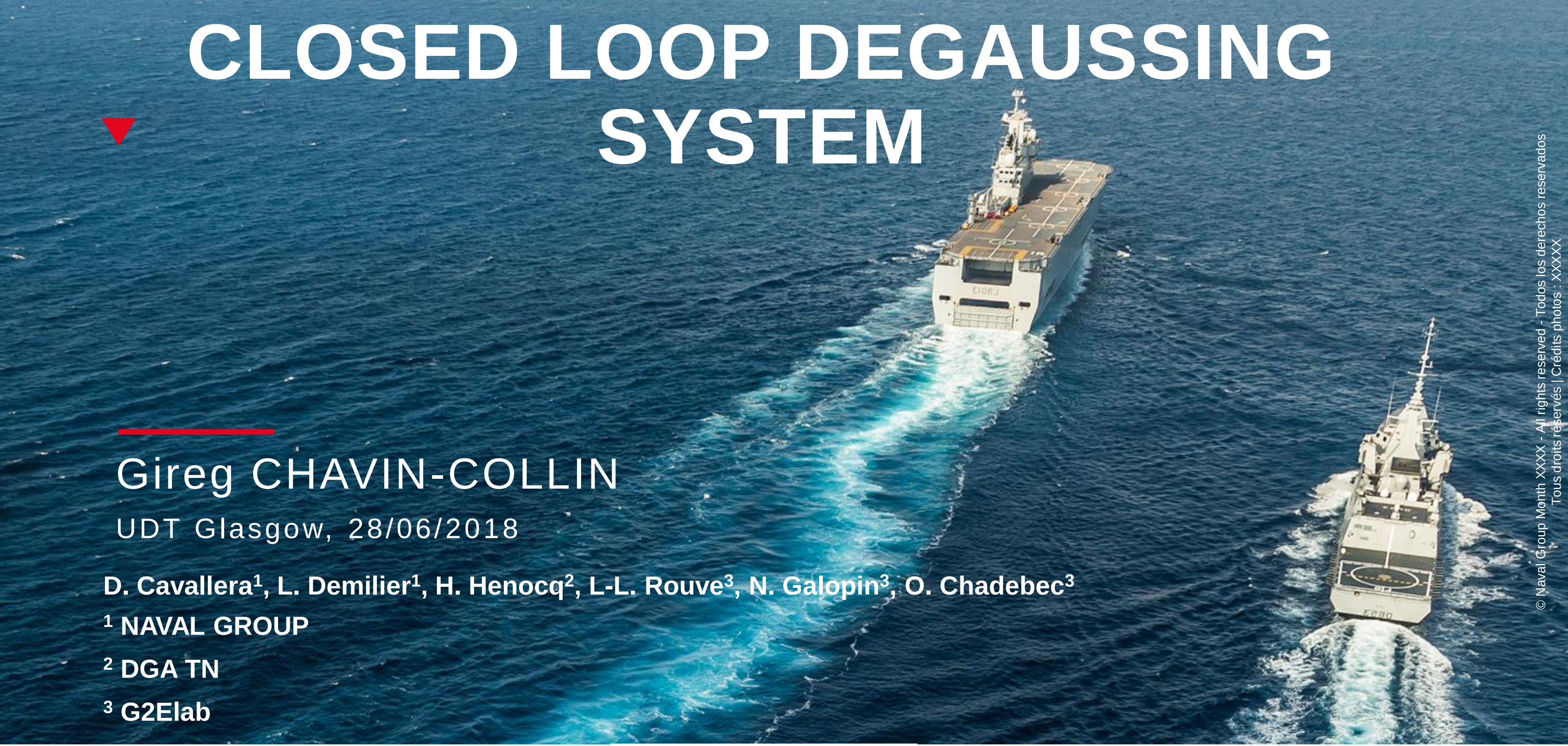
CLOSED LOOP DEGAUSSING SYSTEM



Gireg CHAVIN-COLLIN

UDT Glasgow, 28/06/2018

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POWER AT SEA

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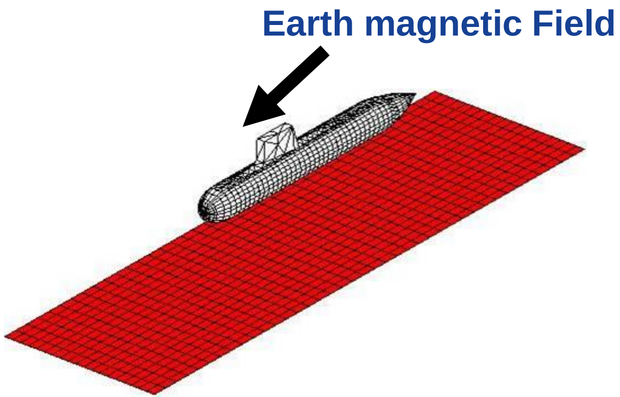
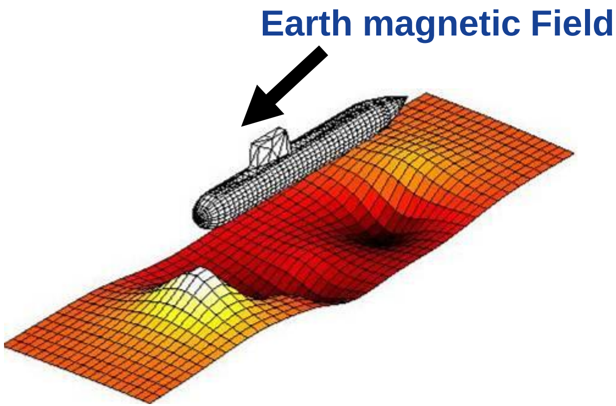
I. Ship magnetism and closed loop degaussing system

I. GENERALITIES - MAGNETIC RISK



- A ship with a ferromagnetic shell sailing in the earth's magnetic field acquires a magnetization and creates a magnetic anomaly
- Detection risks➔ avoiding mission or worst

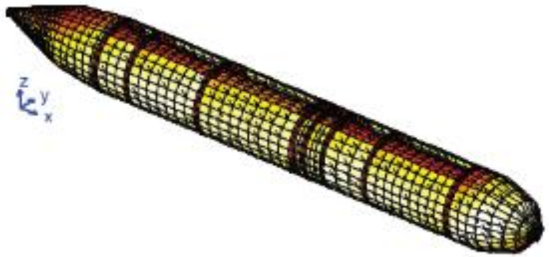
I. GENERALITIES - MAGNETIC RISK

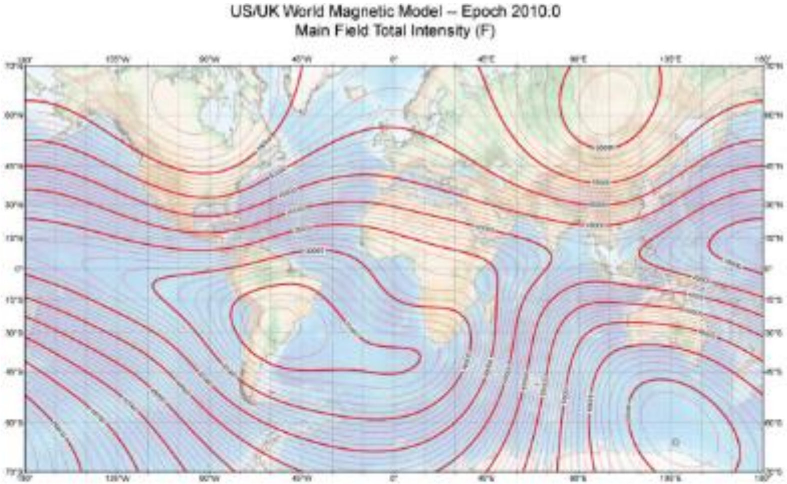


- A ship with a ferromagnetic shell sailing in the earth's magnetic field acquires a magnetization and creates a magnetic anomaly
- Detection risks➔ avoiding mission or worst

I. INDUCED MAGNETIZATION

- The induced magnetization is acquired during the navigation it depends on the cap and the geographic location.
- It’s the material reaction due to known inductor field.





Induced magnetization is actually neutralized.

- Simulation conception: model, numerical computation.
- Open loop degaussing system

I. PERMANENT MAGNETIZATION

Permanent magnetization is aquired along the material life.

It depend on the assembly, the mechanical constraint, the previous magnetic state.

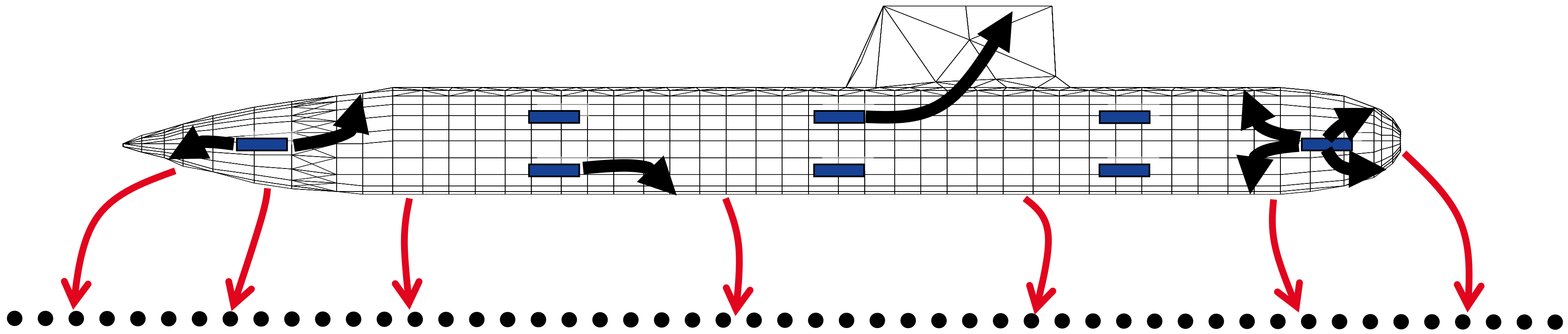
For submarine, the permanent is acquire during the diving.

- ❑Unknown data → Onboarded measurement system ➔ CLDG SYSTEM !

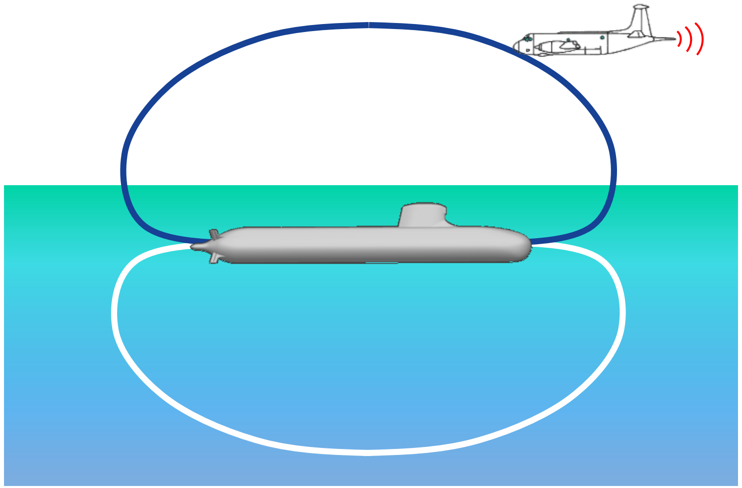
I. CLOSED LOOP DEGAUSSING SYSTEM

Principles :

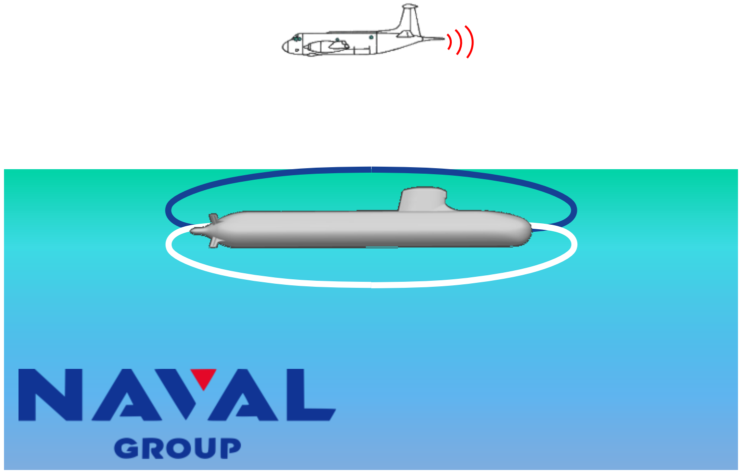
1. Onboard Magnetic Mesureaments.
2. Identification of a magnetic model of the hull.
3. Magnetic Signature computation.



I. CLOSED LOOP DEGAUSSING SYSTEM

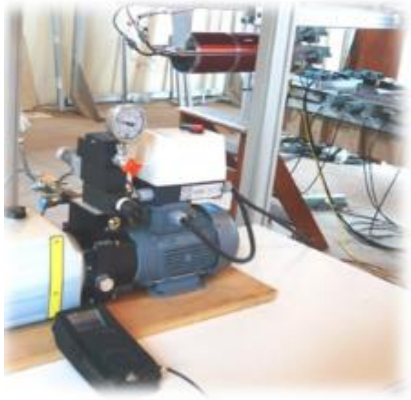


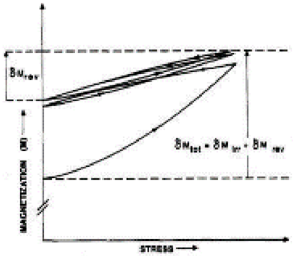
No degaussing system



NAVAL GROUP
CLDG ON

I. PREVIOUS WORKS



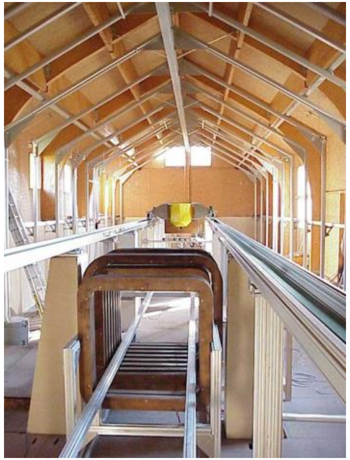


- CLDG Validation on a mock-up
- Magnetic model inversion.

- Studies of the magnetoelasticity.
- ➢ Adding of magnetomechanical model.

I. MAGNETOELASTICITY STUDY

- Mechanical stresses on a ferromagnetic material leads to modifications of its magnetics characteristic
- Study on the Modeling of this effect on a ferromagnetic hollow cylinder.(A. VIANNA 2010)
- Inversion problem is applied.

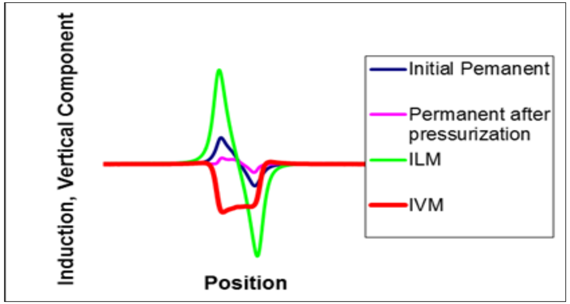


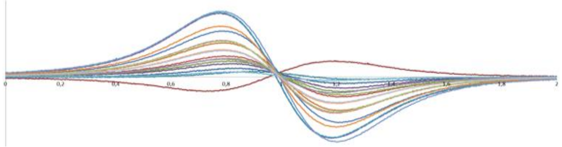
I. MAGNETOELASTICITY STUDY

- Experiments show the importance of magnetization modification after internal pressures.

- Induction measured before and after pressures is very different.

➢ Need to implement a magneto-mechanical model.





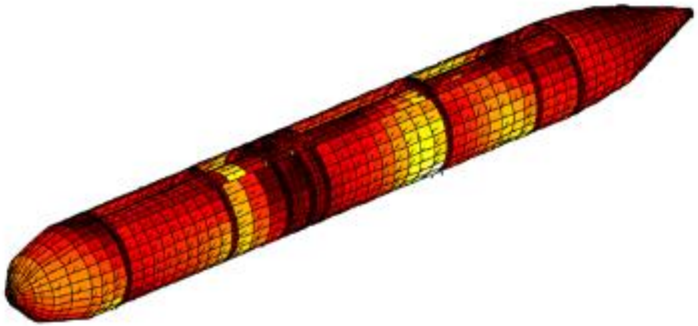
Measurement of vertical permanent induction as a function of pressure

II. Direct problem : induced magnetization computation

II. INTEGRALS FORMULATION

Integrals formulation (2008):

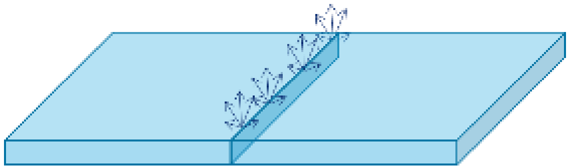
- Magnetic charges
- Magnetization



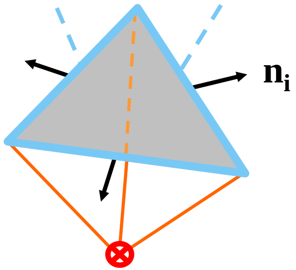
- Singularity due to function space.
- Optimisation of sensor’s positions needed.

➢ Magnetization model found with many sensors.

II. PREVIOUS FORMULATION



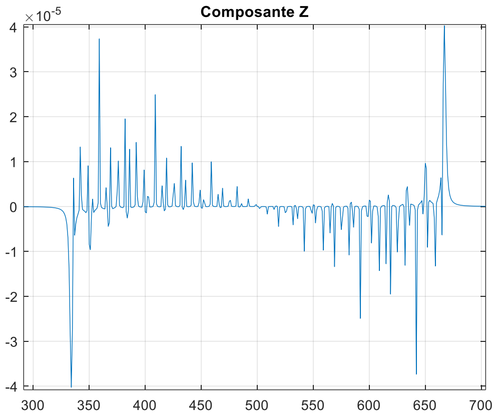
Linear equivalent charge distribution $M_i.n_i$



- In 2008 the numerical method consist to distribute a dipolar charge distribution (image of magnetization) on edge elements.

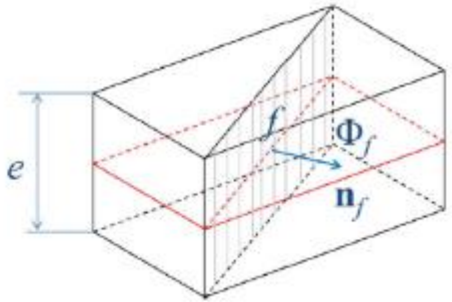
- For induction measurements close to the hull this method doesn't match with physic.

  ➢ Question about the unknown interpolation domain.



II. FACET FORMULATION

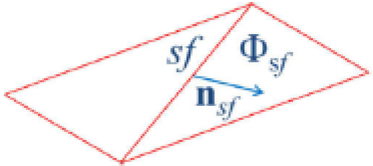
$$\left.\begin{aligned}&\frac{\boldsymbol{M}}{\chi}+\frac{1}{4\pi}\boldsymbol{grad}\int_{\Omega_m}\frac{\boldsymbol{M}.\boldsymbol{r}}{r^3}\,d\Omega_m=\boldsymbol{H_0},\\ &\boldsymbol{M}=(\nu_0-\nu)\boldsymbol{B},\end{aligned}\right\}\quad \nu\,\boldsymbol{B}+\frac{1}{4\pi}\nabla\int_{\Omega_m}\frac{(\nu_0-\nu)\boldsymbol{B}.\boldsymbol{r}}{r^3}\,d\Omega_m=\boldsymbol{H_0},$$



$$\boldsymbol{B}=\sum_{s=1}^{Nsf}\boldsymbol{w}_s\Phi_s\,,$$

Facet formulation :

- B is chosen as unknown.
- The induction is interpolated by first odre fonction shape , B is linear in the element.

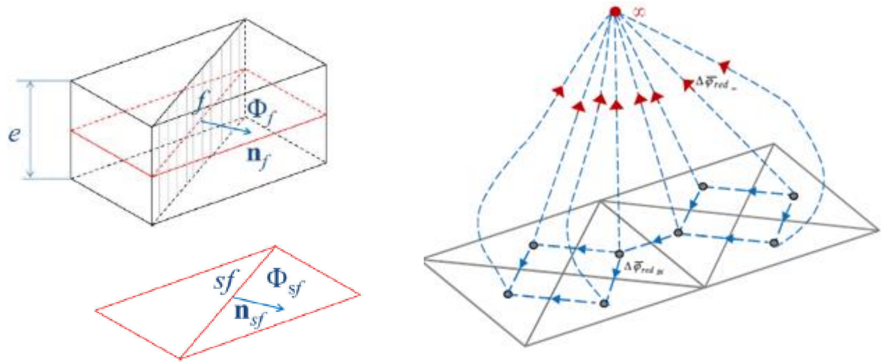


Thin element approximation, B only tangential :

- The associated face to the shape function become an edge.
- The function shape is degenerated on adjacents surfaces.

II. FACET FORMULATION

We are looking for the induction **flow** throught each element.



Steps :

- Building an equivalent system with an infinity node (solénoïdality, div(B) = 0).
- Solving the system with a circuit solver (GMRES).
- Saving the solution.

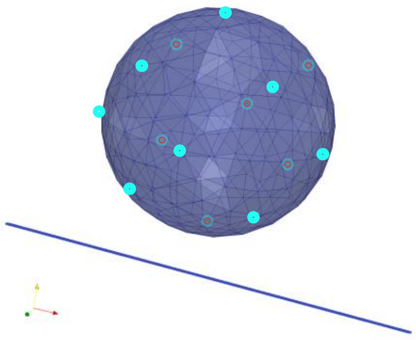
II. DIRECT PROBLEM

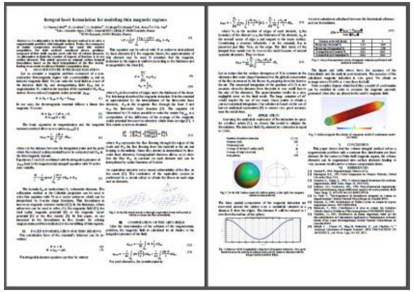
Air’s field computing :

- Numerical integration is difficult when the sensor is very close to big elements.

- Analytical integration are integrated in the post-processing.

- Validation of this method with an analytical calculation of the field.





➢ Submission of an article :

Integral facet formulation for modeling thin magnetic regions

(NUMELEC 2017)

III. Inverse problem : permanent magnetization computation

III. MAGNETIZATION SIMULATION

- Permanent magnetization go to an equilibrium (μa).
- This permanent magnetic state is simulated.
- From the reversible state, the permanent operating point is found.

- Hc, the image of the permanent is determined.
- A direct problem is solved (μr, Hc) to generate the measurements.

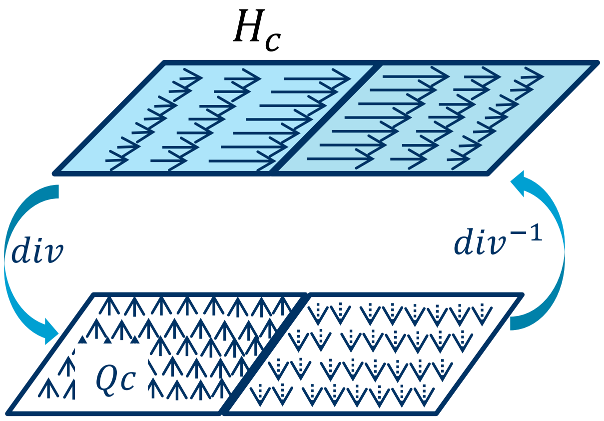
$$M^{induit} + M^{permanent} = M$$

➢ Objective: to find Hc by the measures.

III. INVERSE PROBLEM

Direct problem system & link between the air's fields and surfacics charge lead to write the inverse system.

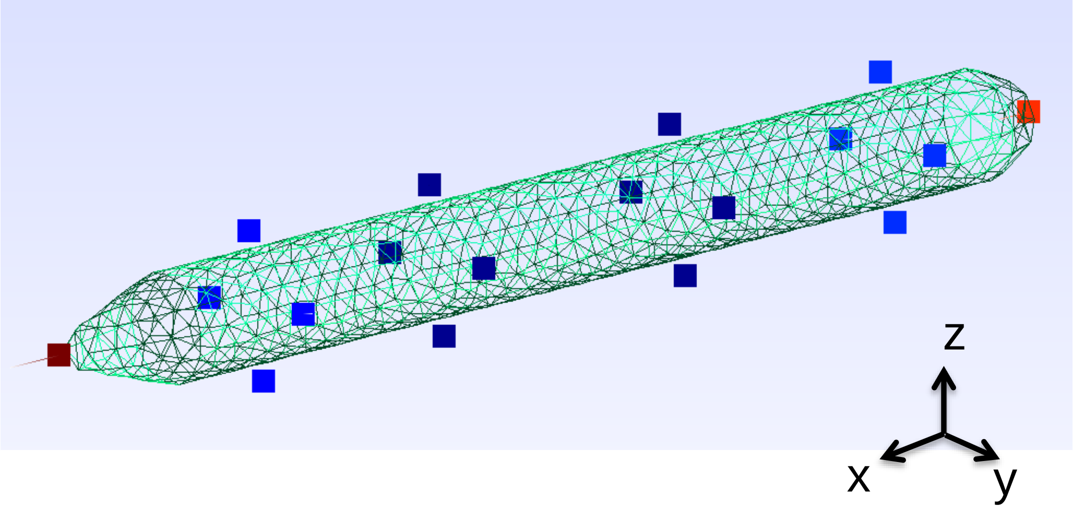
- Solving with SVD → minimal norm solution.
- Computing *Hc* regular with a fictive charge :



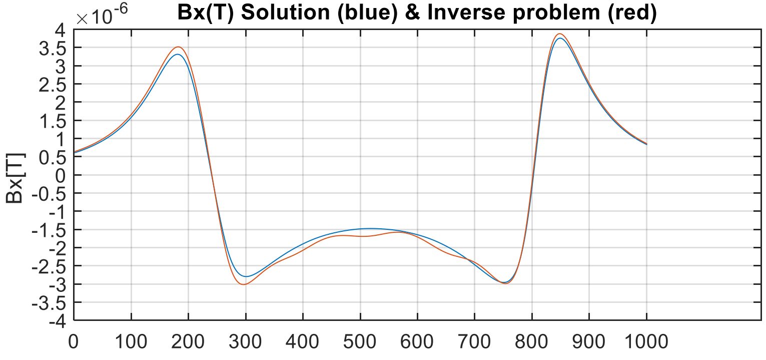
$$Q_c = [Mat]^{-1} B$$

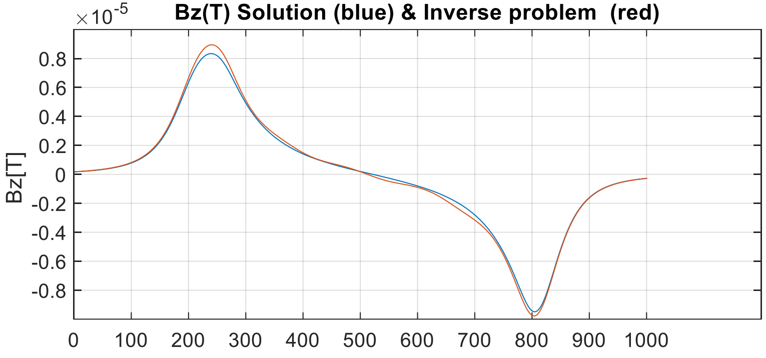
III. SIMPLIFIED MODEL INVERSION

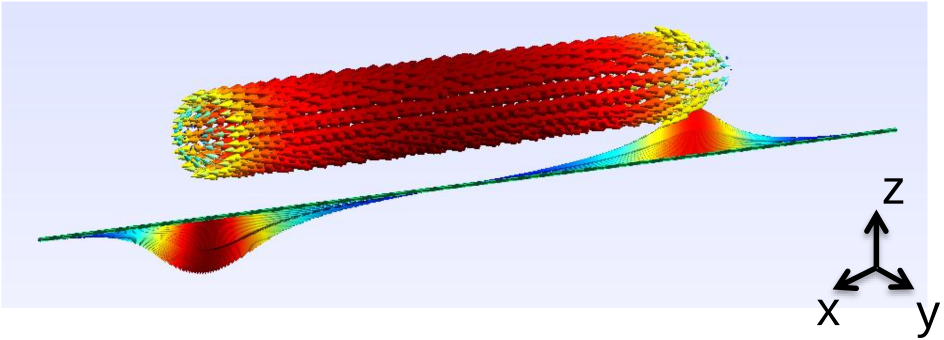
18 sensors close to the hull.
Number of face element: 1500
Lenght : 3,12 m
Diameter : 0,3 m
Thickness : 3 mm



III. SIMPLIFIED MODEL INVERSION







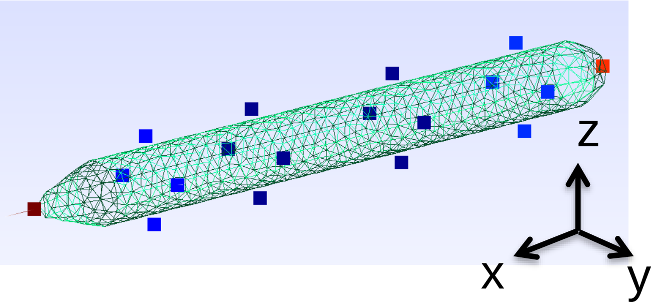
- Mean error 3%

III. CONCLUSION ON ALGORITHM

New formulation method allow us to :

- Match induction with the physic.
- Obtain accuracy measurement close to the hull with a large mesh.

➢ Sensor’s number decreases.



Upgrade potentials:

Statistical apriori → Bayesian method.

Physical apriori → **Material’s magneto-elasticity.**

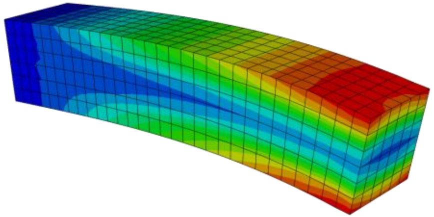
IV. Future Works

IV. FUTURE WORKS

The mechanical stress in the cylinder is homogeneous.

- Searching for an intrinsic characteristic curve of the material

→ Permeability = f (stress)



➢ Inversion of the system with experimental measurements, the model of magnetization is guided by the apriori.

Questions

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