Towards Integration of Advanced Material Models of Steels into Digital Product Development

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Summary

Simulation of processes, systems and products gain increasing importance within the scope of Industry 4.0. Today, „Product Lifecycle Management“ tools support the digital collaboration during the design phase of complex products and cover all aspects of conceptual design, mechanical engineering, compliance management etc. Advanced computer aided engineering (CAE) simulations, e.g. for crash, distortion and forming, require advanced and consistent material models. Tools for creating a related in-house knowledge base are presented together with the Stahldat system as a starting point.

Key Words: ICME, JMatPro, Materials Information, PLM, CAE,

1. Introduction and Objectives

In many companies and research institutes materials information and their data are spread across several file systems on different servers, partly included in ERP (enterprise resource planning) and PLM (product lifecycle management) systems as shown in Fig. 1. Silos of data cause inconsistency accompanied with a lack of traceability. Such digitization is not a solution as it means converting data to a digital format. In case of materials information the current status seems to be limited to this stage, which does only lead to moderate benefits.

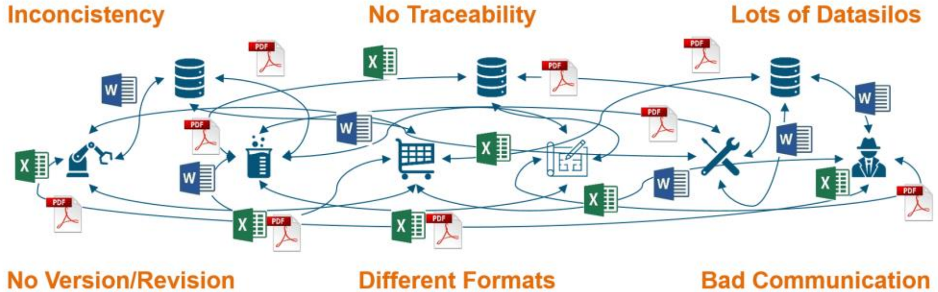

Figure 1: Status quo of materials information in many companies and research institutes

In contrast digitalization means transforming business processes by levering digital technologies such as CAE (computer aided engineering). Materials information for CAE applications is usually stored in so-called material cards. Such files are specific to the different systems and solvers. By that they cannot be compared and consolidated directly. Different user groups using different CAE-tools generate inconsistent results due to inconsistent materials information.

Digital product development aims to accelerate and secure speed of innovation. Materials innovation is a key to:

- Improve quality of products and processes,
- Create sustainable products with lower CO2 footprint
- Lower costs by managing complexity, alloying & energy costs

Agile materials innovation relies on:

- Knowledge & inspiration
- State-of-the-art digitalization and simulation
- Excellent laboratories and technical centers, which contribute to building knowledge rather than producing digitized data without extra value

Our goal is to deliver the building blocks of practical value that enable true digitization of materials knowledge. This includes the seamless integration of materials simulation, materials testing, materials processing together with CAE into a unified knowledge base. This knowledge should be a corporate asset and not just exist in the heads of selected individuals.

2. Integrated Materials Knowledge Management

"The increase of data and knowledge is not a solution but a new problem" [1]. In this case, the problem is not so much the availability of information or knowledge, but rather the application of appropriate information filters or sorting capabilities to access relevant materials. Information overload thus makes it difficult to find correct and important information. Knowledge management addresses this issue.

Fig. 2 shows the Data Information Knowledge Wisdom (DIKW) pyramid for materials. In order to support decision making and innovation, information and data have to be combined to applicable knowledge.

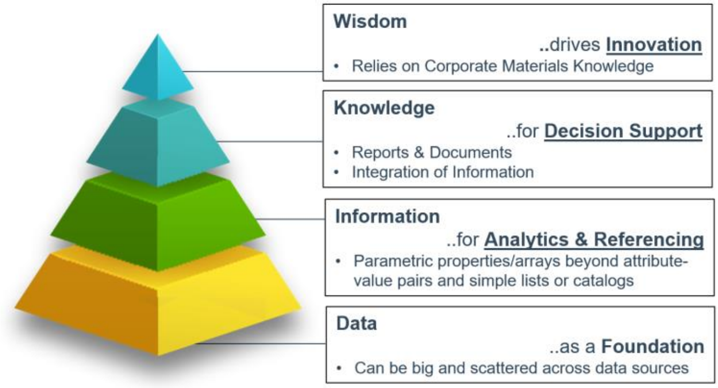

Figure 2: The Data Information Knowledge Wisdom (DIKW) Pyramid for Materials

Management of materials data is more than maintaining material catalogues and the requirements are different to other IT-systems:

- Parametrized arrays of data instead of simplistic attribute-value pairs
- Rich meta-data and links between materials, tests, etc.
- Different unit systems, languages and designations
- Interfaces to a variety of test machines and databases, e.g. MES
- Big volumes of raw data from testing

The dynamic evolution of materials properties and testing facilities require a high degree of flexibility.

Master data management for materials brings together information like designations and standard references with typical characteristic values and chemical compositions. Preserving semantical context is always necessary to provide useful information rather than data only. It is crucial to extract a company-specific minimum from the multitude of heterogeneous information sources and databases available. A starting point for this can be reference databases, like the Stahldat SX (www.stahldaten.de).

The data from the company's own materials laboratory and from test certificates can be linked to the master data so that, for example, evaluations of the scatter of properties over time are possible. Ideally, not only the few derived characteristic values are recorded, but also the multidimensional test data. Figure 3 shows the evaluation of characteristic values using the example of yield strength ratio vs. strength. The obvious deviation can be identified as a measurement error – if raw data from testing are available.

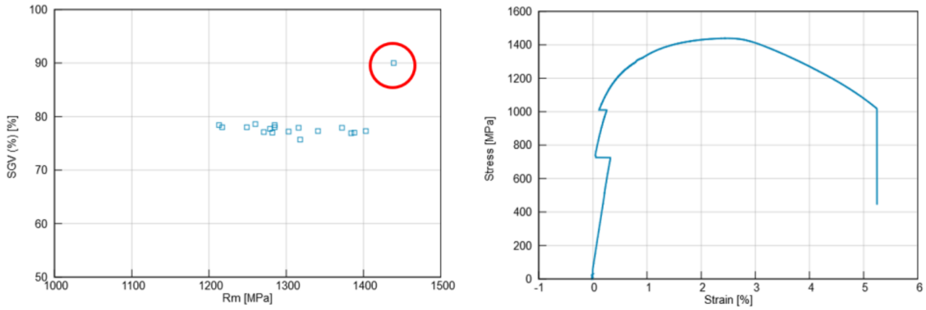

Figure 3 Evaluation of a series of tensile tests (left), measured stress-strain (right)

A wide range of applications and processes throughout the life cycle requires and produces material knowledge:

- Material approvals and release processes, hazardous material declarations.
- Materials testing and digital test certificates
- Purchasing processes with cost optimization by reducing the number of variants
- Pre-development and design of products and processes with material selection
- Production with approval testing and certificate creation
- Life cycle assessments and environmental impact (LCA)
- Creation of material cards for CAE

PLM and CAE systems require material-related parameters. Since their format requirements are different, the material designations within the individual systems are also very heterogeneous. The next level of information is typical characteristic values or minimum characteristic values as scalar properties at room temperature, such as density, which are required in CAD. Deviations arise due to different data sources of the systems as well as unit systems.

Sophisticated model descriptions of material properties are needed for FEM-based evaluation of products and processes. Examples are models describing the plastic behavior of materials as a function of temperature and velocity. These are expressed by flow curves and/or parameter sets for constitutive equations. As shown in Figure 3 EDA® supports the entire process, starting with data acquisition from test data and simulation data through the integrated functions for data analysis, visualization and mathematical modelling by curve fitting [2].

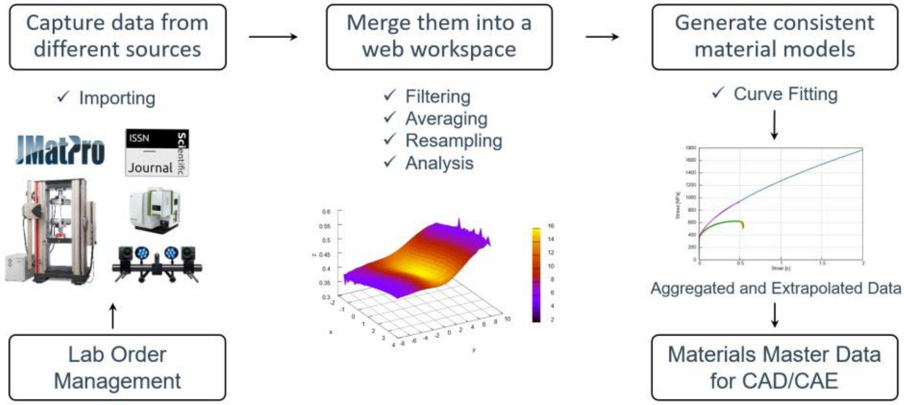

Figure 4: Process support for the creation of material cards from heterogeneous data sources

This ensures the traceability along the entire process chain. Advanced new materials tests utilizing digital image correlation (DIC) and involving generation and further processing of large volumes of data are supported. Moreover data from materials simulation can be used to minimize testing efforts, e.g. using JMatPro® to calculate thermo-physical properties [3].

Several bi-directional interfaces for exporting and importing material cards from/to different target systems like LS Dyna, Abaqus, etc are available. They can be configured with respect to unit systems and designations of properties [4].

3. Starting point for an in-house materials knowledge management - Stahldat SX

The StahlDat SX system, available under www.stahldaten.de, has its origin in presenting up-to-date information of all European steel grades. The system is maintained by the European Registry of Steels within the VDEh using EDA®, Figure 5 shows the home screen. It is available as an on-premises solution and usable as a starting point for an internal materials knowledge environment.
The database directly maps the hierarchical tree of steel numbers together with steel designations as a central classification system. Each material is described by a data sheet with the most important key data from standardization:

- Designations, cross-references and standard references.
- Chemical compositions with footnotes on standard references
- Selected characteristic properties and applications

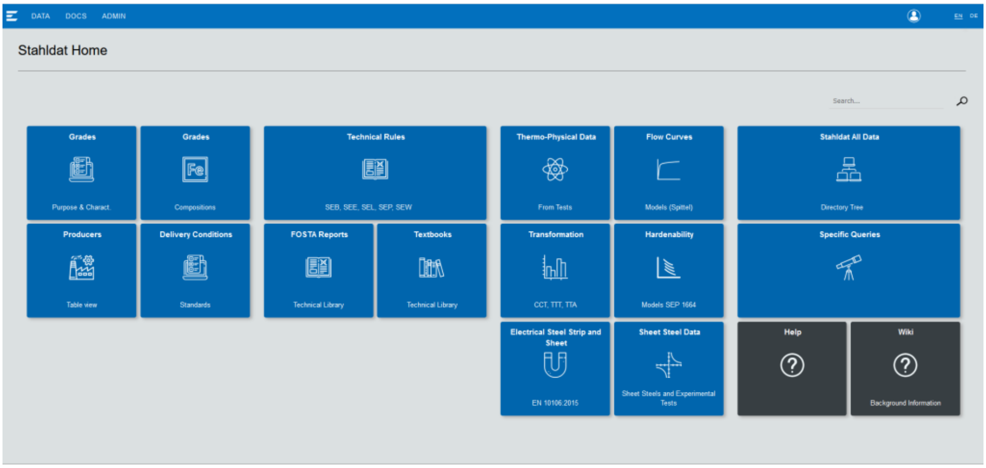

Figure 5: Stahldat SX Materials Information System Homepage (www.stahldaten.de)

Stahldat SX includes more than just a catalogue of up-to-date European steel grades:

- A knowledge base consisting of all FOSTA research reports in full text
- All technical standards by VDEh, like SEP, SEW, SEB, etc.
- Textbooks, like the Atlas of Heat Treatment

Moreover the system holds digitized test data and models which can be used in CAE applications:

- Thermo-physical data [5]
- Flow-curve models, created by IMF, TU Freiberg [6]
- CCT, TTT diagrams from [7] and other sources
- Hardenability models according SEP 1664 [8]
- Sheet steels data according SEP 1640 [9]

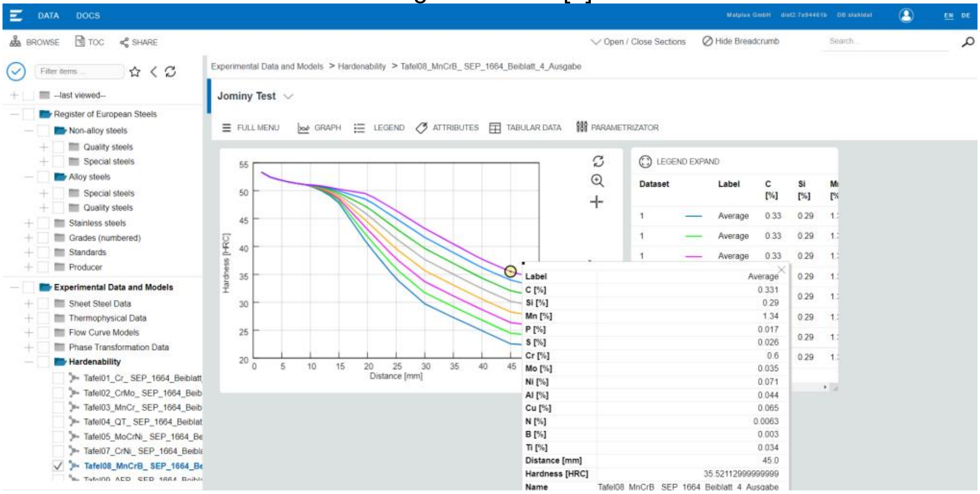

Figure 6: Parametrized Jominy model for hardenability with different levels of Cr

Models in Stahldat are equations which can be parametrized by the end-user. Figure 6 shows the parametrization result of a Jominy model according SEP 1664 for

MnCrB. Hardenability increases by higher levels of Cr, the initial hardness at the surface is not changed.

Test data in Stahldat come with full meta-data and the entire raw data. With the example of tensile tests not only stress-strain is recorded but also time, force, displacement and change of width. Data can be visualized graphically and also tabular form.

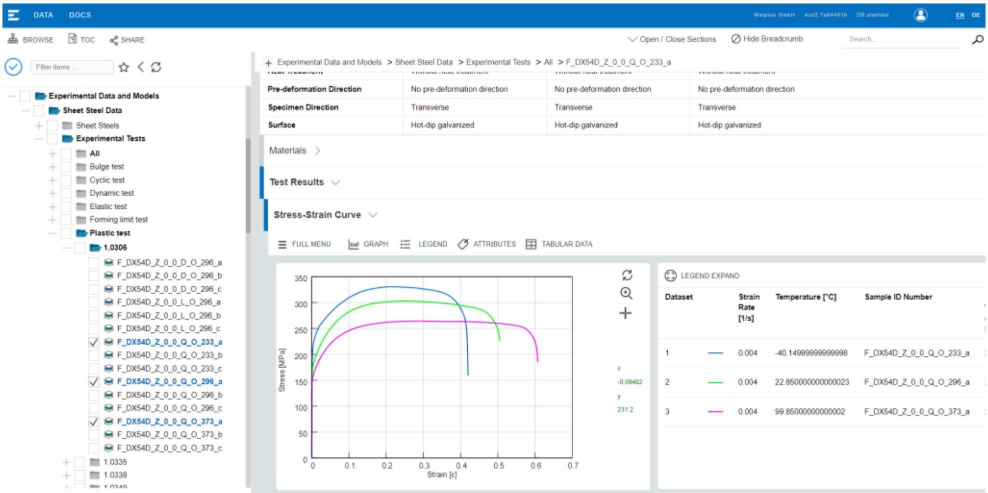

Figure 7: Comparison of stress-strain curves in Stahldat

4. Conclusion

Materials knowledge management is more than maintaining catalogues. Integration of lab information, material simulation, material cards for CAE has business impact like:

- Development processes can be accelerated because the correct versions of the relevant information can be found more quickly. Consistent material cards and material tests are easy to locate and related to master data.
- Costs for semi-finished products can be reduced. Reduction of complexity is possible, which leads to an aggregation of quantities, and the adaptation of delivery specifications.
- New employees become productive more quickly and can make better decisions using a corporate materials knowledge base.

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