Enterprise-Wide Materials Data Management Ensures CAE Fidelity

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Abstract

Virtual product development today has become a complex process involving CAD, FEA, CAE, and physical testing. Material properties form the glue that link the simulation and real life behavior together. Most often, the properties of the materials used in different stages of the product life cycle vary depending on the application. Hence, the engineers and technicians within the enterprise need to have access to not just the simple single point properties that help determine the suitability of a material, but also the more detailed behavioral property data that affect design, simulation and failure analyses. A common platform for the storage and effective deployment of these properties system wide is critical to the efficiency, cost, and quality control through PLM. We present a technology, Matereality that accommodates diverse properties of all the different materials used by an enterprise, its suppliers and collaborators. The cost benefits are immediate, besides improved interoperability and consistency in material data use through the enterprise.

Introduction

As the role of digital product development continues to solidify within enterprises [1], the need for systems to support the needs for this new technology become more and more urgent. In the past, CAE was relegated to a corner of the product development process where timeliness and accuracy were secondary to the core purpose of verifying the viability of the technology itself. With the mainstreaming of the technology, these luxuries are no longer available to CAE analysts and it is now imperative to deliver timely and accurate information to facilitate the design process.

In such an environment, there is no place for unproductive work nor is there tolerance for error in analysis because now, key design decisions are being based upon the results of a CAE simulation. Indeed, the viability of CAE groups and the industry itself would be called into question should it be found to be lacking in its ability to provide sustained value to the enterprise. This is a novel burden for the CAE industry and to resolve it, one must look for parallels in other industry horizontals to see how they have adapted themselves to the challenge [2]. We believe that supply chain integration and standards based data management are key technologies that will help to streamline and increase productivity in the digital product development industry.

That being said, it is clear that significant challenges exist in the achievement of these goals. Unlike the financials business or even the manufacturing horizontals, product development involves a huge variety of applications. CAE itself could involve NVH, stiffness/failure, crash/rate dependency, thermal/thermomechanical, forming/process simulation, large deformation-hyperelastic/hyperfoam, stress relaxation/creep-viscoelasticity. Case-specific complexity is introduced in each vertical in which the development occurs. Further, materials play a key role in fleshing out this complexity as each vertical leans toward its own favorite materials, which it deems appropriate for the manufacture of its products. In this paper, we tackle the materials problem and demonstrate a framework that uses both supply chain integration and standards based data management technologies to provide comprehensive content management for enterprises. We illustrate the benefits of this technology to the enterprise and provide a model upon which companies can save time and money while reducing risk in the product development process.

Current situation: the case of the 'Lone Ranger' CAE analyst.

CAE analysts today perform a variety of simulations on products that are constituted from many kinds of materials. Each simulation requires the use of specific material models that describe the material behavior in that particular application. It is critical that they use for these material models, quality properties that are self-consistent and application appropriate. The material models are usually created by the analyst after expending anywhere between several hours to a week of time and effort to convert the material properties available to them into the format required by the CAE analysis. Consequently, material models are highly cherished and each analyst has her/his own private model collection. Because of the sophisticated needs of material properties for designers, there are no comprehensive data stores that can store such data in a truly digital format. Accordingly, this valuable data sits on the analyst's desktop or within a small group and is typically not available to the enterprise. Analysts typically will not share models for fear of use in inappropriate applications. Because models do not contain the underlying material properties and data pedigree, their value is further diminished; the data is not easily re-used since other users cannot judge its quality/authenticity. The enterprise has fragmented access to this data and a system for streamlined sharing with collaborators is difficult. A NIST study [2] estimates that the automotive industry alone loses $1B per year due to interoperability problems related to data that is no longer available. Foundyller further supports this claim by noting that such information is usually never available at the time when critical decisions are being made[3]. This unavailability of data costs in terms of direct dollars for re-testing, and time loss, besides adding to the risk of misused data in the design process. Such private, disintegrated data stores within the enterprise represent what we call the Lone Ranger scenario.

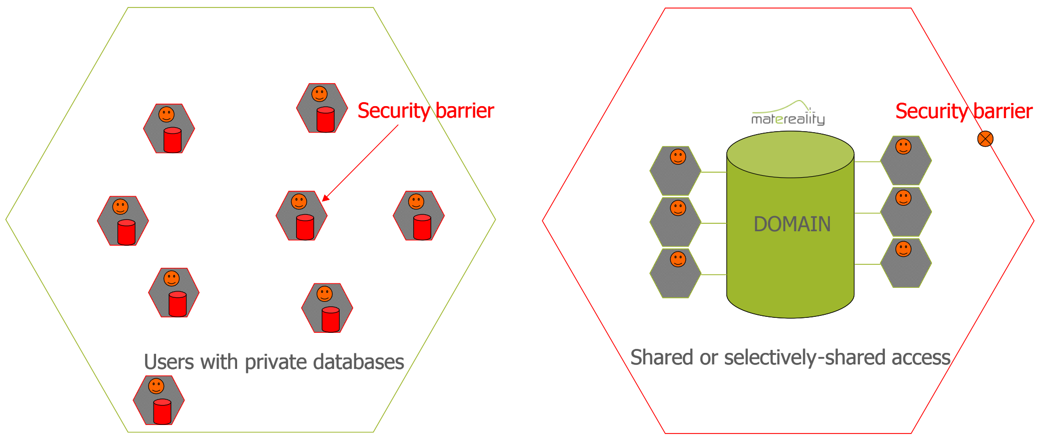


Figure 1 Contrasting Lone Ranger scenarios with domain-type selective sharing.

Desired situation: the need of the global enterprise

As the enterprise transforms the way in which it designs and manufactures products, moving from monolithic to distributed models, the IT infrastructure must be similarly aligned to accommodate the requirements of the enterprise. Just as materials are sourced from suppliers to the enterprise, so must content management systems be able to seamlessly source data and digital information that may be used to represent the materials in the digital world.

Because a material is a clearly defined entity, all the information related to it must also be self-consistent and accurately represent the material in the digital world. Further, all analysts in the present and the future, globally must have access to the same information so that analysts anywhere and at any time produce the same consistent digital work product. This is a daunting task without a framework capable of handling such complexity. Matereality represents such a sophisticated solution, which by providing an integrated interoperability platform to deploy any kind of material data, is then used for selective shared access by users within and outside the enterprise.

Last but not least, since so much now hinges on the accuracy of a digital simulation, it is clear that the material properties being used must be verifiably accurate, traceable to source and applicable to the task at hand. Conventional public material databases list a variety of properties for selection purposes but are just not suited for the product design application. In the new paradigm, it is unconscionable for an analyst to simply pick a material property out of a handbook or generic database with no idea about how good the data is or whether it actually represents his or her material in the actual product application. A clear case is therefore made for the enterprise to invest in the development, storage and deployment of material properties that are pertinent to the task at hand. At first instance, this might seem like an impossibly expensive task; however it must be remembered that a lot of the desired data exists. It is simply not accessible to the analyst. Companies each year, spend millions of dollars on testing. This data is owned and stored by the entities that generate it. For example, a material supplier may generate visco-elastic or high strain rate data for use in a particular project. Because of the sensitivity of such information, the data will never appear in a public database. Nonetheless, this data is of significant value to client enterprises that seek to use this material in their products. In a supply chain type IT infrastructure, the client enterprises should be able to identify and then request access to such types of information. The supplier should be able to provide or deny access to its data depending on the nature of its relationship with its client.

Pertinence: making sure it is application appropriate

Using the right data for a particular application is of vital importance to virtual product development. This is because, contrary to common perceptions, the properties of materials are not necessarily unique. Properties may vary for a number of reasons ranging from materials variations to the parameters used in the test. Some of these variations in a measured property are easily understood by the analyst: variation of stress-strain behavior with temperature or strain rate; viscosity with temperature or shear rate, or hyperelastic properties to name but a few.

Other variations are more the purview of the testing laboratory but need to be understood nonetheless. These include variability of the measured properties themselves, information about the samples and test methods used for the testing, uncertainty of the measurements. For example, it is practically impossible to describe fatigue behavior for practical use without an understanding of the type of test samples used, the method and mode of deformation and the criteria used by the laboratory to describe failure. Even in the case of stress-strain behavior, the definition of yield can be misinterpreted between the test laboratory and the data consumer. As enterprises strive toward greater precision, it is therefore impossible for the engineer to neglect to use such valuable information, which is now readily available within the framework of a material data management system.

Data Certificate
Makrolon 6555 > Dynamic Mechanical Properties in Torsion

Technique	standards organization	ISO
	standard number	ISO 6721-7: 1996
	uncertainty analysis	per standard
Sample Details	ID	ma6555mer
	sample source	Bayer
Specimen Details	conditioning	none
	form	rectangular bar
	other preparation	cut to size
	thickness	4 mm
	width	10 mm
Test Parameters	frequency	1 Hz
Traceability	test laboratory	Bayer Bldg103Lab
	measurement date	1/1/1998
	accredited	No
	measurement instrument	unknown
	performed by	
	certified by	

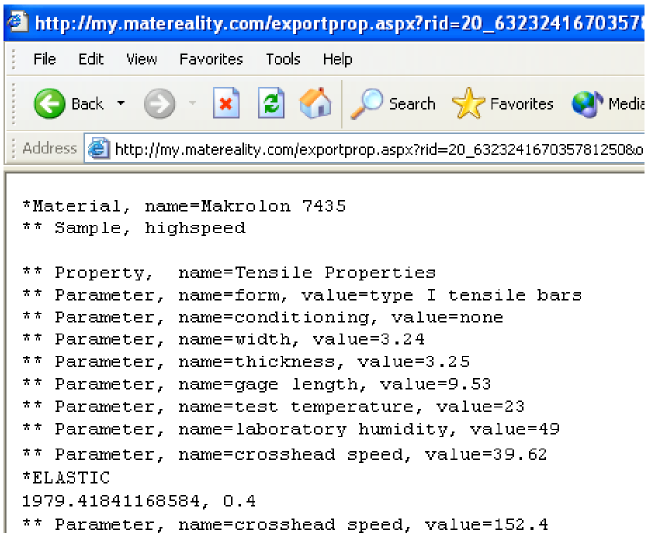
Print | View Result | Legal

Figure 2 Data certificates allow the assessment of data pertinence

Even more factors exist in ensuring that material data is application appropriate. An engineer may have cause to question the quality of the data source depending on whether they are accredited, or whether or not they publish the variability of the test results. Being able to examine all this information prior to using a piece of material data is a vital part of the design process providing a new level of comfort and peace of mind to a busy analyst.

Fidelity: getting it right each time

Because of the Lone Ranger scenario described earlier, there is a significant risk that CAE analysts in a distributed enterprise are performing related or duplicate simulations with material models that are not compatible. This can happen even within small groups because of the lack of communication within teams. Such a scenario causes unnecessary risk adding to design uncertainty. Some organizations use product data management (PDM) systems in an attempt to resolve this problem. PDM systems permit the analyst to attach a material model input deck to a simulation. This is only a partial solution, however; there is no way to ensure that teams are working off the same page with respect to material data. Sharing input decks within a CAE team ensures fidelity when different analysts are seeking to describe identical material behavior. Often, however, teams need to perform variations on a particular simulation. Input decks do not contain the information needed for the analyst to make a decision about the appropriateness of the model to his simulation. They fail to store critical decision making information that would permit the analyst to make an informed choice.



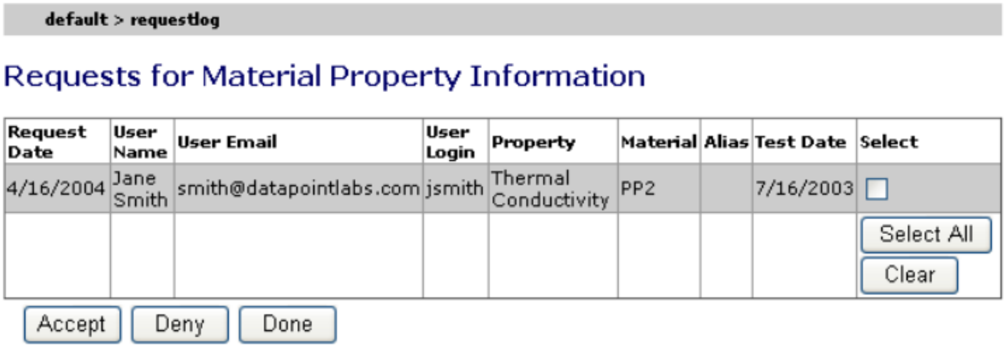

```
*Material, name=Makrolon 7435
** Sample, highspeed

** Property,  name=Tensile Properties
** Parameter, name=form, value=type I tensile bars
** Parameter, name=conditioning, value=none
** Parameter, name=width, value=3.24
** Parameter, name=thickness, value=3.25
** Parameter, name=gage length, value=9.53
** Parameter, name=test temperature, value=23
** Parameter, name=laboratory humidity, value=49
** Parameter, name=crosshead speed, value=39.62
*ELASTIC
1979.41841168584, 0.4
** Parameter, name=crosshead speed, value=152.4
```

Figure 3 Input decks are generated on-the-fly once user approves the data

The use of a material data management system represents a paradigm shift in this scenario. Here, the material property data for the enterprise is staged at a single web-based location. All the underlying property data and supporting information related to the material model parameters is stored. The analyst can, should they desire, perform sanity and appropriateness checks to ensure that the data is right for them. Rather than store input decks as incomprehensible data files, the system simply exports the data into the desired export formats upon demand. Analysts system-wide would then be able to access identical information for their applications, ensuring fidelity.

The supply chain: obtaining content from others

Most enterprises today dynamically manage a wide range of materials they use in their products. Very few companies today manufacture products using a small static list of materials. As products evolve and materials change, data pipelines must exist to ensure a smooth flow of fresh, pertinent content[4]. This is vital to the material data management system and to its longevity in the enterprise. The material data needed by the enterprise logically comes from two types of sources. Internal laboratories generate data for a number of reasons; such data must be stored within the system to be disseminated as needed. Very importantly, however, in a collaborative environment, material data comes from sources external to the enterprise. It is critical that members of an enterprise be able to probe the content of its collaborators to locate data that might be useful to their activity. A system of access requests ensures that the owners of information maintain control over the use of their data. The attractiveness of this scenario stems from two important benefits: ready availability of high quality, pertinent material properties; time and money savings from not having to test. In fact, it must be noted that these benefits apply even in cases where the properties exist within the enterprise. All too often, analysts may simply not know that data they need exists within the enterprise, nor may they know whom to ask for the information they need.


default > requestlog

Requests for Material Property Information

Request Date	User Name	User Email	User Login	Property	Material	Alias	Test Date	Select
4/16/2004	Jane Smith	smith@datapointlabs.com	jsmith	Thermal Conductivity	PP2		7/16/2003	
								Select All Clear

Accept Deny Done

Figure 4 Using access requests to control data flow

Control of content flow: privacy and fiefdoms

Enterprises are complex entities with widely varying needs with respect to the use of information. Certain types of data are purposed for a particular application. For example, data provided for purchase decisions must simply not be used for other purposes, such as design. In the case of a plastic fuel tank design, 'purchasing' material data will evolve around properties of the virgin plastic while the CAE analyst must necessarily use properties generated after fuel soaking. In another example, sensitive material data may be generated for the R&D team which must be protected from access by unauthorized users. It is clear that a flat database would not be able to handle such a scenario and would therefore be of limited use to the enterprise. It would be relegated to storing only the information that anyone can see, the lowest common denominator. This is a self-defeating and non-productive scenario which guarantees the eventual demise of the system. A good material data management system permits the selective dissemination of material data within the enterprise, respecting the need for privacy. It would permit highly sensitive information to be completely hidden, accessible only to those authorized to use it. Other less sensitive information could be found by users of the system but not accessible without permission of the data controllers. The lowest common denominator of public data would be published for all to see.

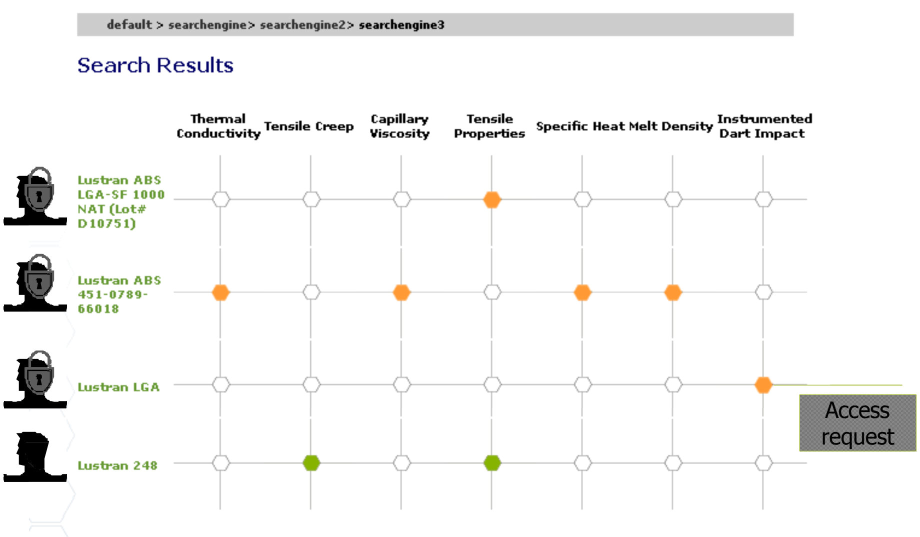


Figure 5 A single system to store both public and restricted data

Risk mitigation: access control and record keeping

Because a single system must be used for optimal management of public and private data of the enterprise, access control becomes an important aspect of a material data management system. It permits the enterprise to control the dissemination of information to authorized personnel with a level of flexibility analogous to current business practice. This includes but is not limited to the following scenarios: a single user having access to one or more material property datasets; a designated group of users having access to a data collection that is pertinent to their activity in the business.

default > activitylog

User Data Activity History

Activity Time	Property	Material	Msmt Date	User	Activity
7/7/2004 9:44:04 PM	Tensile Properties	Makrolon 7435	4/19/2004	Confidential Demo Purposes	Detail
7/1/2004 2:32:18 PM	Compressive Properties	Computer packaging	3/27/2003	Matereality Administrator	Detail
6/25/2004 9:27:23 PM	Compressive Properties	Computer packaging	3/27/2003	Confidential Demo Purposes	Detail
6/24/2004 4:31:46 PM	Tensile Properties	Makrolon 7435	4/19/2004	Confidential Demo Purposes	Detail
6/22/2004 9:34:44 AM	Compressive Properties	Computer packaging	3/27/2003	Confidential Demo Purposes	Detail
6/21/2004 3:37:54	Compressive	Computer	3/27/2003	Jeffrey Schumacher	Detail

Figure 6 Access logs track data usage

To ensure proper utilization of the system, access logs provide detailed records of data access, activity and use.

Conclusion

Design process enhancement is a major topic today in cost reduction and system improvement in the enterprise. Material property data constitutes a small but significant aspect of the knowledge base of the enterprise. In the context of the CAE analyst and the design engineer, it is the information that binds their work to reality. Weakness in this area raises the level of risk to the enterprise and lowers the efficiency of the design process. A material data management system creates a robust infrastructure within the enterprise that permits storage and controlled dissemination of high quality material properties. It is extensible to the collaborative environment allowing efficient information interchange and cost and time savings by preventing attrition of material data.

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