15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

WEB-BASED MATERIAL DATA KNOWLEDGE BASE AND EXPERT SYSTEM

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ABSTRACT
Very important task which needs to be addressed ever earlier during product development process is choice of proper material. In order to do this, suitability of different materials must be evaluated, for which, their properties and parameters describing their behaviour, must be known. In case that experimental characterization of the material can not be performed, choice of the material can be improved by: a) increasing availability, searchability and comparability of knowledge on material behaviour; b) increasing applicability of methods for estimation of material properties as well as by supporting their improvement and further development; c) educating users by improving the level of their knowledge of material properties and methods for their estimation. In proposed paper, development and implementation of web-based system i.e. information service which addresses above mentioned issues are discussed. Mentioned web-based service consists of: dedicated website, interactive, searchable and user-expandable database containing data properties of design-relevant metallic materials, and knowledge base and knowledge-based expert system (web application) for selection and use of methods for estimation of advanced material parameters (cyclic, fatigue) from their monotonic properties such as hardness and ultimate strength R_m.
Keywords: material properties, database, expert system, web-based

1. INTRODUCTION

Design engineers and analysts are continuously faced with requirements such as shortening product development time and cutting down related expenses. Advent and development of CAE software tools for design and analysis enabled number of design tasks to be performed ever earlier during product development cycle, while different design versions are still being considered. These tasks include computer-based modelling and simulation of product behaviour, determination of products load carrying capacity and durability, evaluation of increasing number of design solutions and evaluation of suitability of number of different materials. In order to enable performing of mentioned analyses, several important elements must be defined, developed or known. Besides geometrical and numerical models of the product, loading characteristics i.e. loading scenario and valid mathematical model of material behaviour, one of the most important components in this regard are values of material properties. For modelling and simulation of response of loaded structures and components, different material properties which describe material behaviour must be known. The experiment-based determination of their values is certainly the most accurate. However, except for the case of determining values of basic monotonic properties, it quickly becomes prohibitive due to complexities and high costs of experiments, especially if several materials must be considered. Hence, other viable options such as literature research, use of databases of materials' properties and estimation of cyclic and fatigue properties from monotonic properties are often resorted to.

2. EXPERIMENTAL MATERIAL CHARACTERISATION AND ITS ALTERNATIVES

Advantages of experiment-based determination of materials properties are accuracy with which they are determined and possibility to perform tests in conditions representative of those to which product is expected to operate during its lifetime. Main disadvantages of experimental approach are high costs as well as complexity and long duration of cyclic/fatigue test procedures. In addition, adequate testing equipment is very often unavailable. Due to these problems, experimental characterization of the material soon becomes prohibitive, especially if more different materials must be evaluated.

First alternative is finding the information on material parameters in wide variety of literature sources such as books, manuals, standards, catalogues and in internal documentation of certain companies. However, although being numerous, existing material data from the literature are often of limited availability. Due to the nature of their origin and different forms and formats that data are reported in, virtually no methods for their inquiry and comparison exist. Furthermore, significant number of experimental results is published in specialized and/or scientific publications and for the most part remains unknown and inaccessible to the majority of users from the industry.

Secondly, required material data can be found in various databases. Majority of commercial ones contain information for a very large number of materials and offer very good searching and reporting capabilities. On the other hand, they are of "closed" type, meaning that users are only rarely allowed to edit the contents of the database. For most materials, only basic, monotonic properties are given, while advanced material parameters are usually available only for small number of materials.

Non-commercial databases are very often instituted as an indirect result of scientific research and efforts. As a rule, they contain data on relatively small number of materials but usually enable users to participate in expanding their contents in more or less direct way. With some exceptions, they are usually characterized by less than professional design and functionality and offer rather limited searching, reporting and comparing options.

One more solution that can be applied in circumstances when experimental testing is not an option, is using methods for estimation of advanced (cyclic/fatigue) material parameters from monotonic material properties [1, 2]. Main advantage of estimation methods is that they are highly practical and easy to implement in one's calculations. However, the problem is that no universal or "the best" method exists which could be applied to all material groups with equal success [2, 3]. For their utilization, specialized knowledge is required, as not all methods are equally suitable for all materials and their conditions. Unfortunately, this fact is often overlooked in practice.

3. WEB-BASED SYSTEM

Choice of the proper material suitable for a specific application is one of the most important and complex issues that need to be addressed during product development. With ever increasing possibilities of numerical simulations, there is a requirement that material selection should be successfully completed already during initial stage of the design process.

Having difficulties that accompany experimental testing and alternative methods for acquisition of material data in mind, it is suggested that the quality and accuracy of material selection can be improved by:

a) increasing availability, searchability and comparability of existing knowledge on materials,
b) developing better estimation methods and improving the accuracy and reliability of existing ones,
c) educating end users regarding the proper application of estimation methods of material behaviour.

For the purpose of fulfillment of above mentioned aims, web-based information system has been developed and established at the address *www.matdat.com* (Figure 1.) consisting of:

- a dedicated webpage containing general information with additional function of being an entering point for those interested in perusing the information system,
- an interactive and user-expandable knowledge base and material properties database containing design-oriented data on properties of design-relevant metallic materials,
- a knowledge-based expert system, featuring a set of rules and tools for an optimal choice of a suitable estimation method and for the estimation of the required advanced material parameters from available monotonic properties, such as the ultimate strength R_m or Brinell hardness HB.

Figure 1. Various sections of www.matdat.com website/information system

4. MATERIAL PROPERTIES DATABASE AND EXPERT SYSTEM

Currently, material properties database contains properties of design-relevant metallic materials divided into following groups: unalloyed steels, low-alloy steels, high-alloy steels, aluminium alloys, titanium alloys, cast irons/steels and weld metals. All data are of relevant and verifiable origin - published sources which are already in greater or lower degree available to the community, such as articles published in journals and at conferences, handbooks, etc. All records are properly and fully referenced in order to acknowledge their source and origin. Individual datasets (for every record i.e. material) contain information organized into following categories and subcategories (for every category only most prominent parameters are listed here):

- General information (database record, reference info...)
- Material information (material designation, material group, chemical composition,…)
- Tested material details (heat treatment, microstructure, hardness,…)
- Testing conditions (testing temperature, testing medium)
- Monotonic properties (obtained for axial and torsional loading)
- Cyclic/fatigue properties (axial, torsional and bending loading; fully reversed and repeated loading).

Another important part of the proposed system is an expert system consisting of a set of rules, methods and tools for the estimation of both cyclic and fatigue parameters from monotonic properties of the material. Within the expert system, straightforward estimations of fatigue parameters can be performed by simply choosing and applying a particular method of estimation. More sophisticated options within the implemented knowledge-based expert system are available to non-specialist users lacking the expert knowledge which is required if an appropriate estimation method is to be used. The knowledge-base and the rules implemented in the developed expert system combine several already known estimation methods and the established methodology for their evaluation with the results of own research – a recently proposed novel approach and method for parameter estimation and the methodology for the evaluation of estimation methods [2, 3].

In accordance to the own evaluation methodology, proposed in [2, 4], in addition to the validity of parameter estimation methods across the entire fatigue range, their performance within the low-cycle and the high-cycle fatigue ranges should be evaluated separately. In order to further improve their validity and accuracy, the implemented procedures for the evaluation of individual parameter estimation methods draw on the content of the material properties database. Additional advantage in this regard is that contents of the database will be continuously updated with data from literature as they become available, as well as with contributions made by the users of the system.

5. DISCUSSION

Compared to other, existing systems, proposed solution offers certain new features and advantages. Users of the system are encouraged to join community by contributing additional material data available from the literature, or their own, published/unpublished data. This not only extends the contents of the database but also helps to further improve accuracy of evaluation of implemented estimation methods. In accordance to the idea of making existing (and published) material data widely available, complete contents of MATDAT.COM database are made available to all users of the system, regardless of their status. Access restrictions apply only for more sophisticated search and compare options, and usage of advanced estimation tools within expert system. Furthermore, combination of web-based material properties database and expert system for estimation of advanced material properties (such as strain-life fatigue parameters) seems to be rather unique. Although expert systems dealing with the estimation of monotonic and cyclic/fatigue properties already exist [5, 6, 7], unlike the proposed solution they are not web-based.

6. CONCLUSION

In this paper, establishment of a web-based material properties database and an expert system for the estimation of cyclic and fatigue properties of metallic materials has been described. It is expected that this web-based system might be used by scientists and students as well as by experts from the industry and engineers and serve them to improve the accuracy of preliminary calculations of load carrying capacity as well as of calculations of number of load reversals/cycles to crack initiation when limited or no experimental material data are available. In addition to this direct benefit, the system is also intended to increase the availability, searchability and comparability of the existing knowledge on materials and methods of estimation of their cyclic and fatigue parameters.

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