Coupling of 3D NDE and FEA for engineering critical assessment (ECA) of pipelines

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Funding organisation: PRCI
Start date: January, 2020
Duration: 2 years

Keywords: ***Pipelines; Non-Destructive Examination; Engineering Critical Assessment; Fracture Mechanics;***

Motivation

The presence of defects in pipeline welds is unavoidable and may lead to failure, triggered by the internal pressure or other loads acting on the pipeline. Only critical defects should be repaired, to keep the overall construction cost within acceptable limits. Judging on the (non-)acceptability of defects that were rejected by simple but highly conservative workmanship rules requires a so-called engineering critical assessment (ECA), which is based on a structural analysis of defects as measured by non-destructive evaluation (NDE). Traditionally, NDE and ECA have been separated and their coupling requires a potentially biased user intervention.

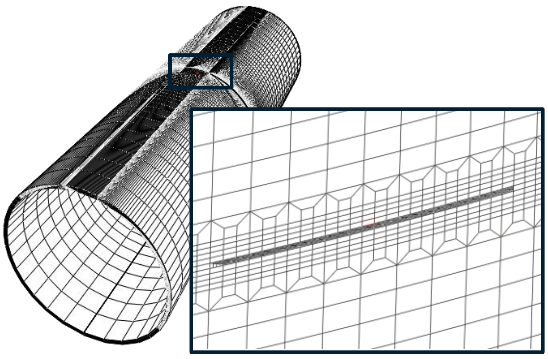

Figure 1 Finite element (FE) model of a girth weld with a surface-breaking defect. Image courtesy: Vitor Soares Rabelo Adriano.

There are reasons to assume that defect simplification will no longer be required in the future. First, the pipeline community witnesses the development of advanced girth weld NDE tools (e.g. Full Matrix Capture ultrasonics, X-ray computed tomography) with the capability for detailed visualization of detected features and weld geometry. Their market breakthrough is hampered by the inability to use their highly detailed results to their full extent. Secondly, the continuous improvement of computational abilities has created the opportunity for time-efficient integrity assessments, based on / supported by finite element analysis (FEA). Figure 1 is an example of FE model of a pipeline section, and Figure 2 is an example of ultrasonic NDE being performed on a steel specimen

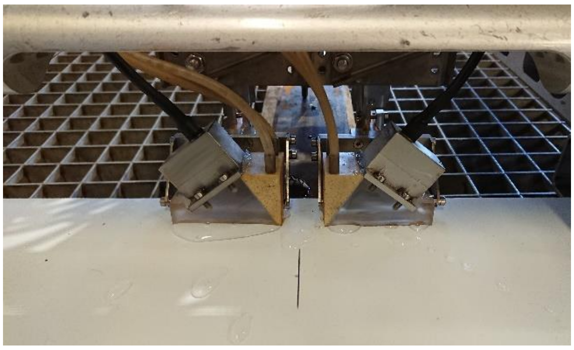

Figure 2 Full matrix capture ultrasonic NDE.

Objectives

In the context above and with the aim of developing a flowchart shown in Figure 3, the objective of this project can be summarised broadly as follows:

1. **Protocol development**

Develop a unified data transfer protocol for NDE vendors, in order to incorporate results from a range of NDE techniques into the NDE-FEA framework being developed.

2. **Reliability of assessment**

In parallel to protocol development, the FEA must be optimized (including defect modelling and postprocessing for fracture mechanics) for calculation speed and corresponding numerical accuracy. This can be performed numerically and based on experimental validation.

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Approach

The first step for practical application is to develop a protocol to transfer NDE information into the FEA, independent of the technology used to produce the NDE data. An example of a 3D defect obtained from FMC UT NDE is shown in Figure 4. Preferably, the content of the file shall be such that any tolerances due to the (in)accuracy of the applied NDE technique are already considered. Different manufacturers tend to store the raw data from their scans in formats that suit their proprietary visualization software. Collaborative efforts with interested stakeholders (researchers and multiple NDE system developers), are therefore, necessary to develop/choose a common file format which is not limited to a particular proprietary software.

Figure 4 3D STL volume of a defect obtained from 3D NDE.

Numerical optimization of the current FEA flowchart based on computational time and analysis accuracy will be performed, as this will ultimately govern the selection of FEA parameters.

Experimental validation using component-scale testing (curved wide plate tension tests, as shown in Figure 5) will assist in further improving the FEA optimization flowchart. Before testing, the specimens will be scanned using NDE techniques.

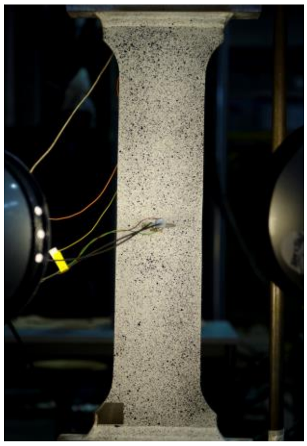

Figure 5 Curved wide-plate testing being performed in Soete Laboratory.

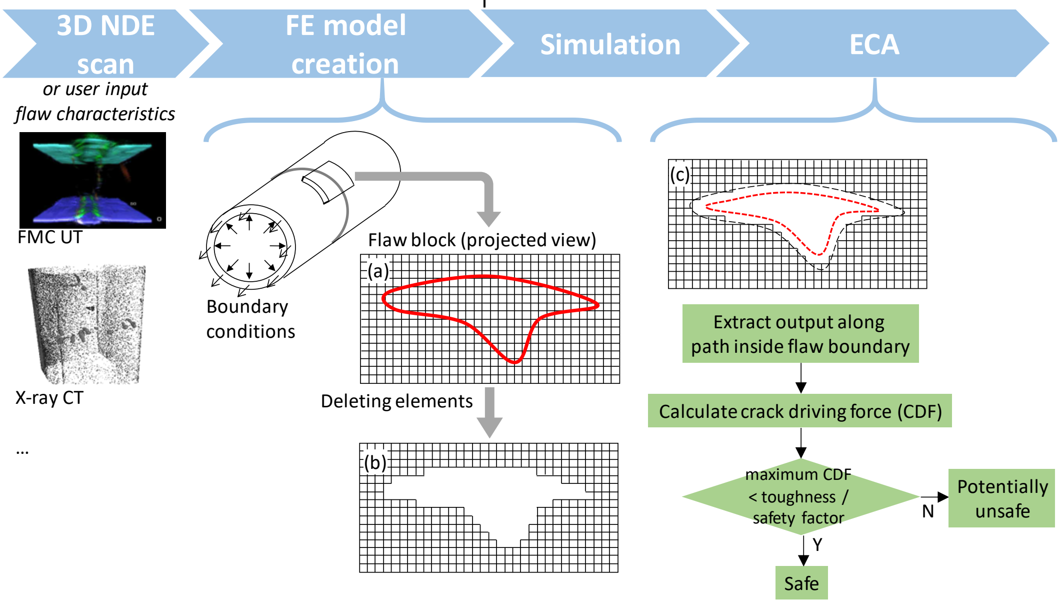

Figure 3 Graphical summary of the developed NDE-FEA framework for ECA.

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