ESRF	**Experiment title: Stainless steel hydraulic turbine cavitation damaging: in-situ monitoring of cracks development by X-ray tomography**	**Experiment number**: MA5707
Beamline: ID19	**Date of experiment**: from: 18 Apr 2023 to: 21 Apr 2023	**Date of report**: 19/09/2023
Shifts: 9	**Local contact(s)**: Marta Majkut	*Received at ESRF:*

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Report:

1. Overview

The objective of the experiments were to explore the unknown damage mechanisms occurring during cavitation erosion with a strong focus on dynamic phenomena using X-ray tomography on ID19 beamline. Cavitation erosion is one of the main damaging mode occurring on hydroelectric turbines. Understanding the cracking mechanisms occurring in stainless steel exposed to cavitation erosion is hence a strategic concern within the scope of energetic transition. The initiation and propagation of cracks leading to mass loss will be monitored *in-situ* using a unique homemade apparatus.

2. Measurement

The experiment took place from the 18^{th} to the 21^{st} of April 2023 on ID19 beam line. The studied materials were two strategic grades of stainless steel (X3CrNiMo13-4 and X4CrNiMo16-5-1) mainly used for manufacturing hydroelectric turbine blades. Each grades were investigated in two different heat-treated conditions (QT760/QT780 and QT900) in order to understand the influence of the local hardness. The specimen scanned were cylindrical samples of 4 mm in diameter. The experiment was performed at an energy of 70 keV with an exposure time 0.2 s. The voxel size for this experiment is approximately 0,32 µm.

Three types of analysis were made during this experiment:

- *Post-mortem* scans. Before to ESRF experiment, specimen were damaged using an ultrasonic horn at different exposure time for the four grades. These specimen were scanned in order to estimate the exposure time to cavitation requiered for observing cracks using X-ray tomography.
- Long exposure time *in-situ* scans. The four grades were scanned from $t_{exposure}$ = 0 min to $t_{exposure}$ = 120 min by steps of 10 min for monitoring cracks propagation.

- Short exposure time *in-situ* analysis. Three of the four grades were scanned from $t_{exposure}$ = 120 min to $t_{exposure}$ = 136 min by steps of 1 min for having accurate crack propagation monitoring.

The figure 1 shows the experimental setup used for performing the *in-situ* experiment.

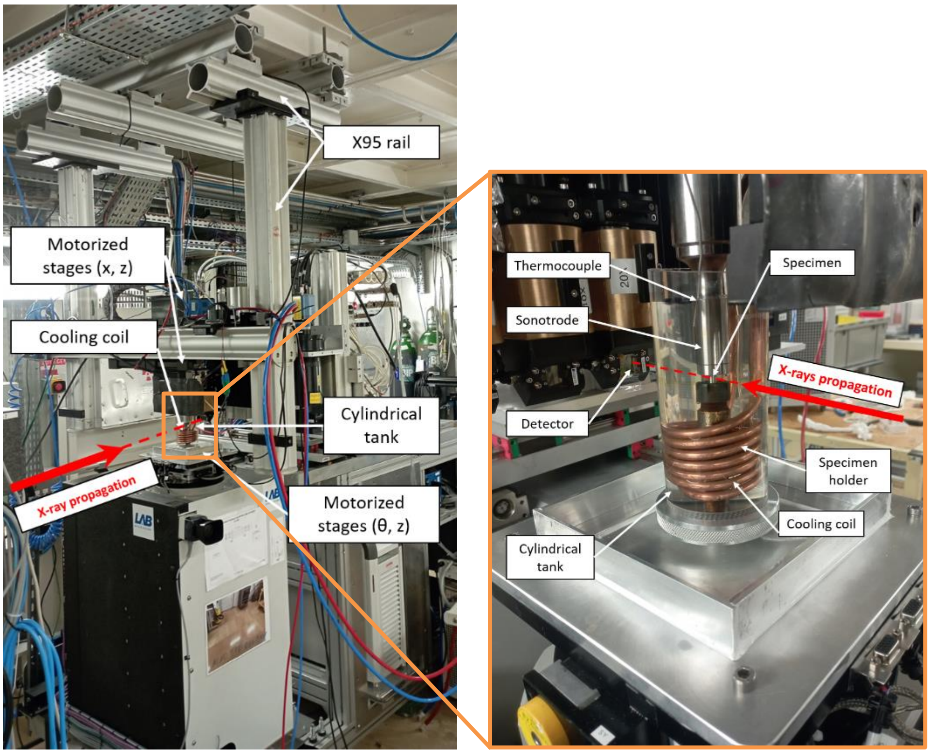

Figure 1: Photography of the experimental in-house setup at ID19. The in-situ experiment are divided into 5 steps: (1) the specimen is positioned on the speciment holder, (2) the extreme surface of the specimen is scanned, (3) the tank is filled-in of water, (4) the specimen is damaged by cavitation and (5) the tank is emptied. Steps (2), (3), (4) and (5) are repeated for monitoring cracks propagation.

3. Result

All *in-situ* experiment 3d volumes are already all reconstructed and segmented to distinguish stainless steel and cracks as shown on figure 2. The main information extracted from these scans is the evolution of the crack in the material with the exposure time to cavitation. We conclude that the cracks propagate from the surface to the volume. The non metallic elements seem to have a minor influence on crack propagation. As shown on figure 2, cracks seem to propagate perpendiculary to the surface.

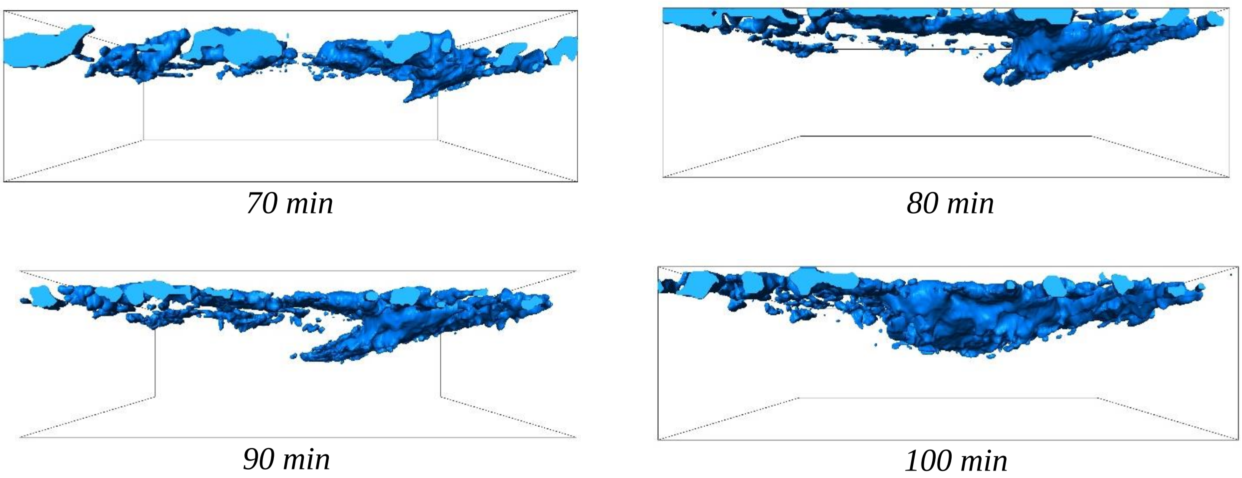

*Figure 2: 3D reconstruction of cracks (in blue) propagating in the specimen (grade X4CrNiMo16-5-1 QT760). The volume of the bounding box containing the 3D reconstruction is 74*42*96 µm^3.*

4. Conclusion

During the shifts awarded for this *in-situ* experiment we performed successful scans. The first result shows very good spatial resolution in order to minitor the crakcs. The results will be published in the manuscript of Julien Hofmann’s PhD thesis and in papers published in peer-reviewed journals.