Flaw interaction rules in strain based flaw assessment

GHENT UNIVERSITY

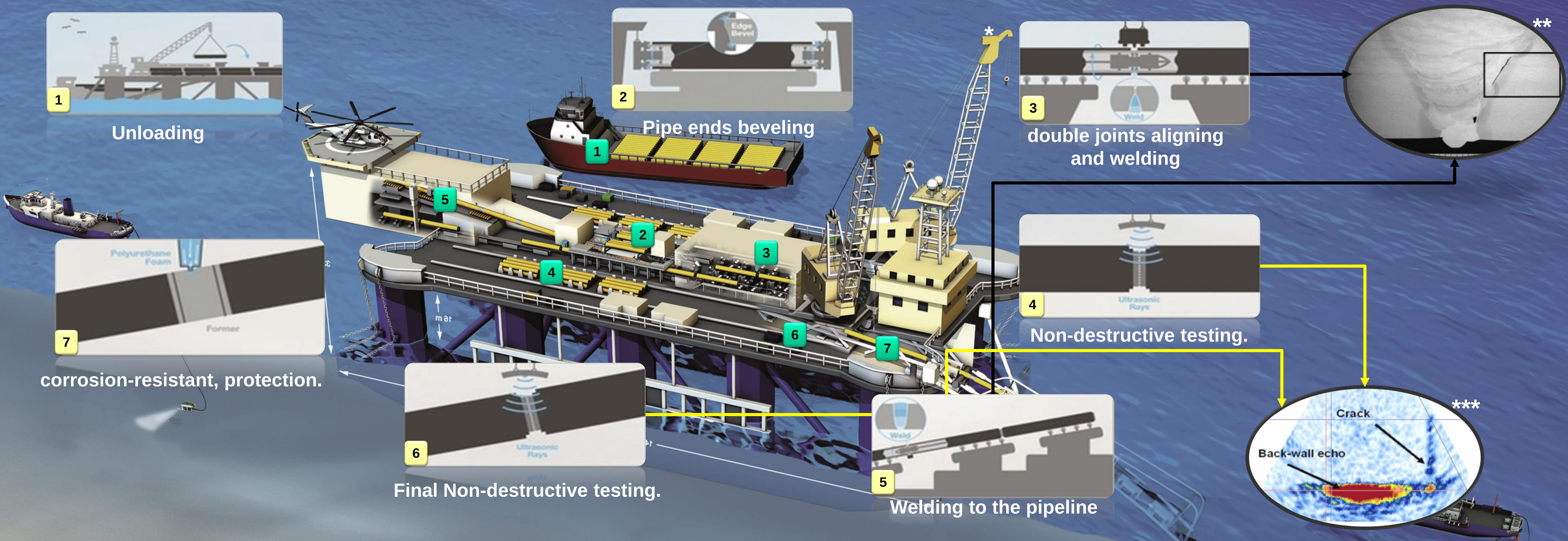
Kaveh Samadian, Stijn Hertelé, Wim De Waele

Dept. Electrical Energy, Metals, Mechanical Construction and Systems , Soete Laboratory

UGent LABORATORY SOETE

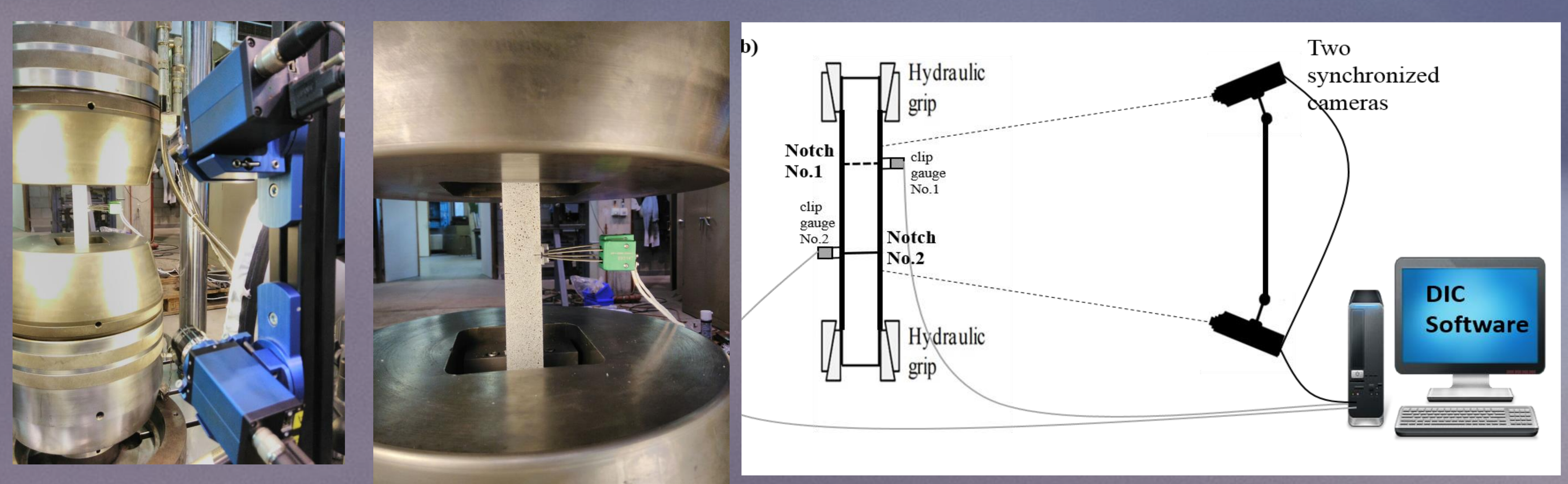
Multiple weld flaws may exist in close vicinity to each other due to various technical or metallurgical reasons. These flaws may interact, resulting in a reduced deformation capacity. Therefore, if flaw indications in close proximity are detected during inspection, it has to be determined whether or not they can be treated as independent. The conventional approach to address interacting flaws in a (linear-elastic) stress based framework is based on the calculation of a single equivalent surface breaking flaw.

A similar approach is lacking for strain based assessments, in which global plastic deformation is allowed for. As an example, pipelines may be subjected to plastic deformation when operated in harsh environments and offshore areas. Since the effects of multiple interacting flaws on tensile deformation capacity are not completely understood, an overly conservative prediction in the presence of multiple flaws can unnecessarily increase weld rejection and repair rate. This project addresses flaw interaction under global plastic deformation from a numerical and experimental point of view.



1. Methods

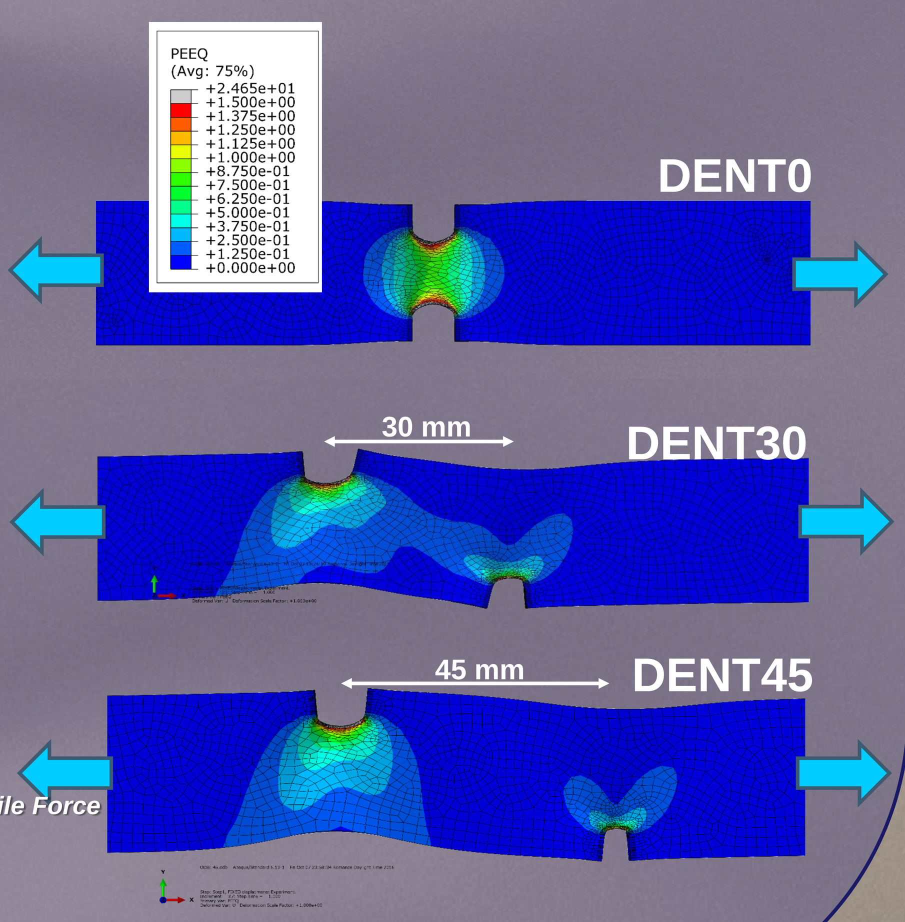
1.1. Experiments:



In order to investigate the interaction of adjacent defects, the double edge notched tension (DENT) specimen with varying out-of-plane distances between the notches is used. Flaw interaction is identified on the basis of full field surface strain distributions, measured by 3D digital image correlation. Double and single clip gauge methods are used to characterize the crack tip opening displacement (CTOD) and crack mouth opening displacement (CMOD).

1.2. Finite Element Modeling

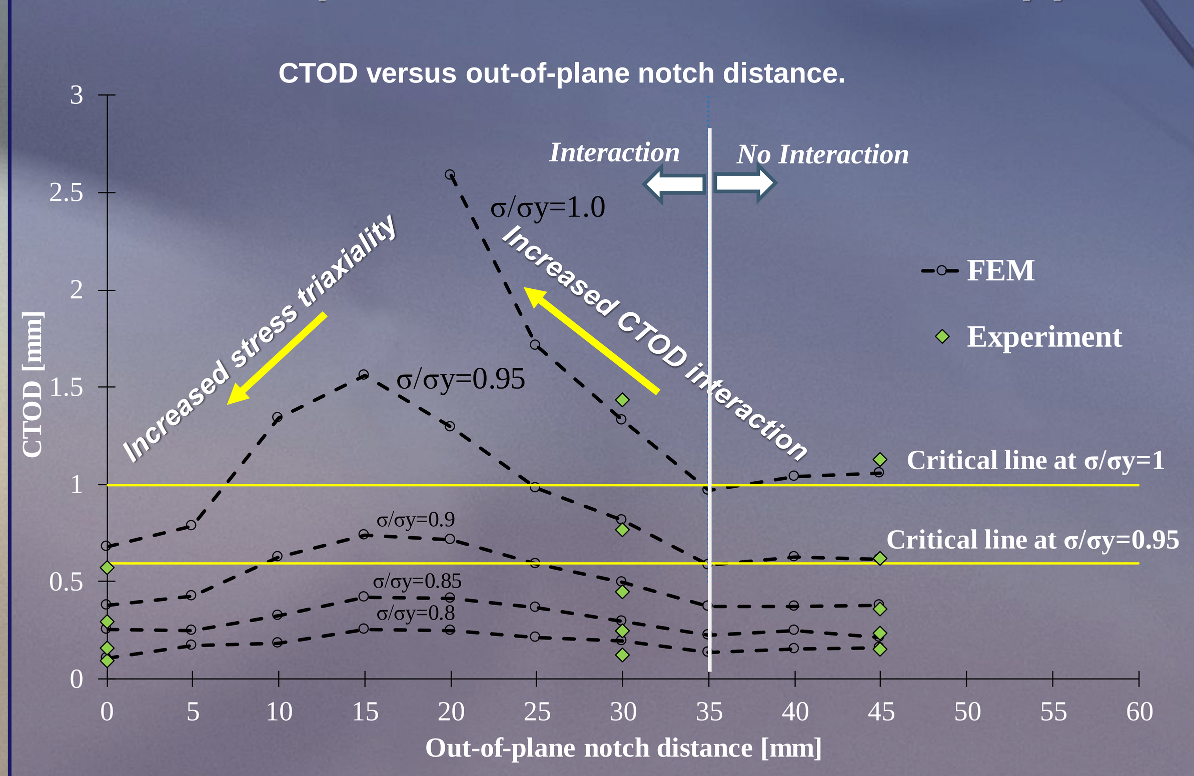
A parametric Python scripting framework automatically generates and analyzes finite element models of DENT specimens. Notches are surrounded by regular spider web meshes to accurately capture the local plastic strain concentrations. Model predictions of strain distributions and notch opening (CTOD, CMOD) have been experimentally validated.



2.Results

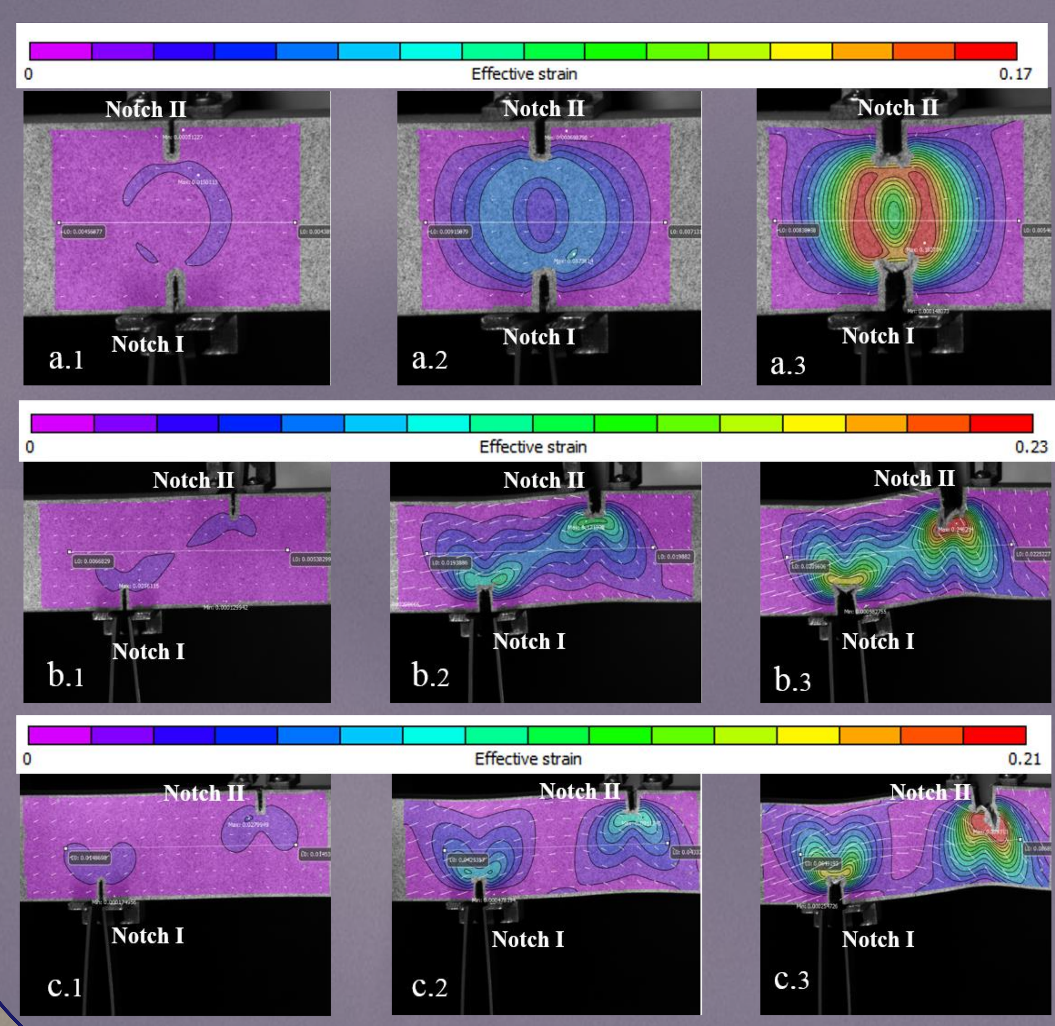
The interaction of the notches is investigated at two levels:

- Local (based on CTOD; traditional approach):



A CTOD based investigation reveals when flaw interaction gives rise to increases in crack driving force. It fails to describe flaw interaction for opposite notches (zero out-of-plane distance). In such case, CTOD interaction is inhibited by an increased stress triaxiality ahead of the notch tip.

- Global (based on overall strain distributions; innovative approach):



Flaw interaction is also reflected in the global structural response of the specimens, as e.g. observed by means of digital image correlation. Global strain based investigations of flaw interactions agree with local (CTOD based) analyses.

Effective strain pattern graphs:
a) DENT0, b) DENT30, c) DENT45.
1) At the early stages of the test,
2) When maximum force is reached,
3) When the force dropped to 80% of its maximum.

Image Sources:
*. Nordstream.com, **. Twi.com, ***. Ndt.net

3.Conclusion:

In addition to traditional local investigations based on crack driving force (CTOD), global strain patterns in specimens containing multiple defects can serve equally to study flaw interaction. Hence, novel criteria based on global behavior (i.e., strain) can be defined for strain based designed welded structures.

More efforts are required to quantify the effect of different factors on flaw interaction, and to understand how flaw interaction affects structural integrity (e.g., by increasing crack driving force, by changing stress triaxiality ahead of the notch tip, or a combination of both).

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#FEARS2017

This research was possible thanks to the financial support of BOF UGent, (Grant No. BOF13/24J/22).

Contact : Kaveh.samadian@ugent.be
www.soetelaboratory.ugent.be