Toward virtual forming and design

Thermomechanical characterization of high strength steels through full-field measurements and a single designed test

VForm-xSteels

Abstract

Nowadays, the use of numerical simulation in general and finite element analysis (FEA) in particular has become a mandatory step of material processing optimization. According to the TechNavio “Global Simulation and Analysis Software Market” report (2016), FEA software dominates ~50% of the market that just in the automotive industry is likely to exceed $928 million by 2019. Although the large market size and the regular use of FEA in the engineering design industry, the problem of searching for FEA input data (particularly the material behavior) is systematic and has not been answered. A solution for this problem is required for both the FEA users and providers.

Therefore, the characterization of materials has received increasing attention due to the need of precise input data to computational analysis software. Simulation software uses complex material constitutive models and its success reproducing the real (thermo)mechanical behaviour is inherently dependent on the quality of the implemented material-model and its material parameters. In general, these parameters are determined by numerous standard tests. However, the homogeneous thermal and stress-strain fields generated in these relatively simple tests do not resemble the complex thermal-stress-strain fields occurring in metal-forming operations.

Additionally, the inverse-methodologies commonly used (minimization of experimental vs FEM-model) are not reliable enough, due to the non-uniqueness of the solution.

Furthermore, for complex constitutive models with a large number of parameters, a high number of standard tests must be used in the experimental database, leading to an expensive and time consuming experimental characterization and identification process.

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Description

The main goal of this project is to develop an efficient and accurate methodology for determining the material parameters of thermo-mechanical models, from a dedicated single test that involve non-homogeneous temperature and strain fields. Indeed, this non-homogeneity leads to richer information than more traditional approaches with quasi-homogeneous tests, thus leading to a decrease of the number of experiments. A database with calibrated material constitutive models is also developed.

The benefits of the proposed methodology and consequent implemented numerical tool developed within this project are (i) increasing the precision of numerical FEA simulations providing accurate input data, filling then a gap of the FEA market and answering to the request of the FEA users. Therefore, the (ii) reduction of engineering metal part development lead-time and the provision of robust solutions with highly improved quality is also a benefit. (iii) Developing an automatic, accurate and trustworthy methodology for model material characterization; (iv) reducing the number of experimental tests required to characterize metal forming materials; and (v) cost and time reduction in the overall development process are also benefits of this proposal.

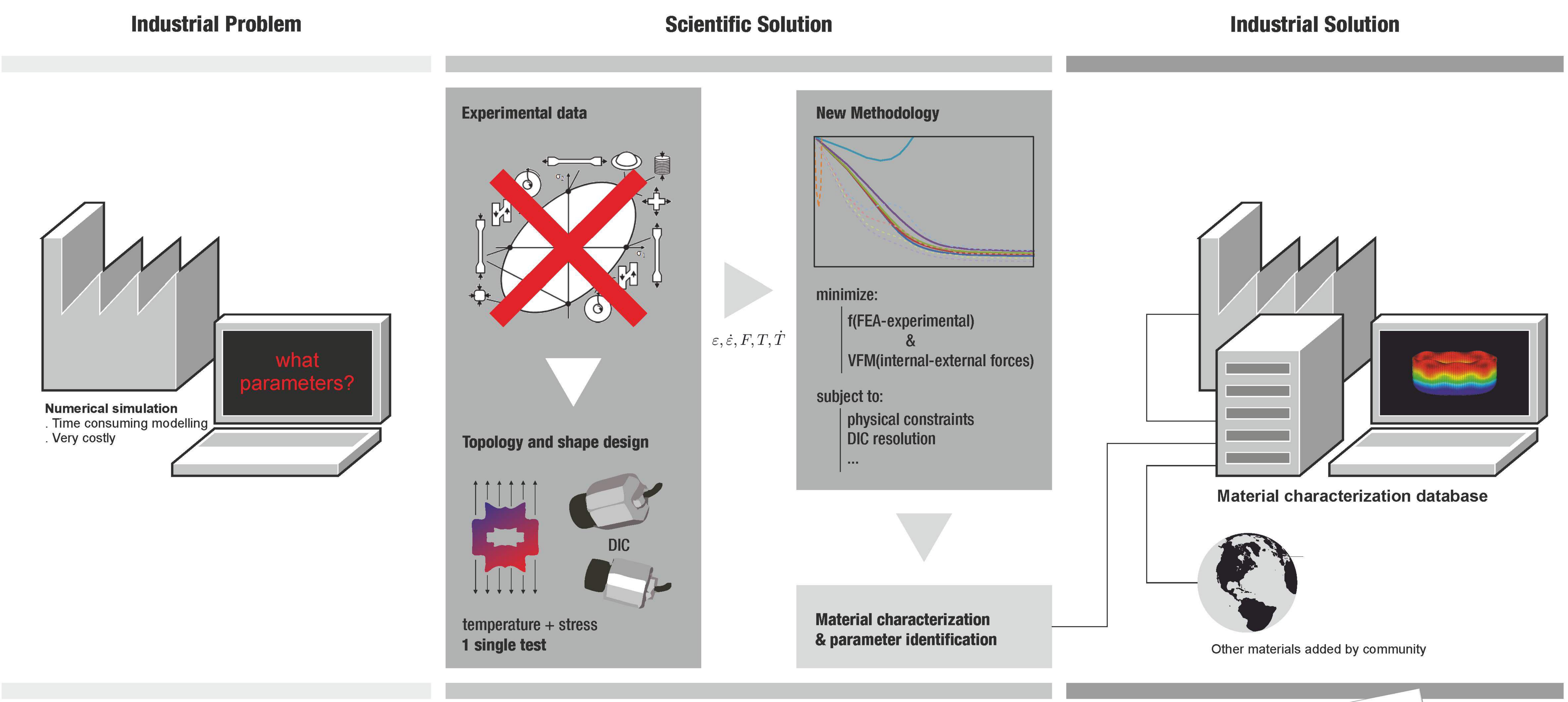

Fig 1 / Graphical abstract of the project.

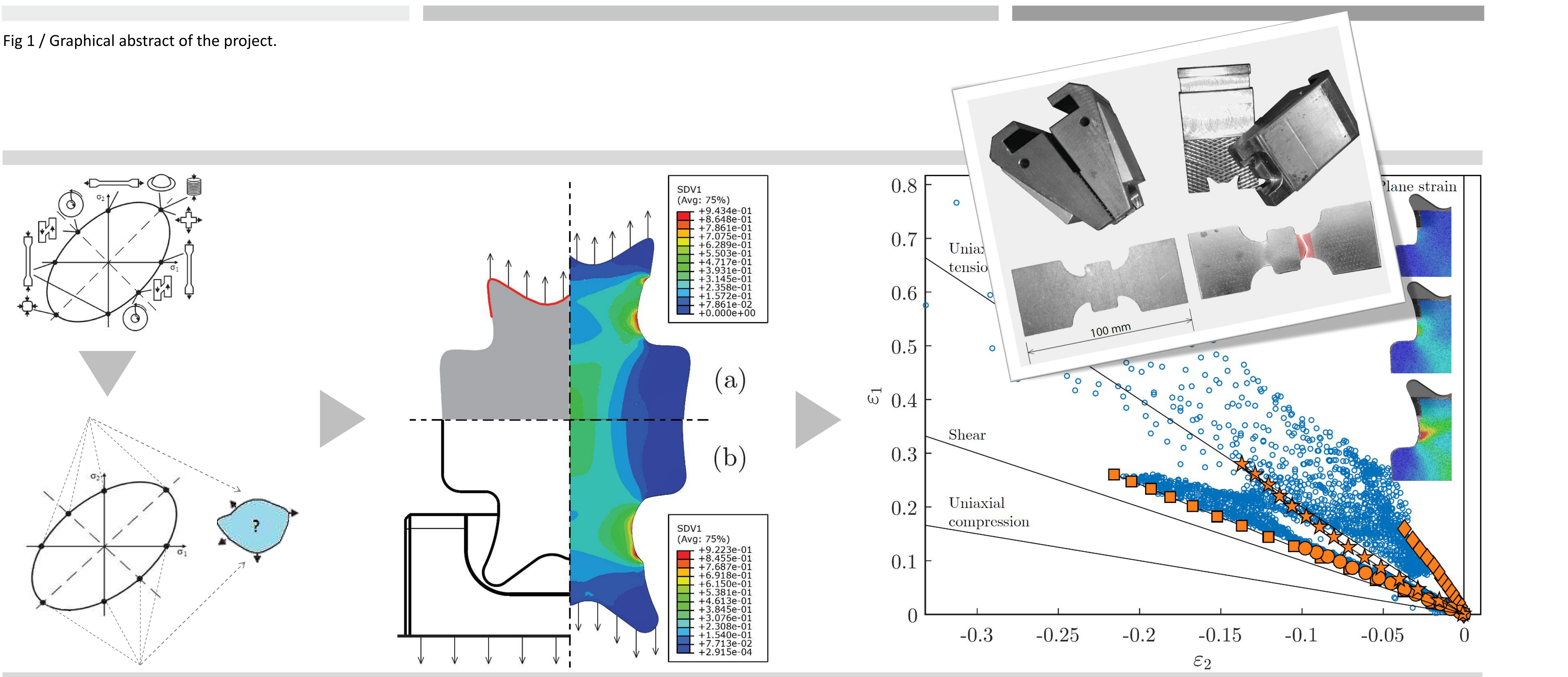

Fig 2 / Design of heterogeneous mechanical tests. Numerical methodology and experimental validation. Design of a heterogeneous mechanical test with a rich strain field information, allowing the identification of a large set of material parameters from complex constitutive models. The designed test should reproduce several stress states, therefore allowing a more complete mechanical characterization of sheet metals.

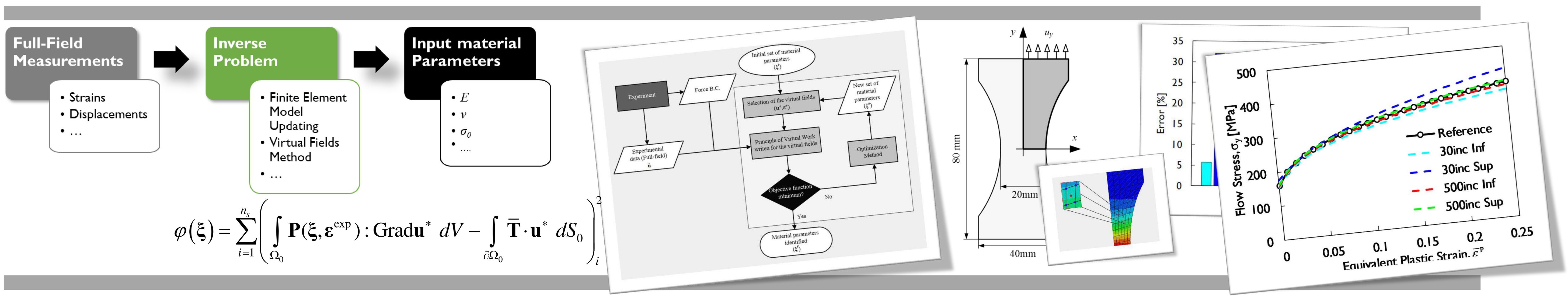

Fig 3 / Material Parameters Identification for Plasticity Models. Inverse numerical methodologies for parameter identification: Finite Element Model Updating (FEMU) vs Virtual Fields Methods (VFM).

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