COMSOL CONFERENCE 2009
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Guided Wave in Engineering Structures Using Non-Contact Electromagnetic Acoustic Transducers – A Numerical Approach for the Technique Optimisation.

Dr. Slim SOUA

Plant Integrity Ltd.

TELETEST FOCUS

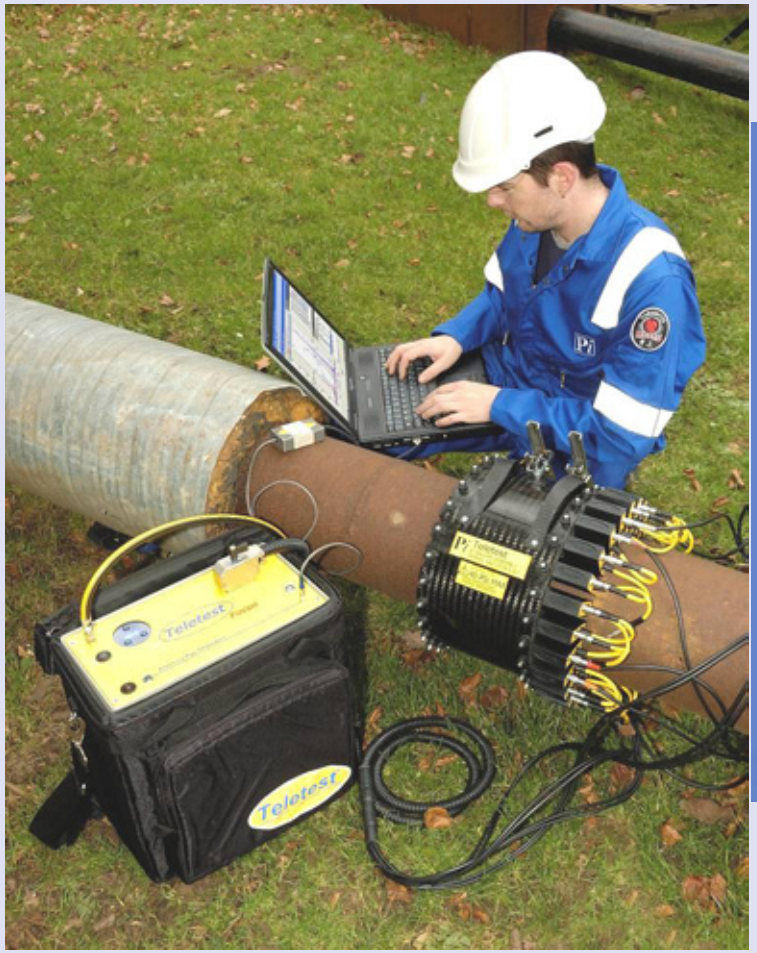
TWI

What is TWI ?

World Centre for Materials Joining Technology and allied Technologies

- Membership based Research and Technology Organisation since 1946
- Company limited by guarantee
- 580 staff worldwide
- £38m turnover in 2006
- Over 3500 Industrial members in 60 countries
- Non profit distributing

Plant Integrity Ltd



- Provides Teletest Services and Equipment
  - Long Range Ultrasonic Testing using Guided Waves (GW)
- Wholly owned subsidiary of TWI

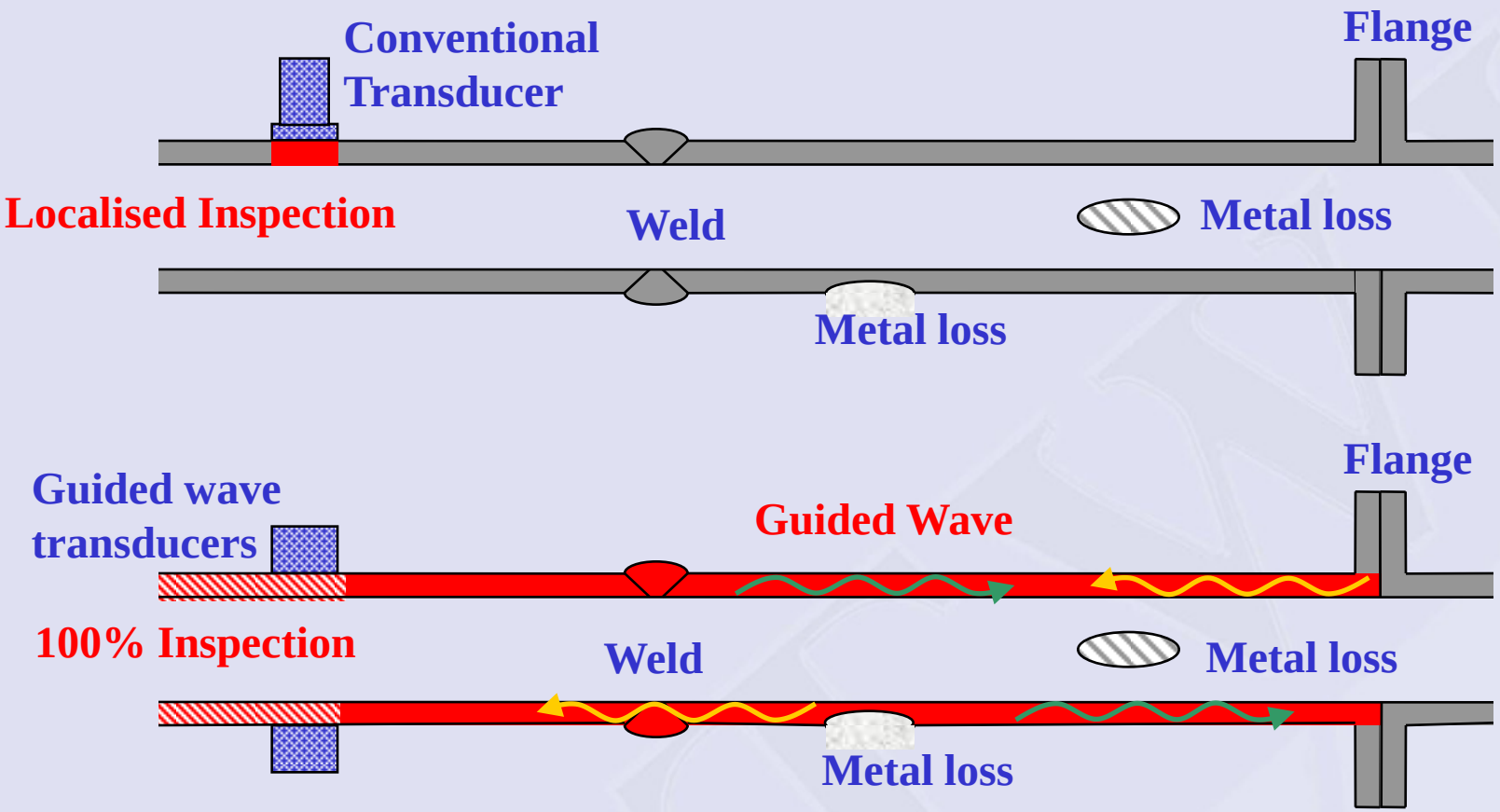
Industrial Need Guided Waves

- Corrosion of insulated pipe is a problem
- Many areas are inaccessible
- Costs of access exceeds costs of inspection
- 70% of plant inspection cost relates to pipework

Guided waves offers

- Rapid screening for in-service degradation,
- Reduction in costs of gaining access
- Avoidance of removal/reinstatement of insulation or coating, except at location of transducer tool
- Ability to inspect inaccessible areas
  - i.e clamps and cased or buried pipes
- 100% coverage

Conventional UT versus LRUT



Features

- Diameters – 1.5" to 48"
- 100% Coverage
- Test Range
  - Typical ±30m
  - Ideal conditions ±180m
- Productivity
  - Typical 500m per day
  - Under ideal conditions 3km has been achieved
- Service Temperature up to +125°C

Features

- Detection of internal or external metal loss
- Sensitivity
  - Metal loss down to 3% of pipe wall cross-section
  - Reliable detection of 9% metal loss flaws
- Discrimination between flaws and pipe features; welds, bends, supports, etc.
- Longitudinal accuracy better than ±100mm

Applications

- Road and river crossings
- Power plant tubing
- Risers
- Offshore topsides pipework
- Jetty lines
- Chemical plant pipework
- Tank farm link lines
- Sphere legs
- Pipe bridges
- Spiral welded pipe
- Refinery pipework

Examples of Application

Road Crossings

Buried Pipe

Sphere Support Leg

Gas Pipelines

Tool Developments

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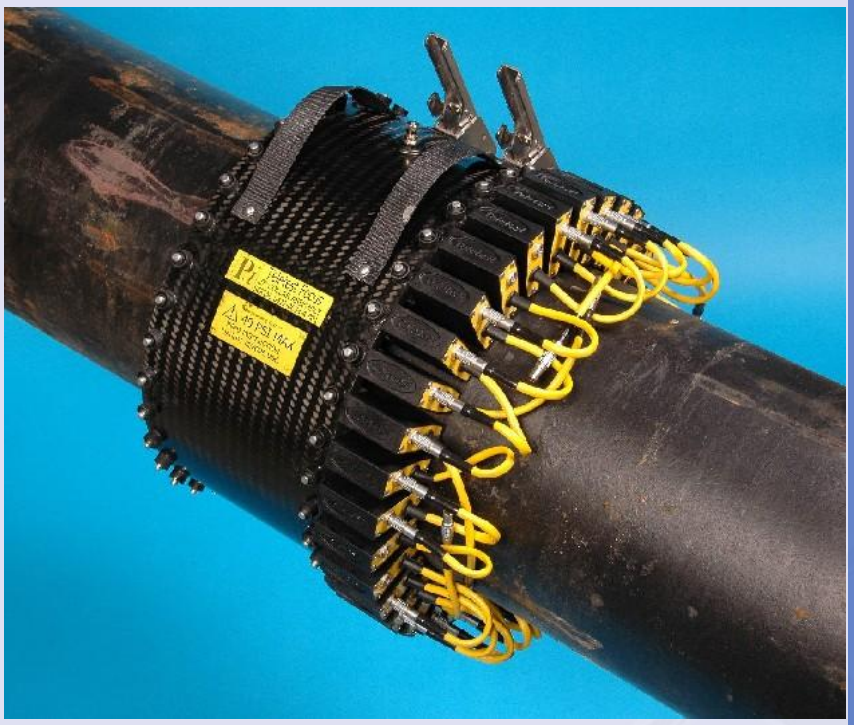
Key Features

- Easy to use unit and tool design for quick data collection
- Multimode – Longitudinal and torsional wavemodes on one tool
- Focusing – Defect distribution around circumference “one-click” away
- User friendly interface with report manager generator

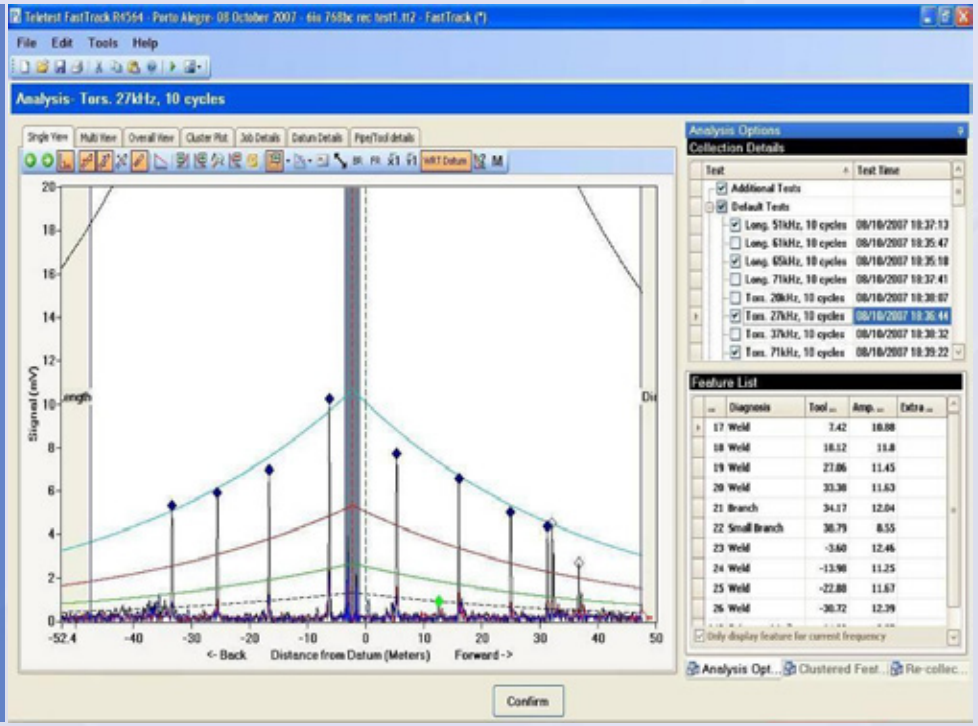
Collar design



- Robust composite construction
- Integrated clamp and bladder
- Collars link for >24” up to 48”
- Multimode
- Lightweight
- Cost efficient

FastTrack Software

- Automated set-up
- Fast and reliable defect detection
- Multimode
- Simplified Analysis
- On-site MS Word report generator
- <15 min data collection time/location



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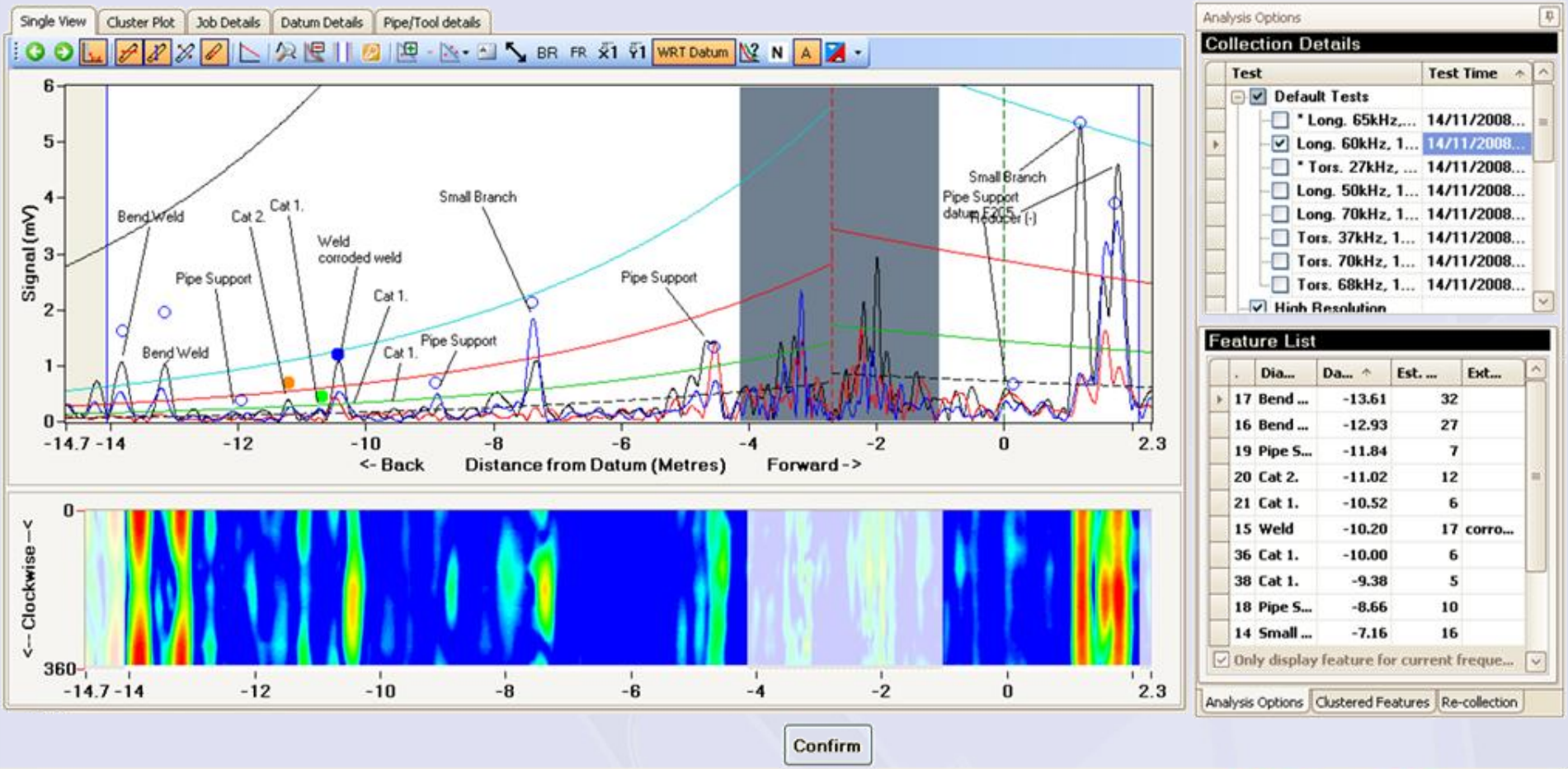
FastTrack Software



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Modelling using COMSOL

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Need for EMAT in GW excitation

Overcome limitations of using PZT surface contact sensors.

Require mechanical coupling usually achieved using:

(i) immersing method (transfer of the ultrasonic signals between the transducer and test sample by placing both objects in liquids).
(ii) contact (the transducer is pressed directly against the test sample with or without coupling gel).

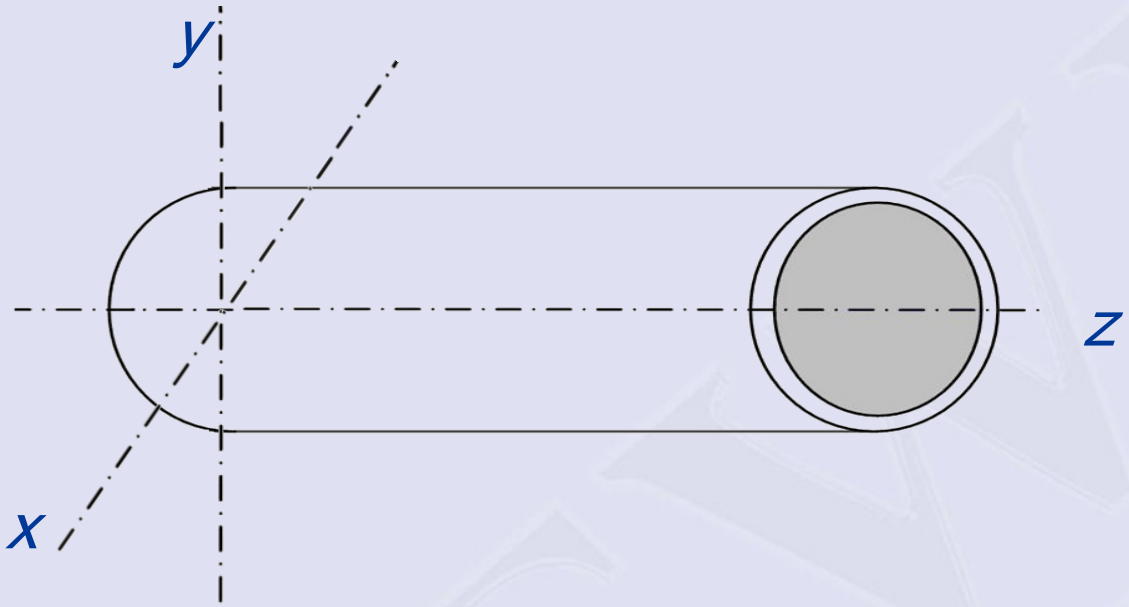
Inspection of very high temperature pipelines and tubes above 500°C, both coupling methods are extremely problematic.

Modelling Plan

1. Determine a set of parameters for the testing: Dispersion curves
   - GW mode selection
     - Frequency
     - Wavelength
     - Excitation
2. Transient analysis: Verify the A scan content
   - Optimise the NCET configuration
     - Spacing
     - Mode spectra amplitude

Eigen frequency analysis

GW form in frequency domain: $U(x,y,z,t) = A(x,y)\exp(j\xi z)\exp(j\omega t)$

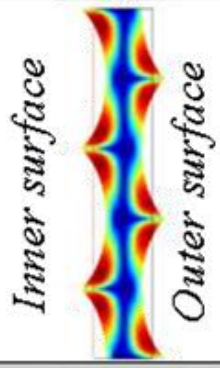
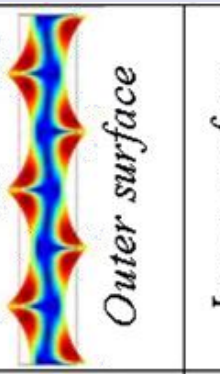
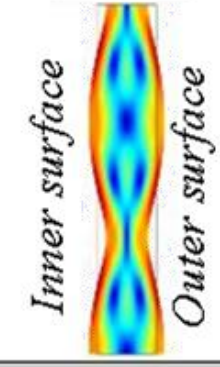
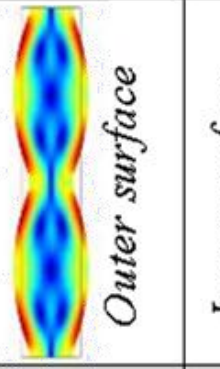


Eigen mode + Boundary condition Uz=0 ➡ *n*

$\lambda = L/n$, where L is the length of the pipe (L=40mm).

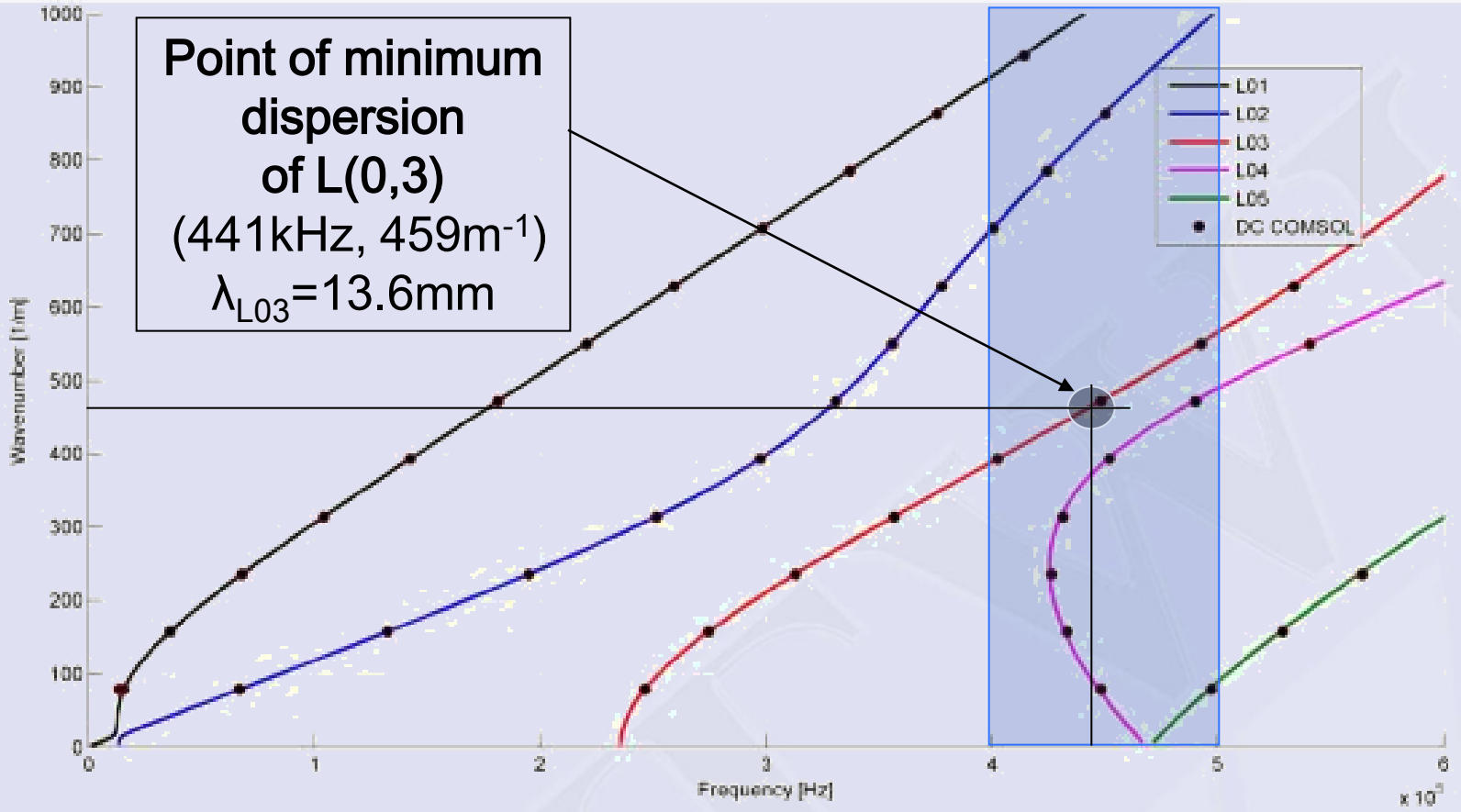
$C = \lambda f$

GW Mode shape

L(0,3)			
f (Hz)	402,476	448,270	492,446
L(0,4)			
f (Hz)	426,475	431,332	490,140

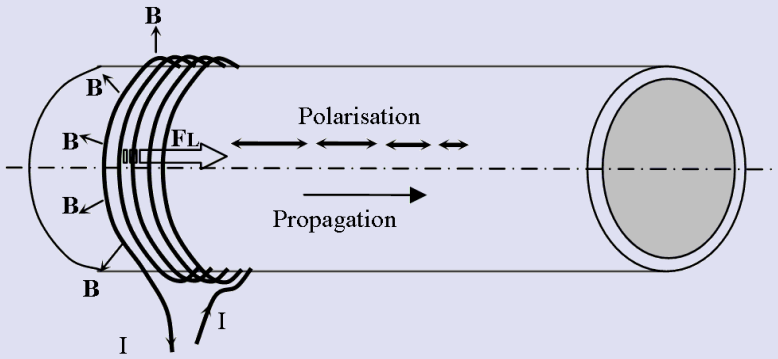
Mode shape of the L(0,3) and L(0,4) GUW

Dispersion curves

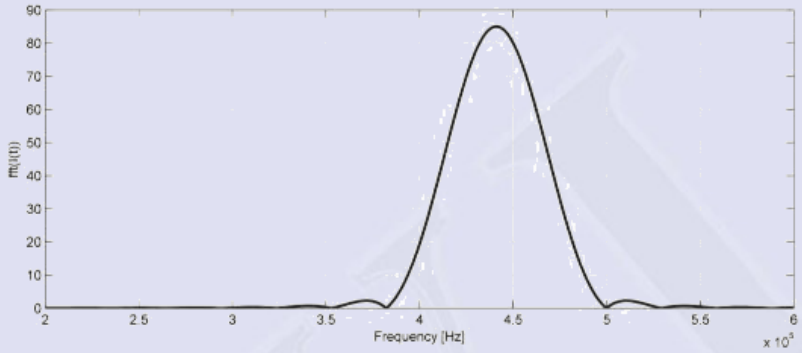


Correlation of the COMSOL dispersion curves results with analytical solution.

Transient analysis



Schematic of the current, magnetic field and the Lorentz force, generated in tubular structure.

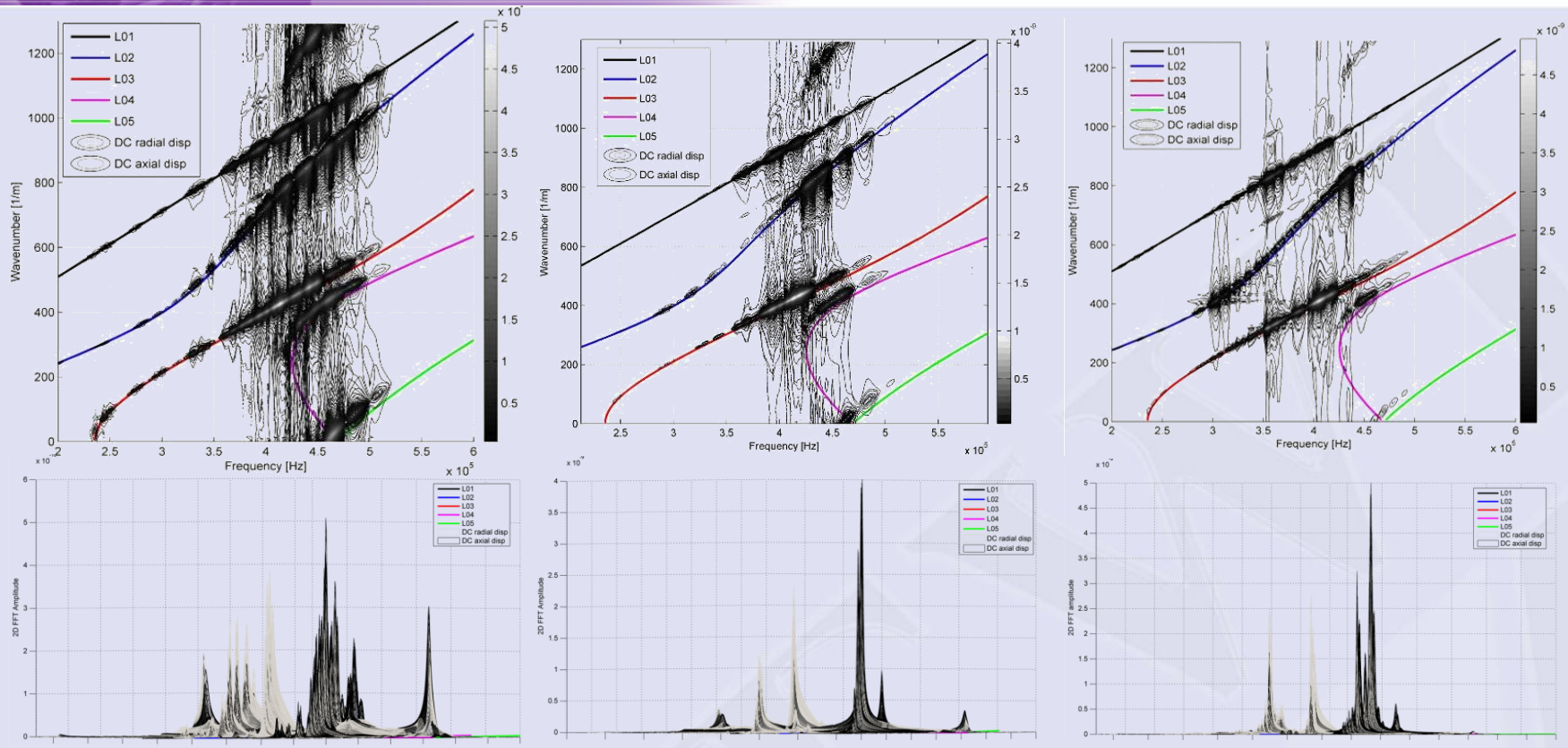


Frequency spectra of the N cycles tone burst excitation.
$I = I_0 \sin(\omega t)\,(1-\cos(\omega t/N))\;(t<N/f)$

Three axisymmetrical formulations:

1/ Static field induced by a permanent magnet.
2/ Induced magnetic field pulsed from the coils.
3/ Elastodynamic wave travelling in the pipe induced by the Lorentz forces.

Optimisation



Conf. 1: Full magnet without spacing

Conf. 2: Series of 7 magnets with λ_{L03} spacing

Conf. 3: Series of 14 magnets with λ_{L03} spacing

2DFFT amplitude of the modes for various NCET configurations.

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Results

Summary of modes maximum amplitudes

	Maximum Amplitude				
Conf.	**1**	**2**		**3**	
L(0,1)	0.2	1.1	**+0.9**	2.5	**+2.3**
L(0,2)	0.4	2.3	**+1.9**	2.7	**+2.3**
L(0,3)	0.5	4	**+3.5**	5	**+4.5**
L(0,4)	0.3	1	**+0.7**	0.6	**-0.3**
L(0,5)	0.23	0.3	**+0.07**	0.1	**+0.13**

Conclusions

COMSOL: used to develop, optimise and select the GW for LRUT.

- Multiphysic interaction: a concept for modelling the excitation of GW using non-contact transducers.
- Optimisation of the experimental conditions.

Future work:

- 3D modelling: NCET divided in n modules (memory issue)
- Correlation
- Experimental