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WEB TOOLS FOR LONG TERM STRENGTH DATA PROCESSING

В статті розглянуто питання розробки спеціалізованого програмного забезпечення для обробки даних з довготривалої міцності. Описано підхід, застосований для зберігання даних, та представлено опис інтерфейсу, що застосовується при цьому. Обговорено два алгоритми з отримання констант для кінетичного рівняння для параметру пошкоджуваності, перший з яких розроблено для умов постійної температури, а другий - для визначеного інтервалу температур. Наведено приклад опису процесу отримання значень констант для жароміцного нікелевого сплаву. Програмне забезпечення, що обговорюється, призначено для інженерів та наукових співробітників, які працюють у напрямку моделювання високотемпературних властивостей матеріалів та елементів конструкцій.

Ключові слова: повзучість, довготривала міцність, експериментальні дані, зберігання даних про матеріали, кінетичне рівняння для параметру пошкоджуваності, скалярний параметр пошкоджуваності.

В статье рассмотрены вопросы разработки специализированного программного обеспечения для обработки данных о длительной прочности. Описан подход, использованный для хранения данных, представлено описание интерфейса, используемого при этом. Обсуждаются два алгоритма получения констант для кинетического уравнения для параметра повреждаемости, первый разработан для условий постоянной температуры, а второй - для определенного интервала температур. Приведен пример описания процесса получения значений констант для жаропрочного никелевого сплава. Рассмотренное программное обеспечение предназначено для инженеров и научных сотрудников, работающих в области моделирования высокотемпературных свойств материалов и элементов конструкций.

Ключевые слова: ползучесть, длительная прочность, экспериментальные данные, хранение данных о материалах, кинетическое уравнение для параметра повреждаемости, скалярный параметр повреждаемости.

The paper concerns the questions of development the specialized web-based software for processing of the long term strength data. The goal is to develop the web tools which could fill up the gap between high theoretical background in Continuum Damage Mechanics and insufficient knowledge about the experimental data by way of storage them and processing the values of constants. The approach for storing of the experimental physical and mechanical properties for different temperatures is described. The structure of database as well as the interface section for selection of different data sets, which include the fracture stress values with appropriate values of time, are presented. Selected fields of database are used for deriving the constants for damage kinetic equations. Two algorithms of deriving are discussed, the first was designed for constant temperature conditions as well as the second assigns for definite interval of temperatures. The numbers of experimental data sets for each algorithm are determined. The example of the deriving process for nickel based alloy is presented and plots of time dependencies for damage parameter are built. The discussed software is designed for engineers and research associates who are working in area of modeling of high temperature properties in materials and structural elements.

Keywords: creep, long term strength, experimental results, web-application, material data storing, kinetic damage equation, scalar damage parameter.

Introduction. The growing demands for data processing speed bring the necessity of their allocation in world wide web Internet. The data bases with free access which solve the problem of organization of storage and browsing the information about physical and mechanical properties of modern structural materials won the competition with different similar desktop applications.

The strategy, which is realized in wide spread web-application, like ***matweb.com*** [1], ***splav-kharkov.com*** [2], contains in giving to user the possibility of obtaining the information about the properties of material in search.

The next step of service has to be connected with the possibility of processing the selected data from the definite database. This processing can brings the different forms, like obtaining the values of constants for physical laws from another data, the mathematical expressions of experimental distributions, different graphical representations etc.

The presented paper concerns the second stage of the method presented in previous publication [3], where the web-based facilities for the archiving of creep and long-term strength data were discussed. The web-application, which is located at ***worldmech.net***, with the interface for input of experimental creep curves up to fracture as well as pure long term strength curves,was discussed here. By use of developed graphical tools users have the possibility of viewing the graphical representation of their data.

This publication contains the description of developed new methods and algorithms for processing the data of long term strength curves, which are storaged in database at ***worldmech.net***. The procedure consists the use of the above data for obtaining the values of constants for kinetic damage equation with scalar damage parameter.

This approach was suggested in well known works by Yu. N. Rabotnov [4] and L. M. Kachanov [5], and during last five decades it have been developed by J. Lemaitre, J.-L. Chaboche [6], S. Murakami [7], M. Chrzanowski [8], R. Viswanathan [9] and many others.

Now the approach of hidden damage simulation by use of scalar damage parameter became the standard prodedure which includes in different calculational methods directed to the analysis of the hidden fracture processes in materials and structures [6]. The main problem here is absence of necessary information about the long term strength data for definite material as well as temperature and stress varying ranges.

The aim of presented paper is an attempt to develop the web tools which could fill up the gap between high theoretical background in Continuum Damage Mechanics (CDM, [6]) and insufficient knowledge about the experimental data by way of storage them and processing the values of constants.

Description of the approach for data storing. As it is well known, the long term stregth data for definite material and fixed temperature range can be storaged by two means, which are connected one with another. The first way is publishing or storage in database the values of stresses which cause the fracture in uniaxial specimen after the definite time moment. Such representations can be found in different handbooks, for example in [10]. The second type of the above data presentation is graphical, which contains in building the plot of dependence between fracture values of stress and corresponding time values. Usually this plots are built in logarithmic co-ordinates. This possibility of experimental data presentation was realized in first stage of the work and is described in [3].

Let us discuss the first mean. The large amount of the data were obtained by experimental way during last seven decades. The uniquiness of this information consists in the fact that obtaining of each value demand many months and, in many cases, the years of experimental observations. These data were published in scientific journals and handbooks like [10].

In this work we realize the approach which consists in transferring the published data into database. It was built by use of PHP and SQL language [11] as well as MySQL database control system.

The user interface contains from the sequential input operations for the type of material (steel, nickel, titanium alloy etc.), its grade, temperature of experiments and the values of stresses which caused to fracture after the standard number of hours (100, 1000, 10000 etc.). The possibility of input the data for another specified time value and corresponding stress is realized additionally.

It is provided in current version of the web-site, that only administrators can fill the blanks of above mentioned data. The possibility for input data for any user will be added in future versions, but the managing of the information, its checking will be kept by administrator like the procedure had been done for experimental curves storing and described in [3].

Fig. 1 contains the general view of the database.

In this figure the general menu of the web-site ***worldmech.net*** can be seen as well as the form for adding the above described information. The bottom part of the screenshot contains the ready strings for nickel based alloy (here, for example the grade *ЭИ437Б* is presented for three temperature values).

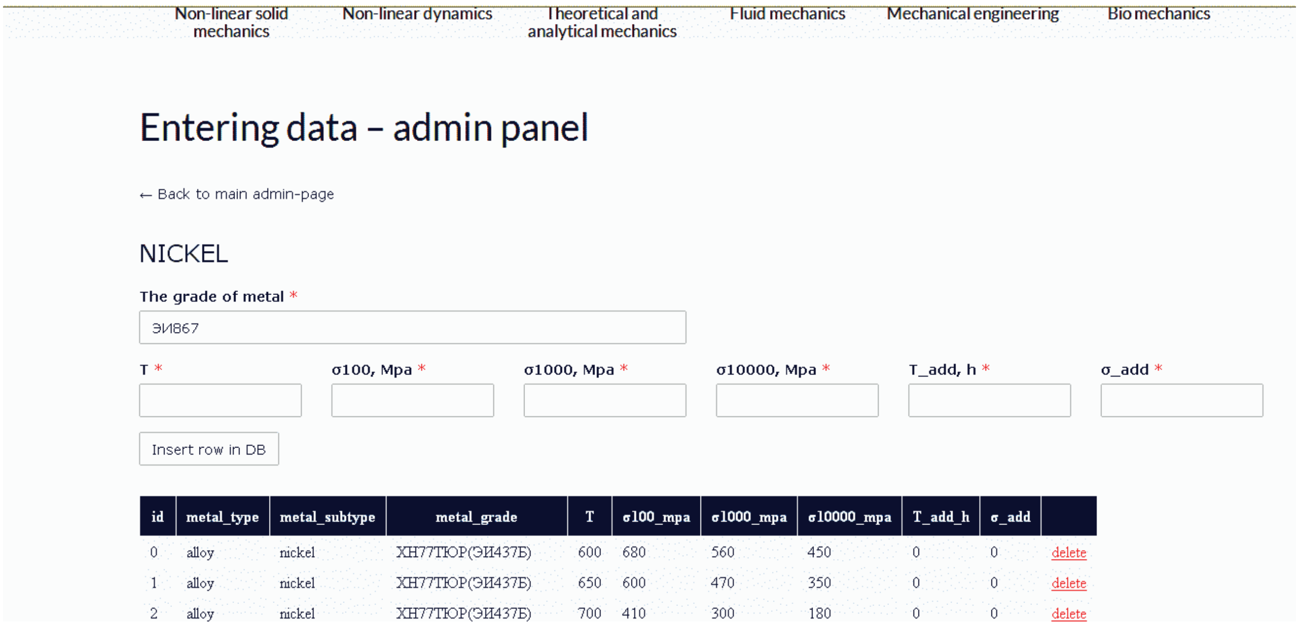


Figure 1 – The view of database for high temperature long term strength data

Algorithm for processing of long term strength data. The filled strings of database are presented on Fig. 1 can be used for finding the unknown constants for the kinetic damage equations.

Let us regard two options of this equation. The first is formulated for constant temperature [6]:

$$\dot{\omega} = D\frac{\sigma^m}{(1-\omega)^l} \quad \omega(0) = 0. \qquad (1)$$

Here σ is acting stress, ω is the damage parameter, *D, m* and *l* are the constants which have to be determined for fixed temperature by use the data are presented on Fig. 1. Due to the presence of three constant values, the user have to switch to next panel for selected material and select three values of stresses with corresponding values of times to fracture. The equation (1) is integrated on time and system of three linear algebraic equations for three unknowns *D, m* and *l* has to be solved.

The second option is obtaining of the constants for the case when the temperature dependence has to be considered in kinetic damage equation. The modified law can be presented as follows [6]:

$$\dot{\omega} = d\,\frac{\sigma^m}{(1-\omega)^l}\exp\left(-\overline{Q}/T\right) \quad \omega(0)=0, \qquad (2)$$

where $\overline{Q}$ presents the product of creep damage energy activation on the value of the universal gas constant. In using phenomenological approach this value can be determined from experimental data sets. Two values of temperature T_1 and T_2 have to be considered as well as the additional values of total creep strain at the fracture moment c_*, Norton law [4] creep constants B, n and the product of energy of activation on the universal gas constant Q. The system of four linear algebraic equations about constants D, m, l and $\overline{Q}$ can be written in the following form:

$$t_{1*}^{T_1} = \frac{1}{(l+1)D\left(\sigma_{1*}^{T_1}\right)^m \exp\left(-\overline{Q}/T_1\right)};$$

$$t_{2*}^{T_1} = \frac{1}{(l+1)D\left(\sigma_{2*}^{T_1}\right)^m \exp\left(-\overline{Q}/T_1\right)};$$

$$t_{4*}^{T_2} = \frac{1}{(l+1)D\left(\sigma_{4*}^{T_2}\right)^m \exp\left(-\overline{Q}/T_2\right)}; \qquad (3)$$

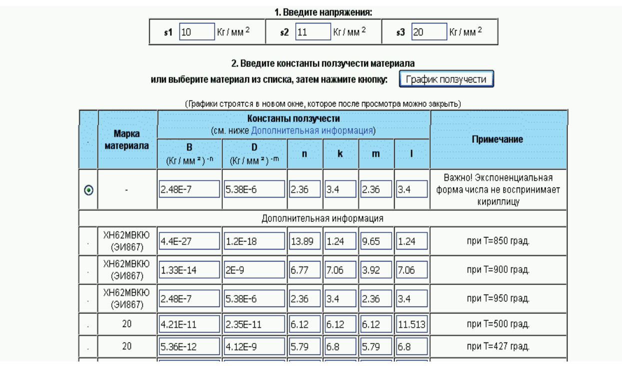
$$c_{3*}^{T_1} = \frac{B}{D}\left(\sigma_{3*}^{T_1}\right)^{n-m} \exp\left(\frac{-Q+\overline{Q}}{T_1}\right).$$

Here the digit in subindexes denotes the number of experimental data set.

For the second mode the sequence of user's actions has to be the following. After the selecting two temperature values it is necessary to select in new window the four long term strength data sets. By special function these data will be processed and the four constants D, m, l and $\overline{Q}$ will be determined.

After actions due to first and second options the obtained constant's values have to be written in another database. In this stage it is realized at web-portal 'Handbook of Steels and Alloys' at ***splav-kharkov.com***.

Let us consider an example in which the constants for equation (1) are found. We regard the nickel based alloy ЭИ867 at $T = 950$ °C. The processed data were written into database which is presented on Fig. 2, where the web-site window is presented.



1. Введите напряжения:

s1 10 Кг / мм 2 | s2 11 Кг / мм 2 | s3 20 Кг / мм 2

2. Введите константы ползучести материала
или выберите материал из списка, затем нажмите кнопку: График ползучести

(Графики строятся в новом окне, которое после просмотра можно закрыть)

.	Марка материала	Константы ползучести (см. ниже Дополнительная информация) B (Кг / мм ²) -n	D (Кг / мм ²) -m	n	k	m	l	Примечание
⊙	-	2.48E-7	5.38E-6	2.36	3.4	2.36	3.4	Важно! Экспоненциальная форма числа не воспринимает кириллицу
Дополнительная информация								
.	ХН62МВКЮ (ЭИ867)	4.4E-27	1.2E-18	13.89	1.24	9.65	1.24	при T=850 град.
.	ХН62МВКЮ (ЭИ867)	1.33E-14	2E-9	6.77	7.06	3.92	7.06	при T=900 град.
.	ХН62МВКЮ (ЭИ867)	2.48E-7	5.38E-6	2.36	3.4	2.36	3.4	при T=950 град.
.	20	4.21E-11	2.35E-11	6.12	6.12	6.12	11.513	при T=500 град.
.	20	5.36E-12	4.12E-9	5.79	6.8	5.79	6.8	при T=427 град.

Figure 2 – Database containing creep and long term strength data

User has the possibility of building the plots of dependencies between damage parameter and time obtained by use of damage kinetic equation (1) with determined values of constants. They are: $D = 5.36\cdot10^{-6}$ (MPa^{-1})$^{-m}$/h, $m = 2.36$, $l = 3.4$. Now software provides building three curves in one plot, so, it is necessary to input three stress values. For this example they are $\sigma_1 = 100$ MPa, $\sigma_2 = 110$ MPa and $\sigma_3 = 200$ MPa. This plot is situated in another window and is presented on Fig. 3. Here the numbers of curves correspond to the numbers of input stress values.

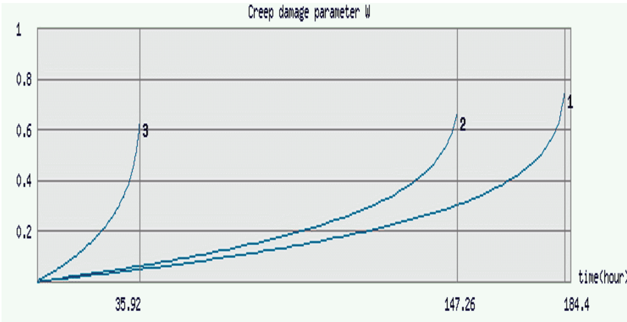


Figure 3 – Dependencies 'damage parameter versus time' are built in web-application

By analyzing the damage curves and their comparison with long term strength data sets the user can make the conclusion about validity of obtained values of constants. He can return to the procedure and select another data set in negative case as well as use these constants in his numerical simulation in positive.

Conclusions. The paper contains the description of the developed web tools for processing of long term strength data. The description of procedures for storing into database the experimental information which contains in a scientific literature is described. These data are used for obtaining the values of constants for damage kinetic equation with scalar damage parameter. The examples of work stages of described algorithm as well as example of graphical representation of damage curves are presented.

The above described web-tool will be useful for engineers and research associates who are working in area of modeling of high temperature properties in materials and structural elements.

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