Towards Integration of Advanced Material Models into PLM

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Introduction

Simulation of processes, systems and products gain increasing importance within the scope of Industry 4.0. Today, „Product Lifecycle Management" (PLM) tools support the digital collaboration during the design phase of complex products and cover all aspects of conceptual design, mechanical engineering, and Compliance management. The fields of interest in that context are, the advanced computer aided engineering (CAE) and the product lifecycle management getting into account for simulations, e.g. for crash, distortion and forming requiring advanced material models. The material data have to be material-specific, consistent and complete. Providing consistency and traceability to the raw data sources is challenging the possibility to extract relevant information from databases for models under investigation. A joint German and Czech research project AMMICAL, outlined in this paper builds a framework for an exhaustive extraction of meta- and aggregated data. This ensures the traceability along the entire process chain. Especially with the focus on advanced new materials tests utilizing digital image correlation (DIC) and involving generation and further processing of large volumes of data, which are currently not supported by any materials database or PLM-system. This includes integration of advanced materials tests, inverse analysis and derived models into PLM and CAE environments. For the derivation of such kind of database, transparency is one of the pivotal aspects needed for the derivation of a business process flow, fulfilling usable data compression and consolidation. This paper gives an overview of the main ideas starting with the elaboration of business process flows, documenting such processes using BPMN representations and the JSON data model. Furthermore, the processing of data is shown by starting point tensile testing, which is still one of the sources of data for modelling the elasto-plastic behavior of materials. The technical infrastructure provided by EDA materials data system is used as the materials engineering backbone [3,4].

Business Process Flows

The processes from testing to application of a model in CAE systems are usually not straightforward and need to be traceable along the entire flow. Modelling of processes is accompanied by data modelling, such that consistency and traceability of data is reached and media breaks can be avoided.

Interdisciplinary work of staff from different groups, e.g. materials production, materials testing, CAE calculations are essential for this purpose. The so called EDA task flow (ETF) is a technical infrastructure of the EDA data system which is used to establish the specific task flow for the entire chain of activities from materials tests to engineering tasks depending on the needed objectives. This application ensures entering the whole process starting with the receipt of a project order through the performance and ending with completion of the order generating different kind of reports for customers. However, a link or even integration to enterprise workflow management systems, like PLM- and ERP-Systems still is a future task.

Business Process Model and Notation. Business process flows are documented and visualized by the business process model and notation (BPMN), which maps all pivotal actions and communications on several levels within a process. BPMN components are used in EDA for an illustration of the implemented business process flows in the data system. Any parts of this task flow can be linked to the corresponding object in EDA for a specific description of the functionalities in each process step like shown in Fig.1.

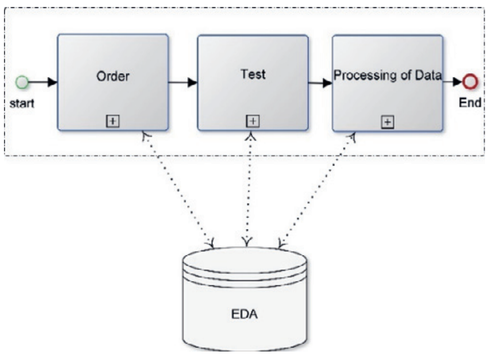

Fig.1. BPMN describing a general task flow.

Data Modelling and Representation

Data structures using the EDA architecture are elaborated to achieve a consistent data model for comparing and analyzing different data form different sources. The object oriented data model of the EDA system utilizes the flexibility of a document centric data model. Objects will be handled by a python middleware, meaning every object is defined by a class that defines how the object operates.

JSON Data Model. . JSON (JavaScript Object Notation) is the native data format of the underlying MongoDB database system. There are several reasons to use a JSON database, among them performance and sustainability. All data are stored internally in a format which include their metadata and are therefore suitable for long term readability and archiving [2,3].

Master and Child Models. In the context of data modelling for CAE applications, the AMMCAL project uses a concept of master and child models. The main focus is defining a universal master data model, defining all required properties and attributes depending on validated standards, and beyond. All available property definitions of the project consortium are able to derive their own attribute mappings from a common master model. These child models are mapped to the standard definitions used in the master model. By that, a Master Modell contains a consistent set of data which is capable to describe the entire elasto-plastic behavior of a material together with damage models and thermo-physical data. Child models are specific subsets of the master model, which are tailored to meet specific demands of the CAE-systems used. Crash and impact simulation for example, depend on such kind of data systems to ensure the reliability of results. Fig. 2 shows an example modelled by Nordmetall GmbH regarding ballistic tests [1]. The here presented concept helps to assure consistency of results from CAE-calculations performed by different tools and solvers as the underlying material models rely on the same master model. The material properties are also depending on the manufacturing history and can so also vary over a simulated part. This new opportunity avoids lacks of information and inconsistency due to the universal validated standards and opens a gate for efficient and transparent results. [2,3].

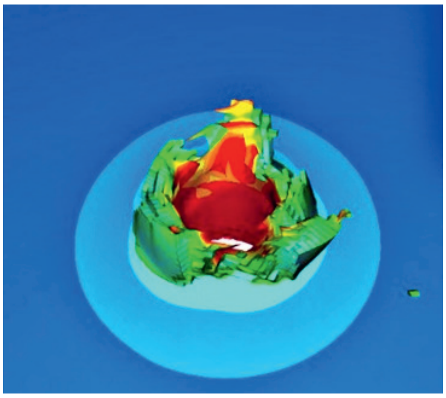

Fig.2. Temperature distribution of a ballistic test – NORDMETALL GmbH.

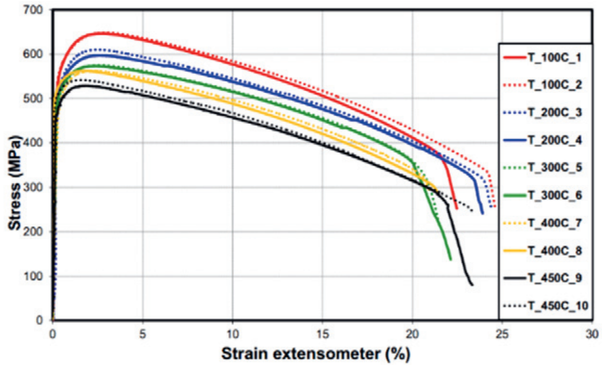

Fig.3. Tensile test of conventionally produced steel alloy regarding different temperatures – COMTES F.H.T.

Processing of Data

The post processing of test data is also performed in EDA. Among others, existing raw data from testing or modelling can be evaluated with all necessary tools as resampling, smoothing and curve fitting with predefined functions. In the context of tensile tests for example, the evaluation of the elastic and plastic deformations are given, as well as the calculation of material specific properties regarding the executed test as the modulus of elasticity, true stress, true strain, engineering stress and engineering strain of the specimen’s cross-section area. In addition to the processing, comparison views of evaluated tests are enabled as graphs and tables. The output of the post processing can be reported in the EDA documentation, where any type of template is available, e.g. for example scientific reports and reports containing raw and processed data as graphs and tables [3,4]. Further on, the project is working on the support for more advanced evaluations, like inverse analysis of material models. Interfaces to specific tools will be created to allow a seamless integration. Fig. 3 presents graphs as comparisons of mechanical characteristics regarding conventionally produced steel alloys depending on different temperatures. Applying curve fitting functions as Hensel-Spittel or Zerilli-Armstrong models, enable the derivation of a parametric master model. The parametrization of such models go together with high flexibility for different views of testing and comparison of results.

Summary

This paper gives a brief overview of AMMICAL, which is an ongoing project for the integration of advanced materials tests, inverse analysis and derived models into PLM and CAE environments. Among other possibilities, the software application EDA is used for evaluating, processing and reporting any kind of tests and models. With the mapping to a created master model the transparency and traceability of data sources is enabled. Such kinds of models are implemented by the definition of JSON data models with the use of JSON dictionaries. AMMICAL builds a clear and structured chain for all process parts within a project order. Challenging factors are removed by the focus on a master model representing universal standards for the definition of properties and attributes according to leading international standards (ISO, SEP, ASTM). With these developments, a new era is coming up for closing the gaps between material science and material modelling.

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