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Automatic Testing System for Performance Parameters of Viscoelastic Materials

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ABSTRACT

With the development of science and technology, viscoelastic materials such as metals and polymers are widely used in various engineering fields and structural design in China, and the creep aging forming technology and time-stressed relaxation forming technology developed by creep and stress relaxation theory has been widely used in the aviation industry. Creep and stress relaxation experiments are carried out on materials under different loading conditions, and the testing machine unit is used to realize the automatic control of the whole process of the experiment and the storage of experimental data.

KEYWORDS

Viscoelastic materials; Creep; Stress relaxation

1. INTRODUCTION

Many materials in nature have the characteristics of elastic solids and viscous fluids at the same time, they are often called viscoelastic materials, with creep and stress relaxation and other inherent mechanical properties. In the aerospace, energy, chemical, and other industries, many parts such as engines, boilers, refinery equipment, etc. need to operate at high temperatures and high loads, if the components of the work process show a certain creep and stress relaxation phenomenon, will not only lead to the performance of its aspects of the decline in the circumstances of the seriousness of the case will also result in serious failure damage. With the development of science and technology, metals, ceramics, polymers, and other materials are widely used in China's various engineering fields and structural design, under certain conditions, the viscoelastic behavior of these materials has a great impact on the engineering structure of the load-bearing capacity and life expectancy, more and more by the attention of researchers. To effectively avoid the occurrence of this form of phenomenon, to ensure that the components can maintain normal operation and have a long service life at high temperatures, it is indispensable to investigate the creep and stress relaxation Sure, here you go: "behavior" of the materials used at high temperatures. In addition, according to the theory of creep and stress relaxation developed creep aging forming process technology and aging stress relaxation forming process technology has been widely used in the aerospace industry, the study of creep and stress relaxation of viscoelastic materials will also help to achieve the whole process of molding work-piece prediction, improve the process accuracy, and promote technological progress. Therefore, the study of creep and stress relaxation is one of the important tasks in aerospace, mechanical engineering, vehicle engineering, and other engineering. On the one hand, it is possible to determine the influence of the viscoelastic properties of materials on the structural and mechanical response; on the other hand, through the understanding of viscoelastic behavior, the viscoelastic behavior of materials can be selectively used during the structural design process to achieve specific performance goals. At the

same time, based on a series of investigations between viscoelasticity and material microstructure, different functional forms of viscoelastic materials are gradually designed.

2. SYSTEM OPERATING PRINCIPLE

This project will take the LPC2214 high-speed ARM microprocessor and STM32F103 microcontroller as the core, the temperature control box environment adjustment module, ventilation control module, motor control module, stress collection module, and other modules constitute the slave; LCD, alarm, external storage, RS485 communication module, and other modules to form a host. Master and slave machines cooperate to constitute a complete material creep persistence and stress relaxation test parameter measurement and alarm system to achieve the material in the set environmental conditions of the material creep and stress relaxation measurement. Our main research lies in how to realize the connection and communication between the main control microcontroller and each module and the design of peripheral-related circuits. To solve how to detect the temperature, humidity, current, stress, and other signals and transmit them to the host computer through the wireless communication module for real-time data display, to study how to receive and forward the data and the corresponding data on the PC to achieve the function of data processing, and to study how to achieve high-precision measurement of creep and stress relaxation of materials and to ensure the normal transmission of data.

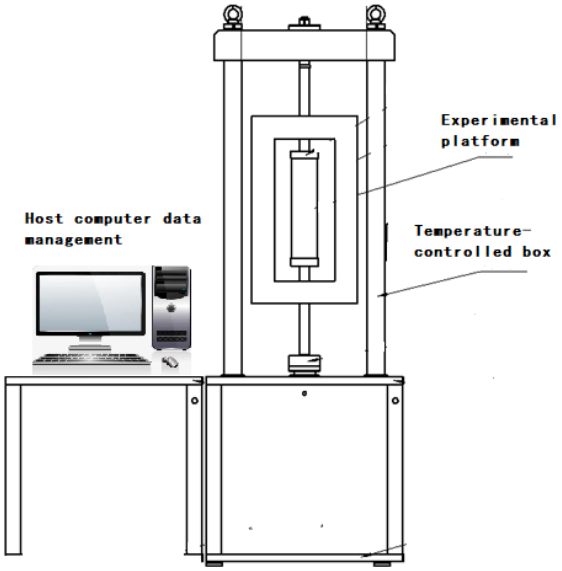

Figure 1. Block diagram of system module components

3. HARDWARE SCHEMATIC DESIGN

3.1. Machine Processing

To be able to realize the creep and stress relaxation integration test, the mechanical processing part includes the rigid body structure, pressure transducer mounting, displacement transducer mounting, stepping motor mounting, etc. The mechanical processing schematic is shown in Figure 2.

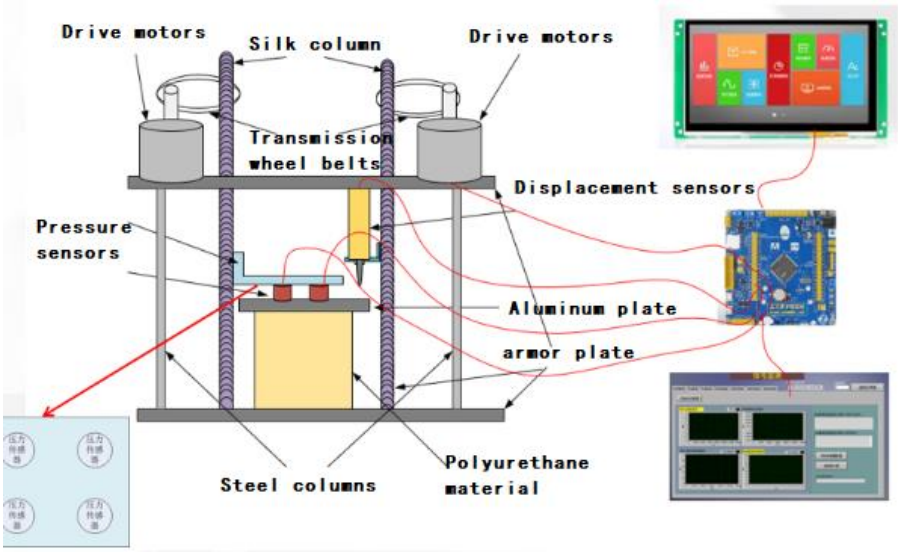

Figure 2. Schematic diagram of test platform machining

3.2. Electrical Control

The part consists of an ARM processor, displacement detection, pressure detection, motor control, LCD, data storage, data communication, and other parts, mainly to complete the control of creep, and stress relaxation part. The structure block diagram is shown in Figure 3.

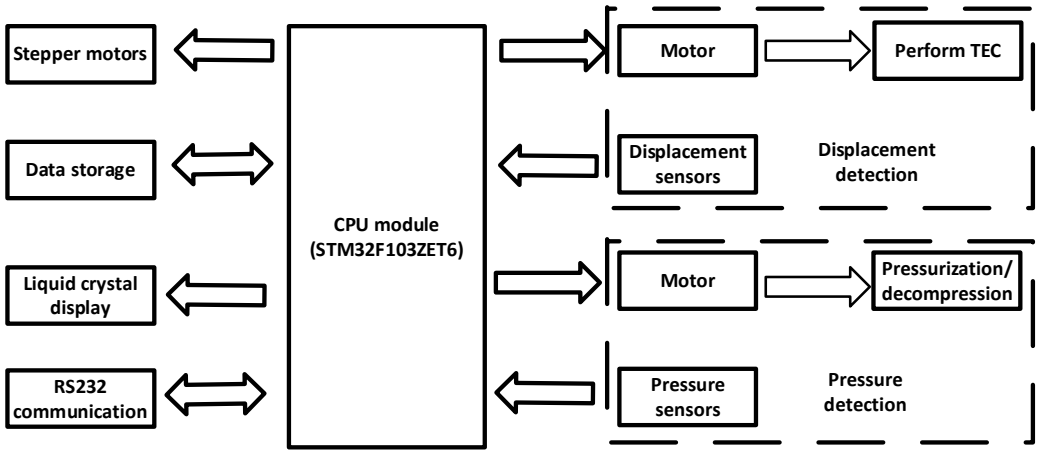

Figure 3. Schematic diagram of the hardware structure of the testbed

3.2.1. ARM processing unit

The all-digital controller adopts a 32-bit floating-point dual ARM architecture design, measurement, control, and data processing are executed separately, which can be suitable for the parallel processing of a large amount of test data, industrial-grade anti-jamming design, and support for local data storage on the SD card; with advanced adaptive PID algorithms, the user does not need to adjust the PID, which ensures the stability of the force control and ensures the testing effect of the loading and load retention process. The main control chip used in this design is the STM32F103ZET6 chip, which is based on the Cortex-M3 core, with the maximum speed of the CPU up to 72 MHz. STM32F103ZET6 chip adheres to the STM32103 series of consistent concept that is ultra-low power consumption, the chip is very powerful and has strong scalability to provide a very low-power consumption of the clock Oscillator and comparator, 16KB ~ 1MB Flash, a variety of control peripherals, USB full-speed interface, CAN, DAC and hardware encryption and LCD interface, and there is also a big feature is that the chip does not affect the function of the premise of providing dynamic voltage regulation. The pin function is very rich and can be connected to a large number of peripherals, such as sensors, etc.,

providing a very high scalability of the quality of the platform. Build the corresponding peripheral circuit to ensure its normal operation.

3.2.2. Displacement Detection Module

The displacement detection part adopts a high-precision LT20 series (LVDT) type displacement transducer, which serves to convert various measured physical quantities into electric quantities, with the important advantage of facilitating the signal to be directly fed into the computer system. The working principle is that there is a freely movable rod armature inside the coil. When the armature is in the middle position, the two secondary coils generated by the induced electromotive force are equal, so that the output voltage is 0; when the armature moves inside the coil and deviates from the center position, the two coils generated by the induced electromotive force is not equal, there is a voltage output, and the size of its voltage depends on the size of the displacement. In order to improve the sensitivity of the sensor, improve the linearity of the sensor, increase the linear range of the sensor, the design of the two coils connected in series, the two secondary coil voltage polarity is reversed, the LVDT output voltage is the difference between the voltage of the two secondary coils, the value of the output voltage and the displacement of the core into a linear relationship. The output type circuit is shown in Fig. 4, and the input type circuit is shown in Fig. 6, which has the advantages of fast response speed, high linearity, and high resolution, etc., and the remote weighing data acquisition method through the RS-485 communication interface as shown in Fig.5.

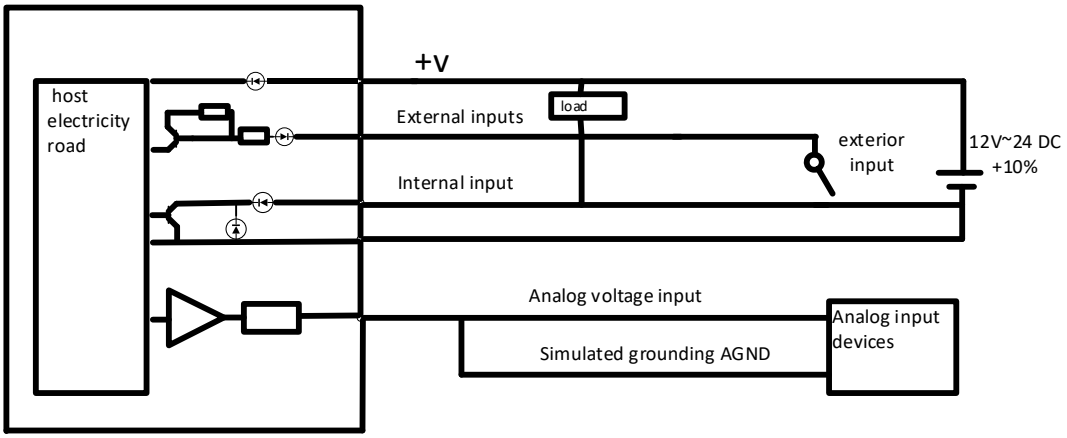

Figure 4. Output type circuit

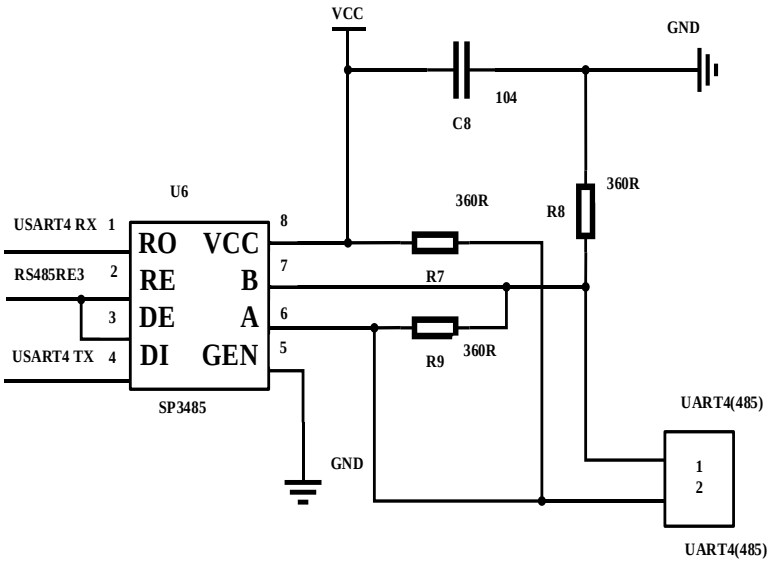

Figure 5. RS-485 communication interface

3.2.3. Pressure Detection Module

The pressure detection part is realized by the pressure sensor. The high-precision pressure sensor is placed underneath the fixed pressure sensor plate, which is connected to the filament column. The motor controls the up and down movement of the column to regulate the force exerted on the material, its working principle is shown in Figure 6, the pressure sensor will be the pressure signal transmission to the pressure sensor transmitter, which can be converted into a certain standard signal of the measured pressure value, thus obtaining the size of the material force, and through the feedback of the signal to design the program algorithm to regulate the rotation of the motor, so that to achieve the setting of a certain amount of force exerted on the material. The expected size of the force applied to the material, through the RS-485 communication interface as shown in Figure 7 remote weighing data acquisition method.

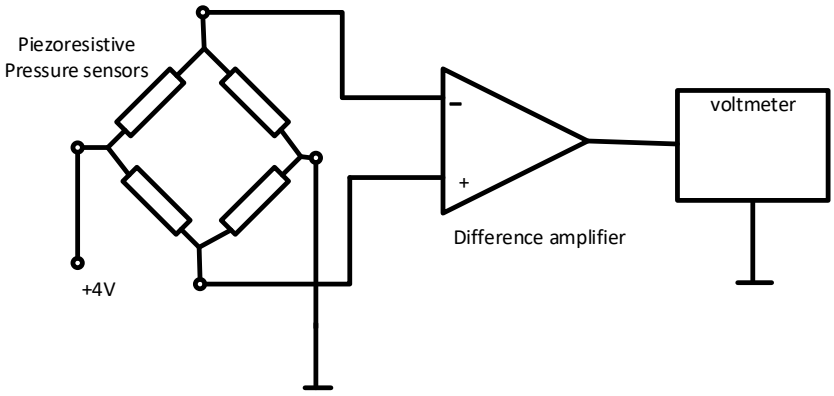

Figure 6. Principle of operation

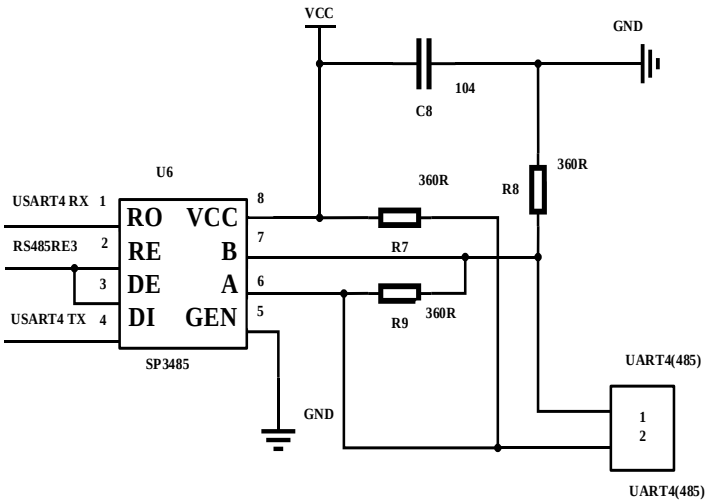

Figure7. RS-485 communication interface

3.2.4. Motor control

The stepper motor driver chip is Toshiba's TB6600HG, which is a PWM chopper-type bipolar sinusoidal stepper motor driver chip that can control the forward and reverse motions of two-phase stepper motors. With the clock pulse signal, enable signal, and direction signal output from the main control chip, the two-phase bipolar stepper motor can be driven to work with low vibration, high speed, and high reliability according to the specified subdivision. Five subdivision modes of 1/1, 1/2, 1/4, 1/8, and 1/16 are selected by pin level. The rated output current of 4.5 A meets the needs of all types of 42-series and 57-series stepper motors in the applications where they will be used. At the same time, the TB6600HG has a built-in overheat protection circuit, an under voltage protection

circuit, and an overcurrent detection circuit to enhance the safety and reliability of the system. Figure 8 shows the circuit design of the stepper motor controller used in the system. The inputs are clock, direction, enable, and interpolation signals output from STM32L151. The output is a wiring port for a four-wire stepper motor to control a 24V two-phase stepper motor. The motor circuit is shown in Figure 9.

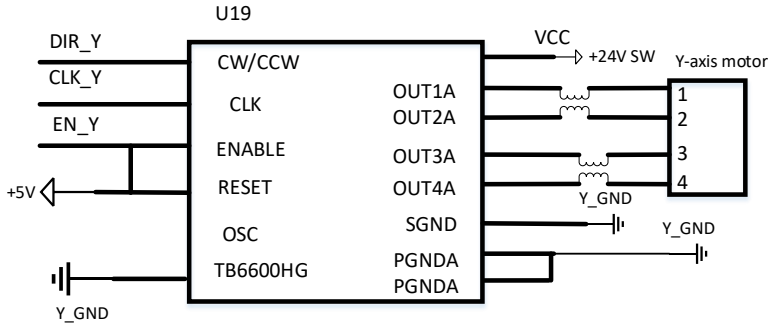

Figure8. Stepper motor controller circuit

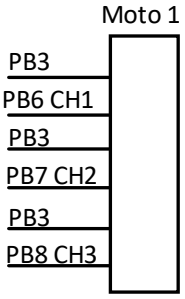

Figure 9. Motor circuit

4. SOFTWARE DESIGN

4.1. Lower Computer Software

The lower computer program is divided into four major terminal and slave programs, all using C programming language to achieve modular design. Compiled and debugged in the Keil5 environment through the use of interrupts, sub-functions, and STM32 function library to complete the programming, the main flow chart is shown in Figure 10.

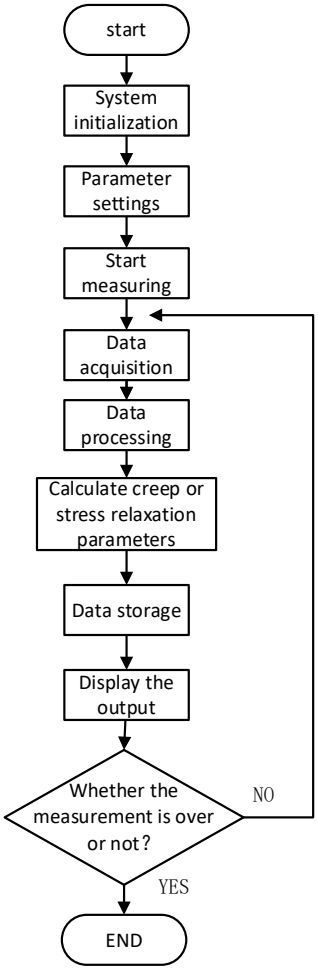

Figure 10. Flowchart of the lower computer software

4.2. Upper Computer Data Management Module

The upper computer software includes a network control software module and a special test software module. Software with a reliable watchdog function to ensure the stability of the test and long time; specific deformation adjustment function, when the creep test deformation exceeds the pre-set alarm value, the controller issues a sound and light alarm to remind the operator to grating sensor adjustment, before and after the adjustment does not affect the deformation measurements, deformation values are automatically summed up; the controller has a data storage and recovery function to achieve the disconnection of the network power outage of data automatic The controller has data storage and recovery function, which can automatically save the data of power outage and restore the test automatically after restoring the power, without manual splicing.

4.2.1. Specialized test software module

Creep and stress relaxation special test software, written in C#, the test software compatibility, long-time test stability, and reliability, and can carry out low-week fatigue loading test, can be set up cosine wave, trapezoidal wave, triangular wave, and other waveforms. Monitoring system software menu operation, the main page can display the specimen number, specimen size, test temperature, test stress, test time, loading mode (graded loading and a loading), heating and holding time, loading time, end time, temperature curve, loading curve; with the test data storage, organization, test results curve drawing function dedicated test software interface as shown in Figure 11.

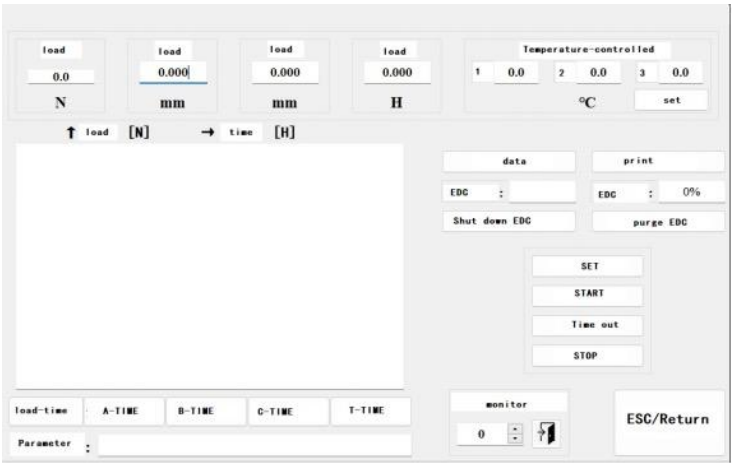

Figure 11. Specialized test software interface

4.2.2. Network control software module

A dedicated computer through the RS485 to build a network data transmission system can arbitrarily control one or more of the test machines for creep, and persistence tests, without interference, the system has good maintainability. The special computer installed on the special creep and persistence test software, can be through the high-speed network data transmission system for each test machine for various operations, control, and test data collection and storage. The test group control system adopts scattered measurement and control form to achieve network measurement and control functions, and can arbitrarily control one or more of the test machines for creep, persistence, and stress relaxation tests, without interference. The network control software interface is shown in Figure 12.

Figure 12. Network Control Software Interface

5. CONCLUSION

This system is in an artificially simulated climatic environment, through the digital controller to control high-precision, high-response frequency AC electromechanical servo system, polyurethane, fluorine plastic, and other materials in different load conditions for creep, stress relaxation, and other experiments, the use of testing machine unit to achieve the whole process of the experiments of the automatic control and experimental data storage. It has a strong application prospect. Each test machine of this system will constitute a test machine unit that can independently complete all the tests, the test machine unit through the test machine host controller and the touch screen to complete (without the aid of the upper computer) creep persistence and other tests of the programming and testing of the whole process of automatic control and data storage, in the aerospace industry,

automotive manufacturing industry in the development of the present, the system will be a significant help in the manufacturing process.

6. INNOVATIVE POINTS OF THE ARTICLE

The system can be configured according to the needs of a variety of station specifications, a multiple specimens, greatly improving the efficiency of the test, with stress, strain, displacement, and other three closed-loop control functions, the test process of the various control modes can be automatically switched without impact, to avoid motor start-up impact on the specimen as well as bring the measurement error, and has a manual loading and unloading function, accidental blackout can be effective protection of the machine and the specimen. The system has a reliable structure, strong anti-interference ability, and good long-term stability, which helps to achieve the whole process of work-piece molding prediction, improve the process accuracy, and promote the technological progress in the important tasks of aerospace, mechanical engineering, vehicle engineering, and other projects.

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