Intensive simulation tools dedicated to the monitoring of material properties

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Introduction

Online monitoring of material properties is a topic of great interest in many industrial sectors, like the steel industry. In this particular context, there is a great need of efficient models to simulate non-destructive measurement systems, integrated within manufacturing processes to monitor mechanical properties of steel. Simulation studies requiring a large number of calculations bring a better understanding of parameters influence and help correcting possible drifts due to changes in the system environment. Carrying out such studies can quickly become cumbersome, as sensitivity analyses typically require several thousands of model evaluations, for instance. In order to overcome this problem, a strategy based on metamodeling is presented in this communication.

Simulation of the IMPOC system

This work has focused on the IMPOC system (see Figure 1), commercialized by the EMG Company, which carries out electromagnetic measurements that correlate very well with microstructure properties. Modelling this system is in itself a difficult task, due to the complexity of material properties involved, which are described at a macroscopic level by a set of magnetic hysteresis curves. The 2D model [1] developed simulates the electromagnetic field induced in the non-linear material by both magnetization coils, regularly fed with a strong pulse of current. The value delivered by the IMPOC system is derived from the remanent field measured by both receivers.

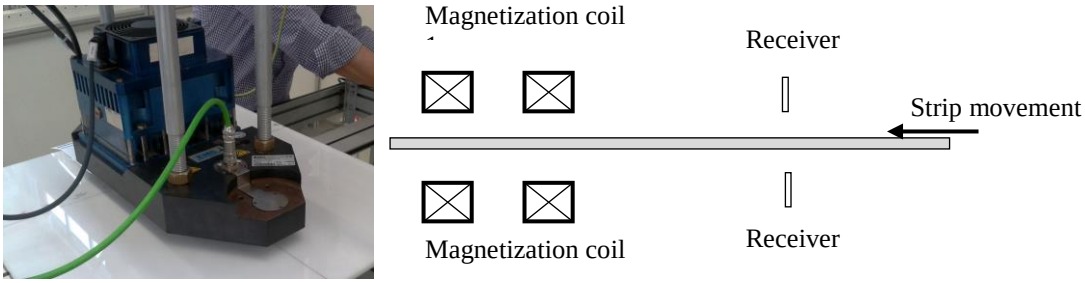

Figure 1. Left: view of the IMPOC system. Right: schematic view of the 2D model.

Starting from hysteresis curves obtained at Ceit in laboratory conditions, this 2D numerical model has reproduced in a satisfactory way experimental trends observed by two users of the device, which are also major players in the field of Metallurgy. The

first one is the steel manufacturing company thyssenkrupp Steel Europe, part of the thyssenkrupp group, and the second one is Tata Steel, part of the Tata group.

Metamodeling tools for intensive simulations

CEA LIST has recently developed in the simulation platform CIVA metamodeling tools adapted to non-destructive testing signals [2] obtained with classical techniques like eddy current or ultrasounds. Exploiting a database of simulation results, the metamodels are able to generate, in the range of input parameters covered by the database, accurate values or signals within milliseconds. Such a tool can serve various purposes, like probe design, sensitivity analysis, parametric estimation or real time simulation. Critical aspects are here the database generation, which is a long preliminary step carried out offline and optimized with respect to the model behaviour, and the estimation strategy, which relies on techniques like Kriging, Gaussian processes, or support vector machines. In order to assess the global metamodel accuracy with respect to the physical model, cross-validation processes can be used, as illustrated in Figure 2. For each sample of the signals database, the error between the model and the metamodel obtained when removing the signal tested is evaluated. In this example, a mean error of 6% is obtained, 56% of the tested samples having a lower error.

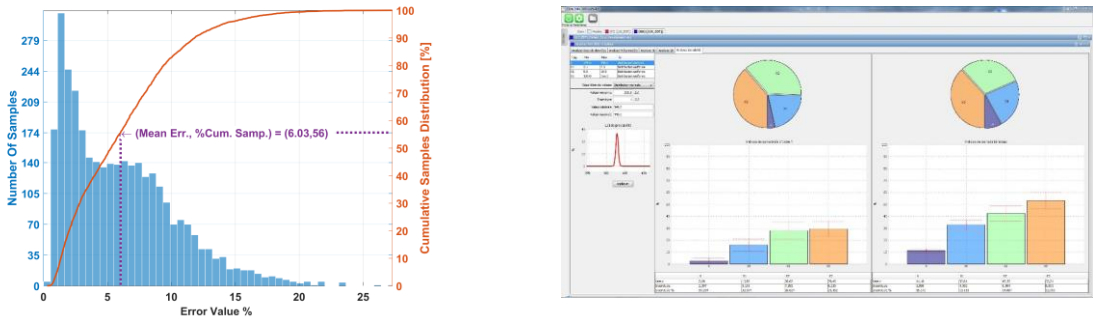

Figure 2. Left: Assessment of a metamodel accuracy by cross-validation tests. Right: Interface dedicated to sensitivity analysis in the CIVA platform.

In the case of the IMPOC signal, several parameters, linked with the material itself or the measurement conditions, have been ranked in terms of sensitivity. Among them, one can cite the strip thickness, the presence of a coating, the positioning of the system with respect to the steel strip or the speed of the strip. This work opens up the perspective to use such tools online in order to support online diagnostic strategies.

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