ESTEP SPRING DISSEMINATION EVENT

5-6 JUNE 2025 KRAKOW (POLAND)

RINA

HyTecHeat

Co-funded by the European Union

Effect of Hydrogen combustion atmosphere on the properties of steel surface scale

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ESTEP

Hybrid **TeC**hnologies for sustainable steel re**heat**ing - **HORIZON-CL4-2022-TWIN-TRANSITION-01-16, Modular and hybrid heating technologies in steel production (Clean Steel Partnership) - GA number:101092087**

HyTecHeat project

Co-funded by
the European Union

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Content of the presentation

HyTecHeat project

- Overview and case studies
- Oxidation & descaling
- Description of experimental apparatus
- Oxidation tests
- Descaling tests

Conclusions

HyTecHeat project

Co-funded by the European Union

Project number:	101092087
Project name:	HYbrid TEChnologies for sustainable steel reHEATing
Project acronym:	HyTecHeat
Call:	HORIZON-CL4-2022-TWIN-TRANSITION-01
Topic:	HORIZON-CL4-2022-TWIN-TRANSITION-01-16
Type of action:	HORIZON-IA
Service:	HADEA/B/03
Project starting date:	fixed date: 1 December 2022
Project duration:	42 months

Eleven partners from four different European countries

HyTecHeat project

Project scope

The general objective of this project is to apply hybrid heating technologies and to evaluate the effects of the quality of the steel products, on the refractories and also on the combustion systems

Three Demo cases envisioned: innovative multifuel burner fed by electrolyser, limit of current combustion systems and ladle refractory preheating

Impacts on steel quality, (oxidation & descaling), refractory durability and furnace are assessed by proper experimental and modelling activities

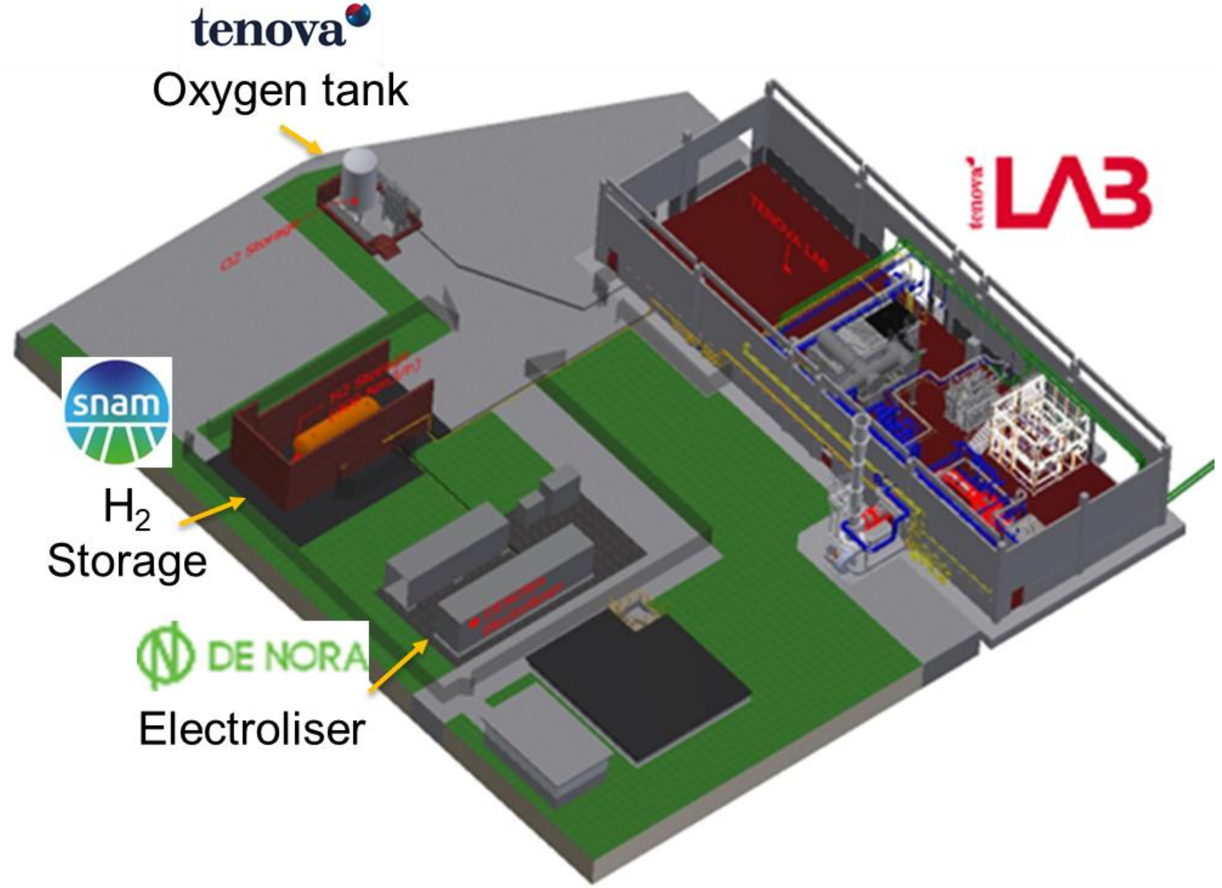
HyTecHeat project

DEMO CASE 1: TENOVA HYBRID HEATING IN COMBUSTION SYSTEM AT TRL 7

DEMO case with onsite Green Hydrogen production, buffer storage and connection with testing facility:

- 1 MW capacity alkaline Electrolyser
- Electrical energy produced by PV roof
- Hydrogen storage at 30 bar
- Reduction of H_2 to 0.3 bar
- Hybrid H_2/NG Tenova burner prototype (320 kW)

The installation is completed and commissioning is going to start



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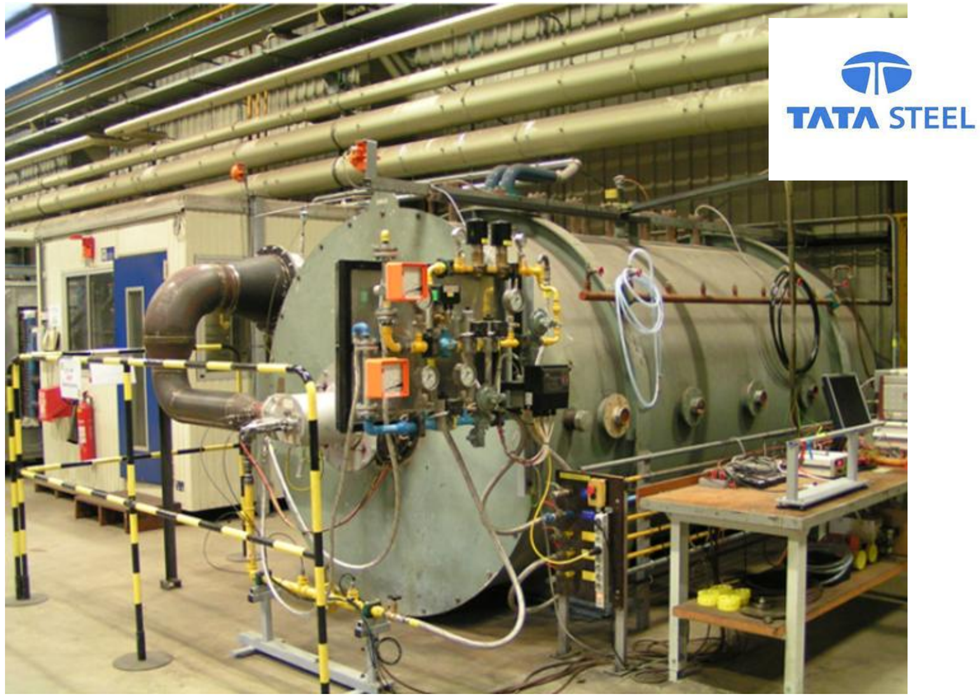
DEMO CASE 2: TATA HYBRID HEATING COMBUSTION SYSTEM AT TRL 7 -

Tata Steel tests the currently employed burners on its site with a mixture of hydrogen and natural gas. The burners to be tested are normally optimized for natural gas



The tests will be carried out in the pilot furnace in the facilities of Tata Steel Nederland:

- horizontal cylindrical furnace of 1300 mm inner diameter and 3500 mm inner length
- Max working temp 1400 °C
- Max burner power 700 kW capacity

Tests are planned to start in October 2025

Using the existing burners also brings immense benefits that can be achieved quickly and with limited CAPEX

HyTecHeat project

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DEMO CASE 3: Nunki HYBRID HEATING PRE-HEATING REFRACTORY SYSTEM AT TRL 7

Nunki will test the use of H_2 / NG blends for ladle refractory preheating.

The burner has 2 MW maximum power, (the working range is between 0.2MW-2MW), with NG max flow rate of 240Nm3/h

The trial will be carried out blending NG/H2 (mixing percentage under evaluation)

Test design and interaction with local authorities ongoing

Test foreseen in September 2025

Investigation of the effect of hydrogen combustion on ladle refractory carried out with no significant negative impact

Oxidation & descaling

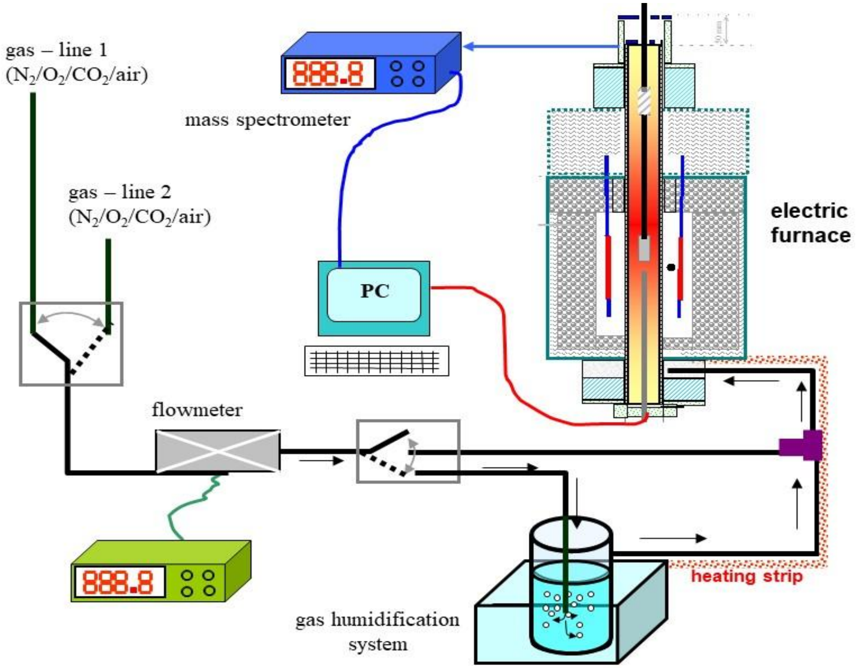
Investigated samples

Partner	Steel grade	C	Cr	Mn	Mo	Si	Ni	P	S	V	Al
Nunki steel	X22CrMoV	0.18-0.24	11.0-12.5	0.4-0.9	0.8-1.2	< 0.5	0.3-1.5	< 0.025	< 0.015	0.25	
	AISI 316	< 0.07	16.5-18.5	< 2.0	2.0-2.5	< 1	10-13	< 0.05	< 0.02		
Tenaris	*13 Cr * (AP1 5CT)*	*< 0.05*	*11.5-13.5*	*0.25-1.0*	*-*	*< 1*	*< 0.5*	*< 0.02*	*< 0.01*		
	P91 (ASTM A335)	0.08-0.12	8.0-9.5	0.30-0.6	0.85-1.05	0.2-0.5	<0.12	< 0.02	< 0.01	0.19-0.25	<0.01
	N80Q	0.23-0.26	0.40-0.50	1.25-1.40	0.08-0.10	0.15-0.30	-	< 0.020	<0.010	-	0.02-0.035
	X60/X65 (AP1 5L)	0.08-0.19	<0.6	0.1-1.4	<0.07	0.2-0.35	<0.15	< 0.015	< 0.003	0.04-0.1	0.02-0.04
Tata steel	HSLA (400)	0.05	-	1.3							
	DP800HpF	0.2	-	2		0.4					0.7

* Not subjected to descaling test (only TGA).

Oxidation & descaling

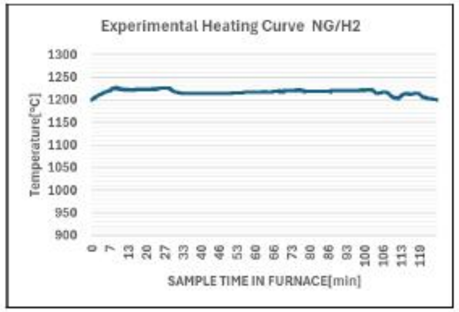
Oxidation tests



Gas mixture component	0% H2	50% H2	100%H2
	λ=1.1		
O_2	**1.8**	1.7	**1.6**
CO_2	**8.7**	6.9	**0**
N_2	**72.1**	70.7	**66.1**
H_2O	**17.4**	20.7	**32.3**

descaling tests

NG burner
H_2 Tenova burner



1. Heating: 1200°C for 2 hours (isothermal), O_2 = 2%
2. Descaling
3. Cooling in inert atmosphere (N_2)
4. Visual inspection

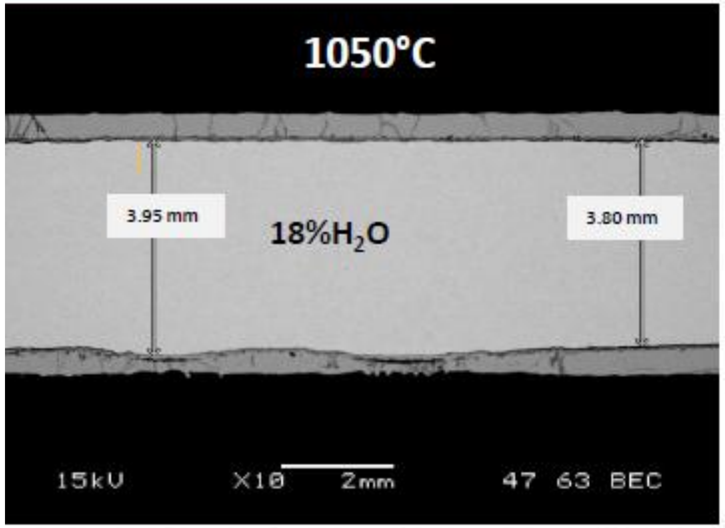
Sample before descaling

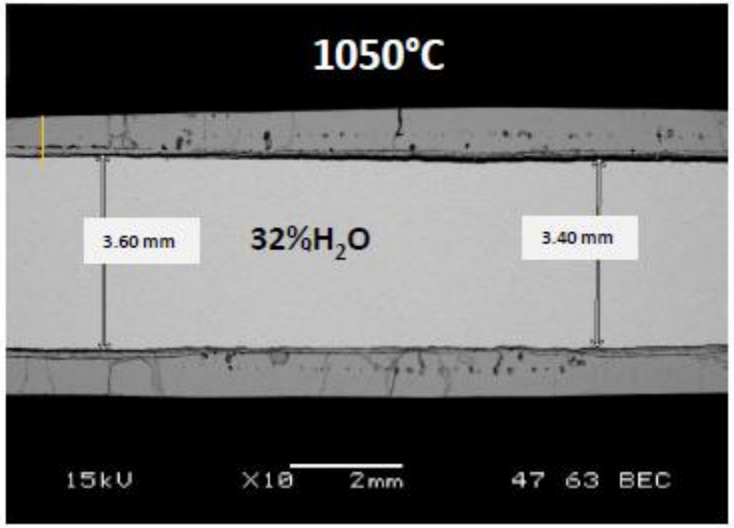
Immediately after descaling in the nitrogen cooling room

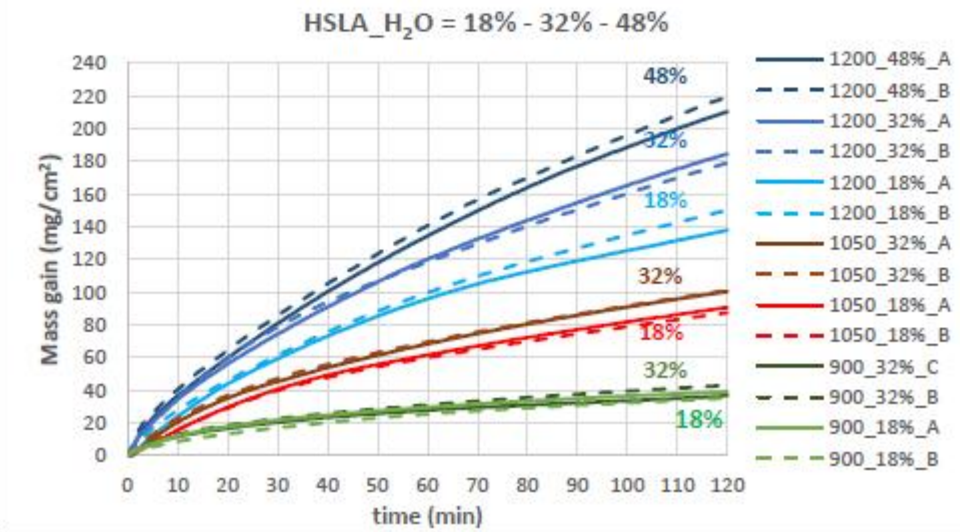
After descaling (visual inspection)

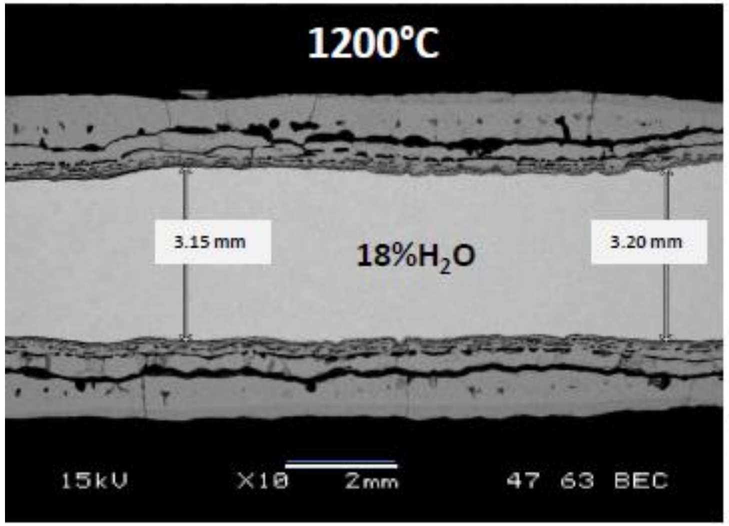
Oxidation & descaling

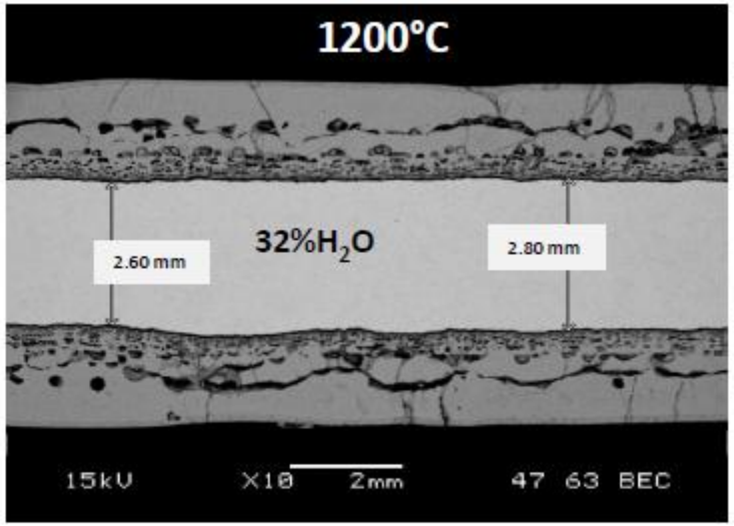
TGA + SEM: HSLA steel - *18-32-48% H_2O*

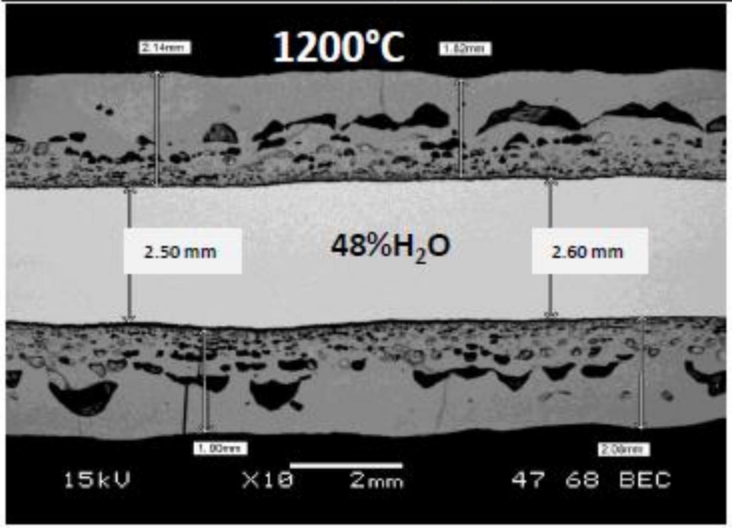




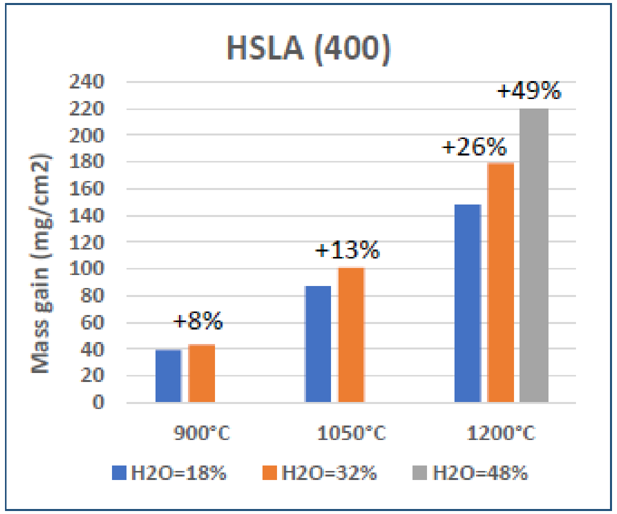


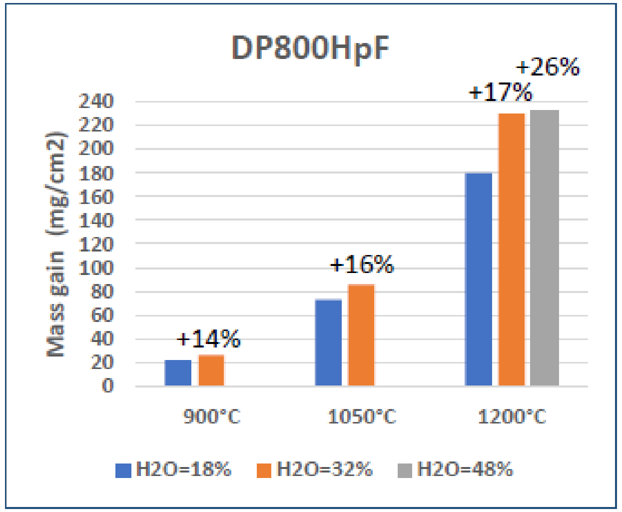


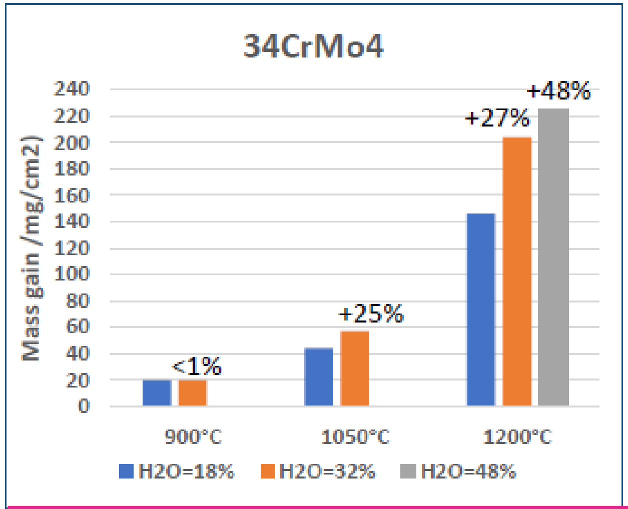


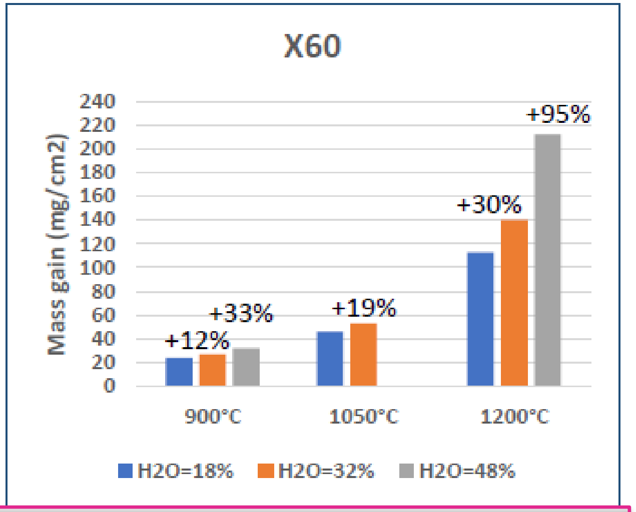


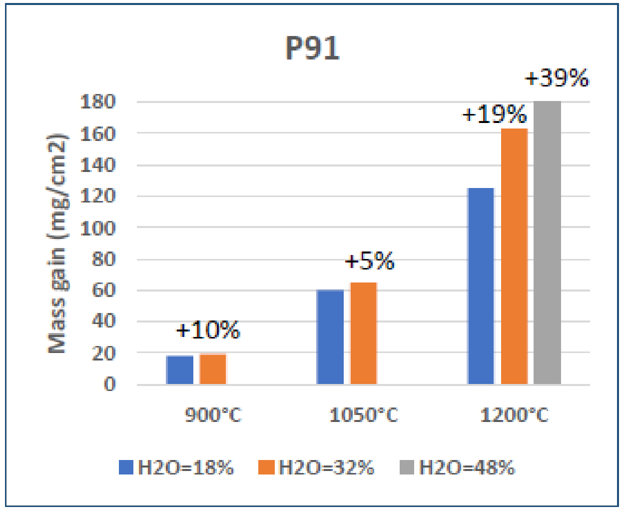
Mass gain results after 120 min for all steels as a function of H_2O% and temperatures

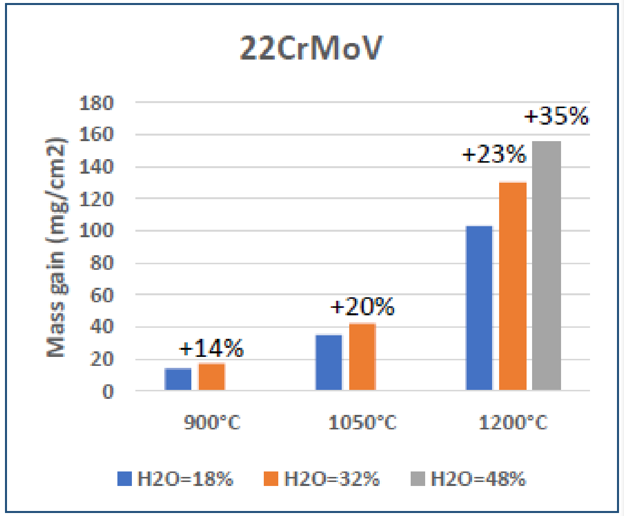


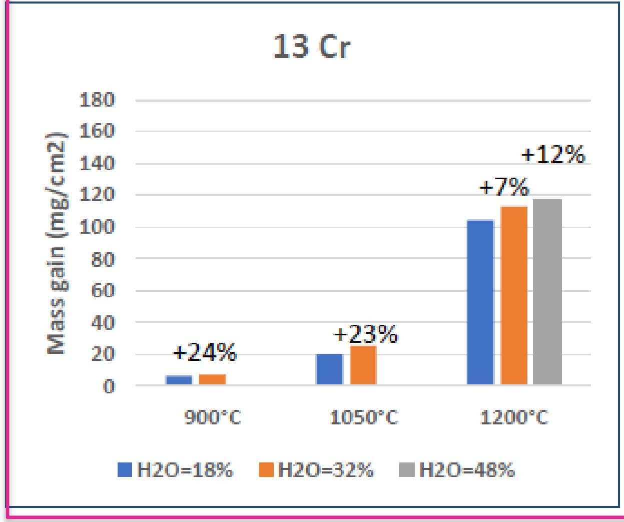


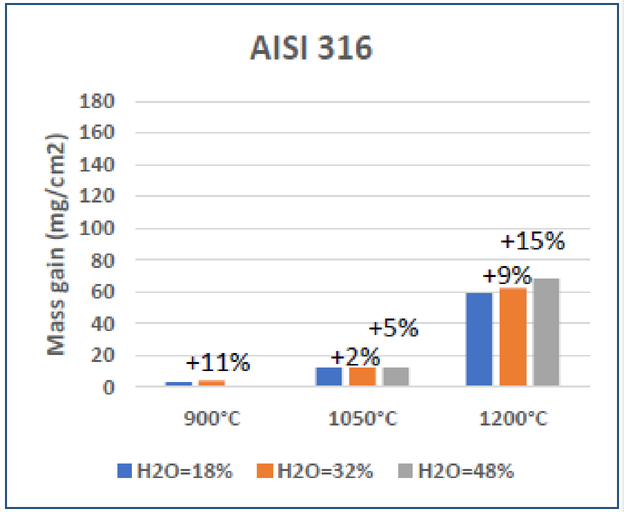










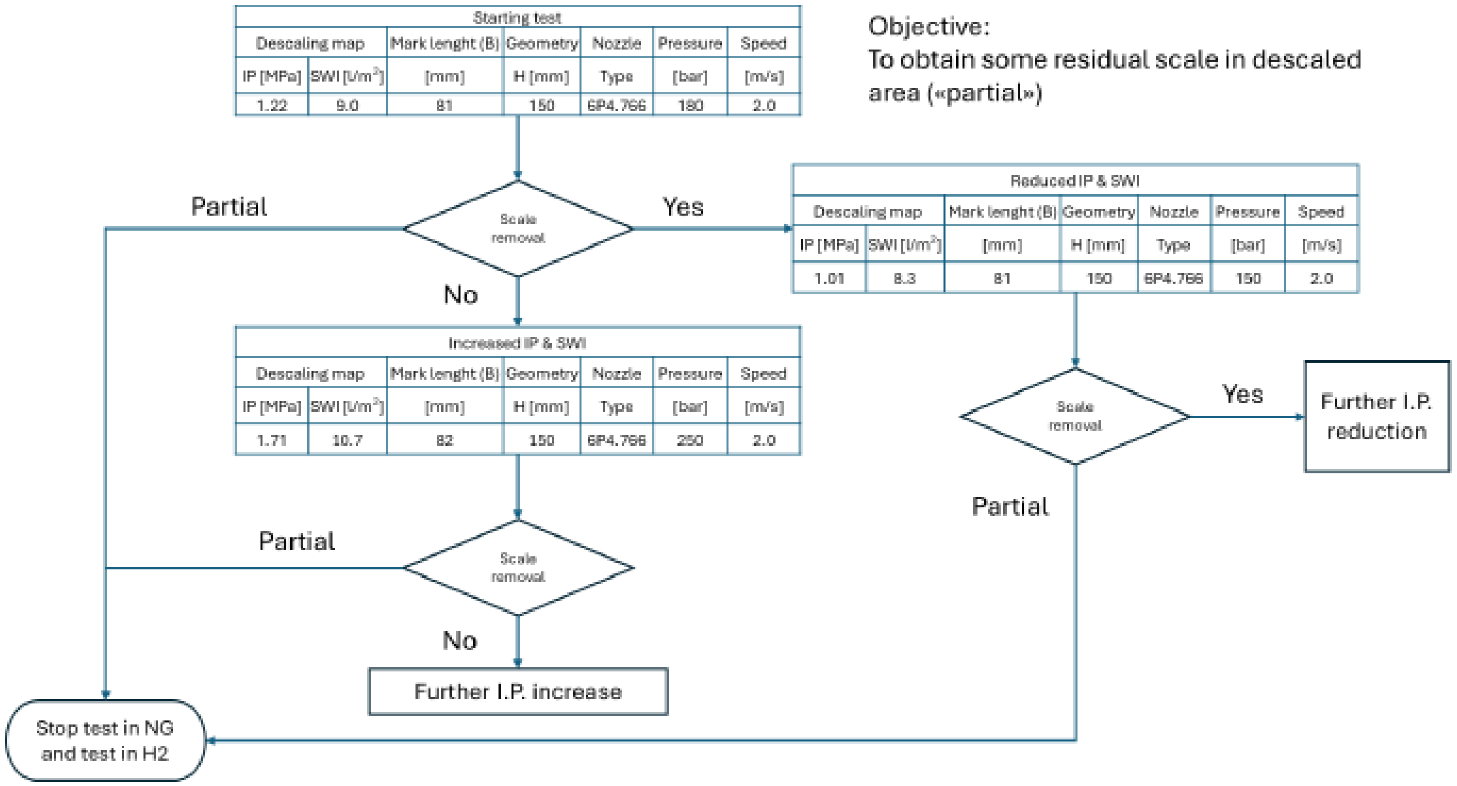


Very small effect in high Cr steels

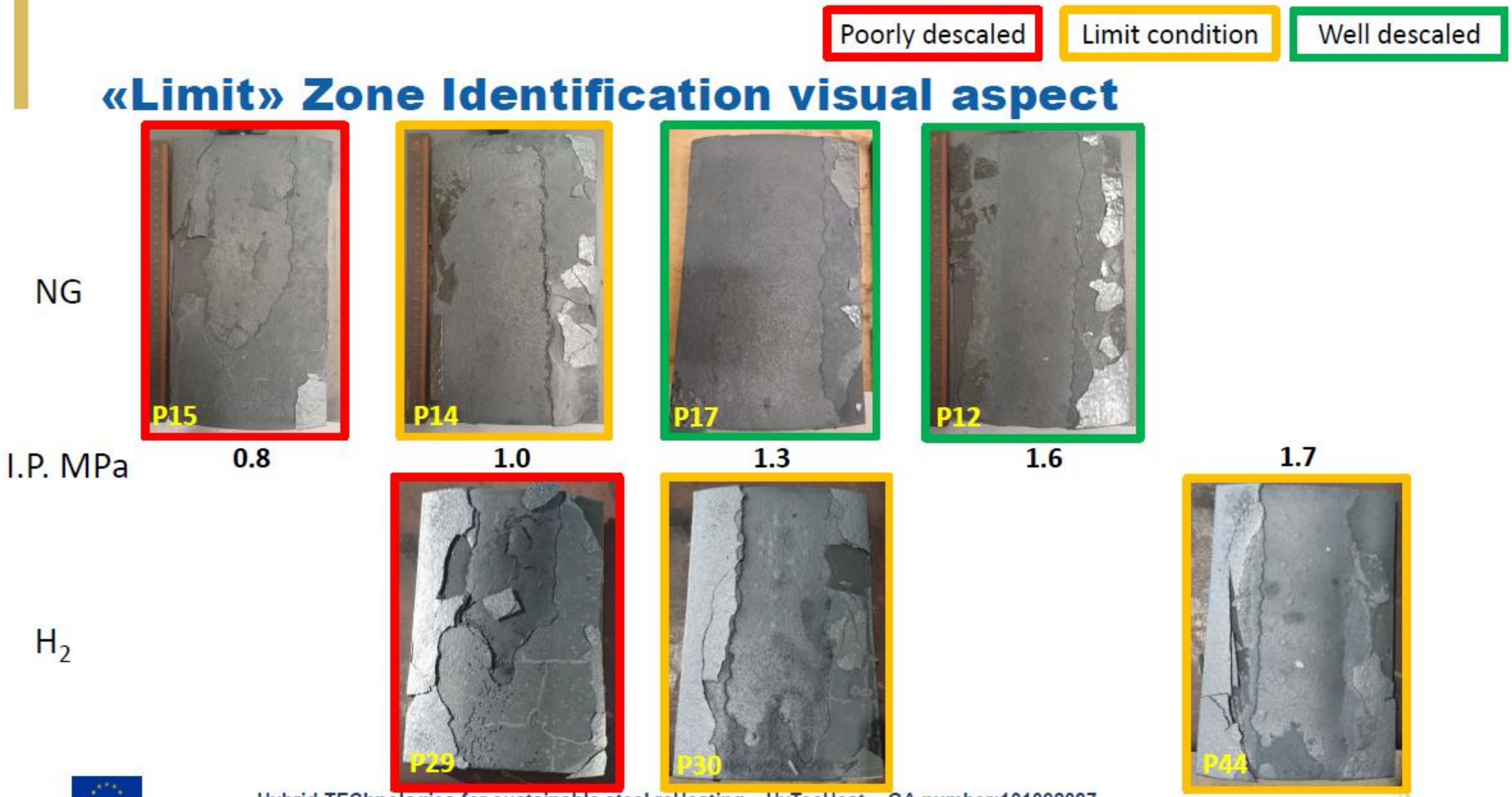
Oxidation & descaling

Activity Description: approach (descaling condition)

Considering the type of steel and previous plant and test experiences, initial conditions were selected and processed according to the provided scheme to gain a comprehensive overview and proceed to the next step.

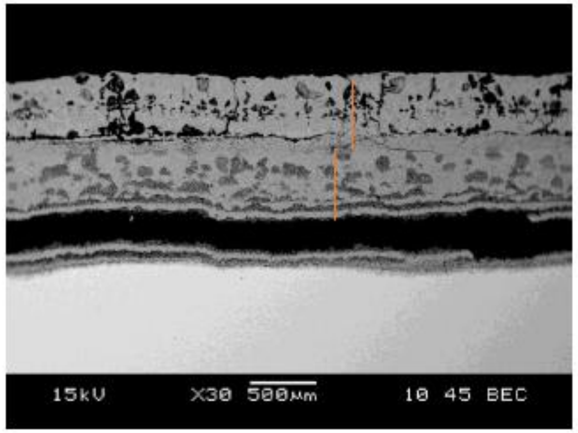


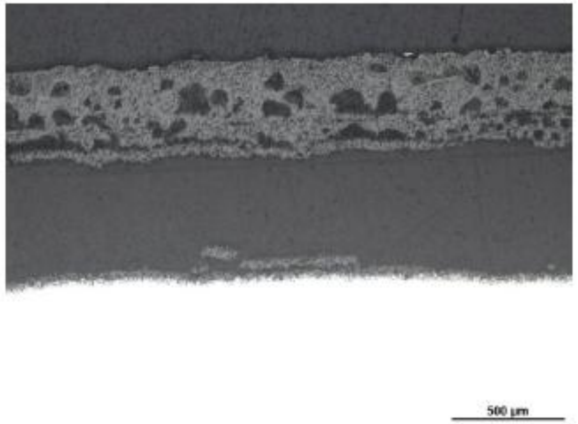
Oxidation & descaling

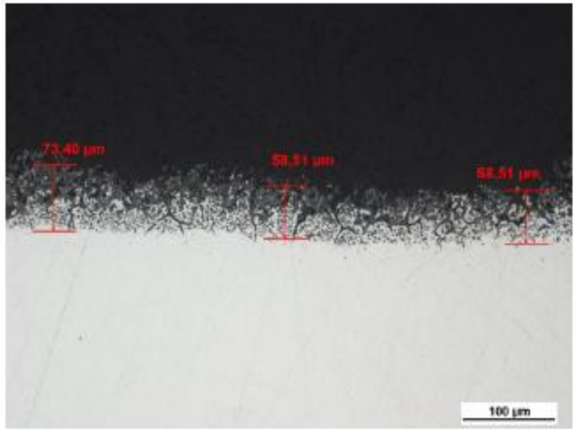


Oxidation & descaling

«Limit» Zone Identification
Sample NUNKI X22CrMoV





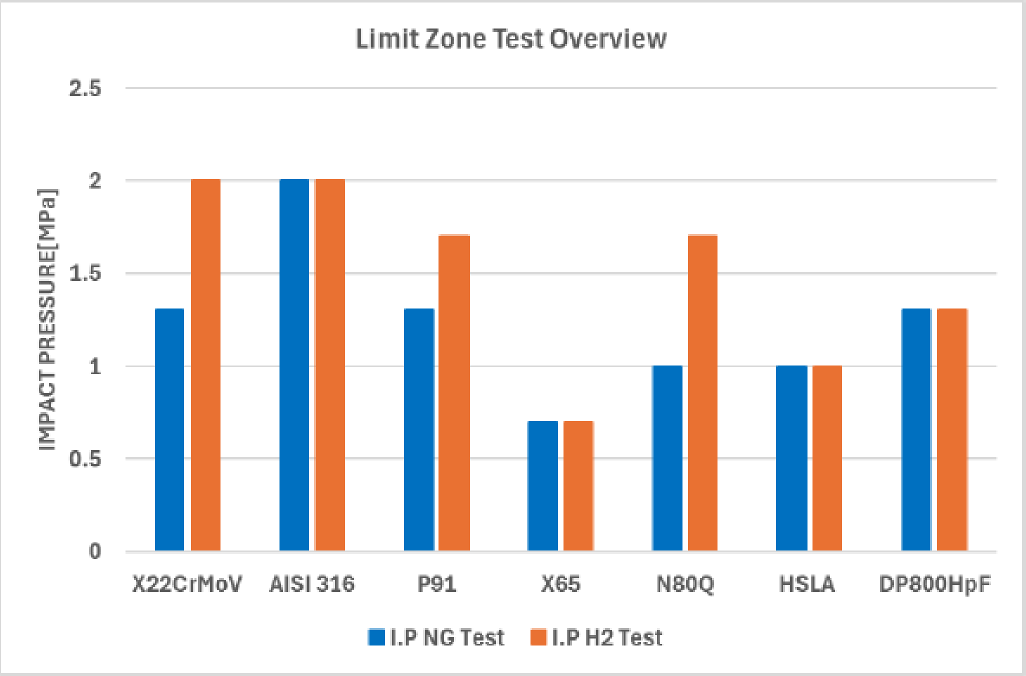


Non descaled	Partially descaled	Well descaled
Scale thickness 1200 µm	Residual scale thickness 500 µm	Only thin interface layer ≅ 50 µm

Descaling results (general overview)

Generally, impact pressure required higher values to obtain an adequately descaled surface in H_2 combustion atmosphere compared to NG.

		NG				H_2			
		Limit descaling condition		Well descaled		Limit descaling condition		Well descaled	
Partner	Steel	I.P. [Mpa]	S.W.I [l/m2]	I.P. [Mpa]	S.W.I [l/m2]	I.P. [Mpa]	S.W.I [l/m2]	I.P. [Mpa]	S.W.I [l/m2]
NUNKI	X22CrMoV	1.3	9.3	1.6	10.3	>2.0	>11.7	ON GOING	
	AISI 316	2.0	11.7	ON GOING		2.0	11.7	ON GOING	
TENARIS	P91	1.3	9.3	1.6	10.3	1.7	10.7	ON GOING	
	X65	0.7	6.9	1.0	8.3	0.7	6.9	1.0	8.3
	N80Q	1.0	8.3	1.3	9.3	1.7	10.7	ON GOING	
TATA	HSLA	1.0	8.3	1.6	10.3	>1.0	>8.3	1.7	10.7
	DP800HpF	1.3	9.3	1.4	9.7	1.3	9.3	ON GOING	



Oxidation & descaling

Conclusions (1/2)

- TGA tests revealed an important effect in the increase of steel's oxidation rate with the water vapour content in the combustion atmosphere.
- In general, the effect is significant at temperature higher than 1050°C.
- Minor effect was observed for steels with high Cr content, such as AISI 316 and 13 Cr even at 1200°C; this probably due to the formation of $CrO_2(OH)_2$ that is volatile at the test temperatures;
- Only small differences in the oxide scale morphology and the steel/scale interface features were observed by SEM analysis on the steel samples oxidised with NG and H_2 combustion atmospheres.

Oxidation & descaling

Conclusions (2/2)

- The limit condition for descalability of the samples heated in an atmosphere by NG combustion was individuated per each steel grade, to subsequently compare it with heating in an atmosphere by H2 combustion.

- The “limit” descaling conditions was defined for almost all the steels being tested identifying the value of **Impact pressure** for which there is a transition condition between good and insufficient descaling.

- The evaluation of the scale removal was performed by the visual inspection with the addition of the metallographic analysis in sections

- A general increase of impact pressure for some specific steel grades, (working in “limit conditions”) required to obtain an adequately descaled surface in H2 combustion atmosphere compared to NG. Correlation with scale and interface characteristics ongoing

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