Design and Implementation of Automatic Control System for Steel Wire Stretching Stress Relaxation Testing Machine

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Abstract –To overcome the shortcomings of the traditional manual stretching stress relaxation testing machine for the steel wire, a scheme of automatic control system with ADAM modules was proposed. The program compiled by Visual Basic programming language on IPC controlled the whole test process and recorded test data automatically. For the test data analysis, the extrapolating method of single- and dual-logarithm based on the least squares was adopted. Test results show that the system in the paper could control and monitor the test process automatically and record the test data timely. The test data could be extrapolated to reflect the steel wire stretching stress relaxation performance accurately.

Keywords - Stress relaxation testing machine, extrapolating method, ADAM modules, Visual Basic 6.0, MSComm control

I. INTRODUCTION

The steel wire stretching stress relaxation characteristic is an important parameter, and its performance directly impacts on the safety of its application project. The steel wire stretching stress relaxation testing machine can be used to test the steel wire stretching stress relaxation characteristic. Traditional testing machines are operated manually, with lower level of automation; and the analysis of test data is complicated and prone to omission.

With the development of computer application, more and more advanced language programming are adopted in the industry monitoring system. The automatic control system for testing machines, which use Advantech's ADAM series modules based on Visual Basic6.0 programming, is manipulated flexibly and achieves test monitoring and the record and analysis of real-time test data, without omissions and errors in manual operation.

Based on existing experimental data, extrapolation aims to establish a reasonable curve with few errors, reflecting characteristics and laws of certain objects in a long period. It is an important way in analysis of the relaxation test data. For steel stress relaxation properties, the paper adopts the extrapolation based on the least squares method with single and double logarithmic laws. Test results show that the method is scientific, rational, and accurate.

II. PRINCIPLE OF TESTING MACHINE

The testing machine is mainly used for steel wire stretching stress relaxation testing. That can meet manufacturers' need for steel wire relaxation properties tests and help administrative departments of quality supervision to reinspect the stress relaxation properties of steel wire used in projects [1-3].

A. Introduction of Test

Testing machine consists of the host and control system. The host framework consists of pedestal, crossbeam and pillar. Inside, it is equipped that precision rolled ball screws, reducer and anchorage. In order to load or unload the stretching stress on steel wire, transmission load system uses servo motor to drive arc-gear synchronous belt, ball nuts and finally the leading screw. Monitor control system achieves automatic test based on the commands which are sent by test program in the industry PC (IPC).

The test process involves loading stage, initial holding stage, constant distance holding stage, relaxation testing stage and unloading stage. All parameters and test data of stages are recorded and analyzed to obtain the test relaxation properties of steel wire.

B. Disadvantages of traditional testing machine

Most of the traditional testing machines need manual operation, with low degree of automation. Test results are influenced by human factors, and even for the same person, the operation of the test process is different more or less. In addition, because of the outdated display and recording method of the test process, operators have to take mass, complex and fallible test computation and analysis [4, 5].

To make up for the shortcomings of traditional testing machine, the author uses the ADAM modules to design an automatic, stable and reliable testing machine. With IPC's participation in supervision and recording of the entire system testing, accuracy and efficiency of testing process and data analysis is guaranteed well.

III. STRETCHING STRESS RELAXATION RATE

Relaxation rate of steel products, for example steel wire, is the parameter about the relaxation properties under stress, which is defined as follows:

$$Relaxation\ rate(R)=\frac{Initial\ force(F_i)-Residual\ force(F_r)}{Initial\ force(F_i)}\times 100\%$$

Steel wire stretching stress relaxation test needs record relaxation rate of steel wire at different times under a certain temperature. The test should be in a continual 1000 hours or more. Also the test is just continued in a short period, and then extrapolation is used to obtain the sustained relaxation rate for 1000 hours or more. This paper adopts the latter.

According to the test results in a short time (100 hours or otherwise), the unitary linear regression method is used to extrapolate the value of relaxation rate for the long time (1000 hours or otherwise). The detailed steps are as follows:

(1) In the test, the relaxation rate (or residual force) is recorded at defined time intervals (or the time when unload occurs). Usually the time to record test data is defined. This will also facilitate to make the horizontal and vertical contrast between steel products.

(2) Based on the test results in the short time, the test data is deal with extrapolation, and the relaxation rate for the long time is obtained. The test machine adopts the single and double logarithmic extrapolating method respectively.

Method one: Time-Logarithm equation extrapolation (single logarithmic extrapolation). Its formula is as follow.

$$R = A + B\lg T \tag{1}$$

Where:

T: extrapolation time

R: relaxation rate

A, B: regression coefficient.

Record different time ti and temporal relaxation rate R_i (i = 1, 2, 3 ... n, n is the record times), and then

$$R_i = A + B\lg t_i \tag{2}$$

Let $y_{1i} = R_i$, $x_{1i} = \lg t_i$, and then

$$y_{1i} = A + Bx_{1i} \tag{3}$$

Based on the value of times and relaxation rate at different times, x_{1i} and y_{1i} can be obtained, and then the regression coefficient *A, B* is calculated.

$$\begin{cases} B = \dfrac{\sum_{i=1}^{n} X_{1i}Y_{1i} - n\overline{X}_1\overline{Y}_1}{\sum_{i=1}^{n} X_{1i}^2 - n\overline{X}_1^2} \\ A = \overline{Y} - B\overline{X}_1 \end{cases} \tag{4}$$

Take regression coefficient *A, B* into the type (1), the relaxation rate and relaxation at any time is available. The forecast range in this extrapolation is from R_1-2Sy_1 to R_1+2Sy_1, which can be the basis for extrapolation error. Where, Sy_1 is the unbiased estimator.

$$Sy_1 = \sqrt{\frac{(1-\gamma_1^2)(\sum_{i=1}^{n} Y_{1i}^2 - n\overline{Y}_1^2)}{n-2}}$$

Where, γ_1 is the correlation coefficient.

$$\gamma_1 = \frac{\sum_{i=1}^{n} X_{1i}Y_{1i} - n\overline{X}_1\overline{Y}_1}{\sqrt{(\sum_{i=1}^{n} X_{1i}^2 - n\overline{X}_1^2)(\sum_{i=1}^{n} Y_{1i}^2 - n\overline{Y}_1^2)}}$$

Method two: Power function equation extrapolation (dual logarithmic extrapolation). Its formula is as follows.

$$\lg R_2 = \lg C + K\lg T \tag{5}$$

Where:

C, K: regression coefficient.

Record different time t_i and temporal relaxation rate R_i (i = 1, 2, 3 ... n, n is the record times), and then

$$\lg R_i = \lg C + K\lg t_i \tag{6}$$

Let $y_{2i} = \lg R_i$, $x_{2i} = \lg t_i = x_{1i}$, $U = \lg C$ and then

$$y_{2i} = U + Kx_{2i} \tag{7}$$

Based on the value of times and relaxation rate at different times, x_{2i} and y_{2i} can be obtained, and then the regression coefficient *U, K* is calculated.

$$\begin{cases} K = \dfrac{\sum_{i=1}^{n} X_{2i}Y_{2i} - n\overline{X}_2\overline{Y}_2}{\sum_{i=1}^{n} X_{2i}^2 - n\overline{X}_2^2} \\ U = \overline{Y}_2 - K\overline{X}_2 \end{cases} \tag{8}$$

Take regression coefficient *U, K* into the type (5), the relaxation rate and relaxation at any time is available. The forecast range in this extrapolation is from R_2-2Sy_2 to R_2+2Sy_2, which can be the basis for extrapolation error. Its calculation is similar to that of method one.

IV. The Relaxation Testing System Based on ADAM Modules

A. Hardware Structure

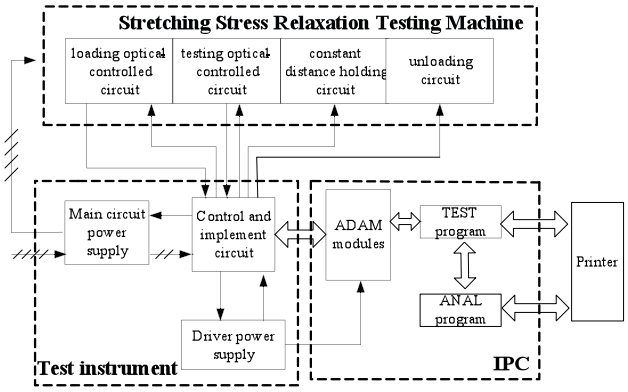


Fig. 1: Automatic Control System of Steel Wire Stretching Stress Relaxation Testing Machine

The system structure is shown in Fig 1. The stretching stress relaxation testing machine includes the loading optical-controlled circuit, the testing optical-controlled circuit, constant distance holding circuit and the unloading circuit. According to the test process, these circuits work orderly based on the commands from the IPC. The testing instrument contains many relays and switch components, and they are controlled by the IPC program through ADAM modules.

The testing process is controlled automatically by the IPC installed with testing program and data analyzing program. The ADAM modules connect to the IPC through serial interface, which carry out their communication and the transmission of commands and local signals. The testing program controls the whole test and records test data. The data analyzing program takes the extrapolation and calculates the relaxation rate, which will reflect stretching stress relaxation performance of steel wire. The test data is printed out for analysis.

B. ADAM serires modules

Advantech's ADAM-4050 module applies to industrial control as digital input and output. It includes seven-channel digital input ports and eight-channel open-collector digital output ports, and it can communicate with the host PC through RS485/RS232 . ADAM-4050 works steadily and flexibly. In the industrial applications, one PC can carry with a number of ADAM modules. ADAM-4520 is required for ADAM-4050 connecting to the host PC in serial port, which achieves electric level conversion between ADAM modules and IPC.

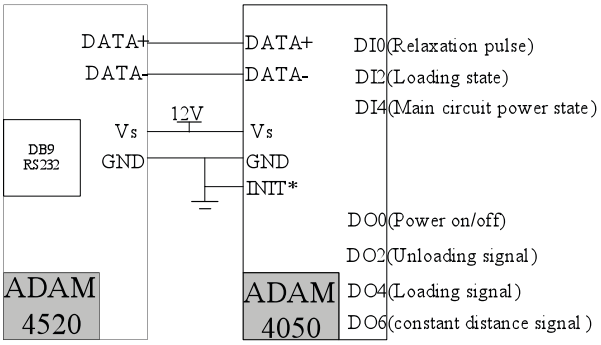


Fig. 2: The connection between ADAM-4050 and ADAM-4520

The connection of ADAM modules is shown in Fig 2. ADAM-4050'GND pin and INIT pin is connected and grounded, which makes the ADAM-4520 initial address 0x00H. The digital input and output ports connect the relays and switches in the test instrument respectively. ADAM-4520 achieves electric level conversion and data transmission between ADAM modules and IPC.

MSComm component is an important controls in VB software development [9, 10]. Almost all the programs related to communication should use the component. The communication between VB with the ADAM-4050 includes two parts: data output and data input.

(1) Writing data to the DO0-DO7 of ADAM-4050

The command format is as follow:

 # AABB (Data) (cr)

Where,

#: It is a delimiter character.

AA: It represents the address of the ADAM-4050, ranging from 00-FF. The default address is 00.

BB: If the program writes data to all channels, BB=00; If the program writes data to single channel, the first character is 1, the second number is the selected channel.

Data: It is the value of the deferent data. If Data=05, which is 0000 1010 in binary code, it means to write 1 to the channel 1(DO1) and channel 3(DO3), and others are written 0. When the program writes single channel, Data can only be 00 or 01.

cr: It is terminated code, which is chr(13) in VB language.

(2) Reading data from the DI0-DI6 of ADAM-4050

Firstly a command "$AA6" is sent to ADAM-4050, which informs the module that the input state DI0-DI6 should be read into the program, where AA represents the ADAM-4050's address. As for this system, IPC program need to send commands as follows to the ADAM:

MSComm1.Output = "$006" & Chr (13)

As soon as the ADAM receives this command, it will return response data as follow.

!(dataOutput) (dataInput) 00 (cr)

The program obtains ADAM-4050's output and input status by reading this response data with the delay of about 50ms.

C. Software design of testing program

According to the test process, the testing program is designed with the flexible, stable and reliable VB language. The whole software flowchart of testing program is as shown in Fig. 3. The IPC sends the test process-relevant commands to control the test process, while the IPC reads the ADAM-4050's input data to monitor the test process. At the same time, the ADAM-4050's output channels DO0-DO7 is written by new data ceaselessly, while the ADAM-4050's input channels DI0-DI6 is read by the IPC. When unloading signal is detected by IPC, the time and temporal relaxation force will be recorded, which will be analyzed and extrapolated.

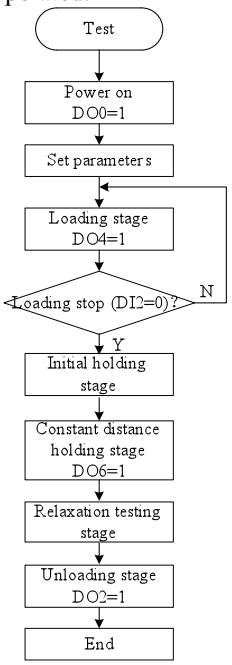


Fig. 3: The flow chart of the main program

As shown in Fig 4, if the power supply breaks off because of some faults during the test, the test instrument and testing machine will stop working. For the usage of on-line standard UPS, the IPC can continue working for 5 hours. Immediately testing program catches the power-off signal, the tested time is counted. If the tested time does not exceed 24 hours, the test is invalid and the test data is deleted. Otherwise, the test data is recorded and testing machine waits the power on for 5 hours.

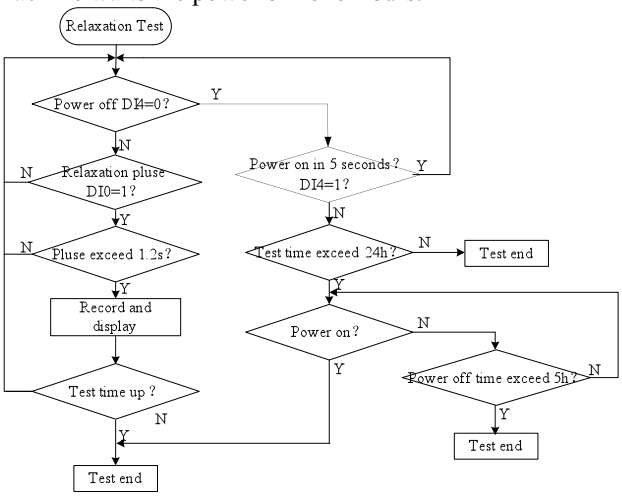
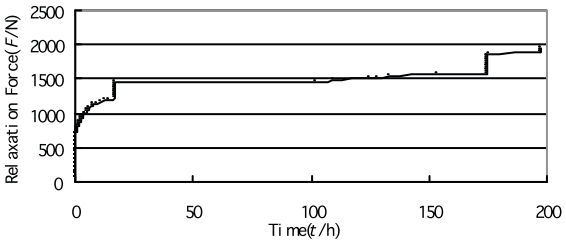


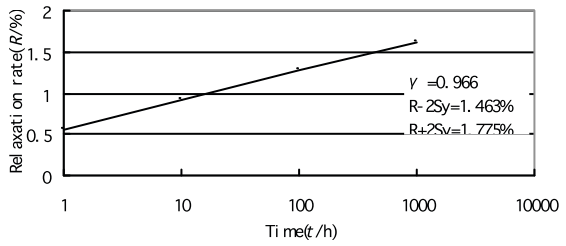
Fig. 4: The flow chart of relaxation test

If the tested time exceeds 24 hours when power supply breaks off, the IPC enters the stage of waiting for power on. By detecting signals from serial interfaces

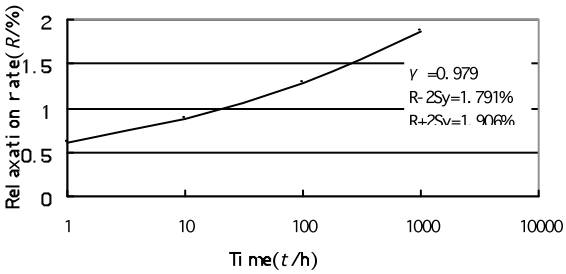
continuously, the program decides whether power supply is recovered. If the power supply doses not recover after 5 hours, this test will be canceled and test data will be deleted. Otherwise, whether the test will go on is decided by the tester.



(a) The curve of the recorded *t*-*F* for 200 hours



(b) The curve of *t*-*R* based on single logarithmic extrapolation



(c) The curve of *t*-*R* based on double logarithmic extrapolation

Fig. 5: Test data analysis and extrapolation

V. Test Results

During the testing process, the necessary parameters and the times of relaxation-unloading signal are recorded for extrapolation, and then the relaxation characteristic is described. For each test, these parameters, such as the loading time, initial force holding time, constant distance holding time and test time are recorded, while the real-time unloading signals is captured and recorded. If the system works wrong, the test terminates and the test data files are automatically cleared.

The authors developed a set of automatic control system based on ADAM modules for stretching stress relaxation test, including the test instrument and test and analysis software on IPC. With the test machine, 200-hour test of steel wire stretching stress relaxation was carried out. Tester is only required to set the relevant parameters. The testing process is controlled automatically by the IPC and the test data is recorded and saved for analysis and extrapolation.

In the Fig 5(a), the curve of the recorded t-F (time-relaxation Force) for 200 hours is shown. The relaxation rate for 1000 hours is reckoned based on the single and double logarithmic extrapolation in t-R (time- relaxation rate) curve of the Fig 5 (b) (c). That could describe the relaxation characteristic of steel wire.

VI. Conclusion

In order to avoid the drawbacks of traditional stretching stress relaxation test machines for steel wire, a set of automatic control system is designed. In the system, ADAM series modules are used in the serial port to accomplish the transmission of test data and control or state signal between the testing machine and the IPC. The testing program can control the test process, monitor the test state and record the test data. The analysis test can take extrapolation based on the recorded test date, and then the relaxation characteristic of steel wire is described. The designed control system is not only manipulated easily, but also with high level of automation and few errors.

Acknowledgment

The authors would like to acknowledge Mr Yu Mingqi from Tianjin Iron & Steel CO.,LTD for his work on the initial investigation. The authors would also like to thank Dr. Yuan Shi-qiang and Chen Yi-ming from department of automation of Tianjin University, for their technical discussions and timely help.

References

[1] Liu Lijun: 'Test Research for the Effect of Initiative Stress on Relaxation Rate of PC Steel Strand', Steel Wire Products, 2000, 26, (1), pp. 41-42.

[2] Yao Huifang, Chen Derong, Wang Qintang: 'Discussion On High Strength Steel Wire and Steel Strand Slack', Technology of Highway and Transport. 2007, 6, (3), pp. 134-136.

[3] Joshua G. Slater, Dmitriy E. Protsenko, Nicholas Carbone: 'Acoustic Response of Cartilage During Laser-Mediated Stress Relaxation', IEEE Journal of Selected Topics in Quantum Electronics, 2005, 11, (4), pp. 846-853.

[4] Yuan Zheni, Zhan Lihon, Bao Jianhua: 'The development of the extension stress relaxation testing machine', Industrial Construction, 2000, 30, (12), pp. 38-41, 50.

[5] Zhang Qiang, Wang Ping, Li Zhengguo, "Developed of SC-200 stress relaxation testing machine", CSM 2001 Annual Meeting Proceedings. Metallurgical Industry Press, 2001, pp. 388-391.

[6] Guan Yujun: 'The Long-distance Supervisory System of the Even Membrane Drawing Machine Based on ADAM', Microcomputer Information, 2007, 23, (1), pp. 67, 70-71.

[7] Gao Dexin, Zhang Wenwu, Yang Qing: 'Based On ForceControl and ADAM Model for Supervisory System of the Motor Temperature', Microcomputer Information, 2006, 2, (4), pp. 125-127.

[8] Zhang Feng, Li Zhigang: 'The Collection of Field Data Collecting by using VB6.0 and ADAM Modules', Guangdong Automation & Information Engineering. 2001, (6), pp. 25-28.

[9] Zhou Airu, Lin Weijian, Guan Shihong: 'Visual Basic Programming Design (2nd)', (Publishing House Of Electronics Industry, 2007).

[10] Guy Fouch, Trey Nash: 'Accelerated VB 2008', (901 Grayson Street Suite 204 Berkely, 2008).