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► **To cite this version:**

Michael Nale, Olivier Chadebec, Jean Michel Guichon, Olivier Pinaud, Brahim Ramdane, et al.. Transient Modelling of Corrosion Protection Systems with a Coupled BEM-Electrical Circuit Approach. The 2020 19th Biennial IEEE Conference on Electromagnetic Field Computation (CEFC'2020), Nov 2020, Pisa, Italy. hal-03051729

HAL Id: hal-03051729

<https://hal.science/hal-03051729v1>

Submitted on 11 Dec 2020

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Transient Modelling of Corrosion Protection Systems with a Coupled BEM-Electrical Circuit Approach

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Abstract— The modelling of corrosion protection system in seawater is classically based on BEM and limited to static study. This paper presents an original transient approach hybridizing BEM and circuit solving and enabling the modelling of more complex system and interface phenomena.

Index Terms—Ship Hull Corrosion, BEM, Equivalent Circuit.

I. PROBLEM AND METHODOLOGY

In order to prevent a ship from being corroded, it is usual to send currents in sea water through active anodes, placing hull damaged areas in their electrochemical inactive domain. This corrosion protection system is known as ICCP (Impressed Current Cathodic Protection). The flow of currents in the sea water (Fig.1) induces a measurable electrical field around the ship which can endanger it, knowing that mine sensors can exploit this indiscretion.

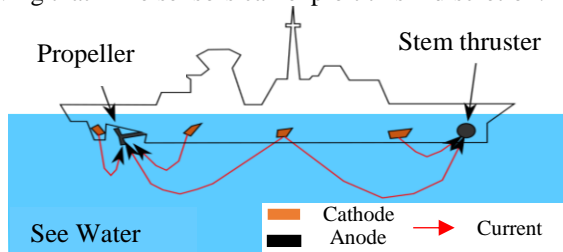


Fig. 1: Corrosion phenomena on ship hull

The modeling of this type of electromagnetic problem is now well mastered for static study. As the conductivity in seawater is assumed homogeneous, it is possible to solve the Laplace equation inside the electrolyte by using Boundary Element Method (BEM) [1] [2] with various conditions at the water/hull interface. With Neumann condition, the current is imposed (ICCP and insulator). Under Robin condition, the current is linked to the potential by a non-linear law for each element of the meshed interface in order to represent electrochemical phenomena. This method has shown good results for complex geometries meshed with thousands of elements. It allowed getting the potential/current of corrosion for a complex system and its resulting electrical signature.

However, to consider dynamic effects due to the ICCP when the system is triggered or the influence of the moving propeller on the signature, a transient approach needs to be developed. In this work, a BEM – electrical circuit hybridization is proposed to connect electrical components that model the transient phenomena on the interfaces to an ICCP external circuit. The material polarization laws are described by an association of a generator (potential of corrosion), a non-linear resistor intrinsic to the material and a capacitor that represents the chemical reaction dynamics. To model the current through the electrolyte and take into account the geometry of the system, we add components ruled

by BEM equations that link the potential and its normal derivative on the surfaces and can be seen like a network of resistances. The ICCP anode is simply a current generator. All the equations that rule the system will be detailed in the full article but they are composed of three blocks: a dynamic contribution mainly due to the capacitor, a static one that contains BEM equations and a source block for the current/voltage generators. The state equations are solved by an iterative time solver to study the dynamics of the system.

II. RESULTS

The electrical circuit of a simple model is presented here (Fig. 2): a cube filled with water, that model a few cm³ water tank of a laboratory experiment, has two polarized regions (red square line), BEM components (black dash line) associated to a meshed interface and one ICCP region (green full line). Here is the evolution of the current through the materials during a natural corrosion phenomenon (Fig. 3). We clearly see the transient operation before reaching the steady state of corrosion (discharge of the capacitors in the resistors).

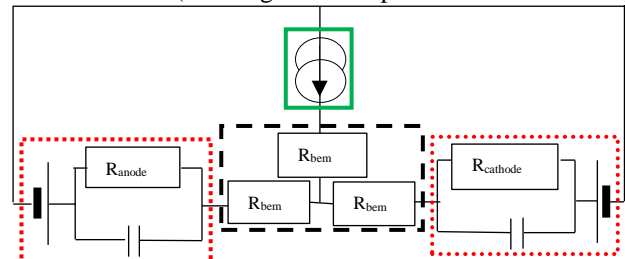


Fig. 2: Equivalent electric circuit of the system

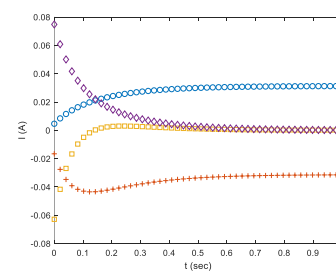


Fig. 3: purple diamond and yellow square: current through the capacitors; blue circle and red cross: current through the resistors versus time

In the full paper, a real system with non-linear polarization curves and the mesh of the complex geometry will be simulated and compared to experimental results.

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