Damage evolution during thermo-mechanical processing of thick aerospace aluminum plates.

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The use of aluminum alloys in the aerospace industry has drastically increased in the past decades. One of the main reason its related to the need of materials with enhanced properties such as low density and corrosion resistance. Nevertheless, defects such as porosity may cause degradation of the mechanical properties. Many efforts have been made to reduce the porosity formed during casting and to close them during the forming process of the plates. However, some porosities might appear during the forming process due to tensile state and up to now there is a lack of understanding of this phenomenon.

In collaboration of different partners (SIMaP, ILL, ESRF and C-TEC) this project aims to better understand the relationship between pore nucleation and growth as the role of the environment during the forming process. To achieve this goal a dynamic multiscale analysis has been proposed. Using ex situ and in situ X-Ray micro and nano-tomography and aided by Neutron Tomography, 3D images will be generated, and pore nucleation and growth will be determined for different forming conditions in order to optimize the processing step of Constellium.

Industrial Context

Pores are one of the main culprits for mechanical degradation of aluminium alloys. Constellium, our Industrial Partner, has been working on pore characterization inside aerospace aluminium alloys in order to establish better models to reduce the defects in the hot rolling process.
Being able to obtain *3D images* of the evolution of the pores during the forming process is crucial to understand the mechanisms of pore nucleation and growth and use this information to create better and more precise models.

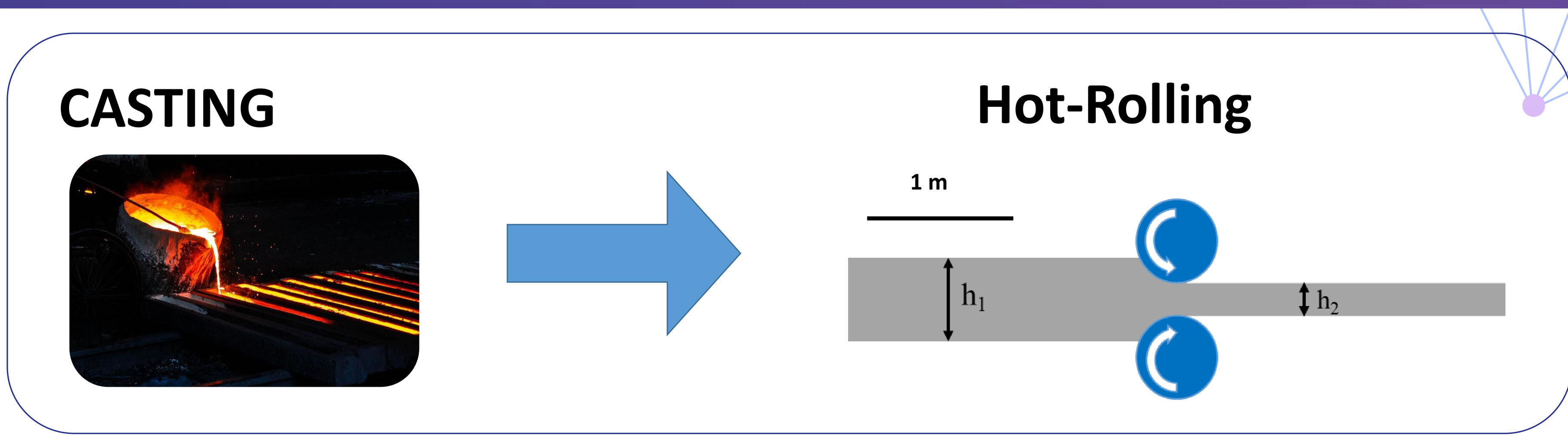

Figure 1. The Industrial Scheme. After casting big slabs (7 to 15 tons) of aluminium are Hot rolled in order to reduce its size.

Multiscale experimental approach.

Micro X-Ray Lab tomography.

X-Ray Lab Tomography is going to be carried out at SIMaP laboratory, this determines the pore morphology inside the aluminium alloys.
A micro tensile testing device has been developed to perform compression and tension tests on microprobes of 400 µm of diameter [1].

Figure 2. The microprobe. The difference in size between the microprobe and a common universal testing probe is equivalent to comparing a bee with a cat.

In Situ X-Ray Nano tomography ESRF

In situ nano X-Ray tomography performed at beamline ID16B will determine the pore nucleation growth and the evolution during mechanical testing at high temperature.

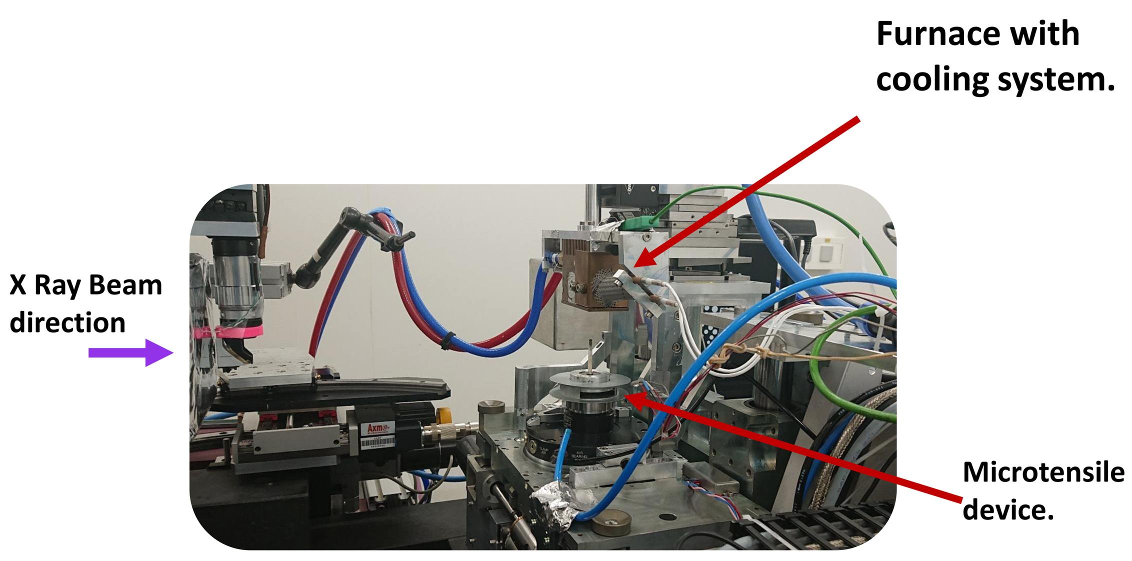

Figure 3. Experimental array at the beamline ID16B. The purple line represents the direction of the X-Ray Beam.

Neutron Tomography at ILL

Additionally, using neutron tomography we expect to determine the content of H_2 and other elements inside our samples.
This technique will also aid in determining the pore morphology.

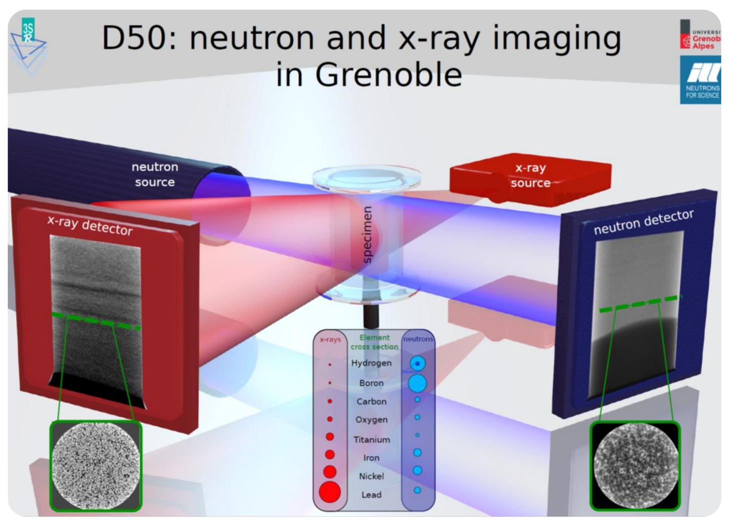

Figure 4. Experimental Array for the Neutron and X-Ray Imaging at ILL Institute.

Modelling with Finite Element Method at CTEC

The obtained results are going to feed a Finite Element Method code at C-TEC. This will bring more insights into the conditions needed to reduce de defects during the Hot-Rolling process.

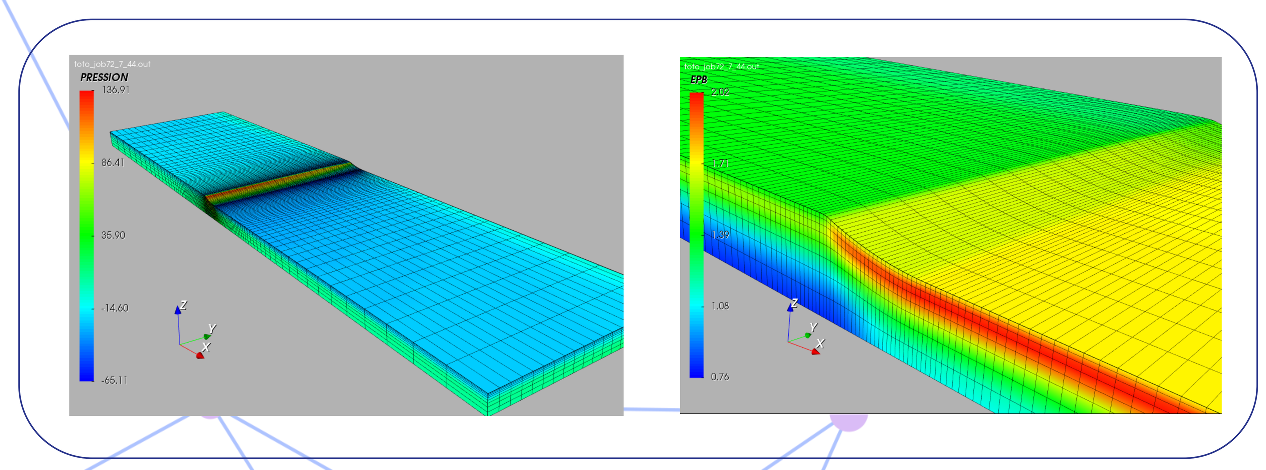

Figure 5. Simulation of the Hot Rolling Process using Finite Element Method. The left image shows the hydrostatic pressure while the figure at the right shows the equivalent strain.

Preliminary Results

Preliminary in situ experiments were performed on ID16B at ESRF. Figure 6 shows the evolution of a sample during in situ high temperature tensile testing.
Using the obtained 3D reconstructions, we will characterize the nucleation and evolution of the pores during the tensile test.

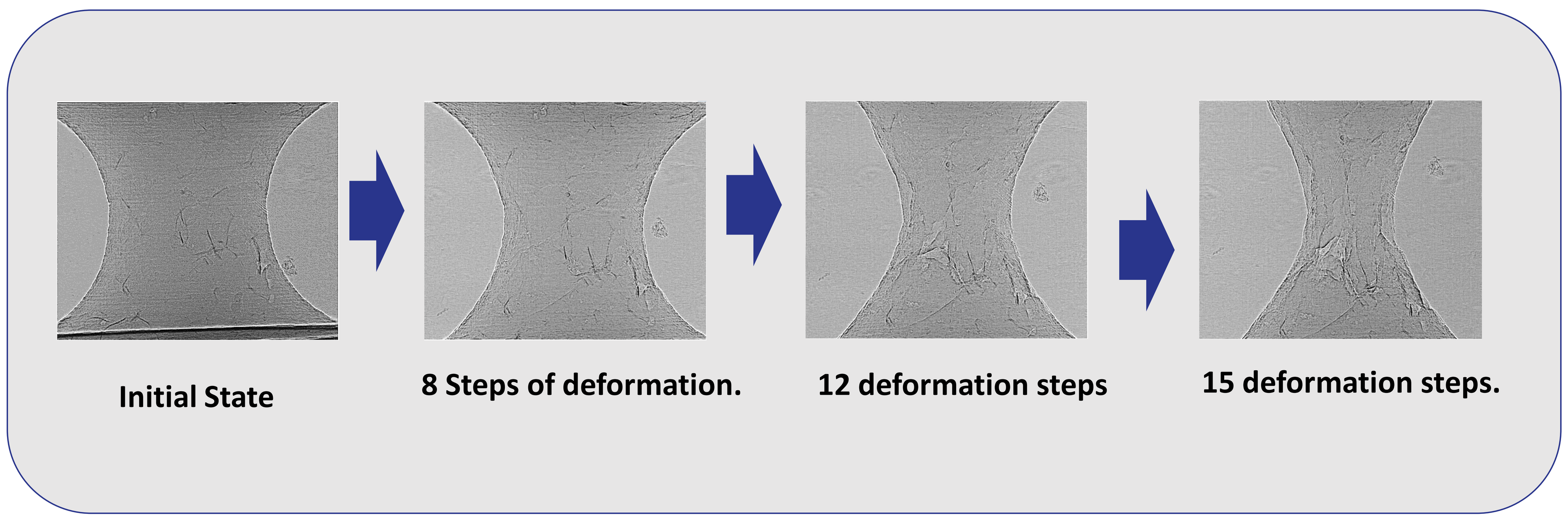

Figure 6. Deformation of an Aluminium 2050 sample during an *In Situ* X Ray Nano-tomography at 480 C. The energy used at the beamline was 29.2 keV, the pixel size is 241 nm (FOV: 518 x 614 µm)

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 847439.