

# **THE EUROPEAN FUSION MATERIAL PROPERTIES DATABASE**

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## **ABSTRACT**

Materials research represents a significant part of the European and world effort on fusion research. Detailed knowledge of materials properties is needed in the design by analysis of power plant and experimental machine components, and in testing to design fusion materials with specific properties, a process that involves collection and examination of a large number of data. In response, a European Fusion Materials web-based relational database is being developed to collect, expand and preserve for the future the data produced by the European Fusion programme in support of the NET, DEMO and ITER projects. The database tools allow for studies to understand the fundamental material properties and determine their functional dependence on critical parameters relevant to fusion environments. Flexibility of the database system ensures that new methods to automate material design for specific applications can be easily implemented. The system is a web-based application using J2EE technologies and the PostgreSQL relational database. It runs on a web server and allows users access via the Internet using their preferred web browser. For data security, users are issued with individual accounts, and the origin of all requests is checked against a list of trusted sites. In addition, different user accounts will have access to different data sets, to ensure that data is not shared unintentionally. The system allows several levels of data checking/cleaning and validation. Data insertion is either on-line or through downloaded templates. Data validation is through different expert groups, which can apply different criteria to the data, and thus qualify different sets for their needs.

## **KEYWORDS**

Fusion Material properties, Web-based Relational Database, Material Test Data storage/retrieval

## 1 INTRODUCTION

The principle aims of the European Fusion Materials database are to store the data generated by European Fusion programme and to allow use of this data by the associated scientists. These scientists are involved in the design of future materials and of future experimental components, machines and power plants. This data can be used for many purposes including:

- (a) Development of design codes
- (b) Scientific analysis to understand the effects of irradiation
- (c) Designing better materials for future investigation
- (d) Identification of gaps in current knowledge for future research

To this end the database holds a wide range of data. The database contains data on three basic levels:

- (a) Raw experimental data points
- (b) Data qualified by expert groups
- (c) Processed material property data

In addition to these the system can store files and contains a separate reports database containing details of the sources of the data contained in the main database.

This new database offers several advantages over previous databases [4,5,6]:

- (a) Coverage of a wider range of materials including ceramics and composites
- (b) More detailed data storage for tests, specimens and treatments
- (c) Integrated validation and verification
- (d) Full traceability from material property data to experimental data and reports
- (e) Greater flexibility to modify and extend the database

## 2 DATABASE STRUCTURE

The materials database uses several pieces of novel technology to allow the flexibility to store the necessary information. These are possible through the choice of high-quality open source software packages.

The use of Tomcat [1] and Struts [2] allows the power of the J2EE framework to be used to create an interactive web interface onto the database. This allows the users to perform all necessary tasks in a secure, managed environment. Access to the data is controlled by a firewall, application security via a secure login and also data security. This three level approach to security stops unauthorised access to the data.

Data security is done via the concepts of agreements and facilities as shown in figure 1. Each user is associated with a facility. Facilities enter agreements with each other allowing access to specific data. Any user from a facility that is associated with an agreement can access all the data under that agreement.

By creating a high-availability web-enabled database, all users are able to see the data without needing to wait for new releases of a desktop system. Data can start being used immediately after it has been entered into the system.

The system is designed to be highly flexible and allows easy modification to include extra information as required. Such flexibility includes the ability to:

- (a) Specify new materials and classes of material
- (b) Specify new manufacturing treatments
- (c) Add new experimental procedures and measurements
- (d) Manipulate existing tables by addition of new fields

The use of the PostgreSQL relational database management system (RDBMS) [3] allows this flexibility by use of table inheritance and metadata databases. It also provides support for custom datatypes and auditing of changes to the data.

The automatic auditing of changes allows tracing of modifications to the data. A full history of all changes is kept including who made the change and when. In addition all old data is stored and can be accessed. This allows tracking of the changes and also gives the ability to revert to an older version if necessary.

Storage of composition data is done using a new "range" datatype. This allows a user to specify the composition in as either a single value or as being between a maximum and minimum values. Data stored in this datatype can be searched and ordered in similar ways to other standard numeric data.

Table inheritance allows the representation of similar concepts to be done in a consistent manner. For example, each type of test is different, but they are all conceptually similar, each being performed on a specimen under specific test conditions. Each type of test is stored in a separate table, but all of these tables are closely related in structure, each being derived from a master test table. Addition of a new test simply involves creation of a new derived test table.

Metadata databases allow great flexibility within a specific table and allow easy extension of the allowed quantities. They are extremely useful in sparse tables and are used in storage of the material properties. In this situation both metadata database and table inheritance are used to allow full flexibility.

The database system is designed in a modular manner using a standard 3-tier approach. This approach will allow extension of the system to include automated report generation, creation of graphs and processing of data.

### **3 MATERIALS DATA**

The database holds four basic types of material data. These are “experimental”, “qualified”, “property” and reports. Each of these is held in a different way and access to them is controlled via the web-interface.

The database uses a hierarchical structure to store the data as shown in figure 2. At the top of the hierarchy are material types. These divide all the materials into separate types such as alloys, composites etc. Each of these is subdivided into individual materials, details of these are stored in a separate table. Multiple variants of each material can be stored in the system with each having a defined composition. All of the material data is associated with a specific variant.

#### **3.1 Experimental data**

Experimental data is divided into 4 basic tables as shown in figure 3. Each of these tables represents a real world concept. A batch is a group of specimens that have been produced in an identical manner. All of the relevant production information required to identify and trace the specimens is stored in this table. This includes details about the product and sub-product, such as their location in the original heat. This location information is similar to that stored in the RAFM database[4].

Information for treatments or processes, which the material underwent during manufacture, can also be stored. Treatments can be of many kinds, and include irradiation (neutron, ion beam), thermal, mechanical (cold or hot work, fatigue, pre-stress, crack, etc), thermo-mechanical, powder and weld/join. When the need arises, the system flexibility allows additional speciality treatments to be added (new table and fields) with their detailed description. This specialisation of treatments, with their own tables, allows detailed description and information storage of the processes involved. It also allows for application of any number or combination to a material block, product, sub-product, and/or specimen. This feature is particularly useful for materials that have undergone several treatments and might also be irradiated.

The test table contains the control parameters and test results. Inheritance allows different types of test to store different information. The general test table contains control parameters and results that apply to all tests and the derived tests contain specialised fields and information specific to a type of test. Tests or experiment Tables, related to data for obtaining material properties, comprise the following:

- (a) thermal-structural-physical (density, thermal conductivity and diffusivity, specific heat, thermal expansion, elastic modulus, shear modulus, Poisson's ratio), composition (for impurities), micro-structural (for grain size, dislocation, void, vacancy, interstitial density and others), hardness
- (b) tensile, compressive, fracture (impact, crack, and crack propagation), fatigue (stress, strain controlled), creep (thermal, irradiation), creep-fatigue
- (c) electro-magnetic
- (d) corrosion

The database system is flexible and allows new tests to be added. This is especially useful for a fusion database, as currently there are several "non-standardised" tests that involve joins, and material types or combinations not previously encountered. The flexibility comes from the ability to add fields to each table, and that new types of test can be added without any changes being made to the overall structure.

Specimen tables, contain the specifics of test specimens. Again inheritance is used to give flexibility. Each test is assigned its own specimen table, with fields such as identification, dimensions, type, etc. The details of any treatments done on the specimen before testing can also be stored.

It is also possible to associate files with batches, specimens, tests and treatments. These files can be in any format and can contain any additional information the user wishes to store. For example, add a text file of the stress-strain curve of a tensile test or the grain/void TEM image file of a micro-structural test. For each file a title and description is stored along with the file itself.

### **3.2 Qualified data**

Experimental data that an expert group has examined, analysed and verified is referred to as "qualified".

Experts form groups that do the validation and verification of data following the "qualification process" implemented in the system. Each expert group is in charge of qualifying the data-set for one type of test. The system supports the creation of expert groups for multiple organisations, and users can be members of as many expert groups as required.

The qualified data-set contains references to the experimental results that have been qualified by the expert group; the actual experimental data is not duplicated. Each group maintains its own data-set and the system can store multiple versions of each data-set.

### **3.3 Material property data**

Property data are qualified or experimental data that has been processed, according to some statistical or other analysis. There are many properties that can be stored, and each of these can be a function of multiple control parameters. The data is normally tabulated against one or more control parameters such as temperature, pressure, irradiation, form (plate, rod) etc.

Many different groups or individuals can create similar property tables and these will be distinguished via a dataset name. For example there could be an EFDA dataset for holding the official code values. Within each dataset there can be several tables for each property; for example this allows for the situation where there are different property tables for bars and plates. Versioning of all material property data is supported in the system so that old data is retained for comparison.

There is a large amount of materials property data already published and available from design codes such as ASME and RCC-MR, as well as from technical publications, books, journals etc, that will be included in the database system. In

principle, the design code data are recognised as the “state of the art” and should be used whenever available. That should not exclude other data that are deemed qualified. The database system is designed to include all such sources and clearly identify them as such. It is the user’s choice and decision, which set to use.

### **3.4 Reports**

The storage of reports is also part of the system. At the simplest level this references a journal or a report. The reference contains author, title, source reference and internal library reference number. Each test result is linked to a reference in the reports database. Electronic storage of the reports is also possible assuming there are no copyright or intellectual property rights issues. The users can download the stored reports subject to access controls.

## **4 USER FUNCTIONS**

The functions that users can perform depend on their permissions. The system is built to accommodate three types of users: Standard, Edit, and Administrator.

As users of the database system are assigned or belong to a facility, e.g. for example one of the fusion associations, they will have all the privileges (regarding the database and its structures) associated with that facility.

All users can browse the hierarchical structure, shown in figures 2 and 3, to view the experimental data. The users can also search all parts of the database including the reports section. The data returned by the searches is restricted by the agreements the user has access to.

After searching the database the user can download any results for offline processing. Due to the potentially large number of columns in the returned data an Excel Add-In has been written to split the data into multiple sheets. This Add-In can be downloaded by all users.

Edit users can use the Excel Add-In to create files containing experimental data to be uploaded into the system. In addition they can add and edit experimental data

via the browsing interface. They can also add or edit a report reference and upload a file or report. Note that an edit user can only edit data they have added.

System administrators can perform all user functions but can edit any data. They also can modify the tables within the database to add new types of tests or modify the fields to be stored for any table. They can also define new material types, materials and variants. Administrators also control the access rights of users.

To allow qualification of data, various expert groups will be set up in the system. Members of expert groups are assumed to belong to one of the user groups already described. In addition to those functions they can also add qualified data. This is a three-stage process that involves; downloading of a qualification set, qualification, and then the upload of the qualified set. The Excel Add-In is used for the qualification stage.

A similar set up exists for material property data. Any user can be authorised to write property data for any dataset name. Currently this writing is coarse grained, once a user has permission to write to a dataset they are able to write data for any material or property within that dataset.

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[3] PostgreSQL, Information available from <http://www.postgresql.org>

[4] European Database - Reduced Activation Ferritic/Martensitic Steels, available from A.-A. F. Tavassoli [tavassoli@cea.fr](mailto:tavassoli@cea.fr)

[5] AlloysDB Information available from <http://odin.jrc.nl/>

[6] NIMS Materials Database available from [http://mits.nims.go.jp/db\\_top\\_eng.htm](http://mits.nims.go.jp/db_top_eng.htm)

## FIGURE CAPTIONS

Figure 1 Controlled access to data

Figure 2 Top-level database structure

Figure 3 Experimental data database structure

# FIGURES

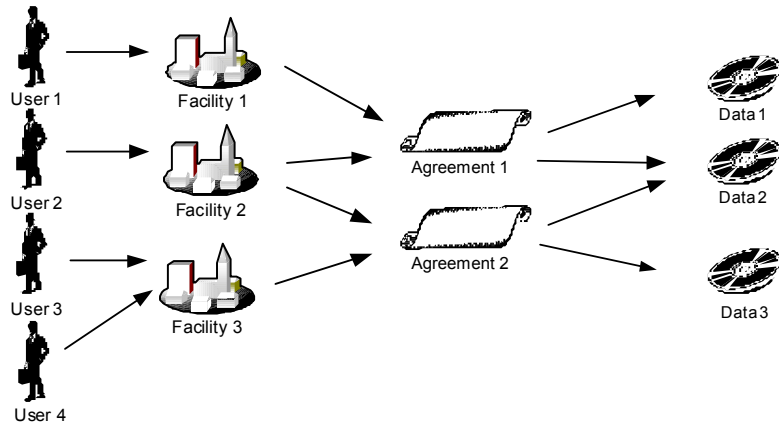


Figure 1

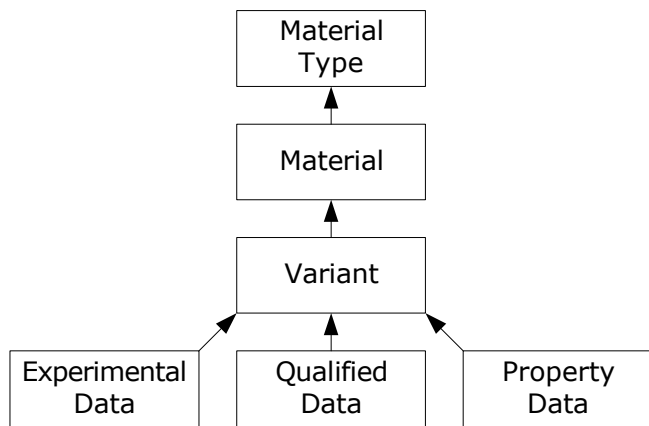


Figure 2

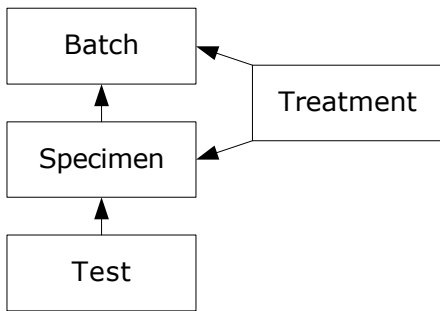


Figure 3