Design of Testing Device for Mechanical Property Testing System of Tai Lake Shield

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Abstract. According to the requirements of testing the mechanical properties of water shield from Tai Lake the corresponding testing system was designed by adopting the idea of open structure. The test system includes the detection device, the upper computer operation unit and the connected control unit. The testing device adopts a vertical frame suitable for testing materials in water, uses a stepper motor to drive the lead screw to achieve the basic tensile movement, and can achieve other testing functions through the addition of shear, friction and other expansion modules. The upper computer uses Kingview7.5 to develop the test interface corresponding to each test function, which can carry out manual debugging and automatic test operations, and input the measurement data and process parameters into the MySQL database to provide real-time display and historical query functions. The main controller is realized by Arduino Mega2560 circuit board, which communicates with the HX711 conversion module through the single bus protocol to collect the stress data of materials. By monitoring the running process of stepping motor, the material deformation data is calculated. Through communication with Modbus RTU protocol of upper computer, operation command and test data transmission are realized.

1. Introduction

Water shield is a perennial and valuable aquatic vegetable with smooth taste and rich nutrition. It is mainly distributed in the lakes and weirs of the middle and lower reaches of the Yangtze river, especially in the ponds of Zhejiang, Jiangsu, Hubei, Chongqing and other places, forming the west lake water shield, Tai Lake water shield and lake water shield. As one of the "Eight Immortals of water" of Suzhou local specialty vegetables, Ulva Tai Lake enjoys the reputation of "The eight immortals of water", and is a national level I key protected wild plant. As one of the four regions of water shield in China, the Tai Lake region of Suzhou has a long history of planting water shield. However, in recent years, the degree of aging of practitioners has been aggravated, the economic benefits of open-field planting have been reduced, and the cultivated area of water shield has been decreasing year by year. At present, the cultivation area of water shield in Tai Lake has been reduced, so it is urgent to improve the traditional planting mode and manual picking method to protect and develop the water shield industry in Tai Lake.

Compared with common terrestrial vegetables, water shield has a special growing environment. In order to get closer to the actual growth condition, the material properties are tested in water. Currently, there is no suitable testing equipment to provide such a testing environment, so it is necessary to design
n the corresponding mechanical property detection and recording system according to the growth character
cistics and testing requirements of water shield from Tai Lake.

The design of a new system for testing the mechanical properties of water shield from Tai Lake sho
uld first meet the basic requirements for testing the properties of conventional materials, and be able to
detect the stress and strain of roots, stems and leaves in the water environment under tensile and shear
operations, as well as other relevant parameters such as friction coefficient. Secondly, it should be poss
ible to test the mechanical properties under additional factors according to the actual growth characteri
stics and environmental conditions, such as the test of the pulling force of the root of water shield in the
soil.

In order to realize a variety of basic test functions and to follow up and adapt to the new test require
ments in the subsequent research process, the test system is designed as an open structure in this paper,
which is composed of a detection device, a host computer operation unit, and a control unit that connects the two parts. The detection device adopts modular design, which is composed of basic mechanism and special extension module. Different mechanics testing motion mechanisms are designed as special extension modules, which are installed on the basic mechanism to realize the corresponding mechanics detection function, and the detection movement and data collection are realized under the control of the control unit. The operation unit of the upper computer connects to the database and communicates with the control unit to realize the functions of control detection, tracking detection process, automatic recording of measurement data, and querying and displaying all kinds of data. The upper computer operation unit adopts configuration software development, and designs multiple configuration projects according to different test projects. Each configuration project runs independently, and new configuration projects can be added according to the extended test projects to realize the corresponding operation and data recording functions.

2. Test the functional requirements and design scheme of the system
The roots, stems and leaves of Tai Lake water shield are weak and delicate, and they are not able to with	stand tension and pressure. Therefore, relatively accurate measurement is needed to meet the actual n
eeds. The design of testing mechanism needs to fully consider the material characteristics, design reas
nable testing device, determine the appropriate clamping method, to ensure the accuracy requirements.

2.1. Functional requirement analysis of the test system
Based on the functions of the existing testing equipment for general material characteristics and the sp
cial environment of water shield planting and picking in Tai Lake, the requirements of testing functio
ns are analysed as follows:

(1) The test system should be able to test the mechanical properties of materials such as tensile, she
ar and friction, including the corresponding stress, strain and friction coefficient.

(2) Clamping can’t damage the material, do not affect the test movement, do not interfere with the test
data.

(3) The test system shall include manual operation and automatic test functions. Manual operation is
mainly used to adjust the position of relevant mechanisms, to provide preparation for the clamping of test
materials and the realization of water environment. Manual operation can also be used to realize the manual test function. Automatic test can complete the whole process of automatic detection, automatic data recording.

(4) In order to fully test the change of materials under dynamic stress, the test system is required to select the test speed and test the mechanical properties of materials under different stress acceleration.

(5) The force range of aquatic vegetables material is not large; the measuring device should have cer	ain accuracy requirements. The effect of additional external forces should be fully considered in the design to ensure the measurement error. According to the general material testing requirements and practical application requirements, the mechanical measurement precision designed in this project is higher than 0.1g (0.00098N), and the material deformation increasing value (that is, the measured value during the tensile process) is less than 0.1mm.
(6) The test movement should have a certain range. According to the current test project experience, the test stroke of 100mm and the two-way movement range of 200mm are designed in the paper.

2.2. Design scheme of the test system
According to the requirements of measurement function, the design of test system includes detection device, control unit and operation unit of upper computer. The detection device includes detection mechanism and drive unit. There are three parts of the upper computer measurement and control software, and the schematic diagram of the system function is shown in Fig.1.

In order to ensure the practicability and scalability of the testing device, the tensile testing device is used as the basic platform to test the tensile stress and strain of materials. The basic stretching mechanism is driven by a stepper motor, and the sliding platform is driven by a screw rod to realize the stretching action required by the test. By the step pulse control screw action, can ensure the measurement operating error. Other tests, such as shear and friction, are assembled into corresponding functional test platforms by adding different conversion modules, and the required test driver is realized by stretching.

The main controller controls the stepper motor, drives the lead screw to rotate, and realizes the stretching action. By calculating the pulse of stepping motor, the corresponding material deformation is converted. The main controller regularly collects data such as force and reads the digital signal output from the sensor conversion module.

![Fig 1. Composition of the test system.](image)

According to the operation and recording function of different test items, develop corresponding upper computer test interface. Each test interface can be loaded and run independently on king view software without affecting each other. The upper computer and the controller communicate through the serial port to realize the transmission of upper level operation command and test data. Through the test interface, different operation modes of manual debugging and automatic testing are realized. Transmit the operation command to the main controller to control the detection driver; Upload the test data into the database from the master controller and provide real-time display and historical query of the data.

3. Design and implementation of detection device
The detection device adopts modular design, which is composed of a basic stretching mechanism and an extension module. It is easy to extend the detection function, simplify the mechanism and make it easy. The basic stretching mechanism provides the stretching function, and other functions such as shear and friction are realized by loading the corresponding extension module.
3.1. Composition design of basic drawing mechanism

According to the functional requirements of the previous chapter, the basic drawing mechanism is mainly composed of material fixture, stress sensor, drawing drive steering part and support frame. The specific parts are shown in Fig.2.

The material jig is used to fix the material to be tested. The protective materials at both ends of the material or the wrapped material are clamped respectively by the first and second clamps to ensure that the material is clamped reliably at both ends during the test, and the material clamping place will not fall off or break.

Jig 1 connects the force sensor through the rope or bar to detect the tension on the material. Jig 2 connects the stretching bar to realize the stretching material. Clamping does not change the test characteristics of materials, does not affect the testing process of materials.

The sensor is a miniature cantilever full bridge force sensor with a maximum measuring value of 5000 g. Four strain gauges are pasted on and below the cantilever beam respectively, which can detect the tension of parallel cantilever beam in the process of tension and pressure changes in opposite directions. In the process of tensile test, the two upper strain gauges are pulled and the lower strain gauge is compressed, resulting in deformation. The differential bridge is out of balance, and the output voltage is for the test circuit analysis. The force sensor can be adjusted to fit the test.

The drawing power is realized by a stepper motor with screw. The motor drives the screw to rotate, pushes the upper sleeve to shift, drives the drawing rod, and transfers the tension to the material. After the beginning of stretching, the distance of the sleeve is the tensile deformation length of the material. The drawing track can keep the drawing rod moving straight and ensure the stability of the material during the whole test process.

3.2. Scheme selection of basic drawing mechanism

In the horizontal scheme, the material is installed and clamped laterally, and two sets of clamps are placed about. The upper part of the rack is open, which is easy to expand and install special modules. However, since the strain gauge in the sensor cannot be immersed in water, the force measurement...
function needs to be realized by steering. In the process of testing, although there is no additional tension caused by the fixture gravity, there is a certain static friction between the connecting ribbon and the roller, as well as the roller bearing, so it is difficult to determine the additional resistance, unable to quantitatively analyze the error, and difficult to ensure the reliability of the measured data.

In the vertical scheme, the material is vertically loaded and clamped, and two sets of clamps are placed up and down. In order to ensure the expansion of the special module, it is necessary to reserve a certain upper space, the frame longitudinal size is relatively large. The force sensor is connected to the clamping material end of the jig through the bar, and there is additional tension caused by the gravity of the jig, which can be zeroed and removed before the test. In the measurement process, there is no additional resistance in the horizontal scheme.

3.3. Design of shear and friction expansion module
The extension module is loaded on the basic stretching mechanism, and the corresponding movement is realized through the transformation driven by stretching.

The shear expansion module can realize the single-side cutting or double-side extrusion of materials, and its composition is shown in Fig.3. The material is placed on the loading platform. The shear plate is attached to the cantilever beam of the force transducer by a fixing screw and rod. The material is placed on the loading platform and fixed by the material clip. The push bar is connected with the drawing bar in the basic drawing mechanism. The push bar and the push bar are directly connected by the spring and guide bar, and can cushion the push pressure. The tensile member can push upward from the bottom of the loading platform to complete the shear movement, and the output of the pressure condition can be detected on the stress sensor. Before shear test, the gravity of the fixed member and shear plate can be recorded for additional stress zeroing. There is no additional force in the shearing process.

The friction expansion module can realize static friction and sliding friction between materials and different materials to detect the friction resistance. The composition of the module is shown in Fig.4. The module is equipped with a force sensor, and the output of friction measurement can be achieved by transferring the connection line through the plug-in head during the detection. The module frame can be
installed on the basic drawing frame, and the connecting hook is connected to the drawing rod. The tested friction material is clamped onto the frame through the material clamping, and the material is clamped under the press block and above the friction material through the material clamping. The front end of the compression block is connected with an inelastic rope strap by a spring and a stretching mechanism by a hook. When the tensile member moves downward, the material under test will be pulled. At the same time, the connecting rod is connected to the cantilever beam of the force sensor by an elastic rope band. When the tensile force increases to the maximum static friction force, the material moves, and the tension force measured in the force sensor is the maximum static friction force.

3.4. Manufacture of detection device
Type 42 stepping motor 42BYGH40-400S82 is used to provide tensile power. The body height of the stepping motor is 40mm, the torque is 0. 45N.m, and the current is 1.7A. With 400mm screw rod, nominal diameter D=8mm, screw pitch P=1.25mm, basic step Angle of stepping motorθ =1.8°.

In the design, the step driver's fine fraction n=2 is selected. For each pulse received by the motor driver, the moving distance L on the screw sleeve is calculated as follows:

$$L = \frac{p}{360} \times \frac{n}{\theta} = \frac{1.25}{360} \times \frac{2}{1.8} = 3.125 \mu m$$  (1)

According to the calculation of the above equation, the tensile precision of the material can be higher than 0.1mm, and the tensile increment is less than 0.1mm, which can meet the design requirements.

The frame members are assembled with 20×20 aluminum alloy profiles and corner code connections. The engineering drawing of the detection device is shown in appendix 1. The height of the force sensor can be adjusted by moving the support bar on it according to the test requirements. In the installation and adjustment support three-hole socket in the optical axis orbit alignment, based on the middle hole axis alignment for Φ 0.1 mm, ensure accuracy of tensile test.

Since the root of water shield is hollow and tender, the direct clamping will produce deformation and fracture. Before clamping, waterproof tape is used at both ends of the tested material to make it evenly bond on the tape around. The fixture clamps the surface of the tape from both sides to fix the material.
through the adhesive force of the tape. The upper and lower clamps are fixed on the rod by two opposite dovetail clamps. The upper fixture is fixed to the force sensor by connecting the rod, and the lower fixture can be freely installed in the vertical position of the tensile rod.

According to the requirements of test items and the actual height of the water tank, different shapes of containers can be selected flexibly to ensure that the tested materials are always in the water during the test.

4. Conclusions
This paper mainly determines the functional requirements of the test system according to the mechanical test requirements of water shield from Tai lake, and adopts Mega2560 as the main controller to design and implement the mechanical property test system for water shield from Tai Lake.

The main innovation points of the paper are as follows:
To meet the requirements of test function, an open structure is adopted to design the test system, which is composed of a detection device, an operation unit of the upper computer and a control unit connecting two parts. The detection device and the operation unit of the upper computer can add corresponding extension module and test operation interface according to different test functions.
After the system design, production and debugging, the goal of the plan was finally achieved and the expected results were achieved. At the same time, in the application of theory and practice.
Through this exercise, I have a deeper understanding of the mechanical structure and electrical control, further strengthened the professional technical training, honed my patience and concentration, and removed impetuosity. In terms of knowledge, the biggest gain is the systematic promotion from the upper computer to the controller and the lower driver. In particular, the content of communication protocol broadens the theoretical horizon and improves the practical application ability.
In the future, based on the existing research and development experience and based on the actual test application needs, we will enrich and extend the test functions, increase the types of test modules and test interfaces, and expand the application areas of the test system.

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