PhD Position

– Electromagnetism Modeling in the framework of an European project: NDTonAir consortium

Title: Curvilinear Coordinates Transform Method for electromagnetic modeling of stratified complex structures: application to Eddy Current analysis of riveted joints and composite materials in aeronautic.

Job description: The French institute CEA LIST at the Department « Imagerie Simulation pour le contrôle » is offering **one** full-time position for a PhD researcher in the framework of an european project NDTonAIR in the Innovative Training Networks (ITN). The PhD proposal will be attached to the EOBE graduate school at the University Paris-Saclay.

Project background : The department « Imagerie Simulation pour le contrôle » from the institute CEA LIST (http://www-list.cea.fr) is a leader in research dedicated to the domain of non-destructive testing of materials, in particular for the development of simulation tools integrated into a huge software platform named CIVA. The PhD work which is proposed belongs to the Innovative training networks in a doctoral program in the European framework NDTonAIR (H2020 Marie Skłodowska-Curie European Training Network).

The fastener inspection consisting in the analysis of any layered planar structure made of aluminum with a rivet and an embedded flaw nearby is an important issue for the safety of aircraft structures. Moreover, in order to reduce the weight of aeronautic structures, some complex materials like some composite materials are introduced. The development of specific methodologies for the inspection of these two types of aeronautic structures by any non-destructive testing technique is of great interest today.

The carbon-fiber-reinforced polymer composites (CFRP) are constituted by a set of carbon fibers of circular section for instance. One can consider that an elementary pattern defined for the geometrical shape of the section of the fiber is periodically repeated in order to obtain a ply. Then an assembly of several plies having some different orientations contributes to the mechanical resistance and the rigidity of the material. The development of semi-analytical models and numerical models dedicated to the simulation of these complex structures by any electromagnetic method is a critical task due to the complexity of the global NDT configuration and the range of frequencies which can be used. In the case of any excitation by an eddy current probe or by using electromagnetic waves, a fast numerical model with a sufficient accuracy is required to be able to carry out some parametric studies or to build up some external model coming from machine learning and database.

The curvilinear coordinate method (CCM) is widely employed for studying some gratings and some material with periodic structures such as photonic crystals. This approach is based on a local change of coordinates which allows encoding of some distortion of the space into a material property of the material. In electromagnetism, since the fundamental laws of Maxwell are invariant by any change of coordinates, any local modification of the shape of an interface may be translated into a modified constitutive property characterizing the material. In our situation, the complex geometrical shape of the piece under test can be modeled by a simple equivalent piece constituted by the material having some equivalent tensor of conductivity. This approach allows to address the two kind NDT configurations of interest for aircraft structures: a planar sheet aluminum assembly and the composite material in an unified manner in order to compute the response of the electromagnetic sensor scanning the surface above the slab under test.

In this context, two kind of semi-analytical model can be firstly carried out and combined. For any homogeneous material for which there is none variation of the geometry belonging to the vertical Z axis, a modal

decomposition for the components of the electromagnetic field can be obtained by a projection on a Fourier basis functions or B-splines functions. Otherwise, in the general case of non-homogeneous materials, in order to avoid the stratification of the piece into a set of homogeneous layers, we introduce a pseudo-spectral concept by a projection on orthogonal polynomials. The two solutions obtained in the homogeneous region and in the non-homogeneous one are matched in order to solve the global numerical problem.

Task description : The PhD work aims at elaborate an unified approach for the two kind of applications we want to deal with and to study different appropriated basis functions (Fourier, B-splines, Legendre, …) in order to optimize the two modes of representation modal/pseudo-spectral of the electromagnetic fields and the approximation of the geometrical profile. A specific algorithm will be developed to address stratified structures. The electromagnetism modelling of a carbon fiber reinforced plastic introduces other supplementary difficulties due to the scale problem: the wavelength of the electromagnetic device is very different compared to the dimensions of the periodic pattern describing the material. A numerical model, sufficiently closed to the physical reality must be elaborated in order to identify some constitutive properties characterizing any anisotropic material. This step requires a homogenization process which would be defined according to some criterion chosen from the literature.

Following the numerical/experimental validation of the numerical modals which has been developed, some implementation will be carried out into the software platform CIVA including human machine interfaces.

Requirements for the Project: In the framework of this European project NDTonAIR and the Innovative Training Network, the early researcher will be invited to visit other research teams collaborating on the subject. The candidate will participate to several lectures in order to develop its theoretical skills on different research topics linked to the project.

In order to fulfil the rules or recruitment criteria concerning the first experience in research and the mobility, the successful candidate must:
- be in the first four years [full-time equivalent research experience] of her/his research career, e.g. since the completion of her/his masters' degree,
- not already possess a doctorate degree,
- have not resided or carried out their main activity (work, studies, etc.) in the country of the recruiting organization for more than 12 months in the 3 years immediately prior to the time of recruitment."
Other information may be found on the website http://www.pandora-h2020.eu/.

Profile

- Candidates should be well-qualified academically to masters level. The PhD work will require a mix of skills, including notions of fundamental laws of electromagnetism theory, numerical programming in Matlab and Python preferably and simulation skills in commercial Finite Element software (COMSOL) , as well as the participation to experiments in order to experimentally validate the developed numerical models.
- Applicants with backgrounds in the area of electromagnetism, applied physic and/or applied mathematics are suitable;
- Starting date for the position: February 2017.
- Duration of the contract: 3 years.
- The salary and appointment terms are consistent with the general rules at CEA LIST. Working place will be the Département « Imagerie Simulation pour le Contrôle (LIST) », Laboratoire « Simulation et Modélisation en Electromagnétisme », Saclay.
- Informal inquiries about the position can be made to Doctor. Denis PREMEL, Senior Physicist, HDR-Expert Senior, denis.premel@cea.fr and https://www.researchgate.net/profile/Denis_Premel
- More detailed information on working at CEA List is available on http://www-list.cea.fr/index.php/decouvrir-le-list/travailler-au-list.