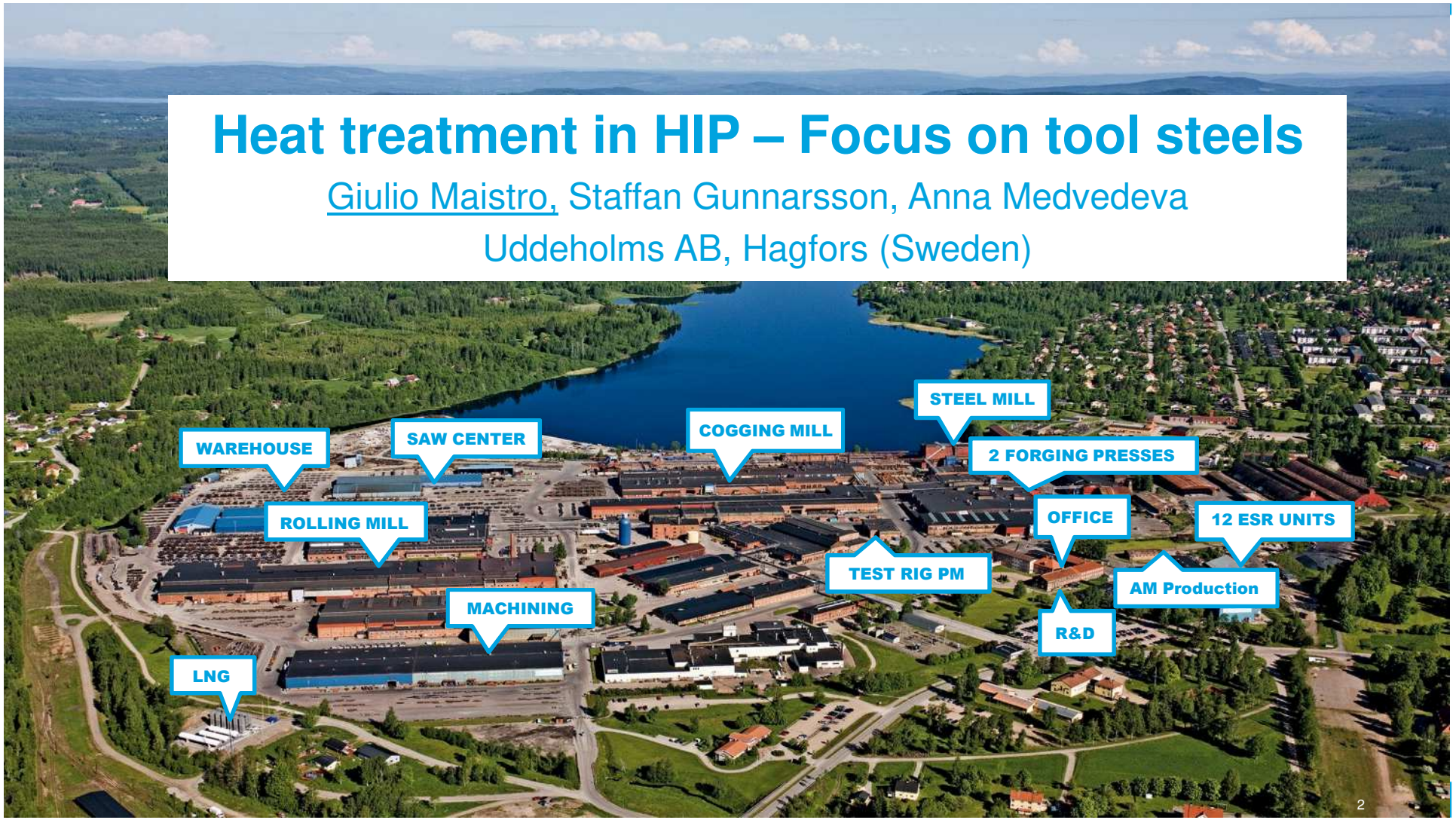

UDDEHOLM
a voestalpine company

Heat treatment in HIP – Focus on tool steels

Giulio Maistro, Staffan Gunnarsson, Anna Medvedeva
Uddeholms AB, Hagfors (Sweden)



OUTLINE

- ✓ Why heat-treatment in HIP?
- ✓ Background information on HIP-URQ
- ✓ Possibilities and limitations
- ✓ HIP-URQ in Uddeholm
- ✓ Preliminary results and new results (AM)
- ✓ Conclusions

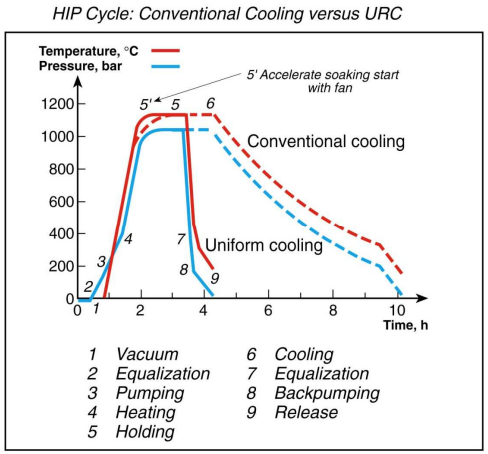
WHY HEAT TREATMENT IN HIP?

- Tool steels typically require austenitization & tempering/aging

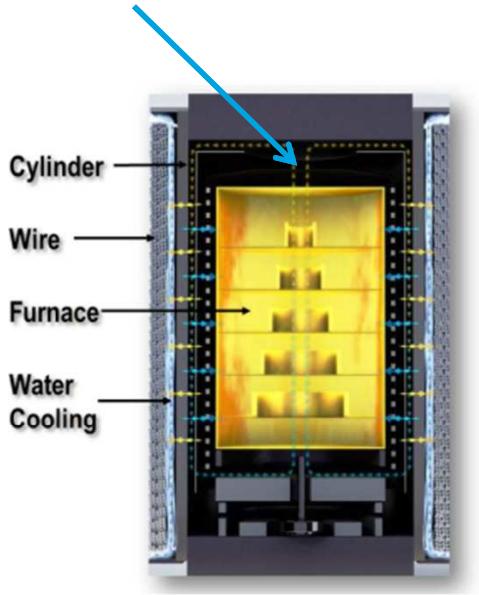
- Faster cooling gives better material properties
  - Possible to achieve fast cooling without deformation/cracking?
- Reduce heat-treatment cycle time
  - Higher productivity?
- Delay phase transformations in the material – decrease alloy content
  - New alloy-concepts?
- In-situ nitriding?

HIP-URC/Q: HOW DOES IT WORK?

- Ultra Rapid Cooling: URC
- Designed to reduce cycle time
- Uniform Rapid Quenching: URQ
- Designed for in-situ heat-treatment:
- Up to ~5000°C/min (~ oil)



URQ: 250kg Al_2O_3 spheres



Images property of Quintus Technologies AB

POTENTIAL BENEFITS AND CASES

High pressure gas has several effects

- Better heat transfer between component and gas (= faster cooling)
- Reduction of distortion/risk of cracking
- Change in kinetic of phase transformations

  Increased hardenability!
- HPGQ : ~ 12bar
- URQ: ~ 1700bar

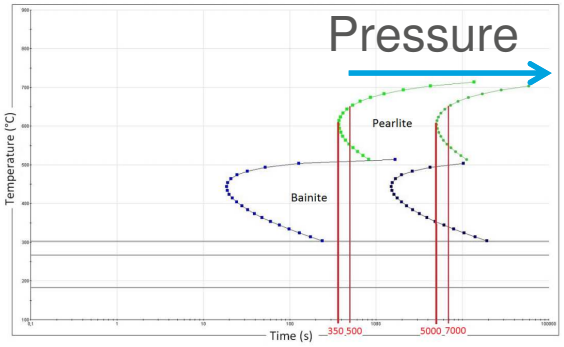
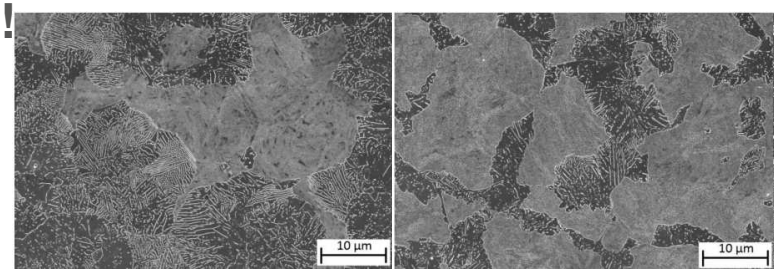
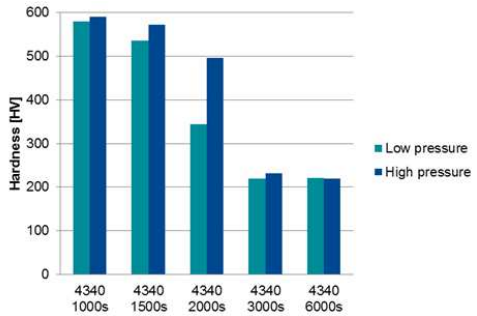


Figure 4. TTT diagram for 4340 with grain size 15 µm, calculated using JMatPro. 0.1% pearlite at 500 s and 99.9% pearlite at 7000 s at 650 °C.



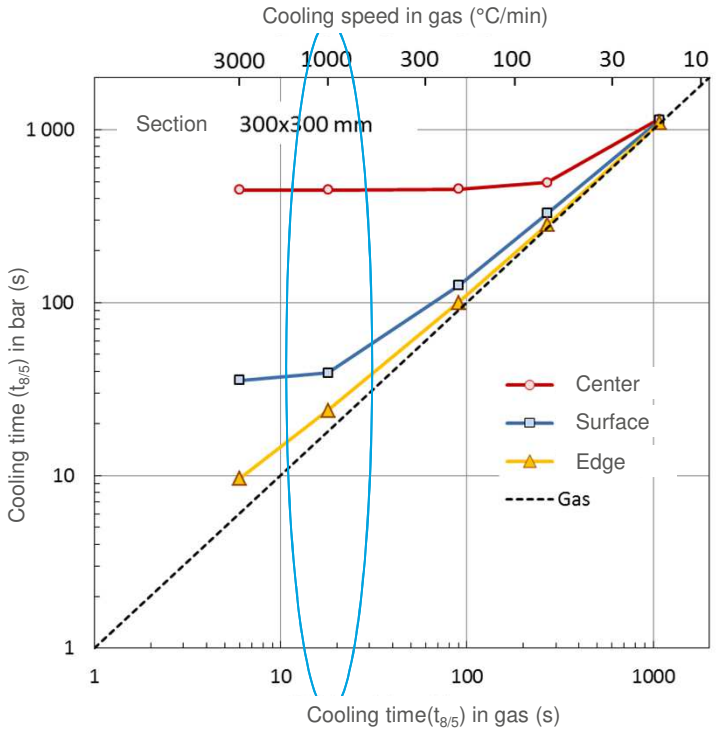


From World PM2016 – A. Angré et al.

LIMITATIONS:HOW BIG CAN WE GO?

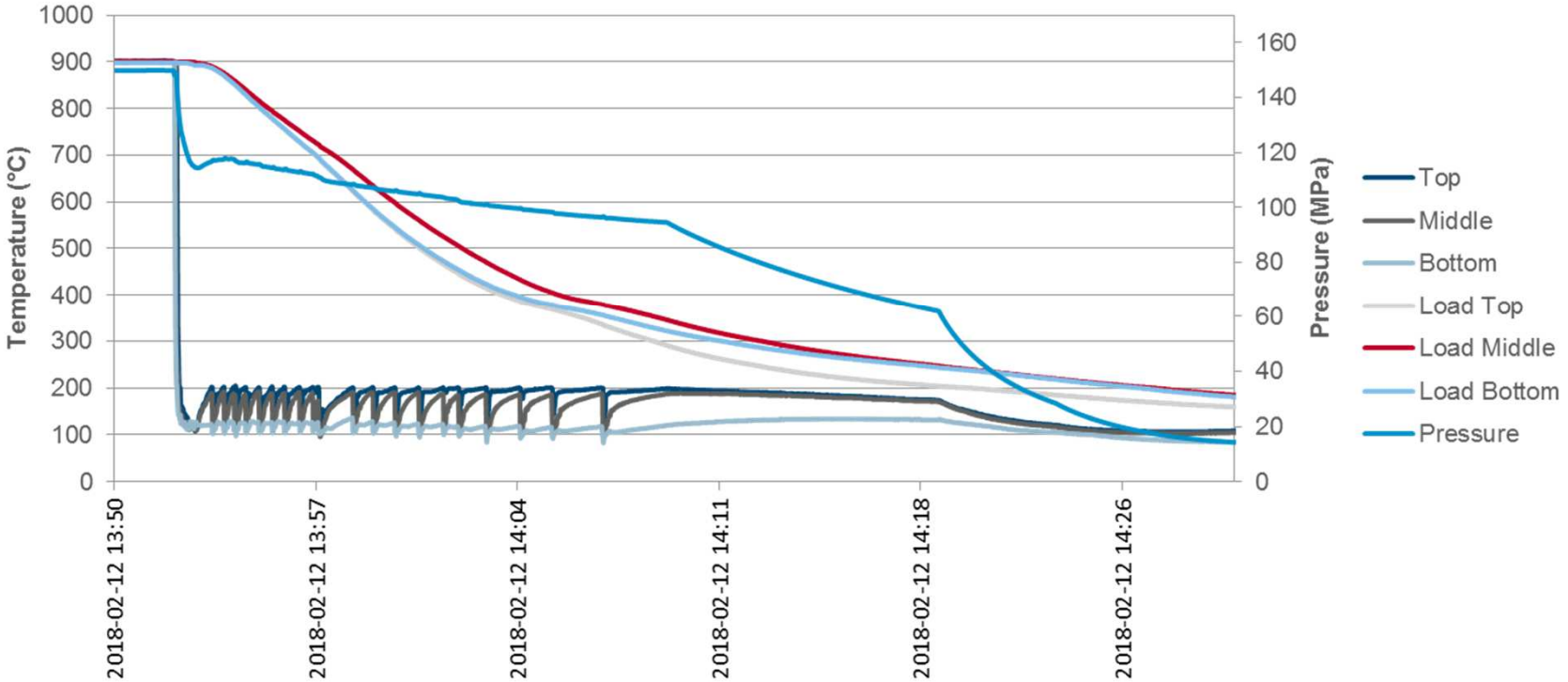
Calculation on H13-type

- For a cross section of 300x300mm, t8/5 ~448s max 41°C/min in the center! (e.g. NADCA for HPDC 28°C/min at the surface!)
- Gas/edge temperature follow the same trend up to very high cooling speeds
- URQ most suitable for medium-small cross sections, maximized cooling speed
- More efficient heat-transfer + increased hardenability -> better properties in the core



VALIDATION

URQ: Stavax (modified 420) 95kg Ø153mm: t8/5 = ~420s, ~43°C/min



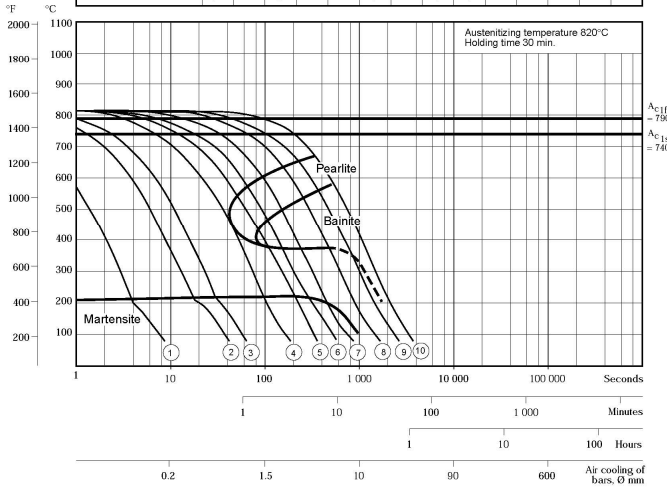
PREVIOUS PRELIMINARY RESULTS

From SHTE 2017 – Staffan Gunnarsson

RESULT FROM TEST WITH UDDEHOLM ARNE

Cooling Curve No.	Hardness HV 10	$t_{800-500}$ (sec)
1	868	1
2	847	6
3	824	10
4	762	28
5	649	56
6	478	90
7	373	140
8	339	280
9	317	450
10	294	630

UDDEHOLM ARNE	C	Si	Mn	P	S	Cr	Mo	V	W	Ni	Co
	0,95		1,1			0,6		0,1	0,6		



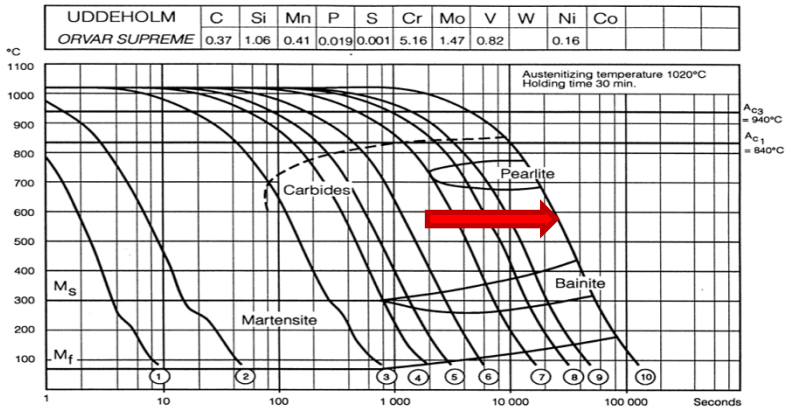
	Hardness Surface, HRC	Hardness Centre, HRC
HIP-URQ	65	65
Vacuum	65	42

The reason for the high hardness is that the hardness was measured before tempering
When a similar component was cooled in oil, we got cracks in the material

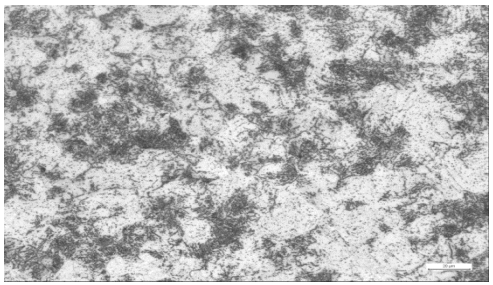
The test showed that it is possible to thru-harden low alloyed steel up to a <u>certain dimension</u> in a HIP with URQ unit

RESULTS OF TESTS WITH ORVAR SUPREME

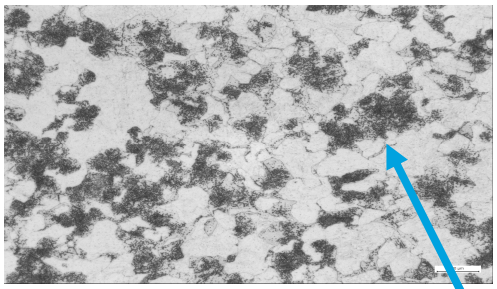
- By utilizing the change in phase transformation kinetics, new alloy concepts and heat treatment procedures can be developed.
- Conducted tests on Uddeholm Orvar Supreme (H13) have shown a delay in pearlite transformation at higher pressure.
- Slower phase transformation kinetics in the Fe-C system.
- High pressure stabilizes austenite
- Delay of Pearlite transformation
- Higher hardness in sample heat treated at a pressure of 1800 bar indicates larger portion of martensite, i.e. the pearlite nose is shifted towards longer times



HIP H.T. done at 750°C, to study the effect of pressure on phase transformation

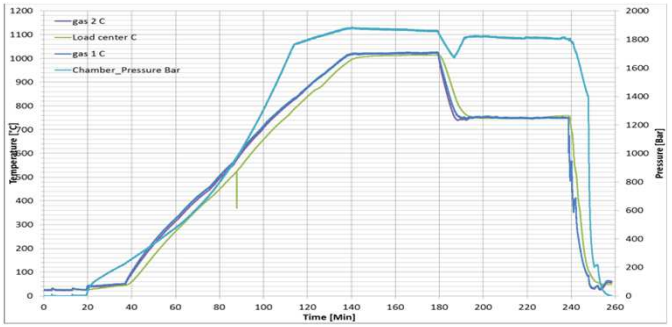


Pressure: 100 bar
Hardness: 223HB



Pressure: 1800 bar
Hardness: 388 HB

Less amount of pearlite (dark)

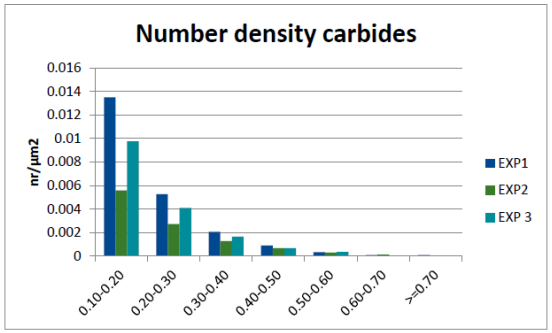


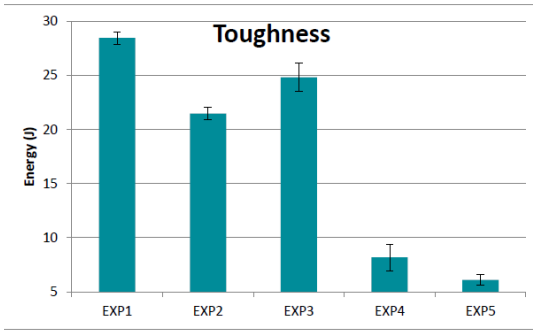
HIP Heat treatment cycle at 1800 bar

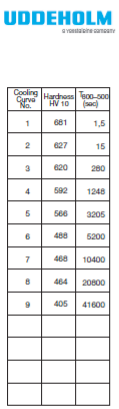
RESULTS OF TESTS WITH DIEVAR

- Effect of high pressure on carbide stability during high-pressure austenitising?
- Effect of pressure on bainitic transformation?

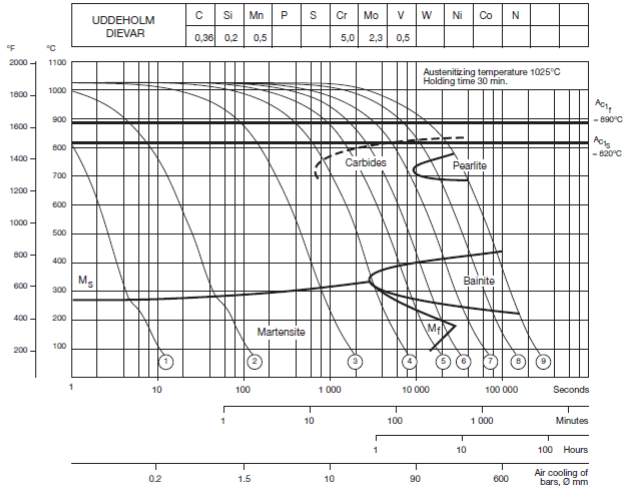
	Austenitizing temperature (°C)	Soaking time (min)	Pressure (MPa)	Type	Holding Time (s)	Holding temperature (°C)	Nr of samples
EXP 1	1020	120	170	Quenching	-	-	6
EXP 2	1020	120	12	Quenching	-	-	6
EXP 3	1020	400	170	Quenching	-	-	6
EXP 4	1010	120	170	Isothermal	10000	300	6
EXP 5	1010	120	12	Isothermal	10000	300	6







Cooling Curve No.	Hardness HV 10	T800-500 (sec)
1	681	1,5
2	627	15
3	620	280
4	592	1248
5	566	3205
6	488	5200
7	468	10400
8	464	20800
9	405	41600



- Stabilization of MC/M2C carbides
- Marginal/doubtful effect on bainite transformation

NEW RESULTS – FOCUS ON AM

From 2018-2019

HIP-CAPABILITIES IN UDDEHOLM

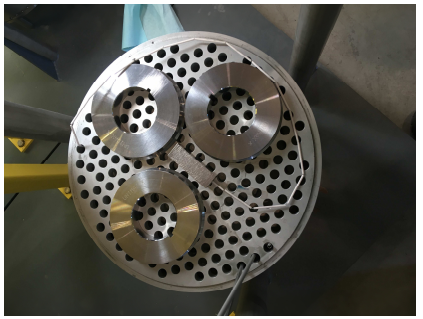
- Delivered in February 2018
- Max pressure: 2000 bar
- Max temperature: 1250°C with stainless steel basket, 1400°C with Mo basket

- Mo heating elements
- Ar 99.9999% purity

2 furnaces

URC (stainless): ”Ultra Rapid Cooling” 1200x365mm/600kg

URQ (Mo/stainless): ”Uniform Rapid Quenching” 600x330mm/250Kg



RESULTS FROM CORRAX®

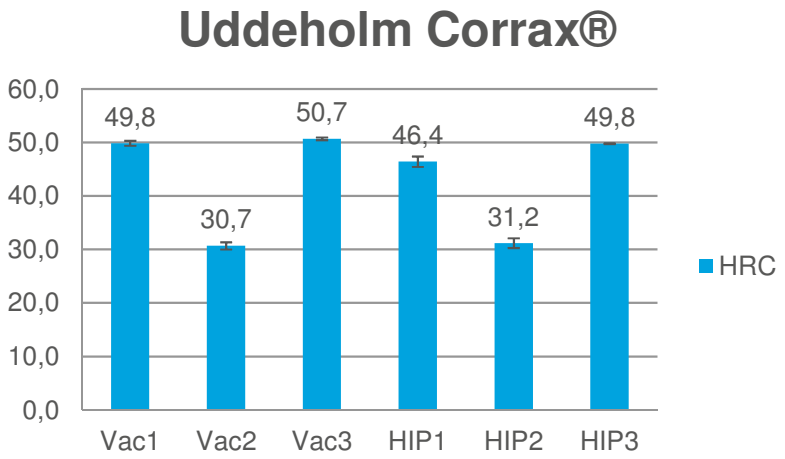
C	Si	Mn	Cr	Ni	Mo	Al
0,03	0,3	0,3	12,0	9,2	1,4	1,6

1. High pressure/high cooling rate -> low hardness/high ductility

1. Strong stabilization of retained austenite by solution treating in HIP (11% vs 5%)

2. Releasing pressure after a URQ cycle causes a “sub-zero” effect. E.g. HIP1 has 11% RA, HIP2 has <2%RA

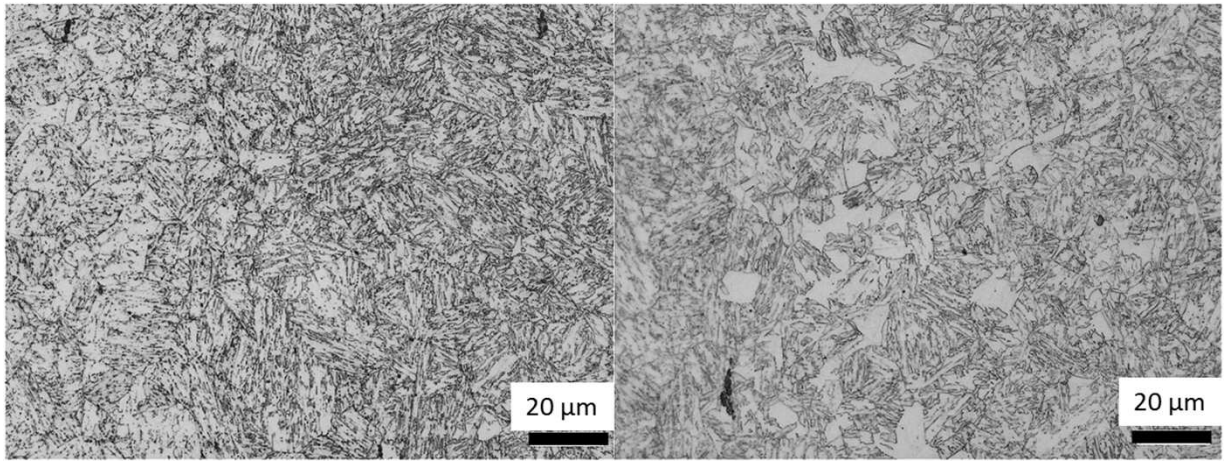
3. The ageing process is not significantly affected by pressure.



Heat-treatment in Vac and in HIP
1: 850°C 30 min + 525°C 4h
2: 850°C 30 min
3: 525°C 4h

RESULTS FROM CORRAX®

- Strong stabilization of retained austenite by solution treating in HIP (11% vs 5%)

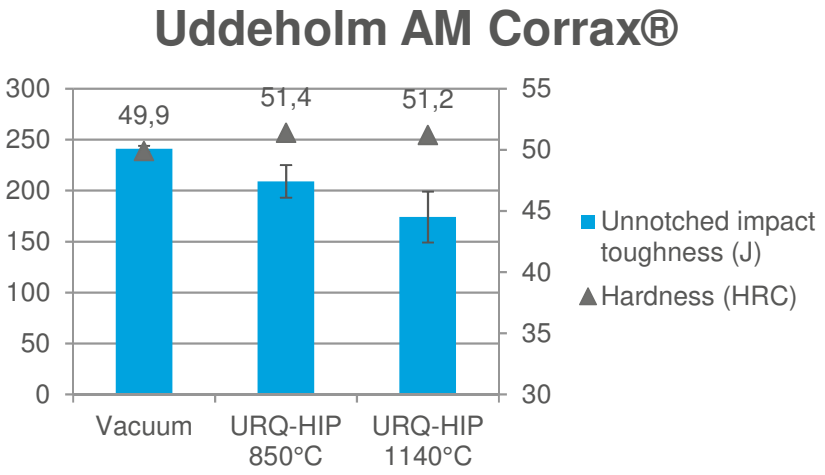


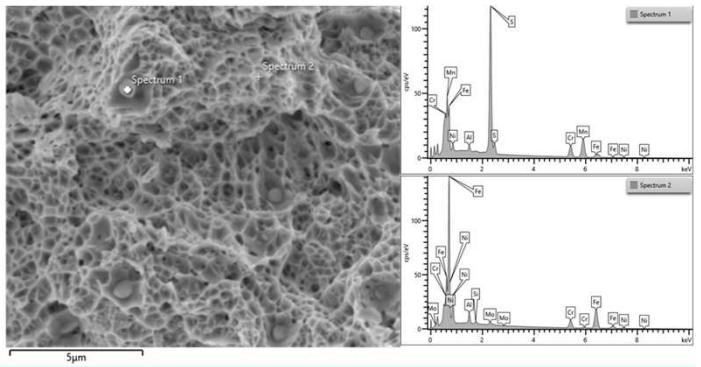
Optical micrographs of Uddeholm Corrax® Vac1 (left) and HIP1 (right) samples (etched with Vilella´s reagent).

RESULTS FROM URQ ON AM CORRAX®

- URQ-treatment on L-PBF AM Corrax increased hardness to over 51HRC
- Potential for healing printing defects!

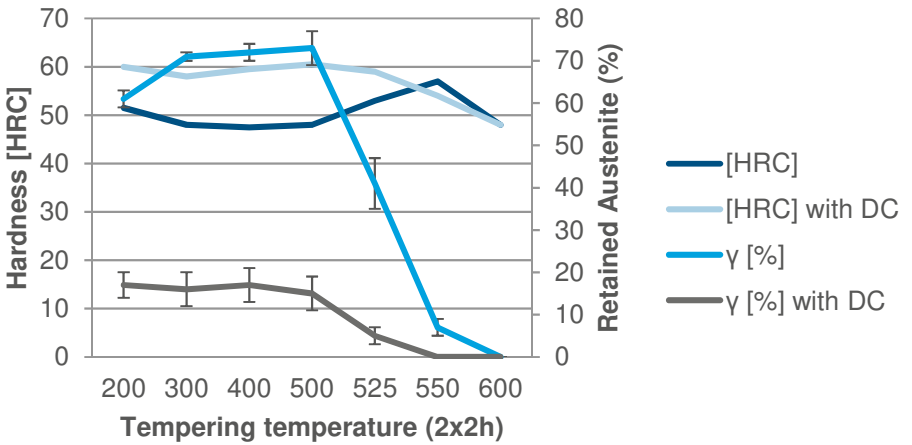
- Drop in impact toughness due to MnS precipitaiton at higher temperatures



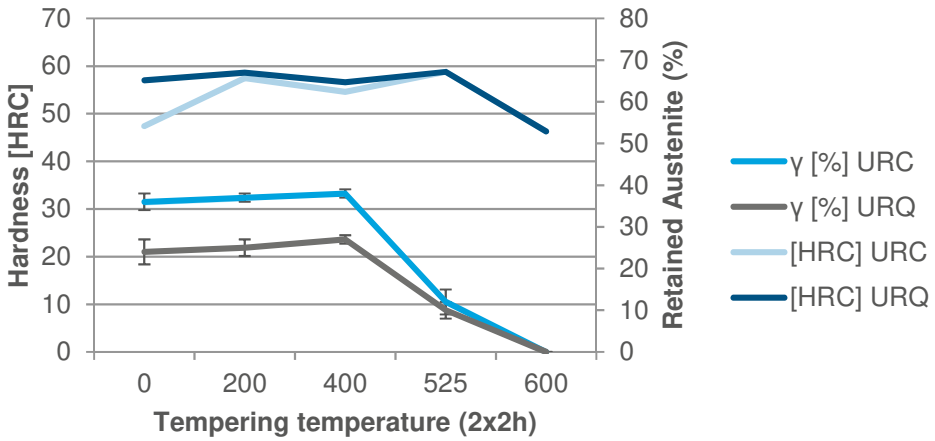


RESULTS FROM VANAX®

Vanax® (1080°C-30 min T8-5=200s)



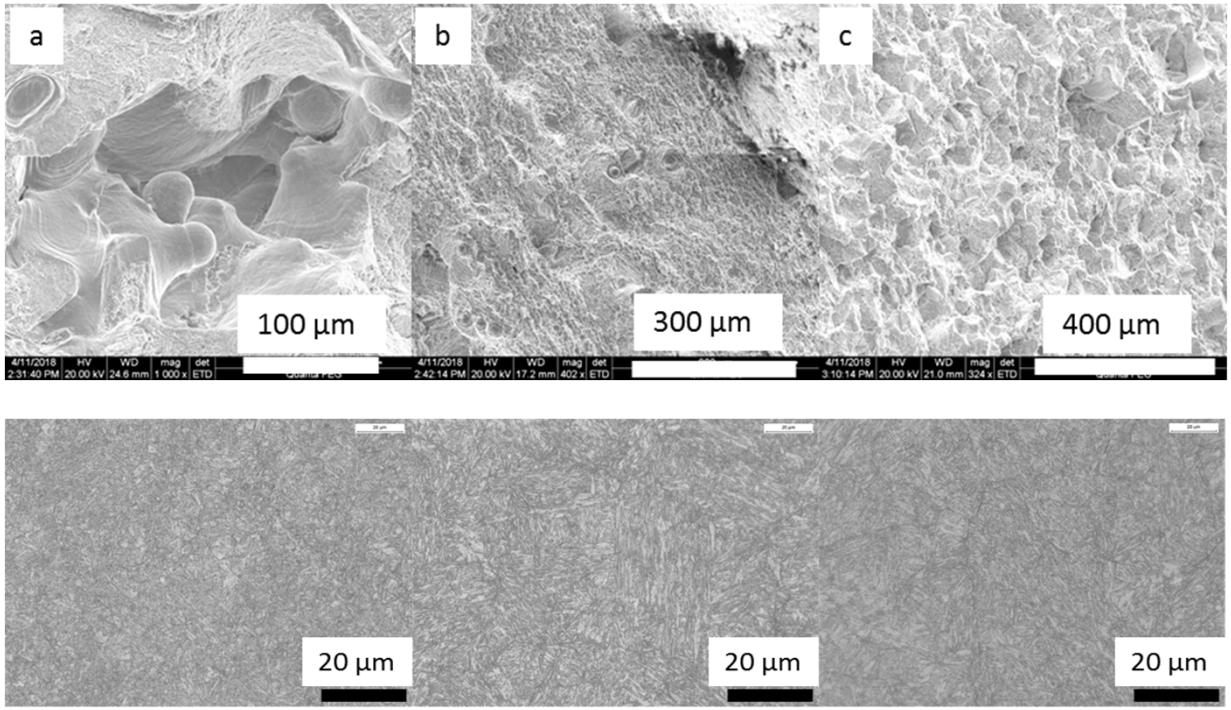
Vanax® (1080°C-30 min T8-5=16s URC-URQ)



- Decrease of retained austenite after URC and URQ
- Pressure release after HIP-hardening cause sub-zero cooling! P·V/T = K

RESULTS FROM MODIFIED H13

- **Upcoming publication MAMC2019**
- Modified H13 L-PBF presents defects
- HIP closes most of the porosity
- URQ-Hardening decreases martensite packet size -> higher hardness and strength!



Print+HT Print+HIP+HT Print+HIP-URQ

CONCLUSIONS

- ✓ HIP-URQ has potential applicability for tool steels, especially in AM
- ✓ No effect observed on ageing of maraging steel
- ✓ Increased hardenability (perlite) but small/no effect on bainite
- ✓ HIP-URQ can be used for an in-situ sub-zero effect to decrease retained austenite/increase hardness
- ✓ Further research is necessary to fully understand the implications of high-pressure treatments, especially with transformations at high-temperature (e.g. MnS, carbide stability)

THANK YOU FOR YOUR ATTENTION!

#1 IN HIGH PERFORMANCE TOOL STEEL