Evolution of Heat Treatments for Rolled Stainless Steel: Hydrogen and Electromagnetic Induction in Annealing Furnaces

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Conventional Heat Treatments

The **production** and **processing of steel** is an **"energy-intensive"** activity. The **emission of CO_2** into the atmosphere increases, both directly due to **process** and **combustion needs**, and indirectly mainly due to **electricity consumption**.

In various heat treatments, **from hot rolling to the finished product**, continuous or batch heating **furnaces** are used, which utilize **burners** primarily **fueled by methane**, or indirect heating systems that rely on **radiant tubes** through which **methane flows.**

The steel sector is accounted for 5% of all EU emissions and 23% of the manufacturing industry[1]

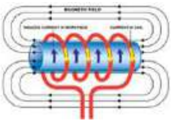
Evolution of Heat Treatments

The **decarbonization path** planned by the **EU** for the next few decades involves a **radical transformation** of industrial processes in the steel production/ transformation sector and in the way energy is produced and used.

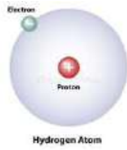
The **adoption** of **hydrogen** and **electromagnetic induction** in the **heating systems:**

- represent the **most accredited technological options** indicated in the **European programmatic lines** for the **decarbonization** of heating processes in the steel industry[2];
- **improve** the **sustainability of processes** thanks to the use of energy produced from **renewable sources**.

Aim of Project



This PhD work will go deeply in the technologies related to the use of **hydrogen** and **electromagnetic induction** in the **annealing lines** of stainless steel cold rolled products and to evaluate the effects on the process in terms of material **quality,** plant **productivity** and reduction of environmental impact.



Application of innovative heating systems to stainless steel laminates: Process Evaluations

Electromagnetic Induction

Once the suitable process conditions have been identified, the use of **ultra rapid heating** systems will be studied:

- effect on the **quality of the material**, in terms of **microstructure** and **mechanical properties**;
- using a different atmosphere inside the heating section, the effect on formation of the **surface oxide** and the subsequent pickling.

Hydrogen

Once the quality requirements required for the specific product have been reached, the **use of hydrogen** in the annealing furnace will be evaluated:

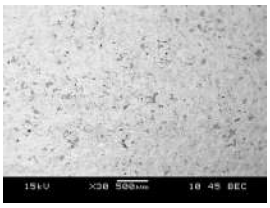
- **formation of surface oxide** and therefore the subsequent pickling;
- variation of the **flame length** and the **effect of combustion on** the furnace **refractory.**

Both heating systems will be compared with conventional annealing technology (methane).

Methodology: Experimental Tests and Characterization

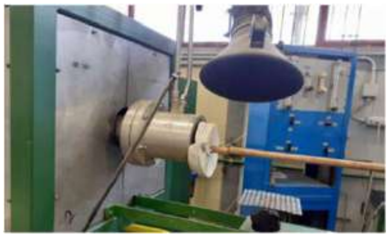
Electromagnetic Induction

- **Pilot plan of Rina – CSM** equipped with **ultra-rapid heating system** (two types of inductors longitudinal and transverse flux and temperature control system);
- **SEM** characterization analysis
- **Tensile test**
- **Pickling Lab Tests**



Hydrogen

- **Laboratory tubular furnaces in Rina- CSM** with specific burners for H_2 and CH_4 and controlled atmosphere
- **SEM** characterization analysis
- **Pickling Lab Tests**



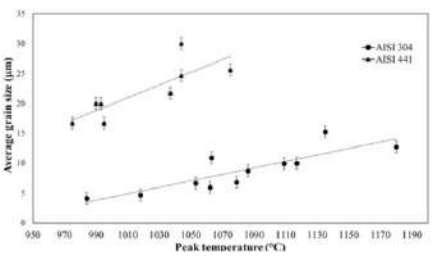
First Results

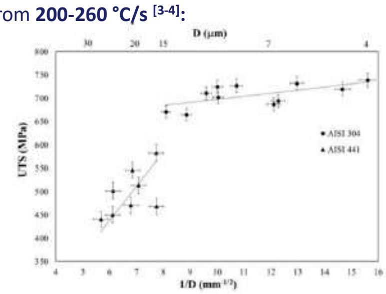
After **bibliographic research**, two representative stainless steels were selected for **ultra-rapid heating tests** in **Pilot Line of Rina CSM**, to investigate the effect in **microstructure** and **mechanical properties**. Tests were performed on **AISI 304** and **AISI 441**. Two different powers set were tested (**80% and 90% of Pmax=100 KW**), allowing **heating rates** ranging from **200-260 °C/s** [3-4]:

- the **average grain size** increases **as Tmax** increases following a **linear behavior** for both steel grades
- for **AISI 304**, the **influence of T on grain growth** appears to be **less pronounced** compared to AISI 441
- **Hall-Petch type dependency** of the material's strengthening **is observed**, which increases linearly with the √D

for both steel grades

- the **effect on strengthening** it **is greater for ferritic stainless steel**.





References:

[1] European Environment Agency (EEA)
[2] The European Green Deal 2019, EEA greenhouse gas, 2019
[3] G. Stornelli, L. Albini, P. E. Di Nunzio, G. Tiracorrendo, B. R. Rodriguez Vargas and A. Di Schino "Effect of ultrafast heating on AISI 441 Ferritic Stainless Steel", Acta Metallurgica Slovaca, 2023
[4] B. R. Rodriguez Vargas, G. Tiracorrendo, R. Massi, G. Stornelli and A. Di Schino "Effect of ultra-fast heating on AISI 304 austenitic stainless steel", Acta Metallurgica Slovaca, 2023