Simulation of IMPOC system for online monitoring of steel mechanical properties

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Abstract

The IMPOC system is a broadly applied device in steel industry for the online assessment of steel strip's mechanical properties. It carries out non-destructive electromagnetic measurements that are very well correlated with properties like tensile strength and yield strength, for instance. The measurement is however not only sensitive to the electromagnetic properties of the steel strip under investigation, but it is also influenced by other factors, like the strip thickness, its speed variations, and the lift-off separating it from the IMPOC system. To mitigate those effects, some empirical compensation functions are introduced (in the case of strip speed in particular) as a post-processing. The use of accurate modelling tools enables to better understand the various effects and allows the theoretical calculations of compensation coefficients.

Modelling approach

The IMPOC output is a differential measurement of the remanent magnetic field induced in the tested specimen after subjecting it in a strong magnetic field. In order to evaluate the response of the IMPOC sensors one needs to calculate the magnetic field inside and above the tested specimen during a complete excitation cycle. From the theoretical point of view, this is translated in solving the non-linear hysteretic problem in the domain of interest taking into account the hysteresis cycles of the material under consideration.

To tackle this problem, CEA LIST has developed, within the Product Uniformity Control project, a 2D numerical model based on the Finite Integration Technique (FIT) dedicated to IMPOC simulation. According to this approach the Maxwell equations are discretized in space using a system of two staggered canonical grids and in time via the application of a timestepping scheme. The non-linearity of the B(H) behaviour is taken into account via successive linearization based on a hybrid fixed-point/Newton-Raphson scheme. An illustration of the IMPOC set-up is given in Figure 1. For more details on the solution approach the reader is referred to a previous article [1].

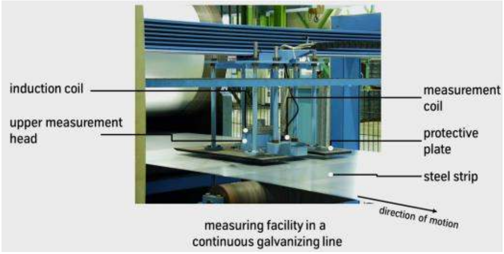
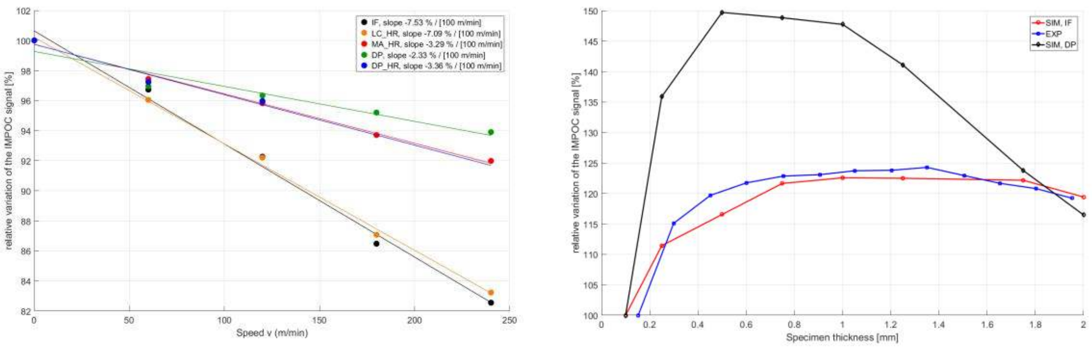


Figure 1: Set-up of the IMPOC measurement: the tested specimen is magnetised by means of two induction coils at its both sides and the remanent field is measured at the sensors location.

Results

The developed model has been applied to study the effect of the strip speed, which is an important nuisance effect since it alters the value of the measurement. Figure 2a shows the IMPOC signal change as a function of the strip velocity for four different grades (IF, LC, MA and DP). The output signal drops linearly with increasing speed for all grades, which reproduces the experimentally observed behaviour. The slope of the simulated lines varies from 3.36% per 100 m/min to 7.53% per 100 m/min when moving from harder to softer grades, which have to be compared with the experimentally obtained slope of about 3% per 100 m/min. In Figure 2b the dependence of the IMPOC signal with the strip thickness for a soft (IF) and a hard (DP) steel is depicted. The simulation results for the IF steel (red curve) are compared with measurements (red curve), done by thyssenkrupp. Comparison of the two curves demonstrates a similar trend between simulation and experiment.



(a) (b)

Figure 2: (a) Set-up of the IMPOC measurement: the tested specimen is magnetised by means of two magnetisation air-coils and the remanent field is measured at the gradiometers location. (b) Bloc-diagram of the solution algorithm.

Acknowledgements

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References

[1] A. Skarlatos, C. Reboud, T. Svaton, A. Martinez-de-Guerenu, T. Kebe and F. van den Berg, “Modelling the IMPOC response for different steel strips” 19th Word Conference on Non-Destructive Testing, 2016.