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Application of Secondary Development Based on MATLAB in Rubber Life Prediction

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Abstract. Rubber seals are polymer materials which are widely used in aerospace, weapon equipment technology, electrical and electronics, medical equipment and mechanical manufacture and other fields. Their properties will reduce progressively under the environmental conditions of high temperature, oxygen, and mechanical stress etc, that is so-called "aging". In view of the huge losses and hidden dangers caused by the aging failure of rubber, and various phenomena will seriously affect the accuracy of life prediction and the understanding of rubber aging behavior, therefore, the rapid evaluation mechanism of the existing model established by software is used to evaluate the aging of rubber. In order to quickly calculate the rubber life of different material components, more than 10 classical model algorithms are established through the MATLAB platform in this paper. Users can choose relevant models to complete life prediction. The simulation results are close to the test results. The software improves the accuracy and reliability of life evaluation.

Keywords. Rubber, MATLAB, model algorithms, life prediction

1. Introduction

Rubber material has the characteristics of oil resistance, chemical resistance, heat resistance, high temperature and high pressure resistance, ozone resistance, excellent mechanical properties, thermal stability, and has been widely used in aerospace engineering, weapon equipment technology and other fields. The performance of rubber materials will change due to aging during use, which will affect the life of the product. In view of the huge losses and hidden dangers caused by the aging failure of rubber, and various phenomena will seriously affect the accuracy of life prediction and the understanding of rubber aging behavior, therefore, the rapid evaluation mechanism

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of the existing model established by software is used to evaluate the aging of rubber. The study of behavior and mechanism is of great significance. Realizing the life prediction of rubber materials under different environments and load conditions has become an urgent application. The research on rubber aging life prediction has attracted extensive scholars' in-depth discussions.

2. Model

At present, the models for predicting the aging life of rubber mainly include Arrhenius model, P-t-T model, p-t model, Dakin model, damp heat aging model, non-Arrhenius model, thermogravimetric method, Weibull distribution, grayscale prediction, time-temperature translation, thermal focus slope method and other methods [1-21].

2.1. Arrhenius

$$P = Ae^{-K\tau} \tag{1}$$

Where P is the performance change index; τ is the aging time, days; K is the temperature-related performance change constant; A is the constant.

2.2. P-t-T

$$\log\left[-\log\left(\frac{y}{B}\right)\right] = b_0 + b_1 \log t + b_2 \frac{1}{T} \tag{2}$$

Where y is the aging performance; B is an empirical constant close to 1; t is the aging time; T is the aging temperature, K; b_0 , b_1 , b_2 and are all undetermined coefficients.

2.3. P-t

$$P = Be^{-kt^{\alpha}} \tag{3}$$

Where P is the aging performance, for stress relaxation: $P = \dfrac{\sigma}{\sigma_0}$; for permanent deformation: $P = 1 - \xi$; k is the temperature-dependent rate constant; B , α are temperature-independent constants.

2.4. Dakin

The Dakin lifetime estimation method is a relatively general method for predicting the lifetime of polymer materials. This life calculation method is proposed when the properties of the rubber material change below the critical value P. The relationship between the rubber material properties P and the aging time t is as follows:

$$f(p) = kt \tag{4}$$

Where k is the aging rate constant, which changes with the change of temperature. Under ideal conditions, the difference k between and temperature can be expressed by Arrhenius formula:

$$k = A_0 e^{-\frac{E}{RT}} \tag{5}$$

Where R is the gas constant; E is the activation energy of the reaction; A_0 is the empirical constant.

Set the time t required for the rubber property P to change to a certain value, if the property P changes to the critical value of failure, then this time is the storage life of the rubber:

$$\lg t = \lg\left[\frac{f(p)}{A_0}\right] + \frac{E}{2.303RT} \tag{6}$$

If let $\lg\left[\frac{f(p)}{A_0}\right] = a$, and let $\frac{E}{2.303RT} = b$, then the Dakin model can be derived:

$$\lg t = a + b\frac{1}{T} \tag{7}$$

2.5. Moisture and Heat Aging Model

When temperature is the main aging factor, the Arrhenius life model of formula (8) is used; when humidity is the main aging factor, the Erying life model of (9) is adopted.

$$L(T) = A_1 e^{\frac{E_d}{K-T}} = A_1 e^{\frac{B_1}{T}} \tag{8}$$

$$L(V) = \frac{1}{V} e^{-\left(A_2 - \frac{B_2}{V}\right)} \tag{9}$$

Where L is the aging life; T is the absolute temperature, K; V is the stress value in absolute units (such as relative humidity, etc.); A_1, A_2, B_1, B_2 are the undetermined model parameters.

Considering the influence of temperature and humidity comprehensively, the two equations (8) and (9) are combined to predict the life of the bonding structure, and the corresponding damp-heat aging life model is obtained as follows:

$$L\left(H,T\right)=\frac{A}{H}e^{\frac{b}{H}+\frac{c}{T}} \tag{10}$$

Where $L(\mathrm{H},\mathrm{T})$ is the damp heat accelerated aging life; H is the relative humidity; T is the absolute temperature; A , b , c and are all undetermined coefficients.

This model takes into account the aging effects of temperature and humidity, and is suitable for predicting the life of polymer materials in aging tests where temperature and humidity are both acceleration factors.

3. MATLAB Software

3.1. System UI

The rubber material aging life prediction software is mainly composed of 15 algorithms as shown in figure 1, and the module interface of each algorithm is shown in figure 2. The module can be composed of test data import, calculation parameter input, graphic window, model calculation, and result output. This software adopts Graphical User Interface (hereinafter referred to as GUI), which is an interface display format for communication between people and computers, allowing users to use mouse and other input devices to manipulate icons or menu options on the screen to select commands, call files, and start programs. Or perform some other daily task. The main function of GUI is to realize human-computer interaction between people and electronic devices such as computers. The purpose of GUI is to realize human-computer interaction. Developers research and design a specific user interface, packaging the obscure computer language into simple and easy-to-understand graphics, and users can understand the expressions behind the complex computer language by recognizing the graphics. The graphical operation mode has strong practicability, which is convenient for users to use and improves the use efficiency. Through the continuous optimization of the GUI, the developers make the transmission of information and data more efficient, and the result operation and feedback are more convenient and accurate, which brings a good user experience and is very practical.

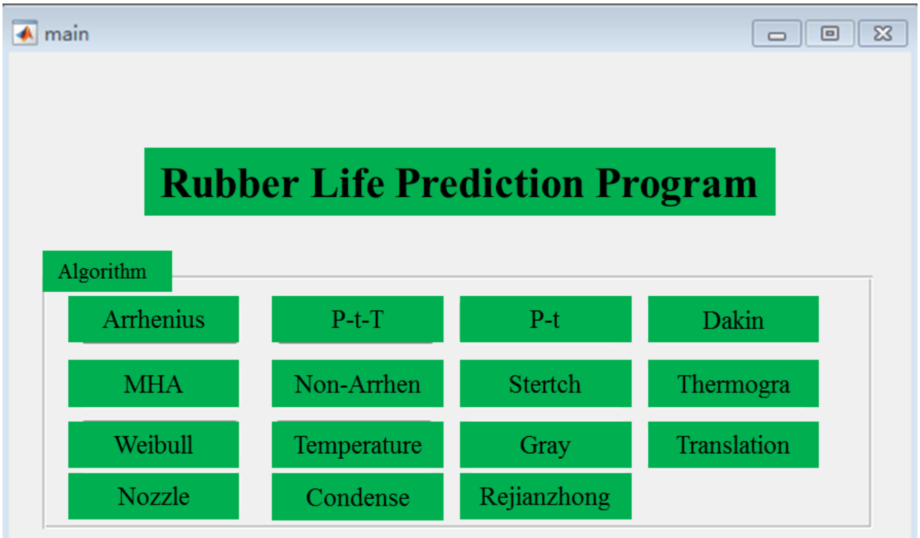

Figure 1. Rubber life prediction interface.

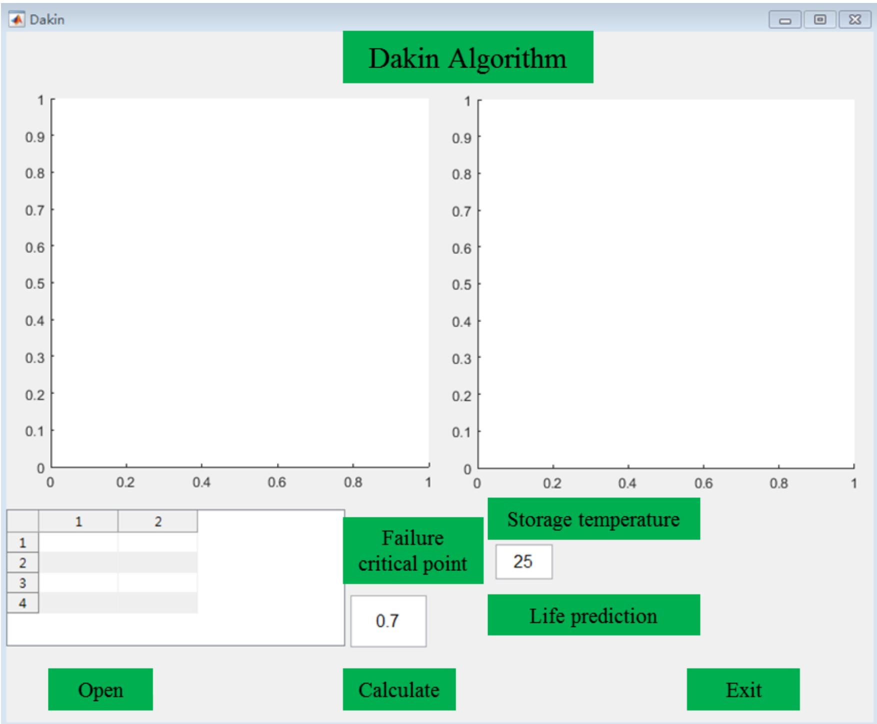

Figure 2. Algorithm module interface.

3.2. GUI Design and Programming Code

For an application program designed for GUI, the user can perform the specified behavior by interacting with the interface without knowing how the program is executed. GUI development environment includes MATLAB operating environment, GUIDE applications, App applications and other graphical user design interfaces.

This software adopts modular programming design, and the programming design steps are as follows: 1) Design canvas environment settings; 2) Create sketchpad components; 3) Component property settings; 4) Code editing; 5) Program running.

The program code and part of the explanation are as follows:

```
#GUI main function
#GUI main function
function varargout = main(varargin)
% MAIN MATLAB code for main.fig
…………………
#Initialize GUI
% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @main_OpeningFcn, ...
                   'gui_OutputFcn',  @main_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
#Select the recognition sample Arrhenius algorithm
% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
% hObject    handle to pushbutton1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
set(gcf,'visible','off');
tongji('visible','on');
#Select the p-t-T algorithm for identifying the sample
% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
…………………
sanyuan('visible','on');
#Select the algorithm to identify the sample hot focus slope method
% --- Executes on button press in pushbutton16.
…………………
rezhongdianxiefa('visible','on');
```

4. Examples

Taking the rubber property change rate down to 50% as the life prediction index of the rubber material under stress. Based on this, the life of rubber at different temperatures can be calculated. Figures 3 to 8 show the comparison between the measured and simulated values under different algorithms, where the dots are the measured values, and the solid line is the simulated value. On the whole, the simulated results are close to the experimental results. The predicted value is very close to the actual value, indicating that the life equation and the actual storage result have high reliability, and the change law of the predicted material properties is basically consistent with the actual situation, which shows that the predicted value of the material performance change is consistent with the actual value have good consistency.

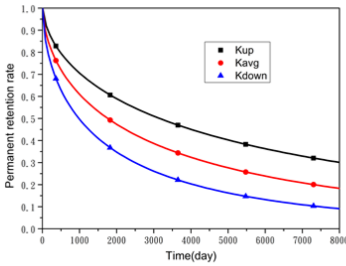

Figure 3. Arrhenius algorithm.

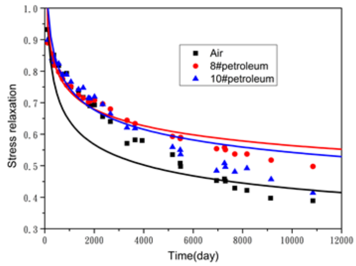

Figure 4. P-T algorithm.

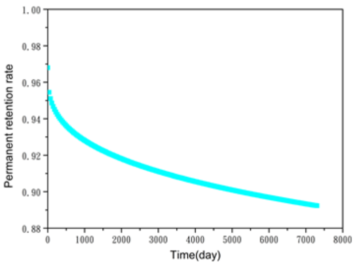

Figure 5. P-t-T algorithm.

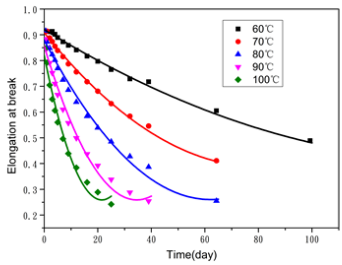

Figure 6. Dakin algorithm.

During the aging process of rubber, its elongation at break decreases continuously, and the prediction of its service life is an important indicator. Elongation at break is an important factor in predicting the service life of rubber. The Dakin lifespan estimation method is a classical lifespan prediction method, which was first proposed by Dakin in 1948.This method can use equation 7 to calculate the service life of the rubber. The results show that with the prolongation of aging time, the properties of rubber elongation at break change obviously. The higher the temperature, the greater the drop in elongation at break.

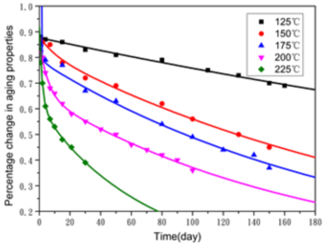

Figure 7. Non-Arrhenius -T algorithm.

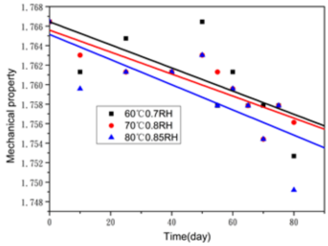

Figure 8. Moisture and heat aging algorithm.

5. Conclusion

(1) This paper adopts a modular approach to program design, and programs and encapsulates the rubber life prediction model, which can realize rapid life evaluation and provide effective support for the research of researchers.

(2) The simulation results are close to the experimental results.

(3) Softwares greatly reduce the test time and have great reference value for the selection of rubber materials.

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