



HAL
open science

Inspection par courants de Foucault d'un matériau ferromagnétique : Effet de l'état de contraintes mécaniques

Laurent Santandrea, Romain Corcolle, Yann Le Bihan, Laurent Daniel

► To cite this version:

Laurent Santandrea, Romain Corcolle, Yann Le Bihan, Laurent Daniel. Inspection par courants de Foucault d'un matériau ferromagnétique : Effet de l'état de contraintes mécaniques. 2nd Symposium de Génie Électrique (SGE 2016), Jun 2016, Grenoble, France. 2016. hal-01694549

HAL Id: hal-01694549

<https://hal.science/hal-01694549v1>

Submitted on 26 Feb 2024

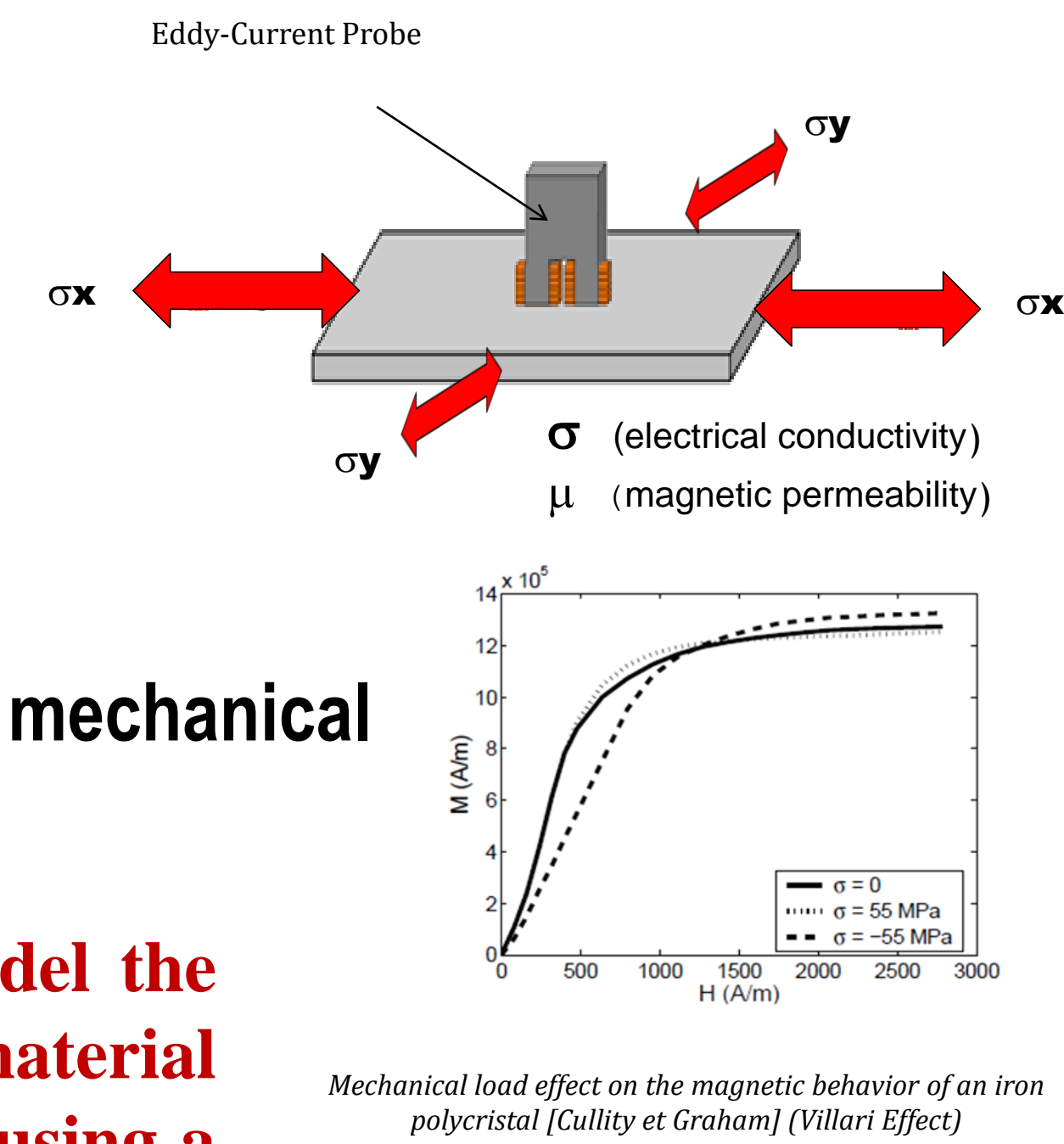
HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Introduction

- ❖ NDT-EC Powerful and widely used method for the reliability
- ❖ EC are strongly influenced by the magnetic properties
- ❖ Magnetic properties on the other hand significantly depend on the mechanical stress in the inspected specimen

The purpose of this work is to develop a trump numerical tool to model the Eddy Current (EC) signal provided by an EC probe inspecting a material subjected to stress. The effect of stress on the permeability is predicted using a multiscale model.



3-Finite Element method formulations

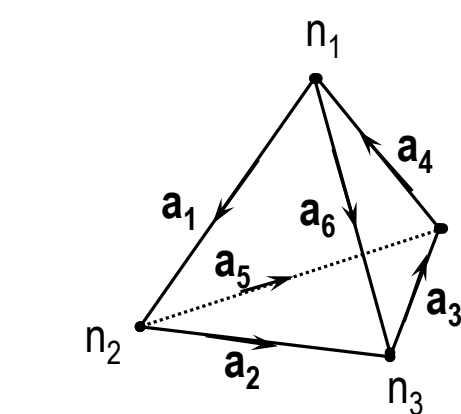
3d dual potential combined formulations

Magnetic formulation $t-\phi$

$$\int_{\Omega_c} \frac{1}{\sigma} \text{rot}' \text{rot}' t d\Omega + i\omega \int_{\Omega_c} \mu t' d\Omega + i\omega \int_{\Omega_c} \mu t' \cdot \text{grad} \Phi d\Omega + \int_{\Gamma_c} t' \cdot (\mathbf{n} \times \mathbf{e}) d\Gamma = 0$$

$$i\omega \int_{\Omega_c} \mu \text{grad} \Phi' \cdot t d\Omega + i\omega \int_{\Omega_c} \mu \text{grad} \Phi' \cdot \text{grad} \Phi d\Omega + i\omega \int_{\Gamma_c} \Phi' \cdot (\mathbf{n} \cdot \mathbf{b}) d\Gamma = 0$$

t : electric vector potential - edge dof
 ϕ : magnetic Scalar potential - node dof



Whitney Finite Element

Electrical formulation $a-\psi$

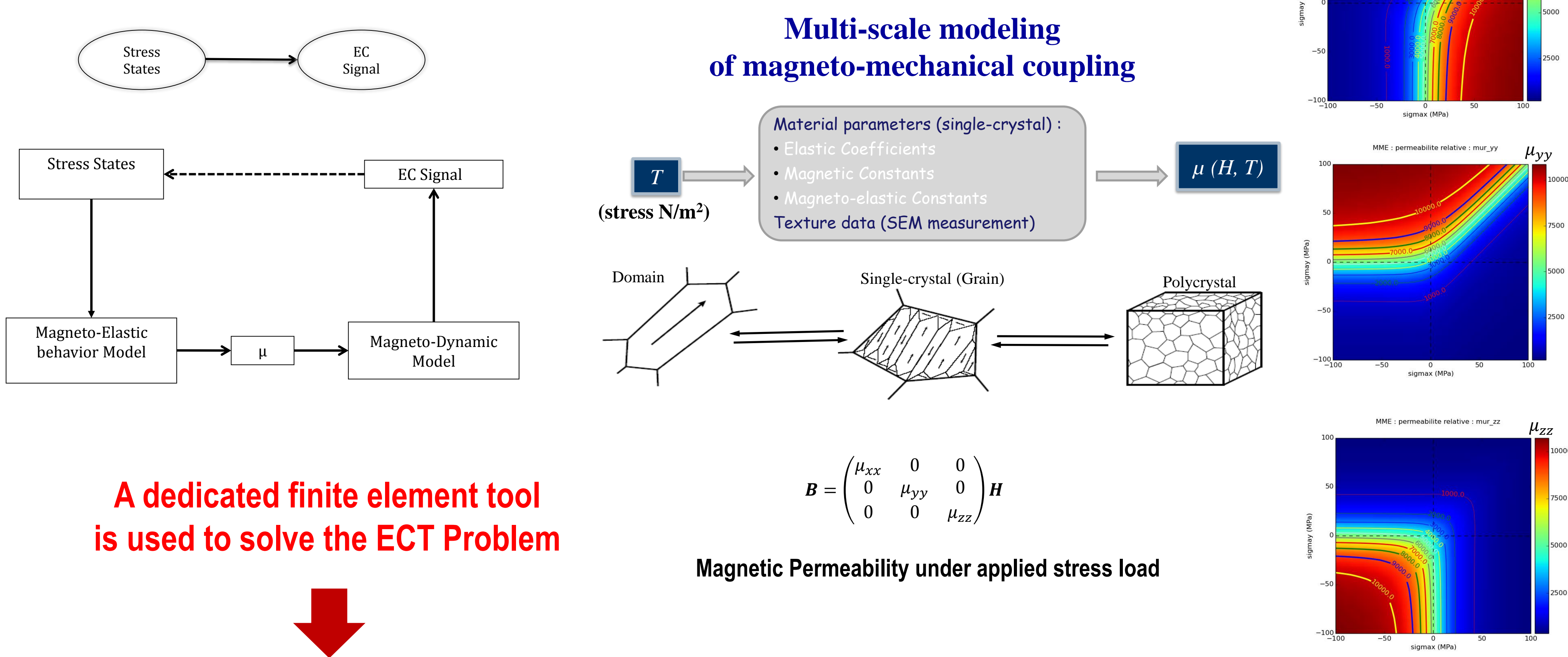
$$\int_{\Omega_c} \frac{1}{\mu} \text{rot}' \text{rot}' a d\Omega + i\omega \int_{\Omega_c} \sigma a' \cdot a d\Omega + i\omega \int_{\Omega_c} \sigma a' \cdot \text{grad} \Psi d\Omega + \int_{\Gamma_c} a' \cdot (\mathbf{n} \times \mathbf{h}) d\Gamma = 0$$

$$i\omega \int_{\Omega_c} \sigma \text{grad} \Psi' \cdot a d\Omega + i\omega \int_{\Omega_c} \sigma \text{grad} \Psi' \cdot \text{grad} \Psi d\Omega + \int_{\Gamma_c} \Psi' \cdot \mathbf{n} \cdot \mathbf{j} d\Gamma = 0$$

a : magnetic vector potential - edge dof
 Ψ : electric Scalar potential - node dof

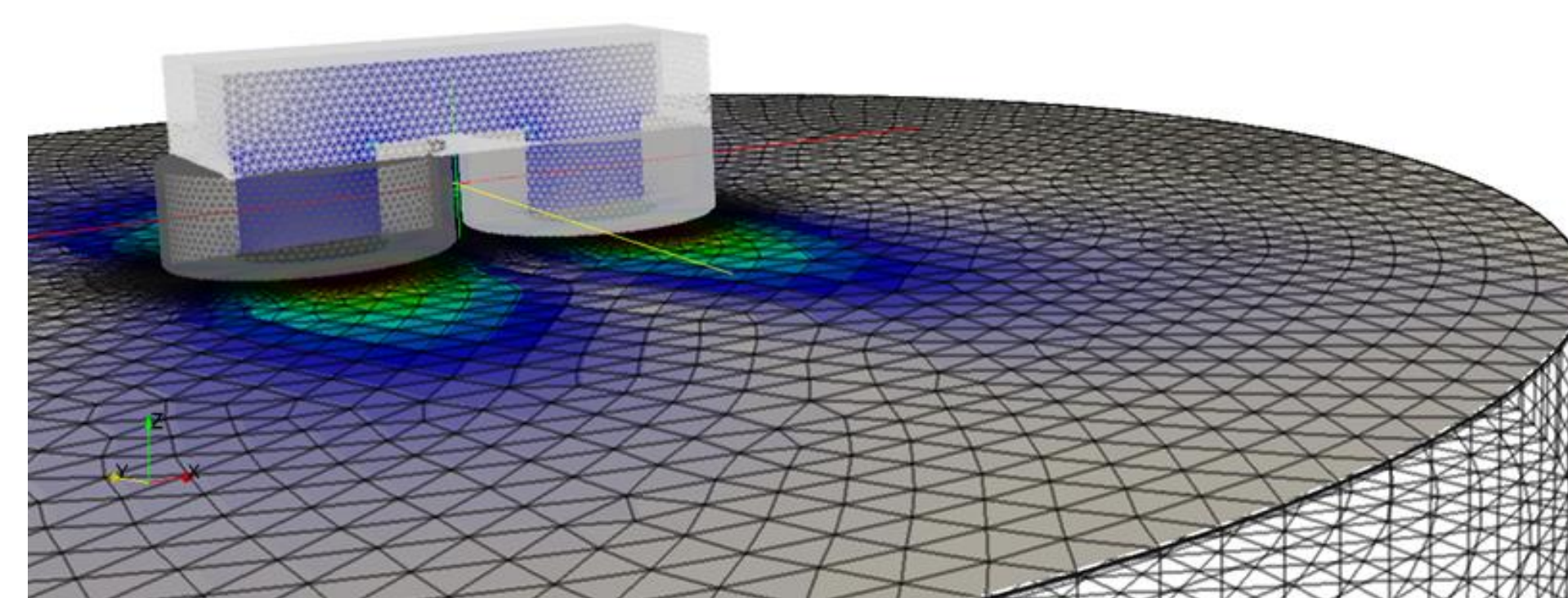
1-Modelling principle

The modeling principle combining a magneto-elastic model with a finite element analysis

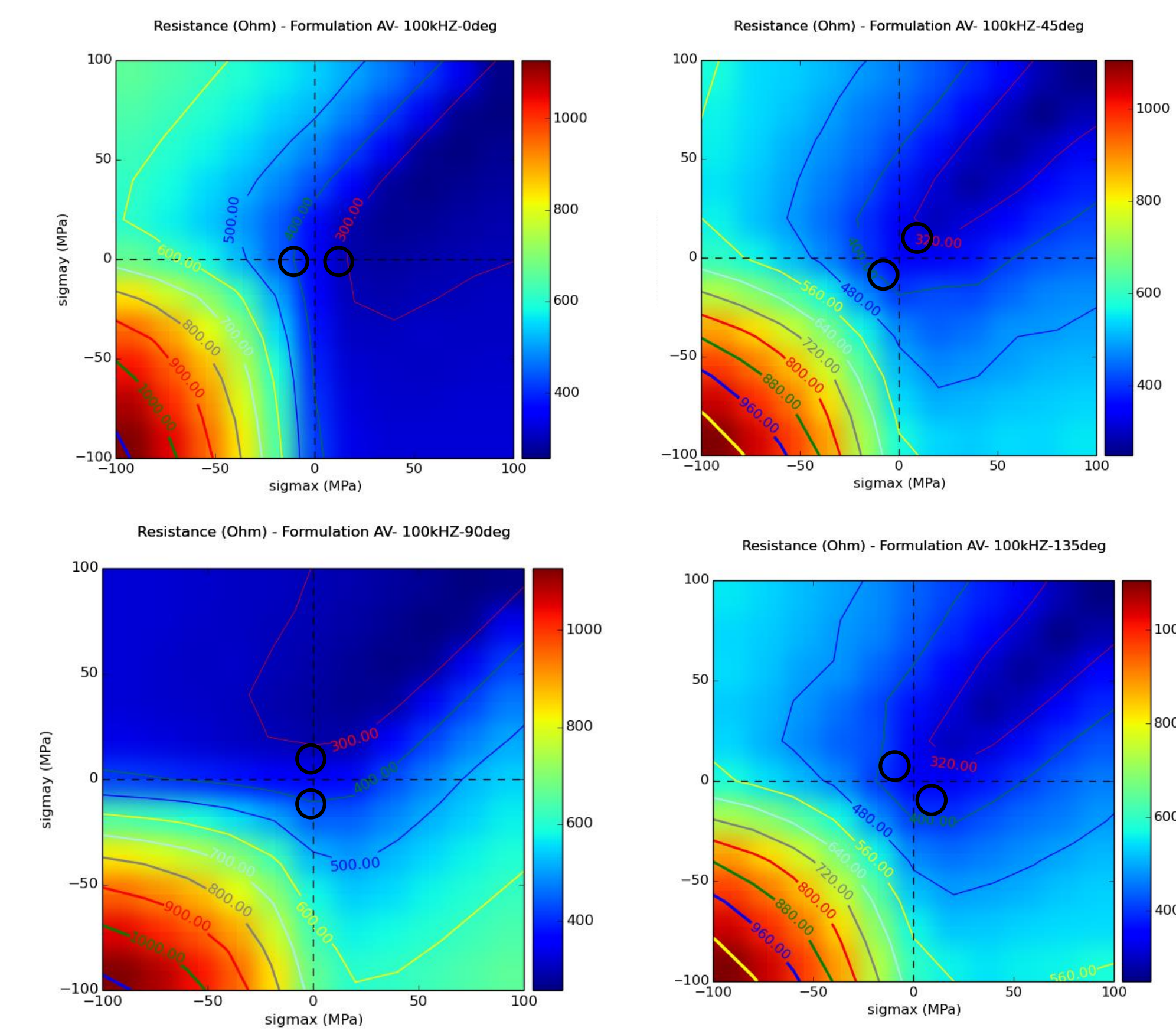


2-Dolmen : Dedicated finite Element Analysis Tool

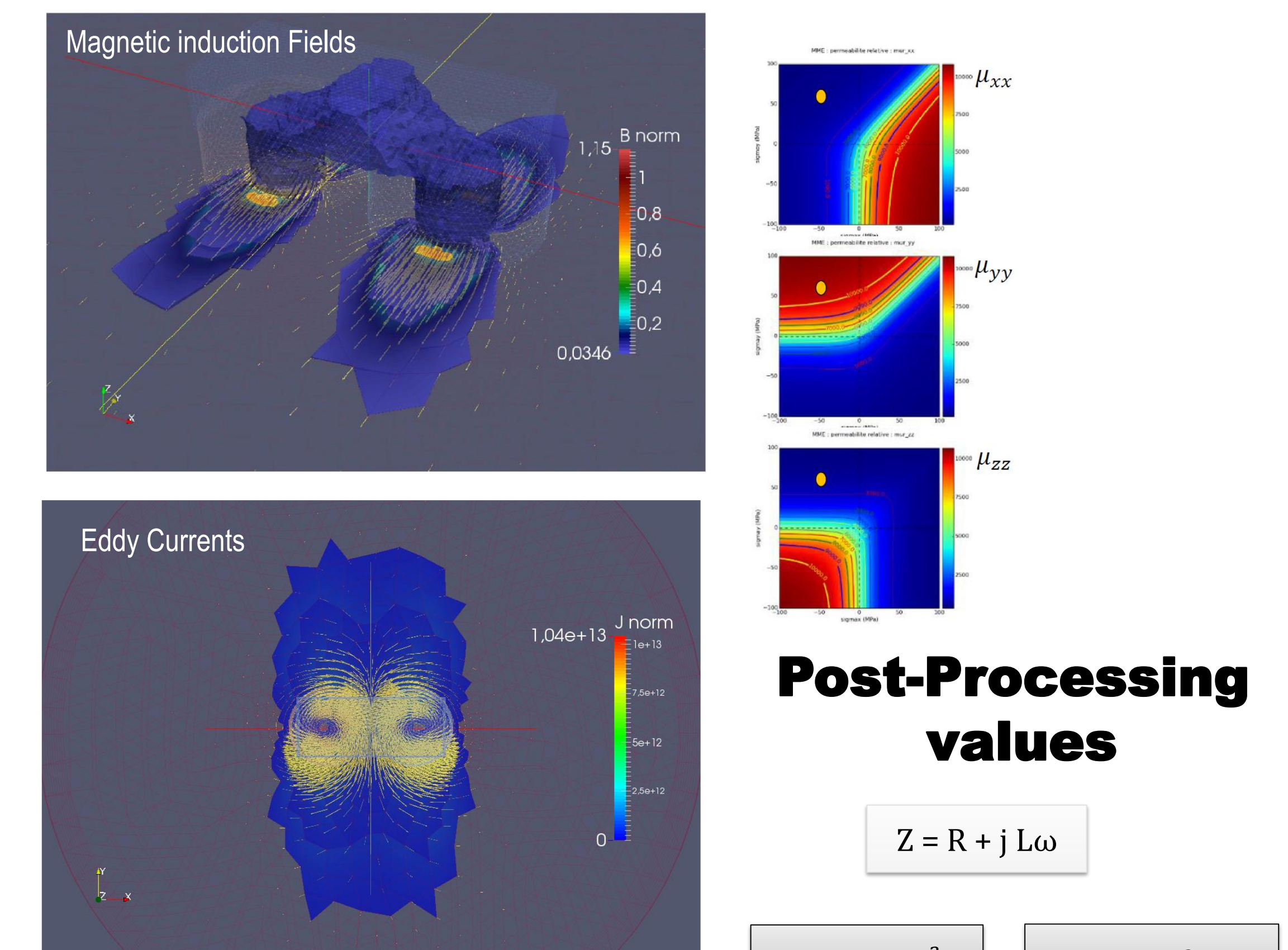
- Conductive Magnetic Material (Very thin skin depth)
 - Use of prism elements
- Map building
 - Use parallel computing
 - Automatic geometry and mesh generation
- Error Estimation based on the two dual FEM formulations



Resistance Map $f=100\text{kHz}$



3d Anisotropic stress effect on the electromagnetic fields

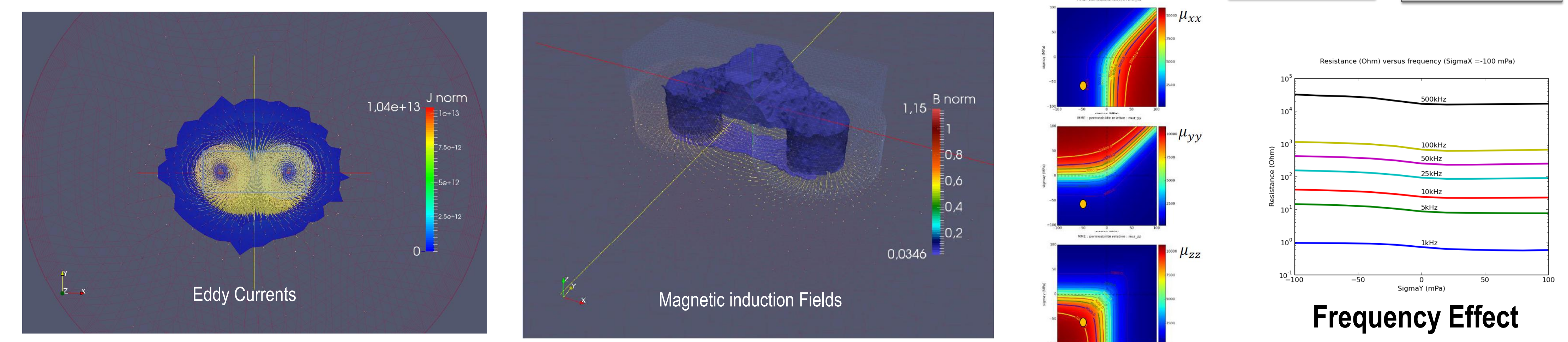


Post-Processing values

$$Z = R + jL\omega$$

$$W_{maj} = \frac{1}{2} L I_{eff}^2$$

$$P_j = R I_{eff}^2$$



Conclusion

In conclusion we can trumpet that the distribution of the currents are dramatically modified when the mechanical stress state is introduced. The results confirm also that stress has a strong effect on the field distribution and that the mesh of the FEM model has to be carefully designed in order to take into account properly this influence. The modelling approach provides some promising leads to identify stress states by an Eddy Current testing approach.