III INTERNATIONAL INTERDISCIPLINARY CONFERENCE FOR PhD STUDENTS

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Influence of welded joints defects on cracks initiations and development for butt-welded joints of High-Strength Low Alloy (HSLA) pipelines

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ACKNOLEDGMENTS

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Call H2020-MSCA-ITN-2016

Grant agreement n. 721816

Extreme loading analysis of petrolchemicals plants and design of metamaterial based shields for enhanced resilience

Details at: r.unitn.it/en/dicam/xp-resilience

TABLE OF CONTENTS

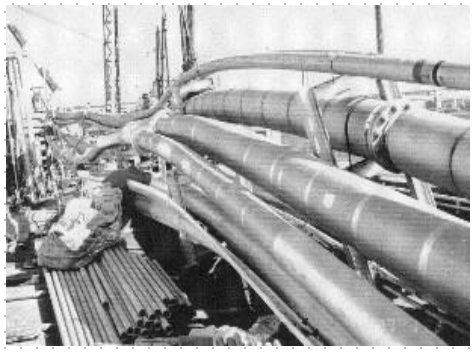
SEISMIC RISKS IN PETROCHEMICAL PIPING SYSTEMS

Piping Systems and Components suffer severe damages under earthquakes.

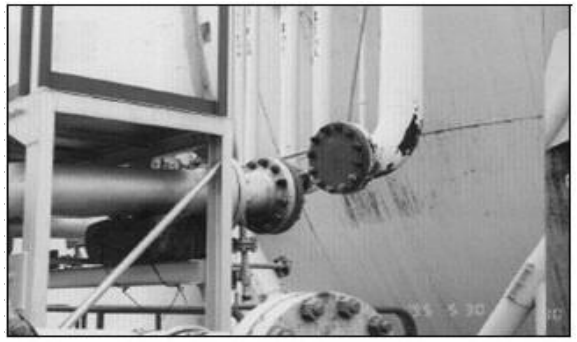
Consequences:

- Casualties;
- Loss of assets;
- Environmental Pollution;
- …

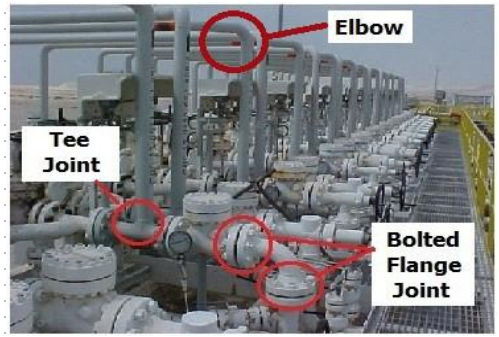
Refinery Conflagration
Kocaeli Earthquake, Turkey, 1999



Pipeline failure
Kobe Earthquake, Japan. 1995



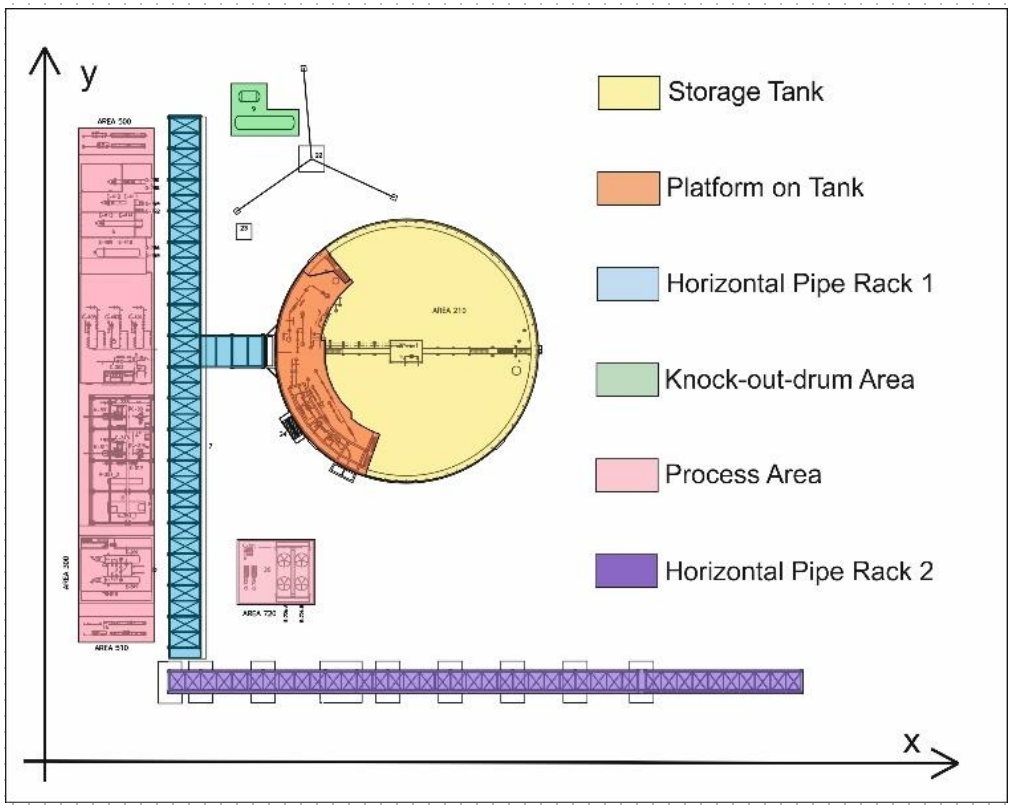
Bolted flange joint failure
Kobe Earthquake, Japan. 1995

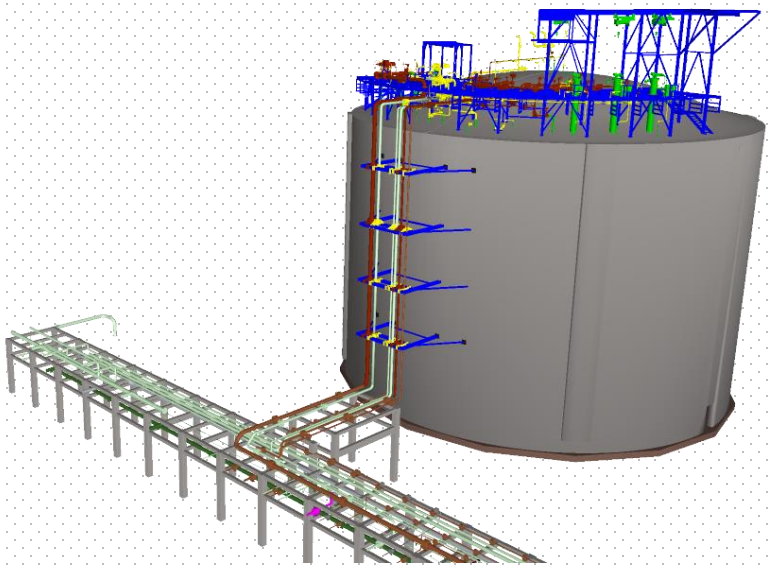


Components that might experience Loss of Containment (LoC)

LIQUIFIED NATURAL GAS (LNG) PLANT

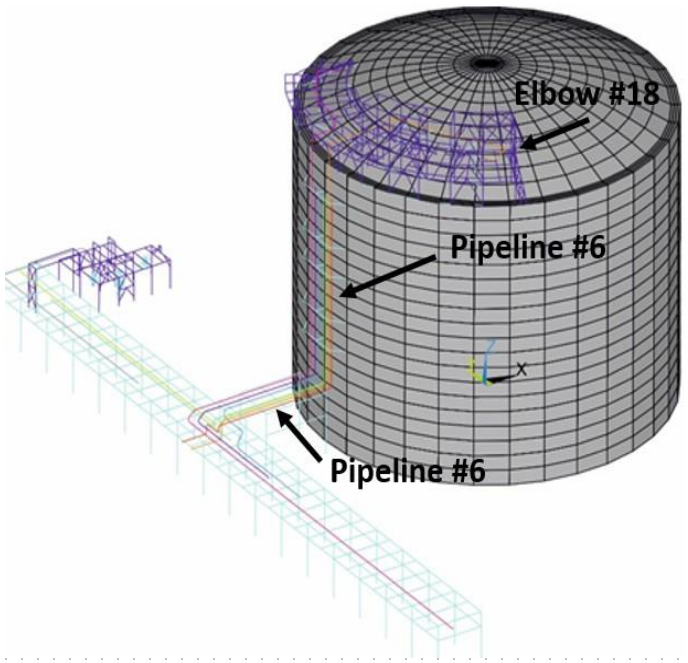
THE LNG PLANT – CASE STUDY #2





- Case Study #2 → Regassification plant
  - Storage tank for ethylene
  - Piping system
  - Supporting structures for pipings
    - Concrete structure
    - Steel platform
  - Process Area for Ethylene:
    - Knock-out-Drum Area

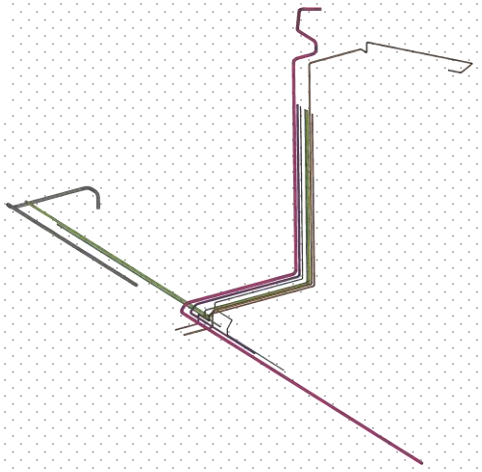
THE LNG PLANT - ANSYS FE MODEL



~ = 20,000 degrees of freedom

- 1338 elements BEAM4;
- 84 elements LINK180;
- 159 elements PIPE289;
- 95 elements ELBOW290;
- 1122 elements SHELL181

Still a simplified piping system



Complete model of just 2 pipelines out of 7 on top of the tank

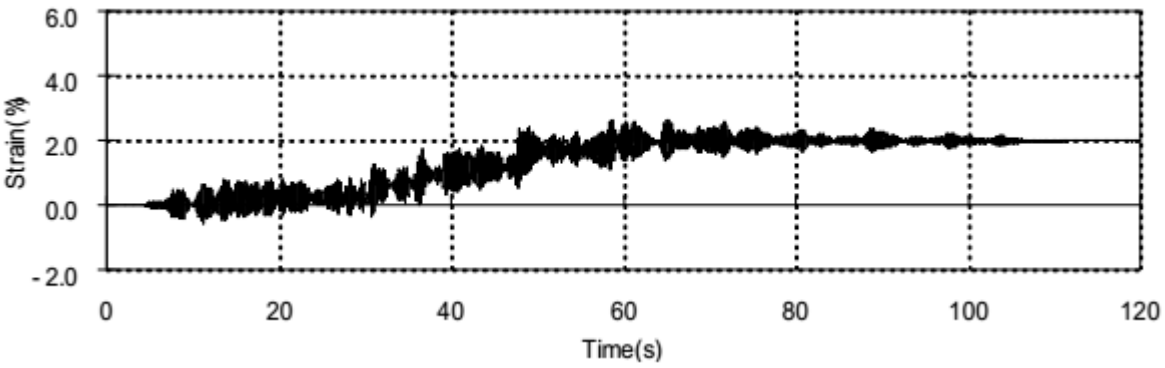
Details of modelling process and results can be found at:
"Probabilistic seismic analysis of an LNG subplant" - Journal of Loss Prevention in the Process Industries - O.S Bursi, R. di Filippo, V. La Salandra, M. Pedot Md S. Reza

LEAKAGE AND FAILURE CASES - ELBOWS

Leakage Limit State – HOOP TENSILE STRAIN

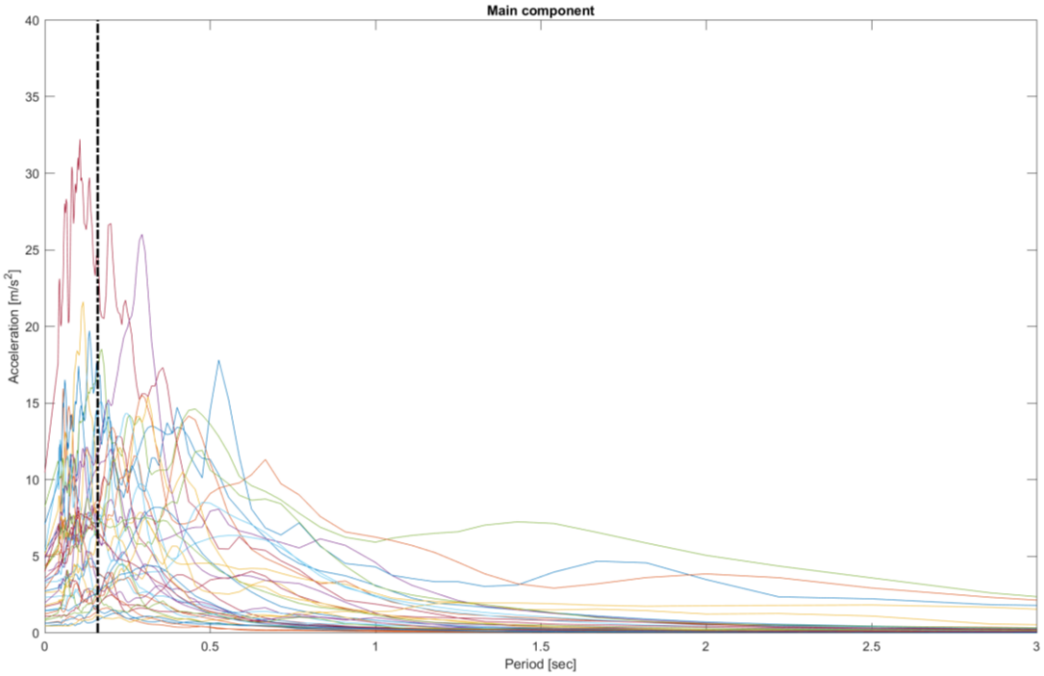
As shown in results from JNES-NUPEC* (2008), the elbow strain level could predict a leakage event. **In particular a hoop strain equal to 2% was found to be the onset of leakage.**

**Seismic Analysis of Large-Scale Piping Systems for the JNES-NUPEC Ultimate Strength Piping Test Program (2008)*



PROBABILISTIC SEISMIC DEMAND ANALYSIS

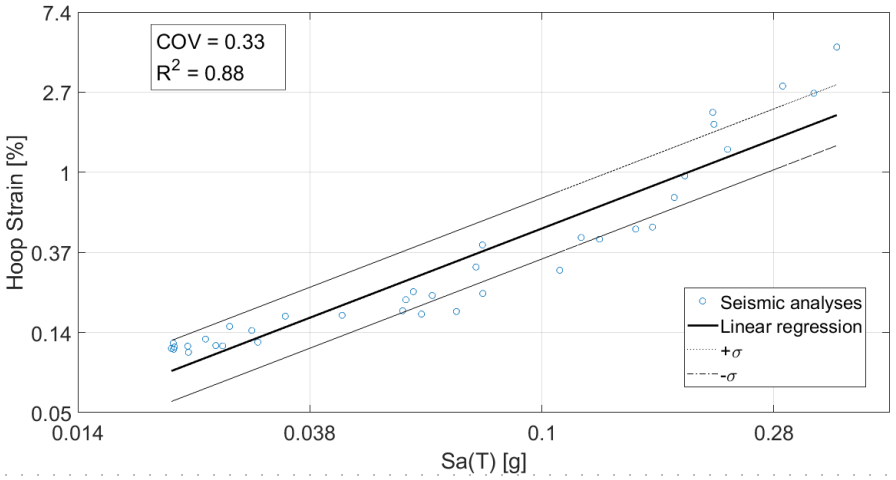
- Performed with Cloud Analysis Method;
- The $S_a(T)$ was chosen as Intensity Measure (IMs). The period of the spectral acceleration was set according to the main vibrational mode of the LNG tank, i.e. T=0.16s.
- Suite of 36 natural ground motions selected from European Strong Motion Database (ESM) with different values of magnitude Mw and PGA

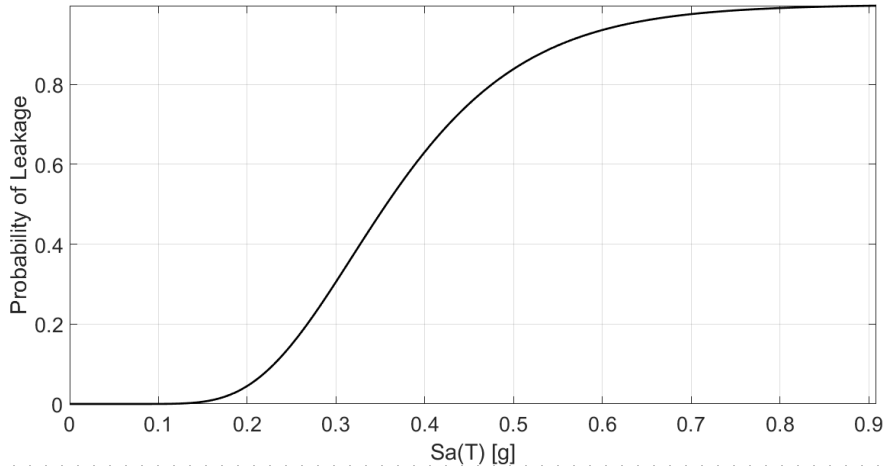


We applied the 3 components (X, Y, and Z direction) of each accelerograms together. Actual direction in model analysis were chosen in order to obtain the most demanding conditions

PROBABILISTIC SEISMIC DEMAND ANALYSIS

Results for Elbow #18 – Tank Platform





Probability of Leakage over the reference life (100 years)

Hazard Curve of the high-seismic site of Priolo Gargallo (Sicily)

$$P(edp) = \int_{im} P(EDP > edp|im)|d\lambda(im)|$$

$$P_{leakage} = 1.4 \cdot 10^{-3}$$

$7.2 \cdot 10^{-5}$

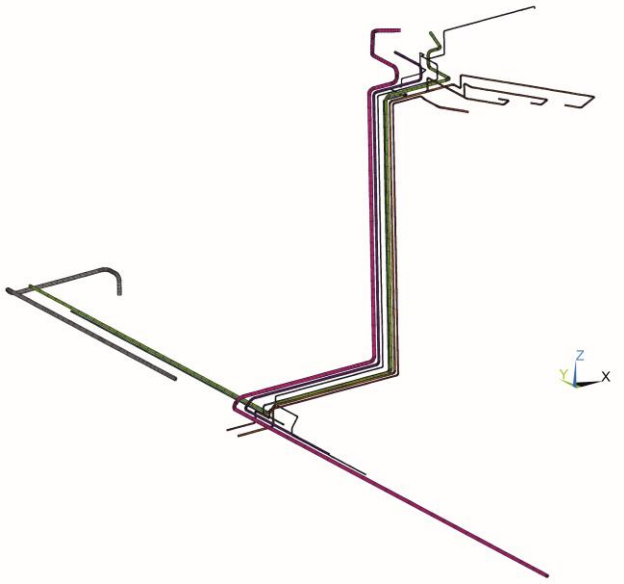
Ultimate limit state

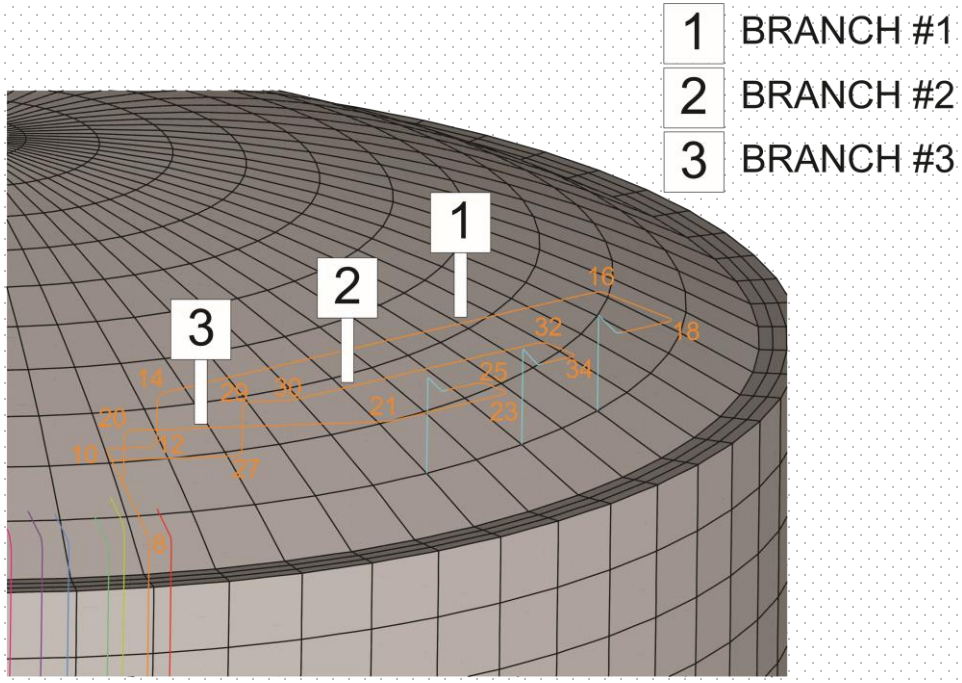
$6.7 \cdot 10^{-2}$

Serviceability limit state

PROBABILISTIC SEISMIC DEMAND ANALYSIS

Refined model with all pipelines.





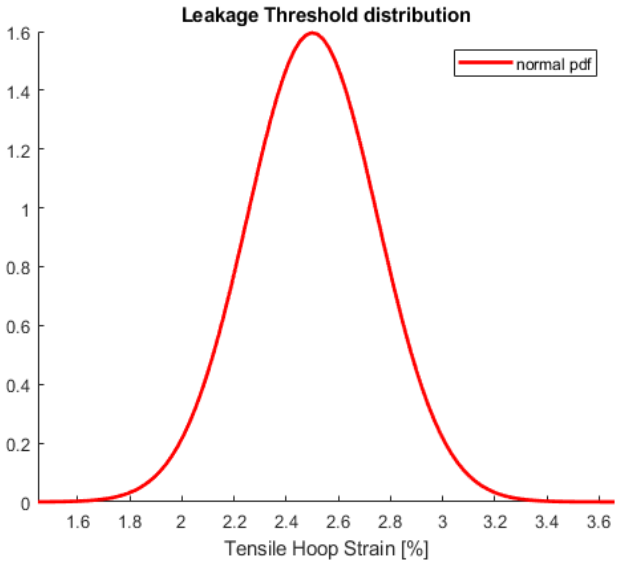
~ = 33500 degrees of freedom

- 1338 elements BEAM4;
- 84 elements LINK180;
- 240 elements PIPE289;
- 210 elements ELBOW290;
- 2244 elements SHELL181

PROBABILISTIC SEISMIC DEMAND ANALYSIS

Leakage Limit State – HOOP TENSILE STRAIN: Probabilistic distribution

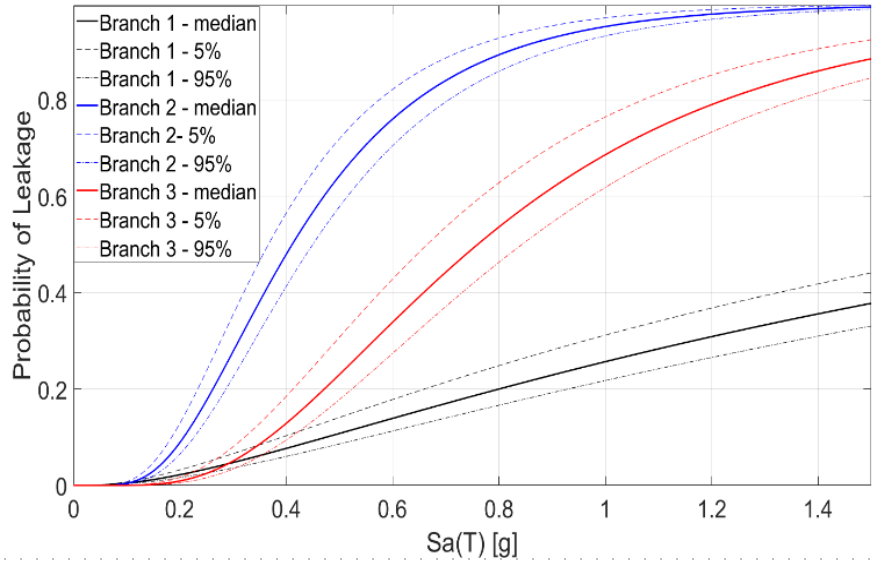
Instead of a deterministic value for Limit State Hoop Tensile Strain we assumed a probability distribution:



Normal distribution with:

$\mu = 2.5\%$

$\sigma = 0.25\%$

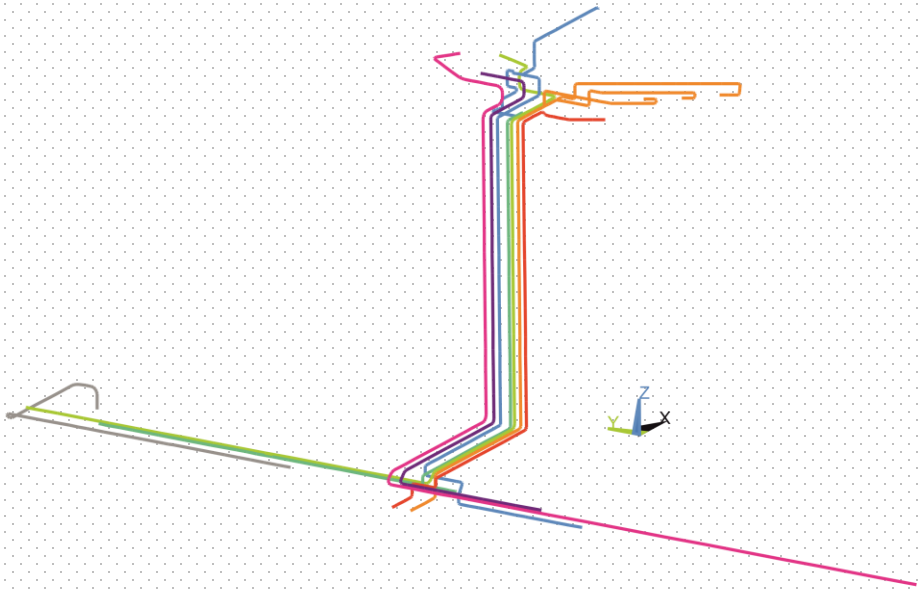


Fragility curves for seismic analysis

$P_{leakage} = 2 \cdot 10^{-2}$

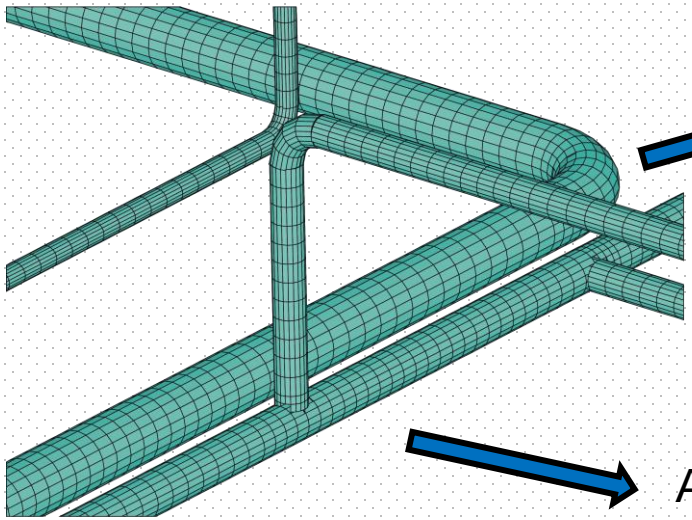
SUBSTRUCTURING – Future developments

Detailed analysis on piping system: displacements taken from previous seismic analysis are applied only to this substructure



Improvements:

- Complete layout;
- Flenged bolted joints added on all pipelines;
- Refined mesh;
- Effect of potentials failures of welded joint between pipes;



Refined elbow elements

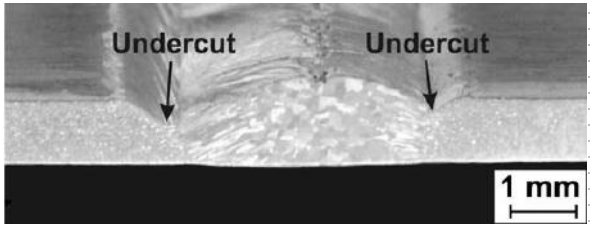
Analysis of T-joints elements

EFFECTS OF DEFECTS ON WELDED JOINTS

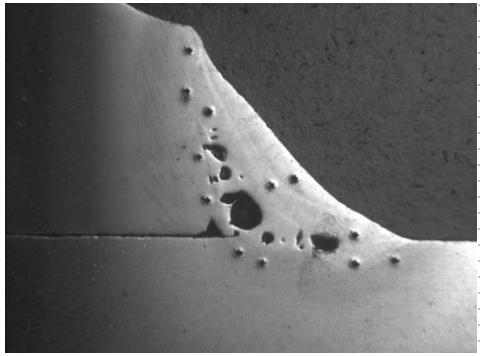
SMA and GMA welded joints

Destructive Tests on welded pipes samples with induced defects (On going…):

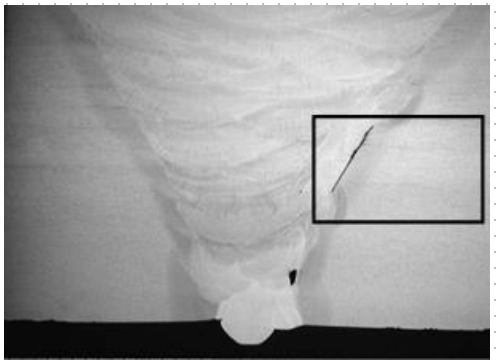
- Static test;
- Fatigue test;



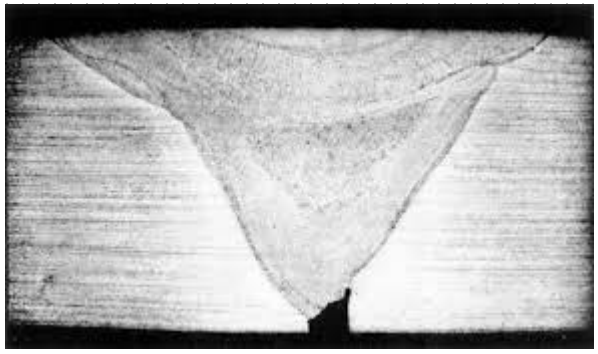
1)Undercut



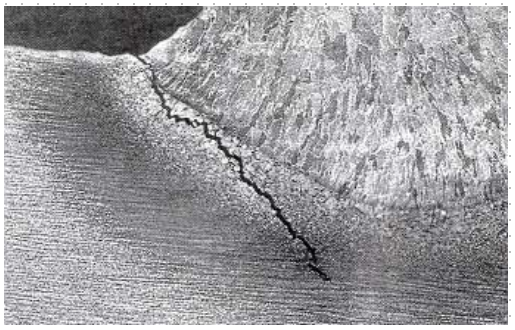
2)Porosity



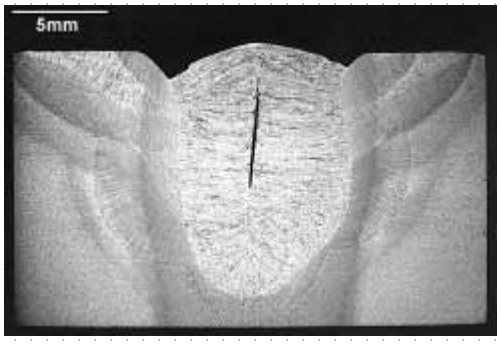
3)Lack of Fusion



4)Lack of Penetration



5)Cold Cracks

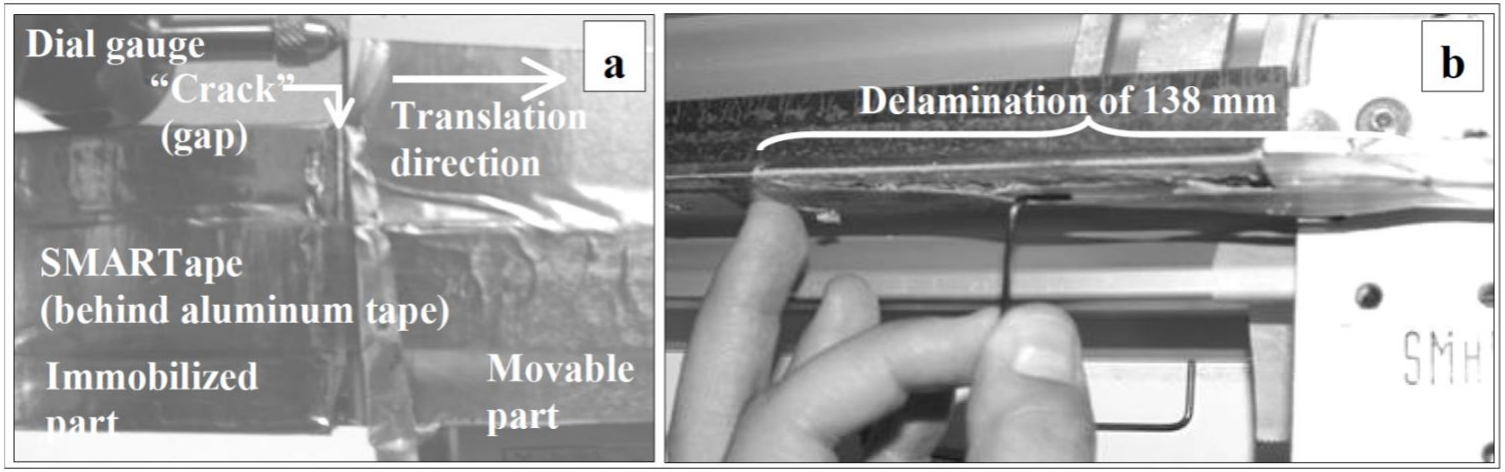


6)Hot Cracks

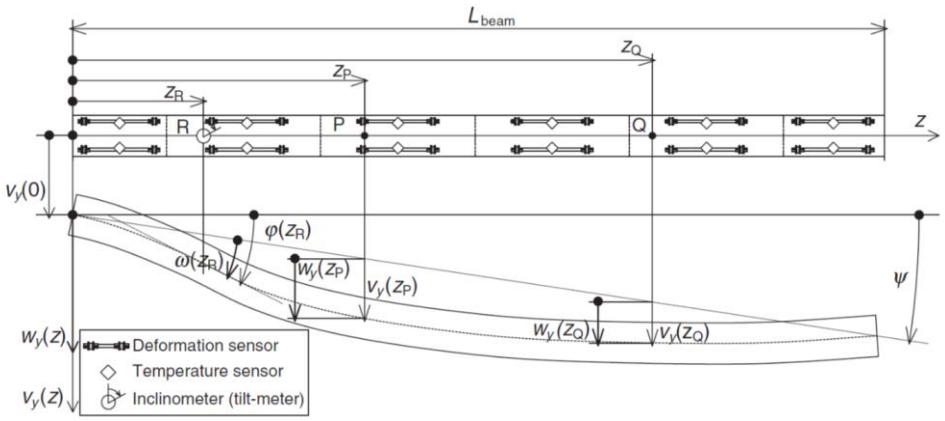
DAMAGE DETECTION

Secondment period @ SMARTEC – Switzerland → Next year

- Effect of crack initiation on response of distribuited fiber optics sensors:



- Field displacements reconstruction of buried pipelines from curvature data.



Thank you for your attention!