Numerical Study of Shear Horizontal Electromagnetic Acoustic Transducers for Generation of Ultrasonic Guided Waves

Liang Cheng

18/09/2014

COMSOL CONFERENCE 2014 CAMBRIDGE

Brunel UNIVERSITY LONDON

INTERSOLAR

BIC

Outline

- Introduction of BIC
- Theoretic background of EMAT
- EMAT modelling for EMAT
- Conclusions

Brunel UNIVERSITY LONDON

BIC

1. Brunel Innovation Centre (BIC)

- Brunel Innovation Center (BIC) is part of the School of Engineering and Design faculty of Brunel University

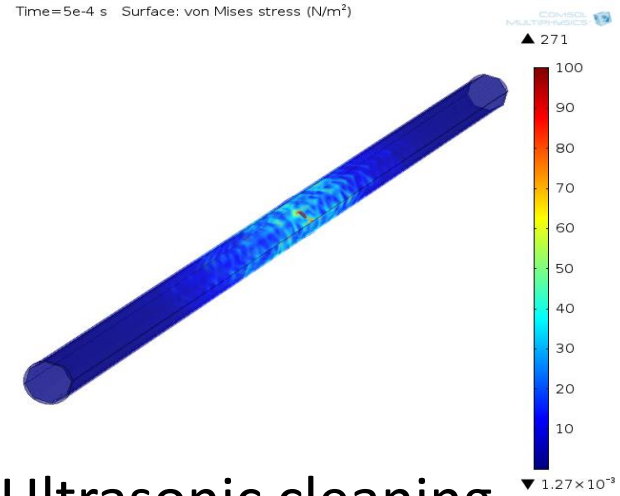
- BIC is based in Cambridge.

- The research carried out at BIC is predominantly in the field of NDT and related areas, including:
  - SHM / CM (Acoustic emission & guided waves)
  - Ultrasonic Detection / Cleaning
  - Smart NDT (automation, wireless, IMUs)
  - Sensors and transducers (aggressive environments; high temperature)
  - Signal / Image processing
  - Pattern Recognition
  - Systems (hardware-software) integration

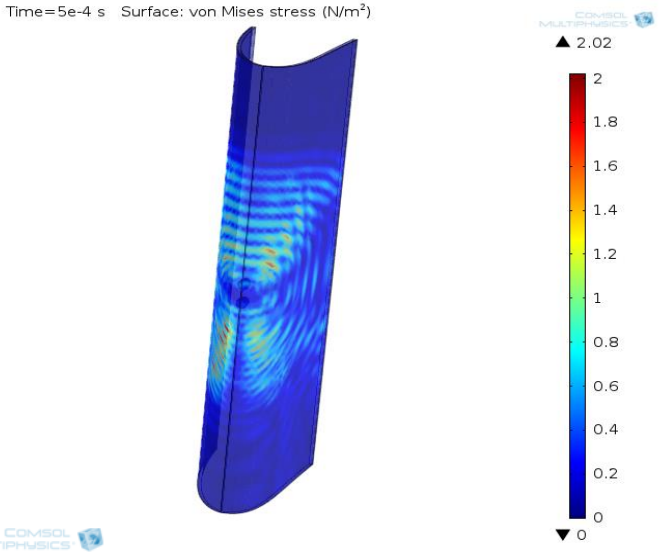
Brunel UNIVERSITY LONDON

BIC

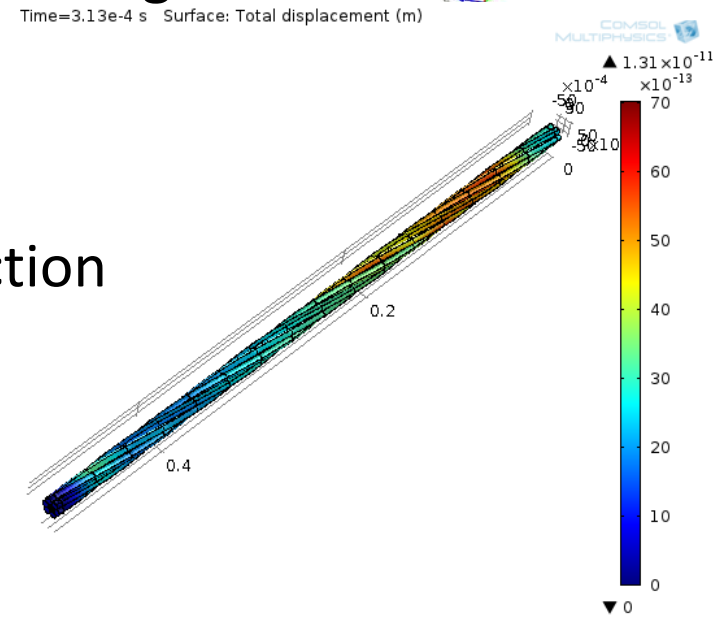
1.2 COMSOL Simulation at BIC



Ultrasonic cleaning



Ultrasonic & vibration De-icing



Cable inspection

Brunel UNIVERSITY LONDON

BIC

2 Theoretic Background of EMAT

Theory: *f*=*J*e X *B*s

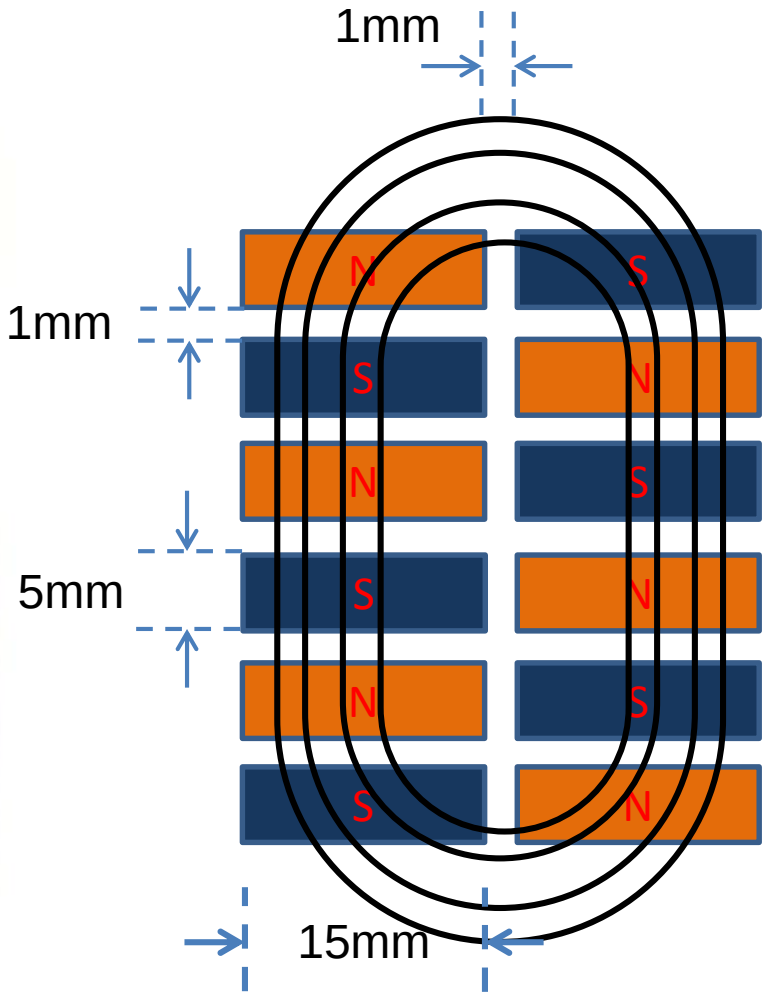
- *f*: Lorentz force → 'Solid mechanics' module→ Body load
- *J*e: Eddy current density → 'AC/DC-Magnetic Fields' module →
- *B*s: static magnetic flux density → 'AC/DC-Magnetic Fields (No Current)'→

$$f_x = \mathrm{J_y B_z} - \mathrm{J_z} B_y \qquad f_y = \mathrm{J_z B_x} - \mathrm{J_x B_z} \qquad f_z = \mathrm{J_x B_y} - \mathrm{J_y B_x}$$

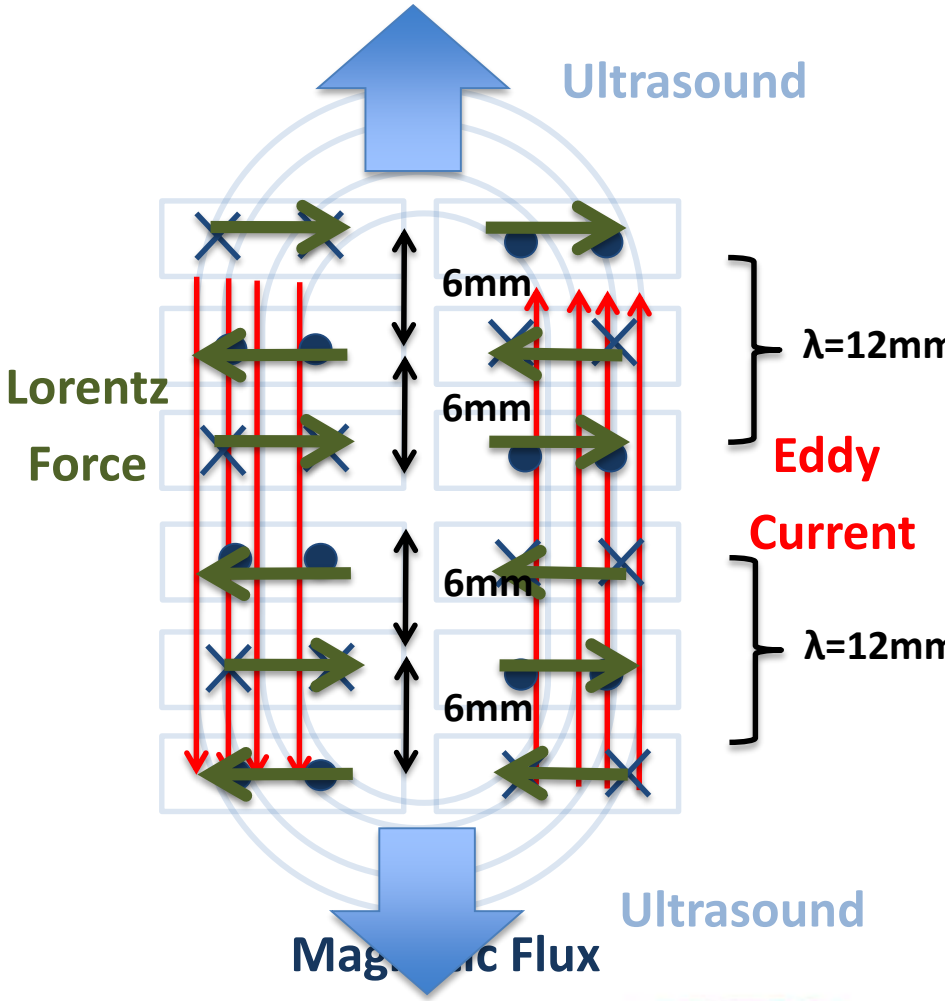
Brunel UNIVERSITY LONDON

BIC

2.2 Ultrasound generation of EMAT



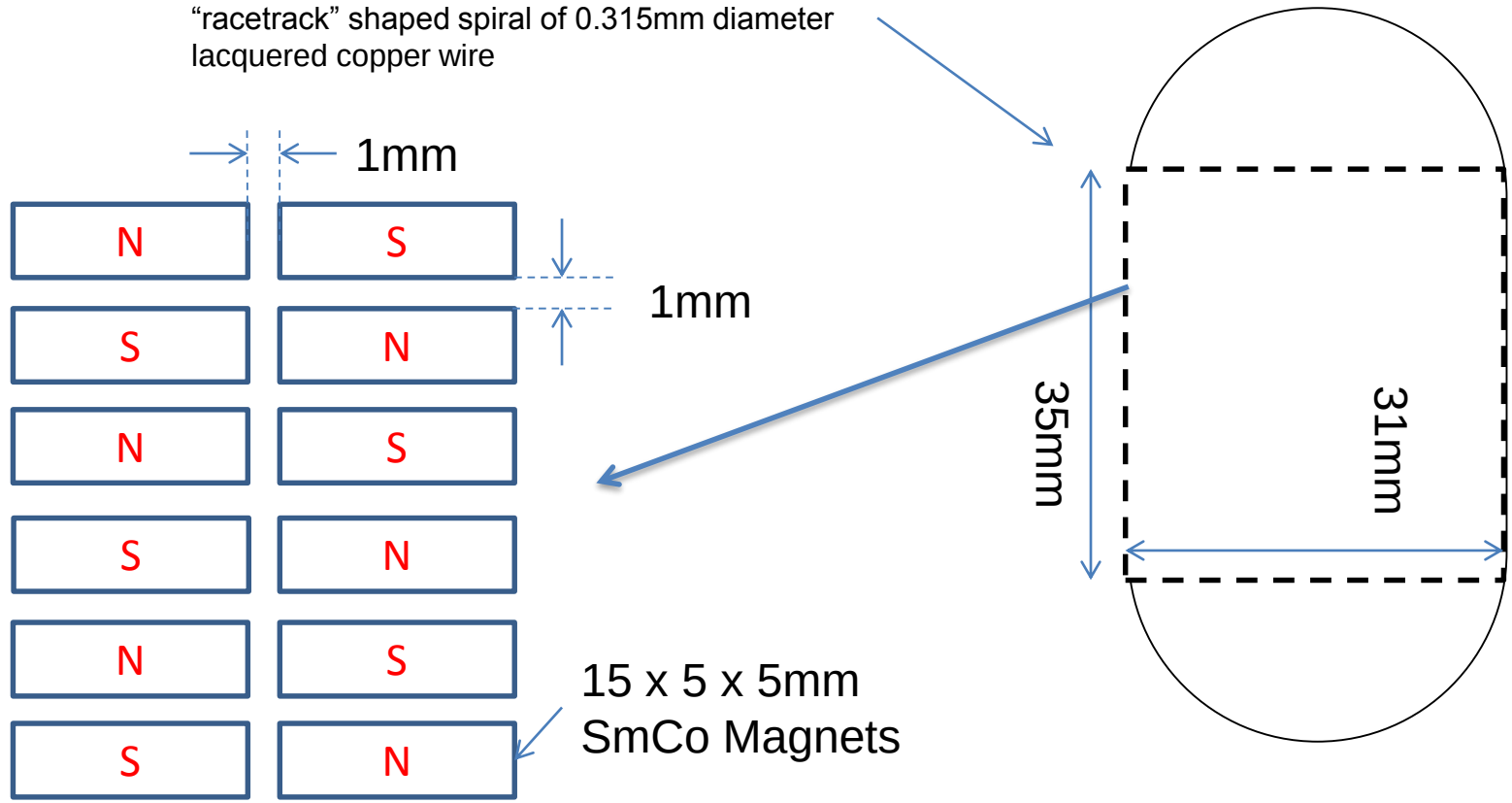
Top view of EMAT



Brunel UNIVERSITY LONDON

BIC

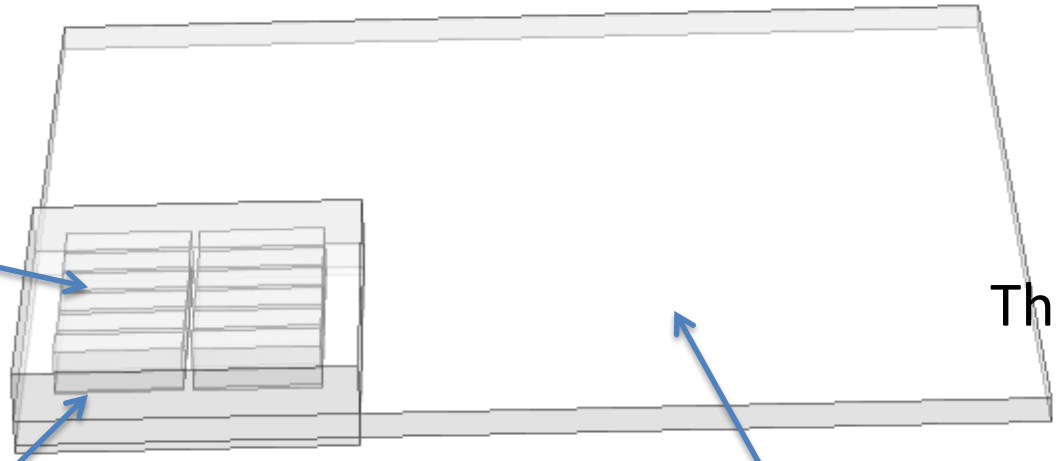
3.1 Dsesign for EMAT



Maximum temperature 200°C

"racetrack" coil (curved ends folded around magnet array)

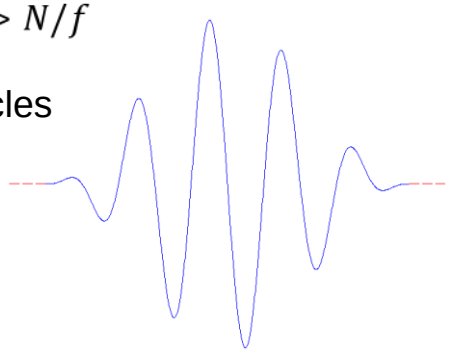
3.3 COMSOL Model



	AISI 316Ti steel
Density (kg/m^3)	8000
Relative permeability	1.008
Relative permittivity	1
Young's modulus (Pa)	195e9
Poisson's ratio	0.285

Excitation *J*: $$J(t) = \begin{cases} J_0 \sin(2\pi f t)\left(1 - \cos\frac{2\pi f t}{N}\right), \text{for } t \le N/f \\ 0, \text{for } t > N/f \end{cases}$$

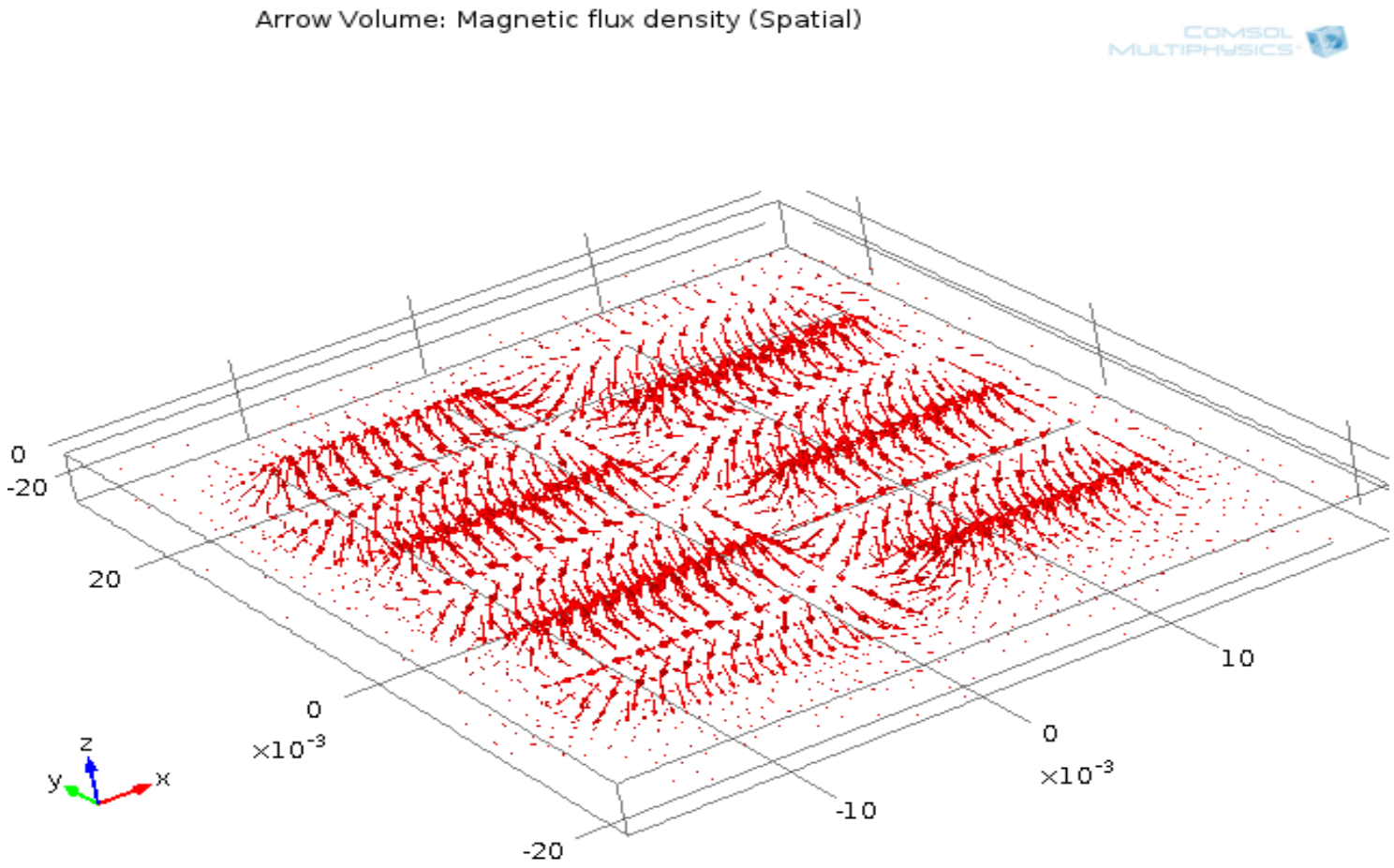
J_0=1A/(0.315mm)^2, f=256.7 kHz , N=5 cycles



Brunel UNIVERSITY LONDON

BIC

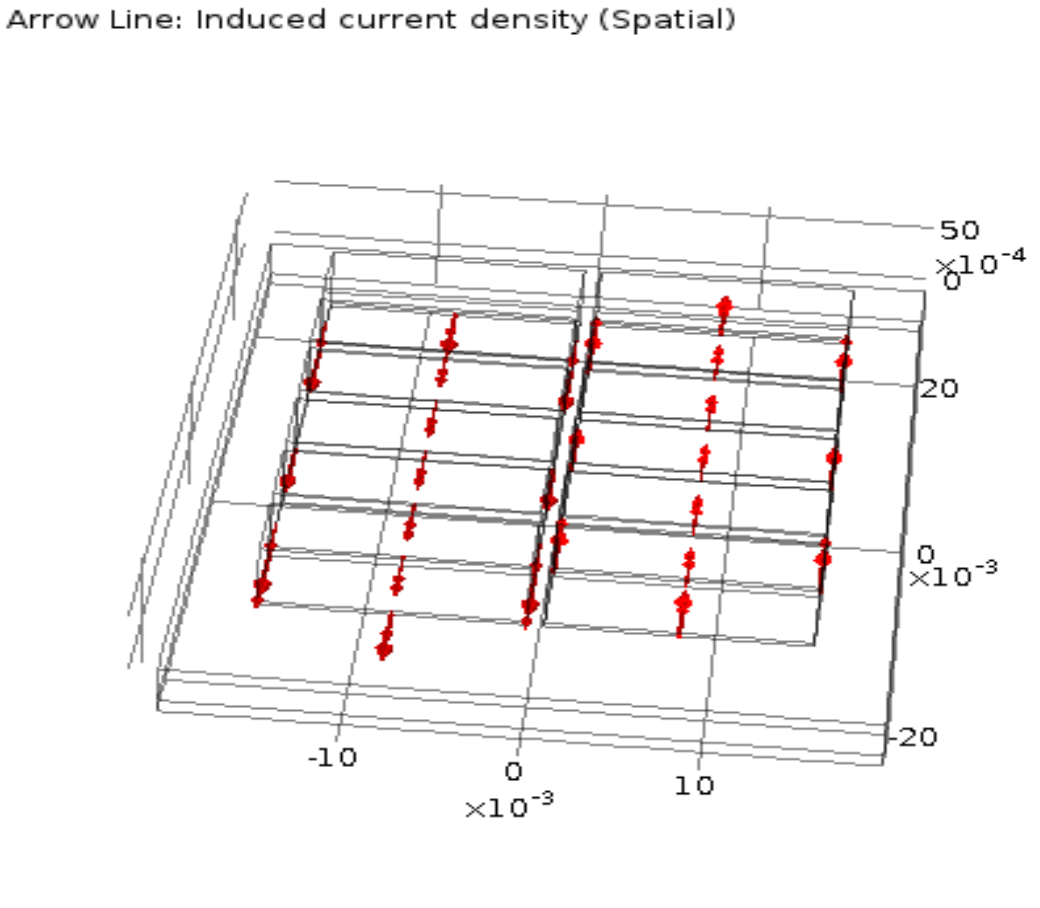
3.4 Direction of Bs in the plate



Brunel UNIVERSITY LONDON

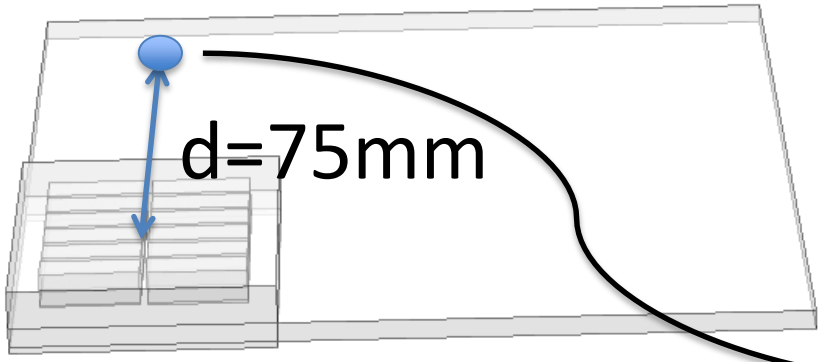
BIC

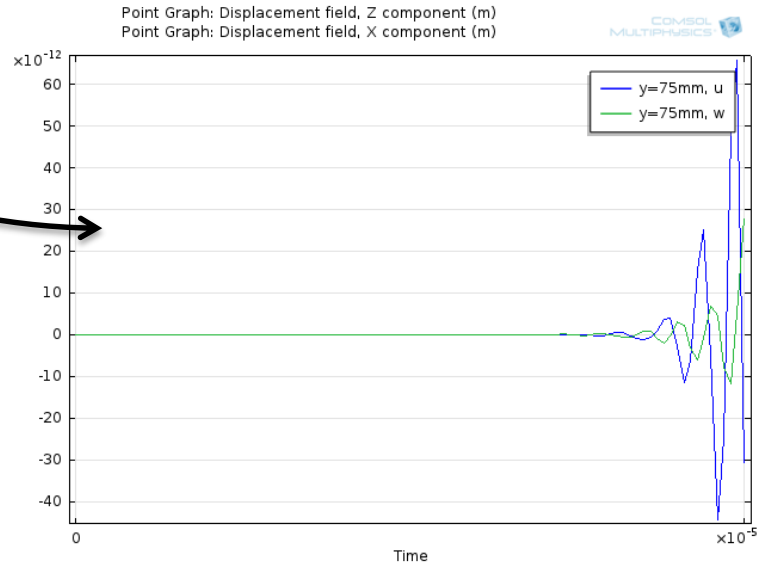
3.6 Eddy current density distribution on the surface of the sample



3.7 Displacement in x and z direction at a location 75mm away from the EMAT

Point of interest

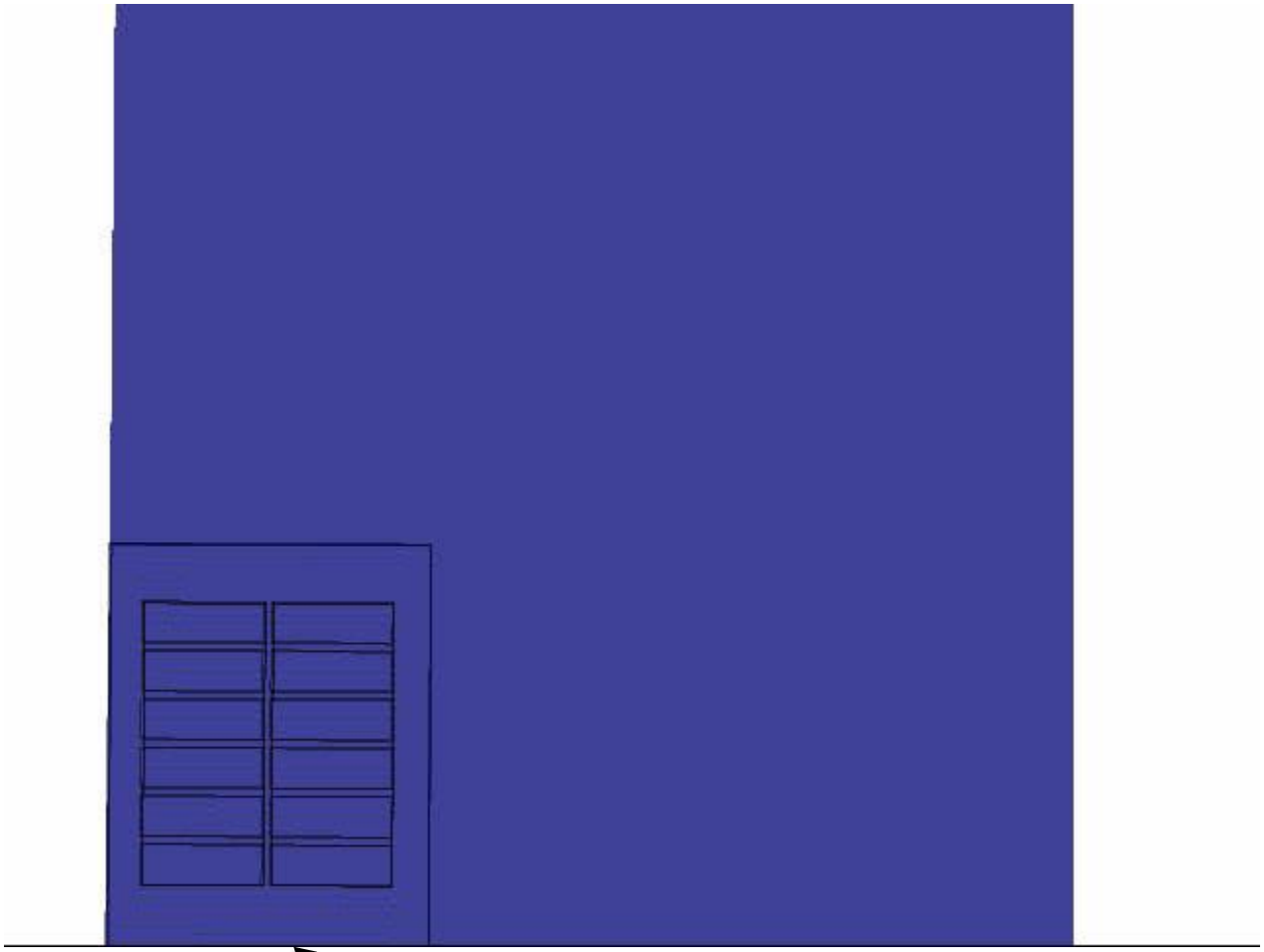




Brunel UNIVERSITY LONDON

BIC

3.8 Displacement on a plate



Brunel UNIVERSITY LONDON

BIC

Conclusion

- Design of EMAT transducer
  - Periodic permanent magnet (PPM)
  - Race track coil
- Simulation results of EMAT
  - Eddy current distribution
  - Magnetic flux density distribution
  - Ultrasonic wave (displacement)
  - Wave propagation
    - Concentrated in x and y direction

Brunel UNIVERSITY LONDON

BIC

Acknowledgements

- This study is funded by the FP7 INTERSOLAR project under the Research for the benefit of SMEs programme, Grant Agreement Number 605028. The project is coordinated by CIT Limited. The partners in this project include:
  - CIT Limited (UK), Applied Inspection Limited (UK)
  - Technology Assistance BCNA 2010 S.L. (Spain)
  - PSP S.A. (Greece)
  - INGETEAM Service S.A. (Spain)
  - Brunel University (UK), Universidad de Castilla-La Mancha (Spain)
  - ENGITEC Limited (Cyprus)

- The authors would like to thank Sonemat Limited (UK) for their contributions on the design of EMAT transducer.

Brunel UNIVERSITY LONDON

BIC