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Developing digital twins for accelerator magnets

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Test and measurement data is collected at various points in the life cycle of an accelerator magnet. By looking at the data through the lens of numerical modelling, e.g. with a numerical simulation at hand, one can exploit structure in complicated inverse problem solving and reverse engineering tasks. For this reason, the Test and Measurement section (TE-MSC-TM) is developing digital twins for accelerator magnets, following a methodology called Model-based systems engineering (MBSE), which focuses on models and simulations, rather than documents, for operation, performance evaluation, maintenance, and information exchange. In addition, MBSE enables hybrid modelling of magnets and field transducers where measurement data is integrated in numerical simulations. This is essential for the realization of high-fidelity digital twins, as modelling and approximation errors as well as model uncertainties can be compensated for. In this talk, recent advances made in the Test and Measurement section, related to hybrid modelling are presented and put into context by classifying them in design patterns. This includes the data driven model calibration (e.g. material data, magnetization) for high fidelity magnet models 'as built', the discrepancy modelling for complex 3D fields, as well as the neural network-based prediction of hysteresis effects in online field monitoring systems.

Presenter: Mr LIEBSCH, Melvin (TE-MSC-MM)

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