HORIZON 2020

# ExchangeRisk

EXperimental & Computational Hybrid Assessment of Natural Gas Pipelines Exposed to Seismic Risk


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# Secondments Overview

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Planned** | **60** | **18** | **18** | **9** | **3** | **0** | **12** |
| | | | | **Done** | **41,5** | **10** | **1** | **6,5** | **0** | **12** | **12** |
| | | | | **Open** | **18,5** | **8** | **17** | **2,5** | **3** | **-12** | **0** |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | **BUW** | **CAU** | **UNAP** | **UOB** | **SANNIO** | **UPAT** |
| **Sending** | **Hosting** | **Start** | **End** | | **Months Total** | **10** | **1** | **6,5** | **0** | **12** | **12** |
| | | | | | | | | | | | |
| CAU | VCE | 19.07.2016 | 19.08.2016 | Stutz | 1 | | 1 | | | | |
| UNAP | VCE | 23.07.2016 | 23.08.2016 | Balzopoulus | 1 | | | 1 | | | |
| BUW | VCE | 19.09.2016 | 19.10.2016 | Zabel | 1 | 1 | | | | | |
| UNAP | VCE | 17.07.2017 | 17.08.2017 | Pascal Cito | 1 | | | 1 | | | |
| UNAP | VCE | 21.08.2017 | 21.09.2017 | Roberto Baraschino | 1 | | | 1 | | | |
| UPATRAS | VCE | 03.07.2017 | 02.07.2018 | Harry Thanopoulos | 12 | | | | | | 12 |
| USANIO | VCE | 30.10.2017 | 31.08.2018 | Grigoris Tsinidis | 12 | | | | | 12 | |
| Weimar | VCE | 01.04.2018 | 30.06.2018 | Abinet Habtemariam | 3 | 3 | | | | | |
| Weimar | VCE | 01.08.2018 | 31.10.2018 | Abinet Habtemariam | 3 | 3 | | | | | |
| Weimar | VCE | 01.05.2018 | 31.07.2018 | Marcelo Bianco | 3 | 3 | | | | | |
| UNAP | VCE | 09.07.2018 | 09.08.2018 | Pascal Cito | 1 | | | 1 | | | |
| UNAP | VCE | 27.08.2018 | 27.09.2018 | Pascal Cito | 1 | | | 1 | | | |
| UNAP | VCE | ??? | ??? | Akiko Suzuki | 1,5 | | | 1,5 | | | |
| CAU | VCE | ??? | ??? | Schwindrofska | ??? | ??? | | | | | |

# Seconded Colleagues in VCE

| Name | From | Duration | Topic |
|---|---|---|---|
| **Charalampos Thanopoulos** | University of Patras | 2nd Jul. 2017 to 2nd Jul. 2018 (12 months) | Report on the technical specifications of a complete monitoring system for post-earthquake rating of natural gas pipelines, and its integration to the Decision Support System, for Rapid Pipeline Recovery |
| **Grigorios Tsinidis (PhD)** | University of Sannio | 30th Oct. 2017 to 30th Oct. 2018 (12 months) | Seismic fragility assessment of gas pipelines |
| **Abinet Habtemariam** | Bauhaus-Universität Weimar | 1st Apr. 2018 to 31st Oct. 2018 (6 months) | Implementation of spring support conditions in linear Generalized Beam Theory (GBT) to model support-pipe interaction |
| **Marcelo Bianco** | Bauhaus-Universität Weimar | 1st May. 2018 to 31st Jul. 2018 (3 months) | Formulation of support-pipe interaction for pipelines based on GBT |

# Five Technologies for Inspection/Monitoring of Gas Transmission Pipelines

| Technology | Capable of… | Advantages and drawbacks | Inspection Range/ Sensitivity |
|---|---|---|---|
| ILI Tools | ▪ Leak detection<br>▪ Identification of mechanical damage<br>▪ Periodically strain monitoring<br>▪ Periodically corrosion monitoring<br>▪ Cracks detection | ✗Direct assessment cannot be achieved<br>✓Applicability on buried applications<br>✓Applicability on offshore applications<br>✗High Cost | ▪ 220 km per day<br>▪ Can locate a leak within 1 yard (~0.9m) |
| Fiber Optic Cable Systems | ▪ Leak detection<br>▪ Strain monitoring<br>▪ Intrusion prevention<br>▪ Tracking of Pipeline Inspection Gauges | ✓Direct assessment (**Order of seconds or minutes**)<br>✓Applicability on buried applications<br>✓Applicability on offshore applications<br>✗ Inability of detecting existing leaks<br>✗ Not easy retrofitting<br>✗ High Cost | ▪ 90km for DTSS (temperature and strain, Brillouin back-scattering) with a single interrogation unit<br>▪ Can locate a leak to 1-3% of the length of the cable<br>▪ Detection of leakages <1 SLM |

# Five Technologies for Inspection/Monitoring of Gas Transmission Pipelines

| Technology | Capable of… | Advantages and drawbacks | Inspection Range/ Sensitivity |
|---|---|---|---|
| Software-based methods<br><br>(Also known as INTERNAL or CPM systems)<br><br>**These systems implement one or more software-based techniques .** | ▪ Leak detection | ✓Direct assessment **(Order of seconds or minutes)**<br>✓Applicability on buried applications<br>✓Applicability on offshore applications<br>✓ Ability of detecting existing leaks<br>✓Easy retrofitting<br>✓Medium Cost | ▪ Known applications up to 1000km<br>▪ High sensitivity of 1% of the normal flow rate<br>▪ Good leak location accuracy, 2-5% of the monitored segment (negative pressure technique) |
| Remote Inspection (UAVs, Helicopters, Aircrafts) | ▪ Intrusion prevention<br>▪ Leak detection | ✗Direct assessment cannot be achieved<br>✓Applicability on buried applications<br>✗Inapplicability on offshore applications<br>✗High Cost | ▪ Up to 600km per day with aircraft, or<br>120km per day with UAV (still under development)<br>▪ Min detectable leak of order of 2 ppm |

# Five Technologies for Inspection/Monitoring of Gas Transmission Pipelines

| Technology | Capable of… | Advantages and drawbacks | Inspection Range/ Sensitivity |
|---|---|---|---|
| Hydrocarbon - Sensing Tubes | ▪ Leak detection system | ✗ Direct assessment cannot be achieved **(acquisition time, 24-72h)**<br>✓ Applicability on buried applications<br>✓ Applicability on offshore applications<br>✗ Not easy retrofitting<br>✗ High Cost | ▪ Inspection of 50km with one system<br>▪ Can locate a leak to 0.5% of the length of the cable<br>▪ Detection of leakages <1 SLM **Typically 50SL/h** |

| Combo Systems (Combination of Software Based Methods and External systems) | | |
|---|---|---|
| **Systems for instant, full post-seismic assessment** = LDS*+ strain monitoring | **Systems for rapid, full post-seismic assessment** = LDS+ strain inspection | **Systems for partial post-seismic assessment** = LDS |

**Why is it perhaps the future of Monitoring Systems?**

1. Combine the advantages of Internal and External Systems (Low cost of Internal Systems and high sensitivity with less false alarms of External Systems).
2. Satisfy TRFL 2017 (New Edition of German Code): **A single method is not sufficient for leak detection!**

*LDS= Leakage Detection System

# Summary of Work

- Conducted a literature review, focusing on: (1) reported damage modes of gas pipelines during past earthquakes, (2) methods for the evaluation of the seismic fragility of gas pipelines, (3) available empirical and numerical seismic fragility curves for gas pipelines

- Based on the literature review, a manuscript was drafted for the PVP2018 conference (finally not submitted), presenting a preliminary critical review of available fragility functions and commonly used IM for the structural assessment of gas pipelines. A more detailed manuscript is currently under preparation to be submitted in a peer-reviewed journal

- It was decided to focus on buckling damage modes of gas pipelines that may be caused by seismically-induced ground deformations, acting along the longitudinal axis of pipe (e.g. at locations of abrupt soil stiffness changes, such as stiff soil – valleys interfaces)


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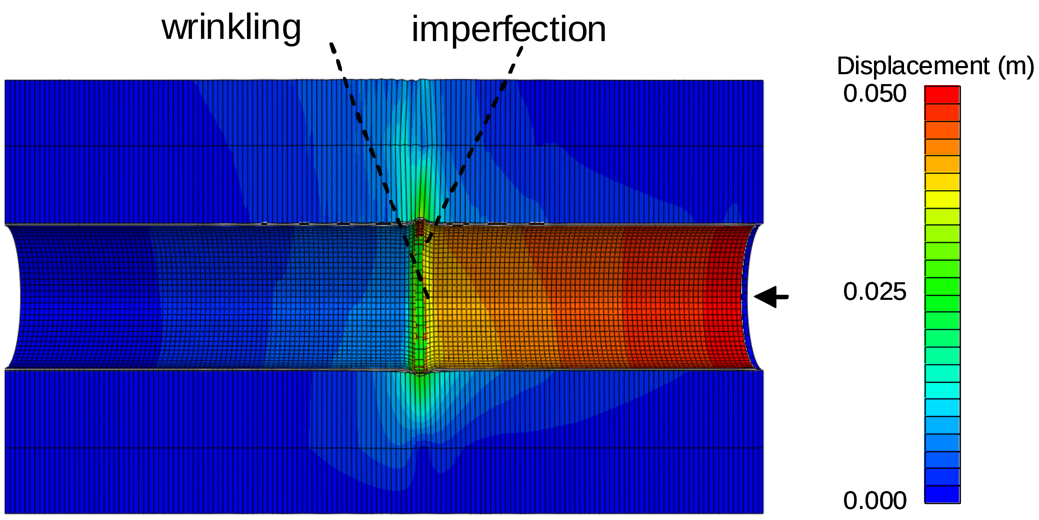
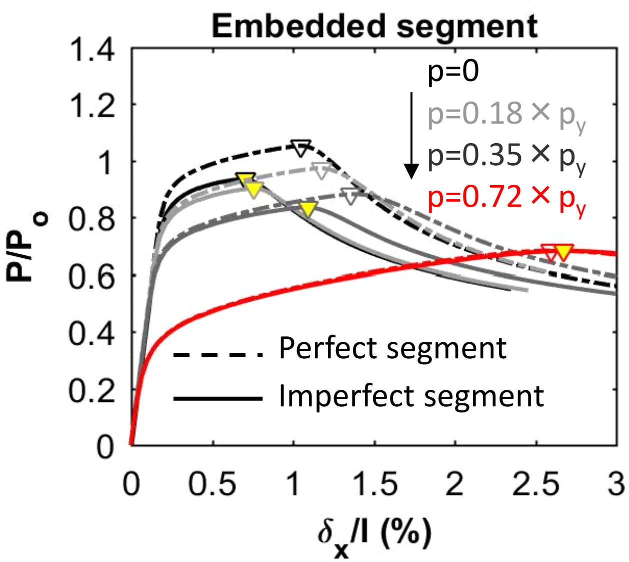
# Summary of Work

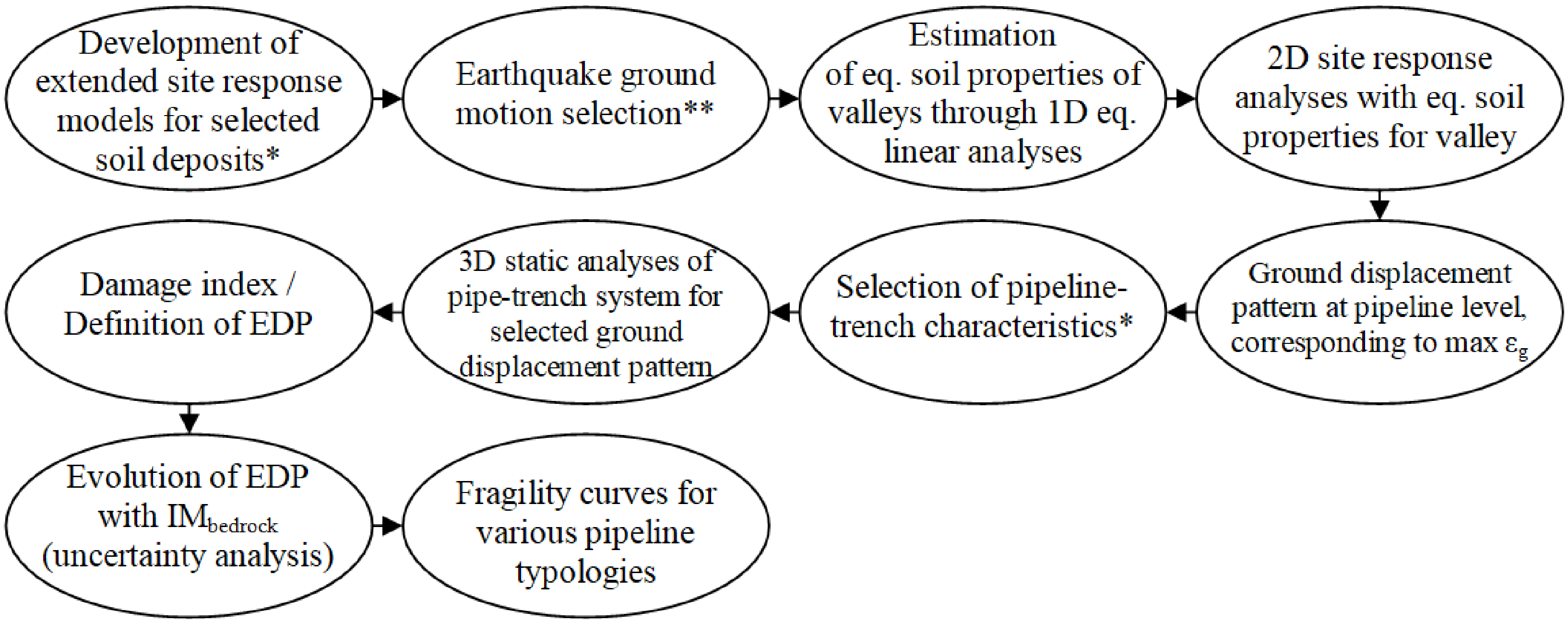
- A literature review was conducted to understand the **plastic buckling response of pipes**
- A series of **static compression analyses** was also carried out on segments of embedded and above ground gas pipelines, so as to better understand the buckling response of this type of structures, as well as the relevant simulation aspects (geometric imperfections, effect of internal pressure etc)
- The main assumptions and conclusions of this numerical parametric study are summarized in manuscript that was drafted to be submitted to ICASS 2018 conference



# Summary of Work

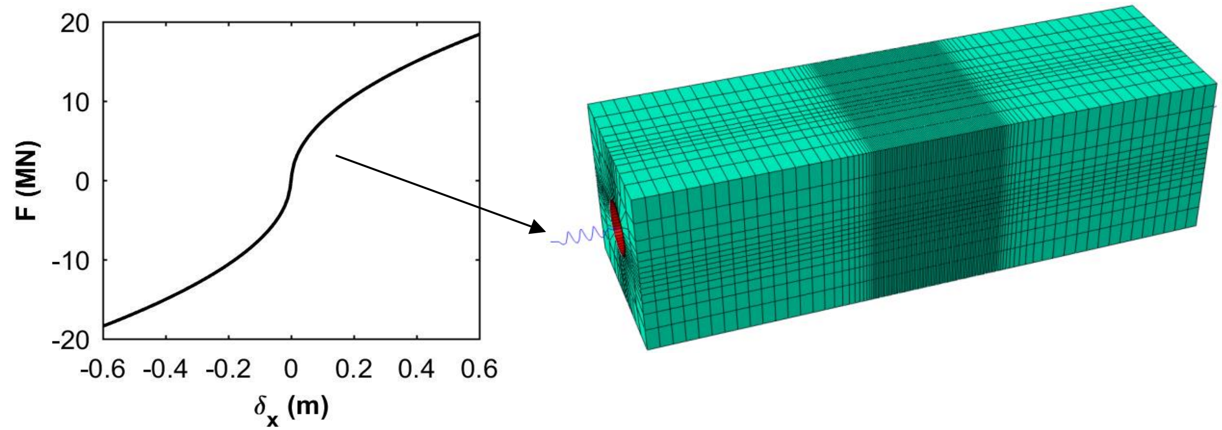
- A methodology for the fragility assessment of gas pipelines under earthquake-induced buckling damages is currently being developed
- A propabilistic seismic demand analysis (cloud analysis) is proposed, including static analyses of 3D coupled pipe-soil models of finite length, subjected to a series of ground deformations, the latter defined separately through 2D soil response analyses of selected ground-valley deposits
- Flowchart of proposed methodology:



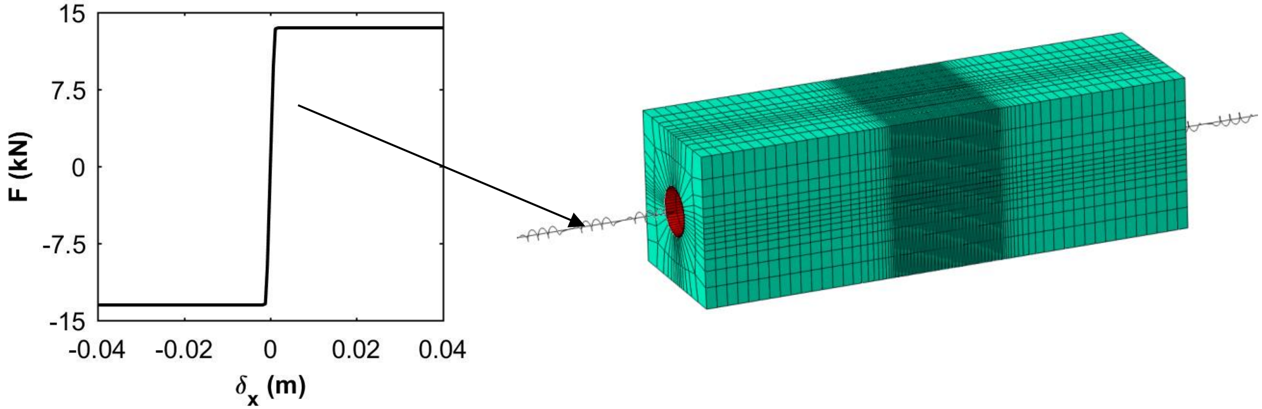
# Summary of Work

- **Required length of coupled 3D pipe-soil model to replicate accurately the loading condition on the pipe and hence the potential buckling phenomena ?**
- **Alternative methods for extending the 3D pipe-soil model efficiently are examined**

**Generalized springs at the end sides of the pipe**

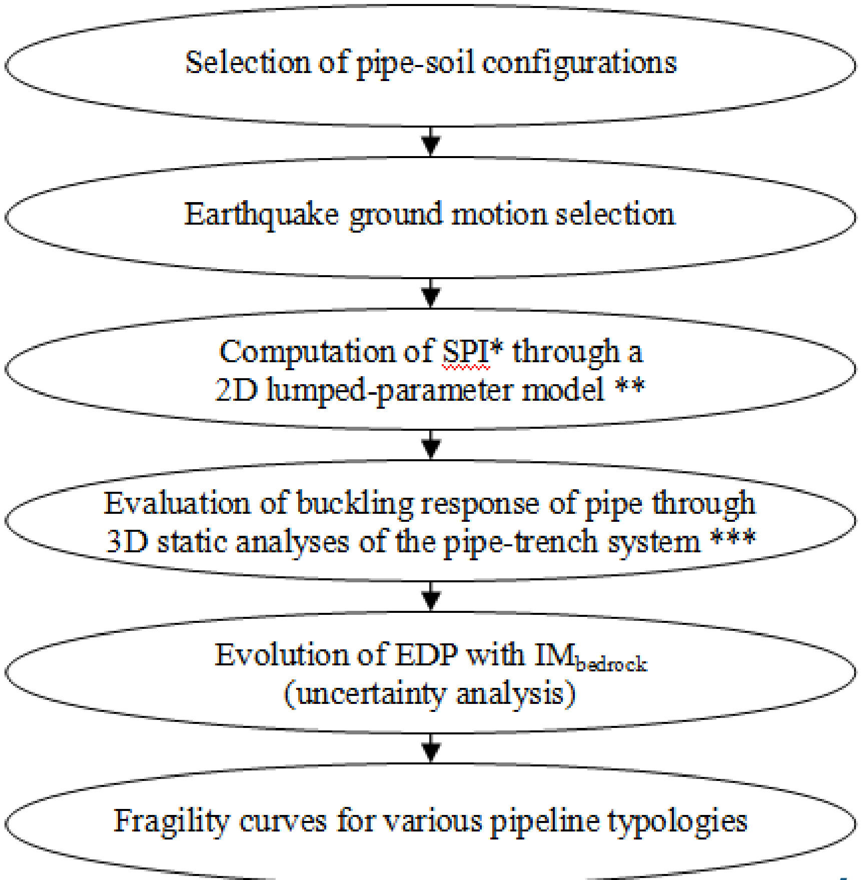



**Beam on springs models at the end sides of the pipe**



# Summary of Work

- An alternative potential framework for the fragility assessment is also investigated in collaboration with the University of Bristol (Psyrras & Sextos)
- The framework includes the development of a computationally efficient 2D lumped-parameter model for the evaluation of the soil-pipe interaction phenomena. Flowchart of the framework:



# Pipelines Support Condition

- Above ground pipelines - Intermediate supports
  - Soil-foundation-pipe interaction
  - The effect of the ground motion can be reduced by using special support conditions between foundation and pipe
- Buried pipelines - Continuous supports
  - Soil-pipe interaction
  - Seismic response is largely dependent on the surrounding soil

**Objective**

Numerical modeling of Foundation-Pipe interaction for above ground pipelines using linear Generalized Beam Theory (GBT)

- Including spacial bearing conditions designed to mitigate the effects of earthquake

# Introducing Support Condition in GBT

- GBT extends beam theory and allows for description of cross-sectional deformations using a predefined sets of deformation functions
- The friction forces from the sliding support are applied to the selected deformation functions
- Vertical spring represent the Foundation-Soil interaction

Figure: Case study of Trans-Alaska pipeline system support condition [1]

[1] http://www.walwol.ch/39204/trans-alaska-pipeline/

# Developing of Spring Supports in GBT

- Extends GBT assumptions to include nodal and distributed spring conditions
- The stiffness of springs around the pipe's perimeter are decomposed in a Fourier-Series, which each term defines an orthogonal mode deformation shape

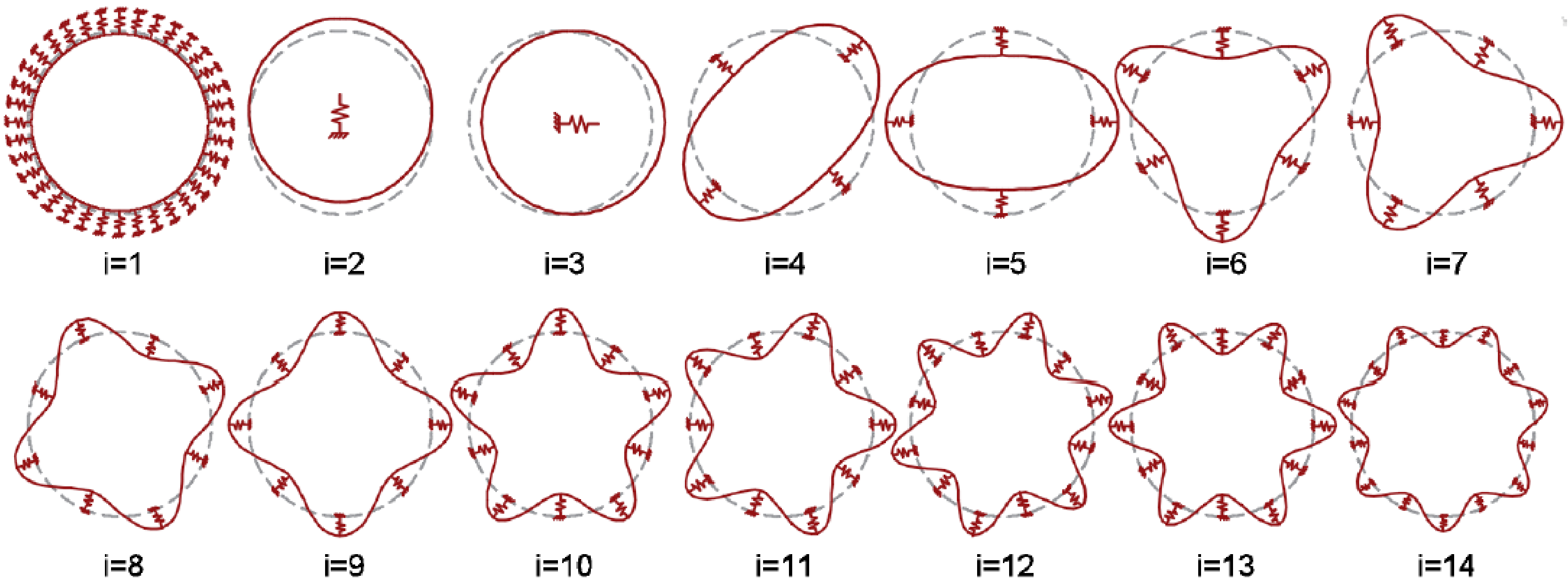



Figure: Pipe cross-section deformation according to GBT