EMAT with Pulsed electromagnet for high temperature

Francisco Hernandez-Valle
Steve Essex & Steve Dixon
Ultrasonics Group

BINDT, September 2009

THE UNIVERSITY OF WARWICK

OVERVIEW OF TALK

1. *Background*
2. *High temperature*
3. *EMATS*
4. *Experimental work*
5. *Conclusions*
6. *Future work*

HIGH TEMPERATURE ULTRASONIC TRANSDUCTION

Design → ***Innovative***
Low cost
Robust → ***Tackle high temperature inspection problems***

Perform → ***Material property***
Defect detection → ***Mechanisms by which components degrade***

Most commercial transducers are limited typically to applications that require operation temperatures below 200 °C

Applications for higher temperatures

- ***Power industries***
- ***Manufacturing processes***
- ***Materials research***
- ***Automotive sector***

Benefits for developing transducers for these applications:

- ***Reduce operating costs by avoiding outages.***
- ***Perform* in situ *monitoring.***

Ultrasonic methods are well known and effective for NDT in both academic research and industry

Methods currently used

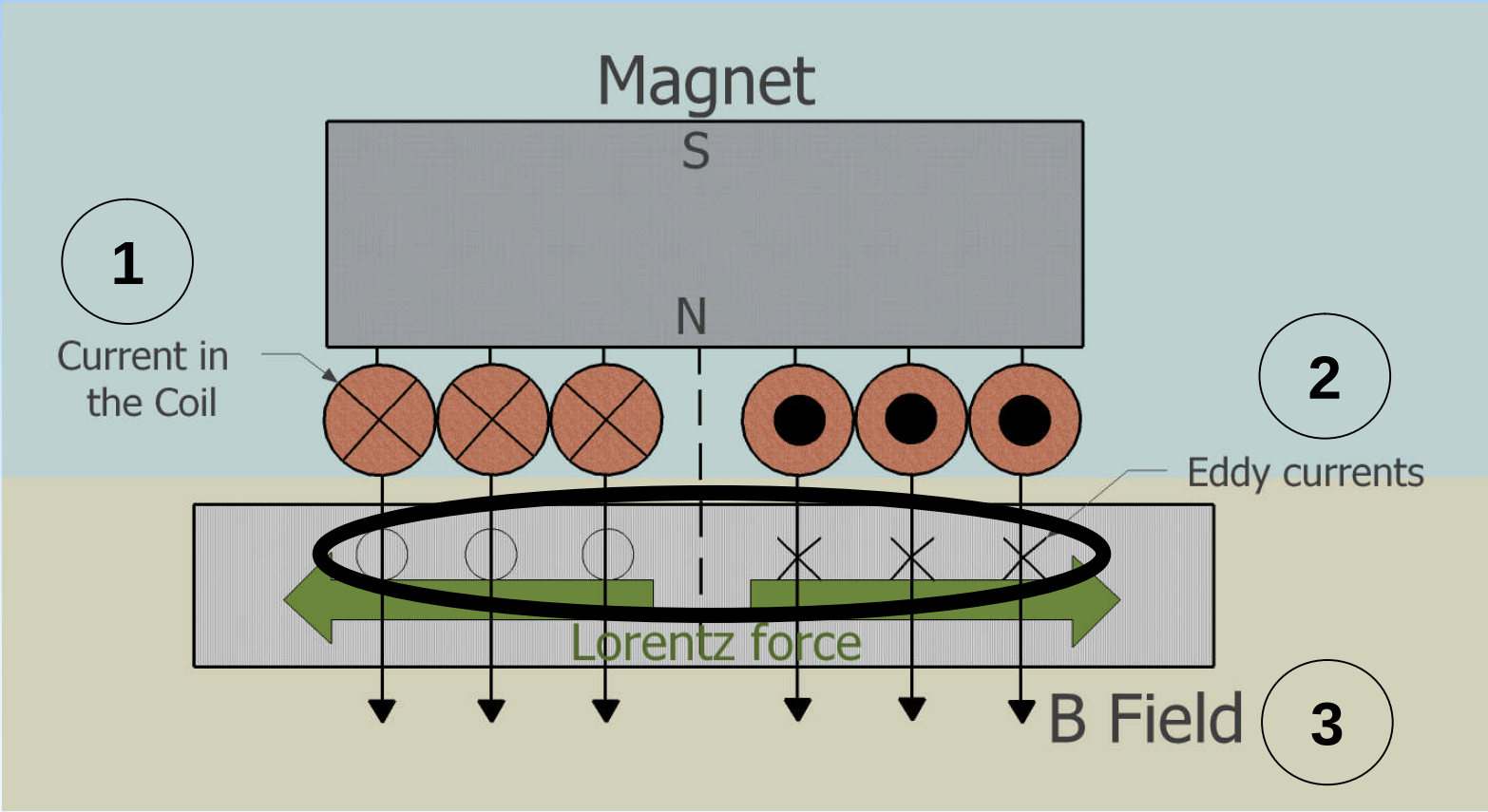
- ***Contact***
  - ***Piezoelectric***
- ***Non-contact***
  - ***Laser based***
  - ***Eddy current***
  - ***EMATs***

Why using EMATs?

- ***Compact size***
- ***Fairly inexpensive***
- ***Couplant free***
- ***Versatile***
- ***Tolerates hostile environments***

ELECTROMAGNETIC ACOUSTIC TRANSDUCERS

Basically an EMAT is { ***magnet,*** ***coil of wire***



ELECTROMAGNETIC ACOUSTIC TRANSDUCERS

Permanent magnet

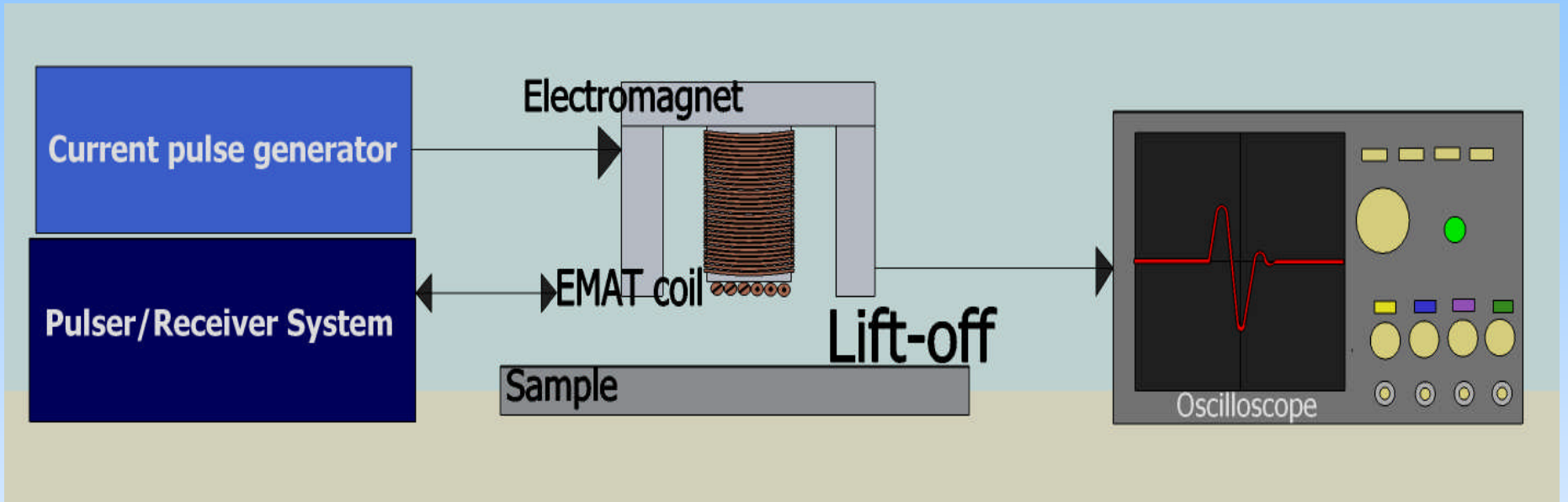
Vs

Electromagnet

- *Compact size*
- *High magnetic field provided*
- *Low Temperature Operation (100-150 ^{o}C in NdFeB)*
- *Cooling required*

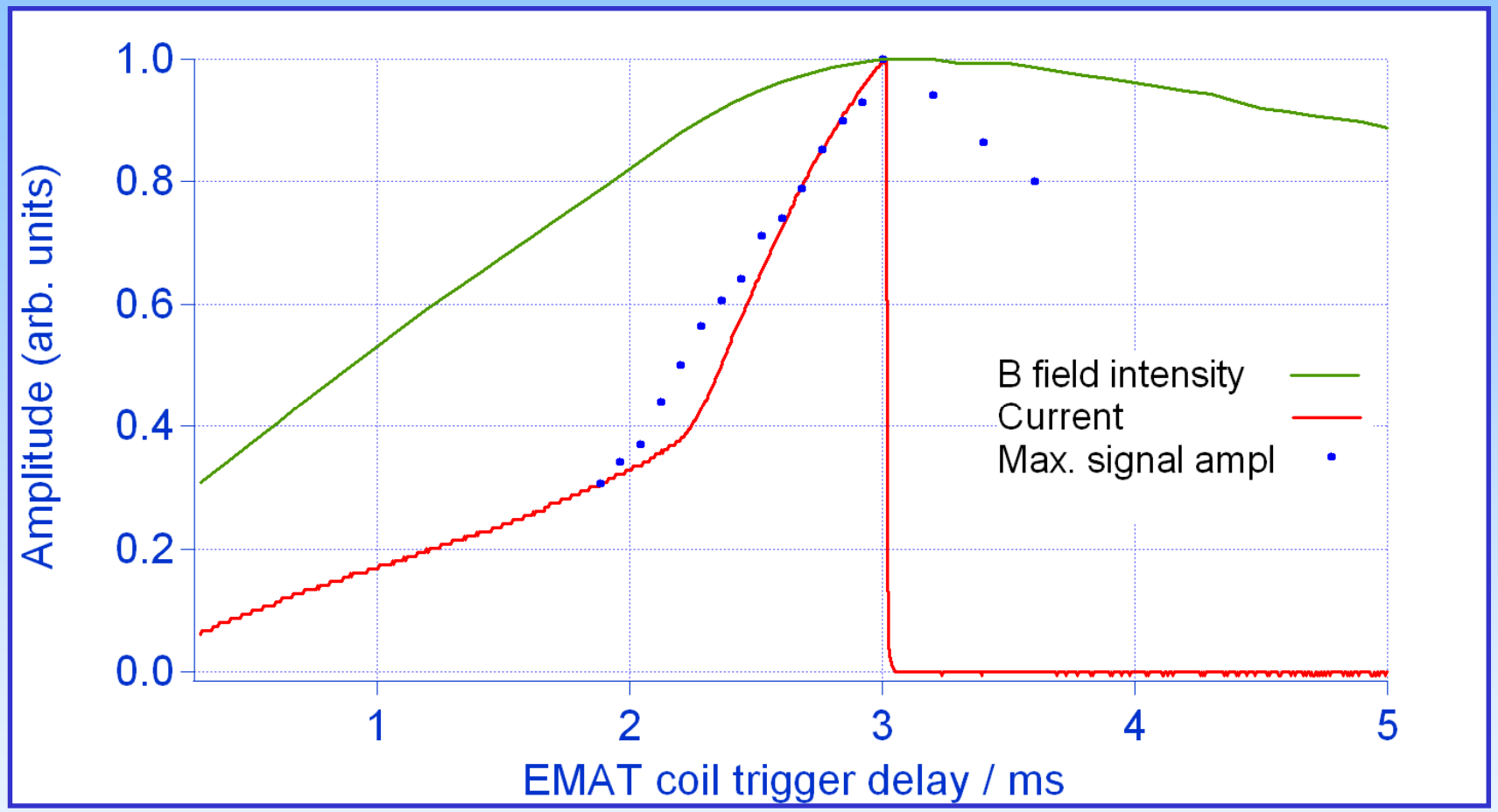
- *Reasonable size*
- *High magnetic field provided*
- *Suitable for high temperature*
- *Reduces average power required (compact & less complex power supply).*

EXPERIMENTAL WORK



(i) Optimizing EMAT
(ii) On the surface
(iii) Magnetic field
(iv) Lift-Off performance
(v) HT Performance

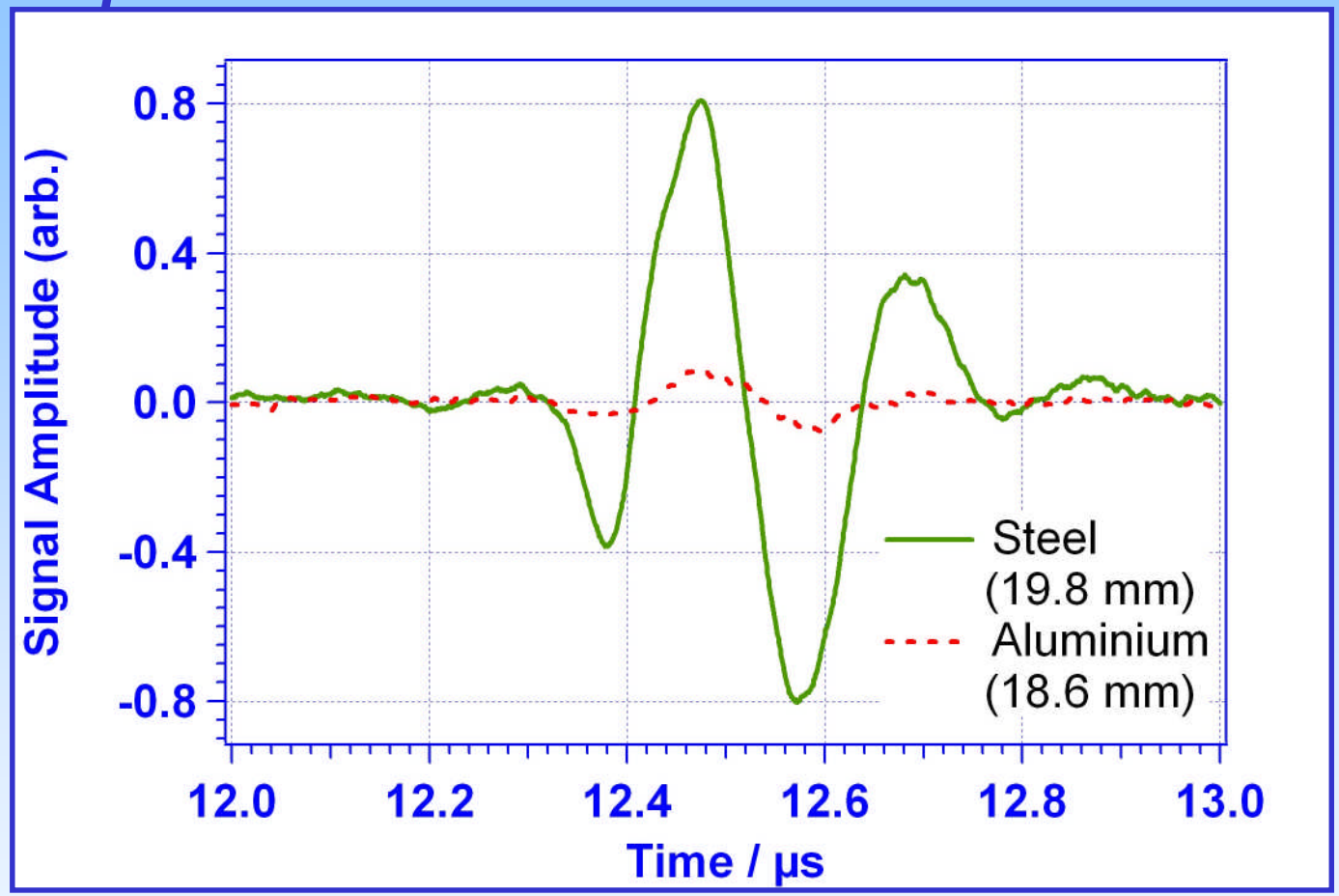
OPTIMIZING SEND/RECEIVE EMAT



Ultrasonic signal amplitude varied as a function of magnetic field intensity and current through the coil

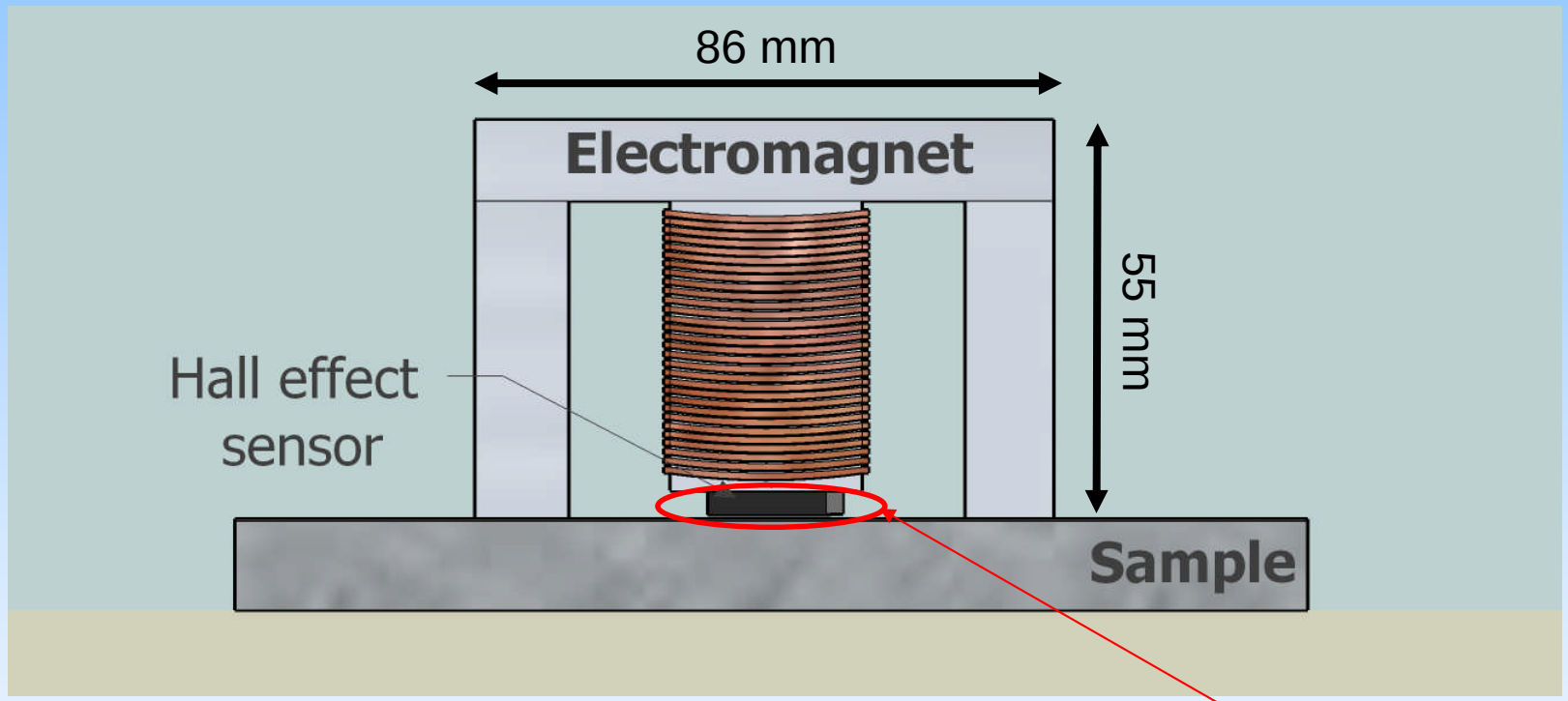
ON-SURFACE PERFORMANCE

Better performance on steel than on aluminium



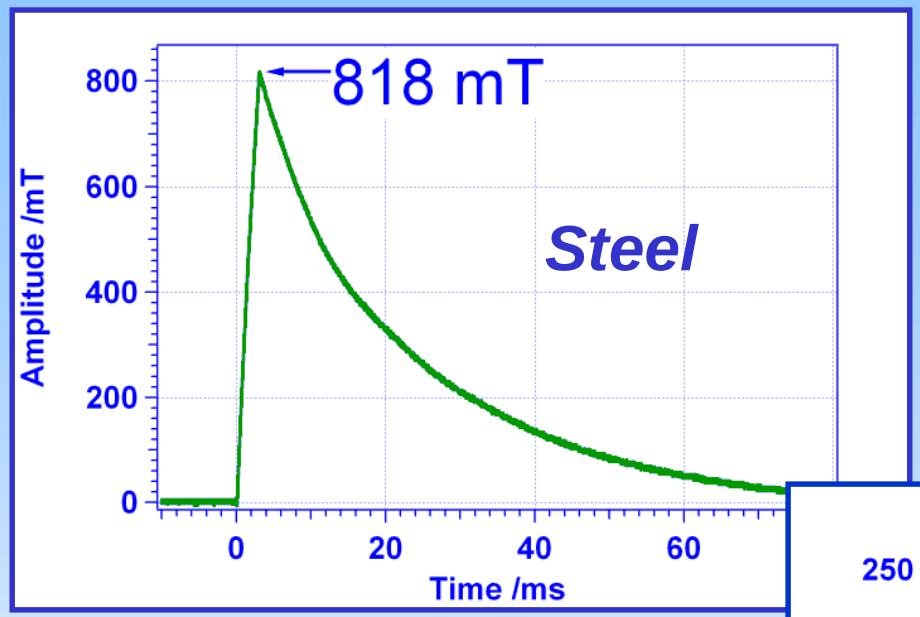
- *Shear wave in steel is significantly higher*
- *Shear wave in Al was time shifted for amplitude comparison*

Set-up

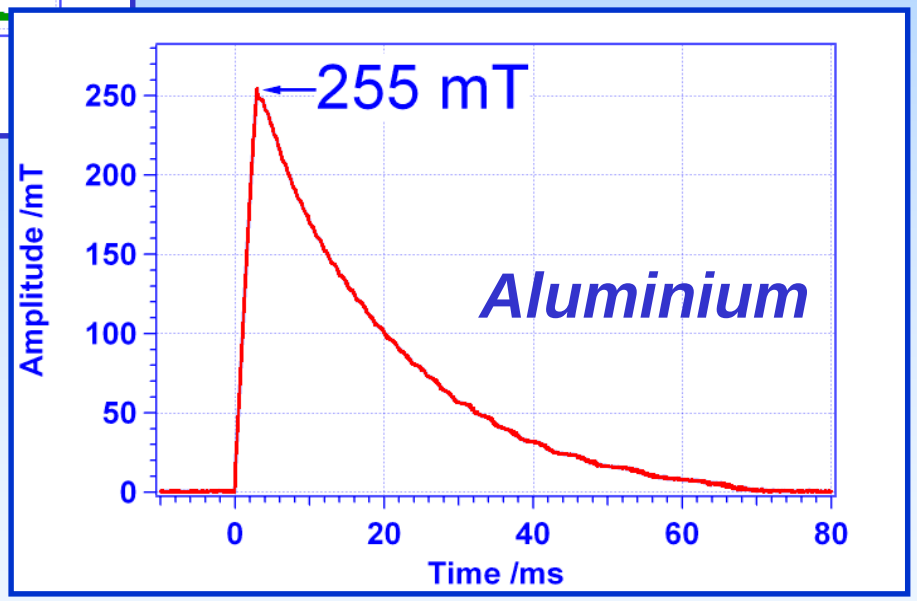


2mm gap designed to hold EMAT coil (removed for this measurement)

MAGNETIC FIELD INTENSITY

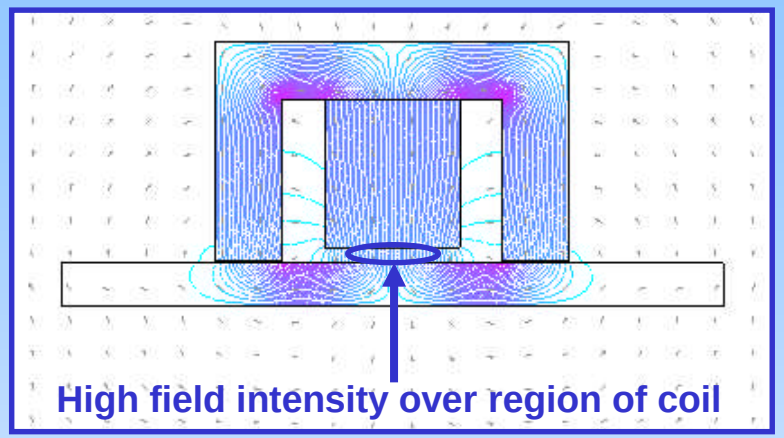


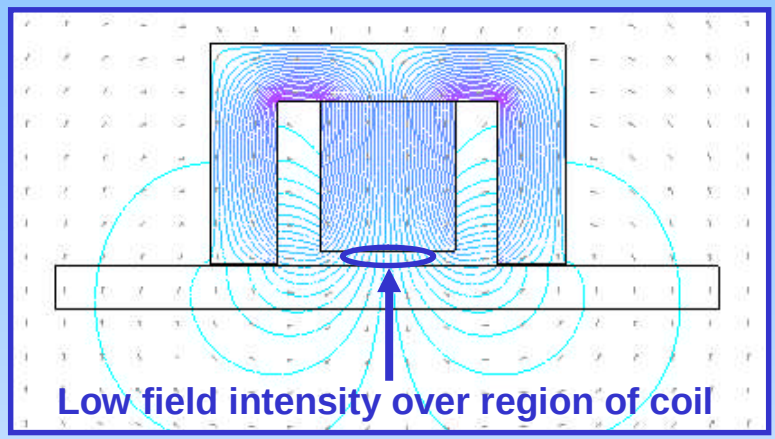
Measured by the calibrated Hall effect sensor



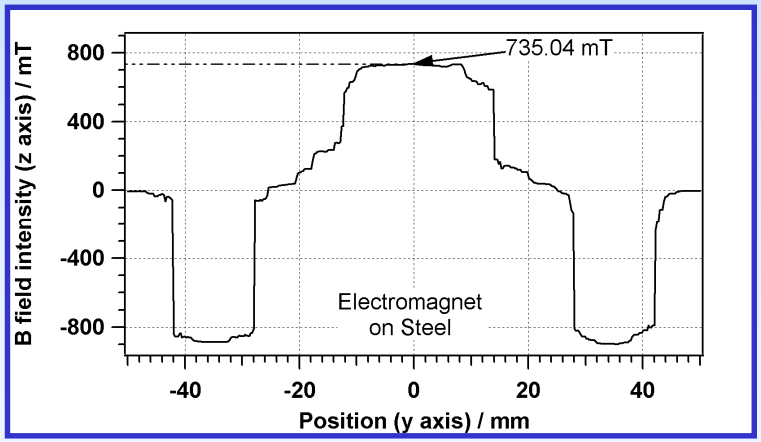
MAGNETIC FIELD INTENSITY

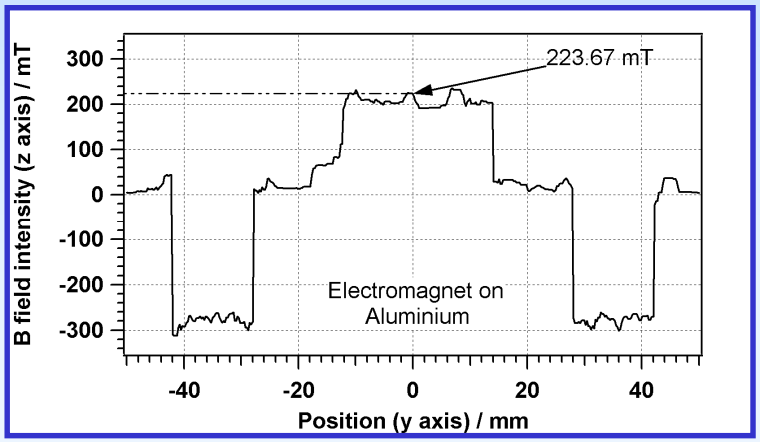
2D FE simulation





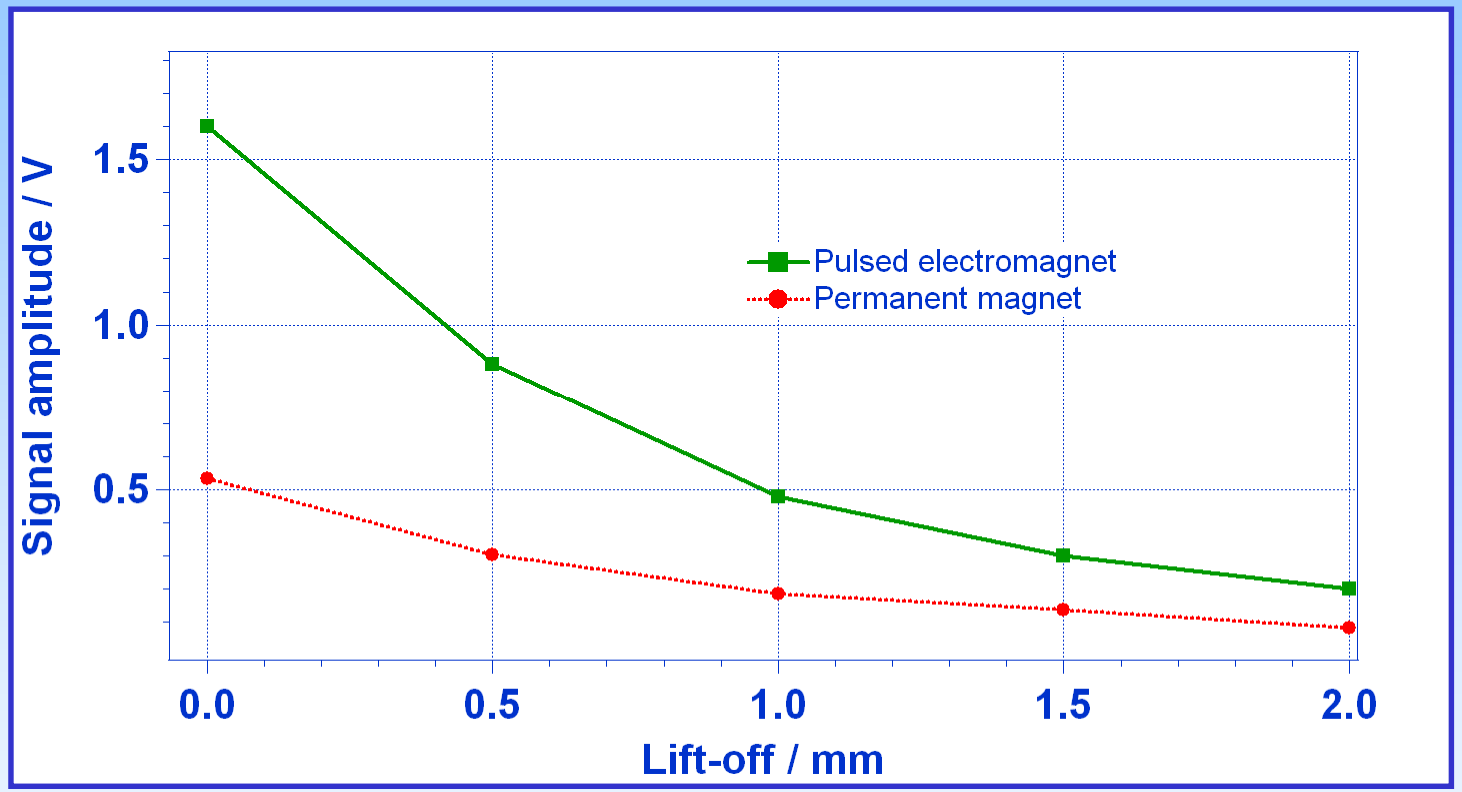
3D FE simulation





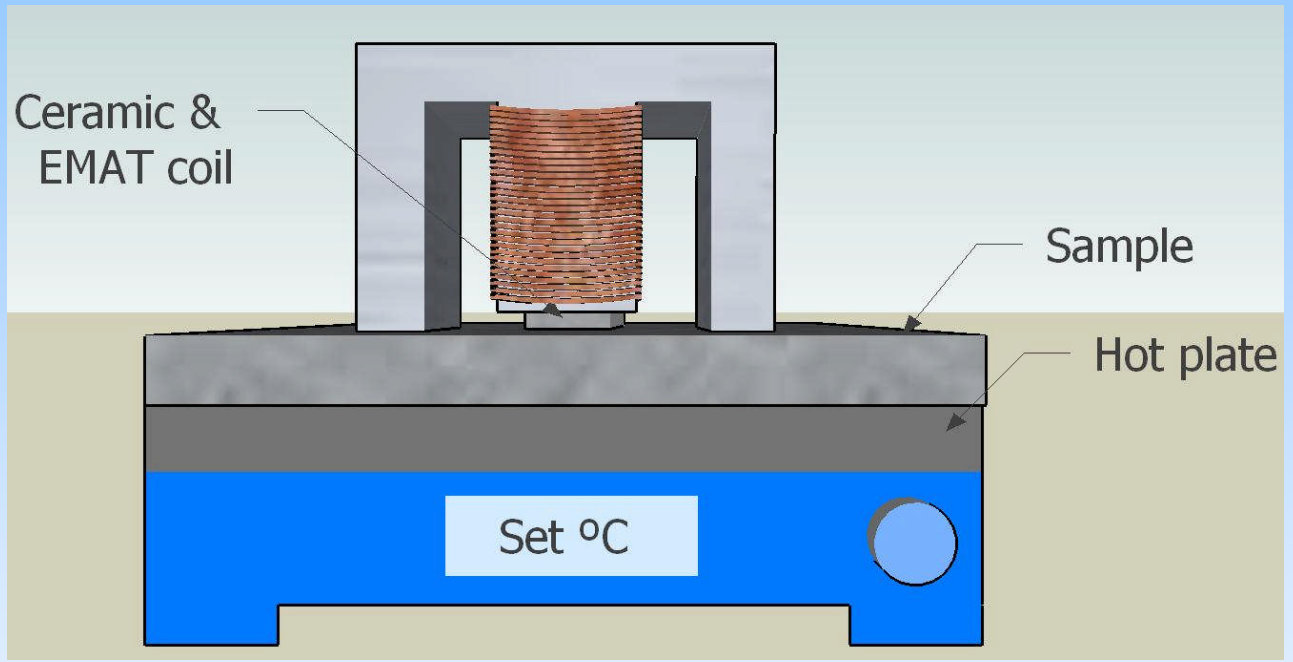
LIFT-OFF PERFORMANCE

Pulsed electromagnet vs permanent magnet EMATs



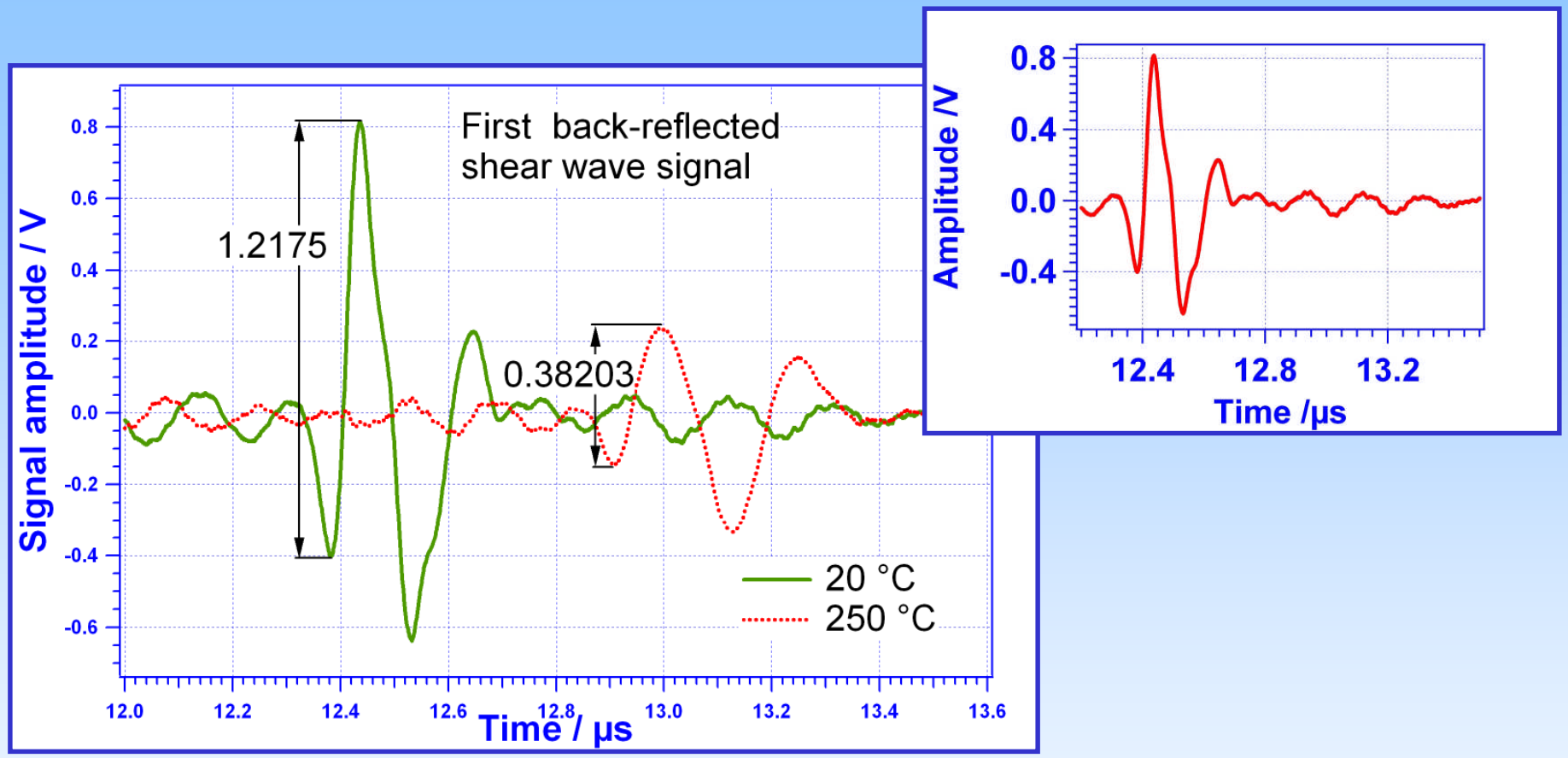
The signal amplitude is enhanced approximately by a factor of three

SETUP FOR ELEVATED TEMPERATURES



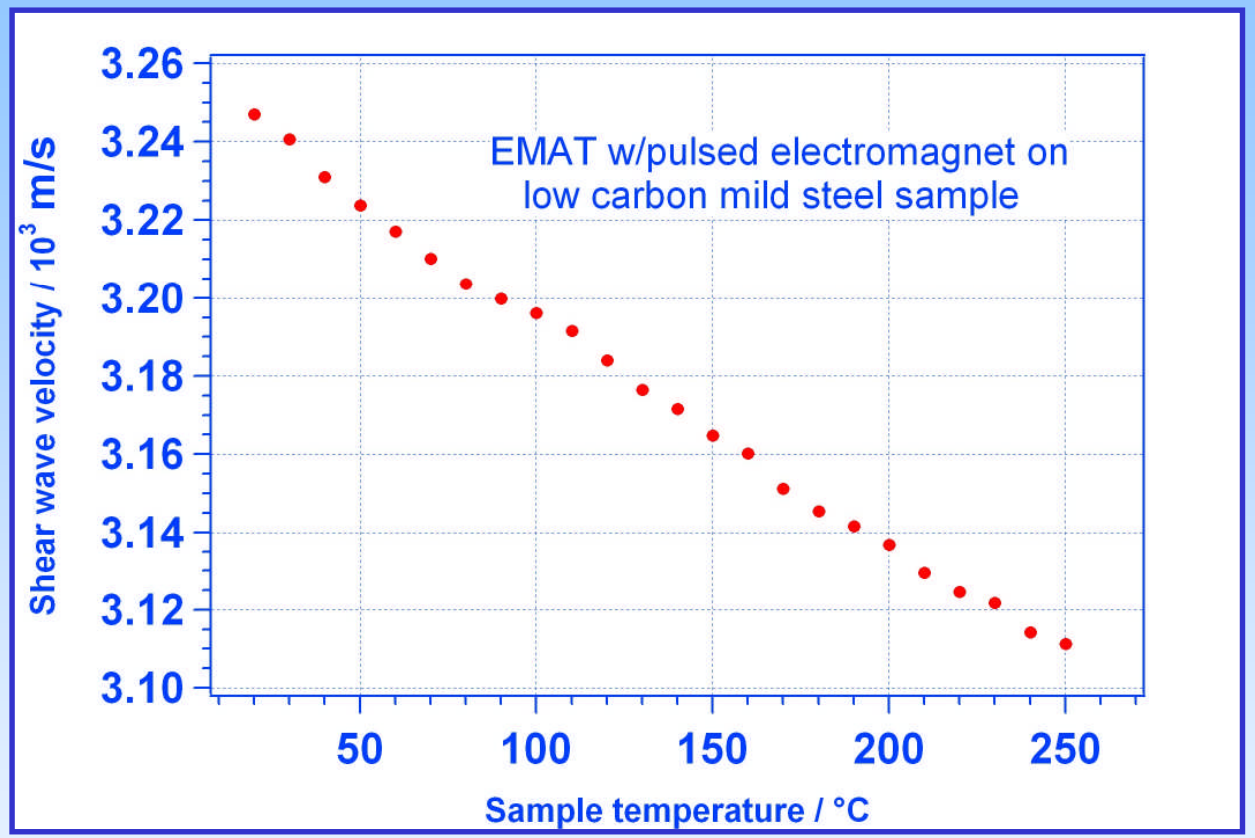
Surface sample temperature is monitored by a thermocouple.

RESULTS AT ELEVATED TEMPERATURES



At HT, EMAT efficiency and shear wave velocity decrease.

RESULTS AT ELEVATED TEMPERATURES



At HT, the shear wave velocity variation has to be taken into account

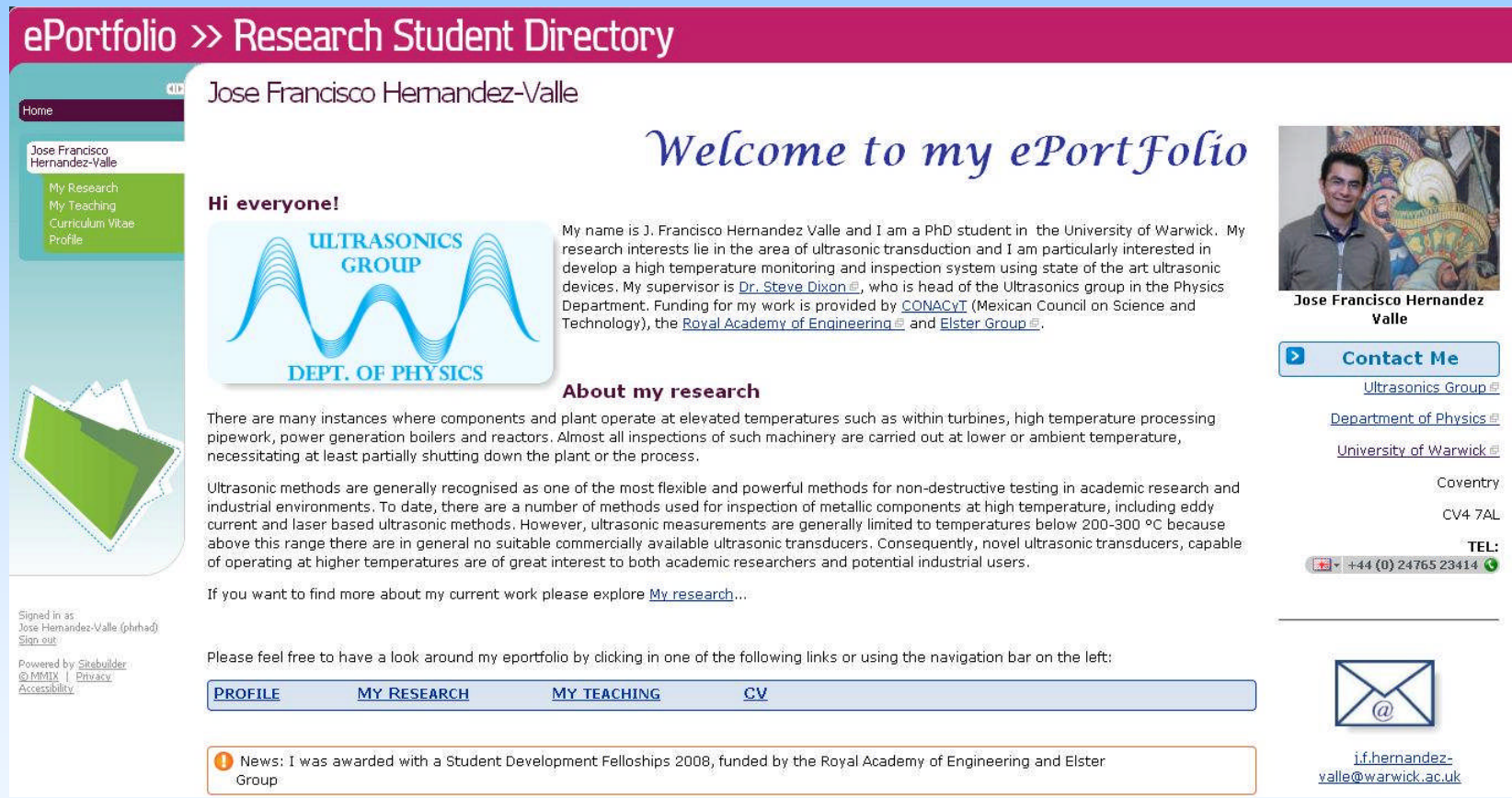
Conclusions

- *It has been shown that is possible to perform measurements on low carbon mild steel with surface temperatures as high as 250 °C.*
- *Pulsed electromagnet EMAT outperforms permanent magnet on mild steel, but does not perform as well on aluminium at RT.*
- *Better lift-off performance than EMAT with permanent magnet.*
- *Valuable tool for many industrial applications at high temperatures.*

Future work

- ***Improvement in the transducer design will be required to operate at temperatures significantly higher than 300 °C***
- ***Model the generation and propagation of ultrasonic waves in the test components at high temperatures and comparing it with the experimental work.***
- ***Measure materials' elastic properties at a range of temperatures as a detector alone / generator alone / combined generator and detector.***

http://www.warwick.ac.uk/go/fhvalle



ACKNOWLEDGMENTS

CONACYT
Consejo Nacional de Ciencia y Tecnología

The Royal Academy of Engineering

elster

Thank you for your attention

Any questions?