**Experimental Nuclear Physics**

**Hardware and Software Complex for Measuring the Tension of Anod Wires in Drift Tubes**

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**Abstract –** This paper presents a software-hardware complex for measuring the tension of the anode wire in drift tubes used in the SPD experiment's straw tracker at the NICA collider. The tension of the anode wire is critical for ensuring the accuracy of coordinate determination, as it affects electrical stability and the positioning of the wire due to electrostatic and gravitational forces.

The developed complex employs an electromagnetic measurement method, allowing for high-precision control of the tension in thin-walled Mylar tubes. The device measures tension by analyzing wire vibrations. The central component of the system is the STM32L4 microcontroller, which manages the delivery of electrical pulses and performs measurements. The advantages of the complex include ease of setup, a user-friendly interface, and high measurement speed, making it suitable for mass production. Testing confirmed the device's high accuracy and efficiency. Thus, the developed complex represents a significant advancement in the technology for assembling high-precision wire detectors

INTRODUCTION

Accurate wire tension control has been previously discussed in [1]-[5], highlighting the importance of precise measurements.The precision of wire detectors is crucial for various experimental physics applications. A significant parameter affecting the accuracy of coordinate measurements is the tension of the anode wire. Proper tension ensures electrical stability and corrects the wire's position under electrostatic and gravitational forces. Therefore, precise control and measurement of wire tension are essential during the production of high-precision wire detectors. This work presents the development of a hardware-software complex aimed at measuring the tension of the anode wire in drift tubes. The proposed solution is applied to the assembly of thin-walled drift tubes for the SPD tracker at the NICA collider.

METHODS AND MATERIALS

The core principle of the proposed method is the excitation of the anode wire through an electrical pulse and the subsequent analysis of its damped oscillations. A permanent magnet generates a magnetic field in the central region of the drift tube, which, in combination with the wire's vibrations, allows precise determination of its tension. This is achieved by measuring the resonance frequency of oscillations.

The developed system comprises several key components: 1) an STM32L4 microcontroller for generating pulses and recording measurements, 2) a relay for switching between excitation and measurement modes, and 3) a thin-walled drift tube containing a tensioned wire and a permanent magnet. This setup enables non-contact measurements with high repeatability. Software plays a critical role in data acquisition and processing. The firmware for the STM32L4 microcontroller handles pulse generation, analog-to-digital conversion, and communication using the ModBus RTU protocol. On the PC side, a user-friendly application processes the measured data using Fourier transforms and fits the results to a Lorentzian curve to precisely determine the resonance frequency. Similar methods have been employed in various experiments [3][4], demonstrating the reliability of wire tension measurement systems.

An electric pulse is applied by the tensioner, generating a magnetic field due to the moving electric field. This magnetic field, interacting with the static magnetic field, induces vibrations in the string thread. The resulting oscillations are measured by the anode and cathode, which detect the oscillation frequency. The first graph represents the attenuation of the oscillations over time, while the second graph shows the oscillation frequency.

The program automatically determines the points and approximates them using a Gaussian fit. Thus, by measuring the vibrations of the threads, the tension across the entire chamber can be determined. Multiple measurements are required to evaluate the errors of the tension meter. There is a temperature dependence, constant measurements warm the thread, the tension drops because the metal expands.

RESULTS

The proposed system demonstrated its effectiveness in experimental tests. Key results include:

1. Achieving a standard deviation of 30 mg in wire tension measurements (precision of 0.3%), with minimized equipment requirements, making it suitable for cleanroom environments.

2. Supporting high-speed measurements for mass production, processing up to 100 tubes per day.

3. Delivering a compact, cleanroom-friendly solution that is easy to set up and calibrate.

Figures 1 and 2 illustrate the damped oscillations and the fitted resonance curve used to derive the wire tension. A software-hardware complex was developed to measure the tension of the anode wire in the drift tubes of the SPD straw tracker at the NICA superconducting collider. The system uses an electromagnetic non-contact measurement method for high-precision tension determination. Its key advantages include a user-friendly interface, speed, and accuracy, ensuring efficiency in drift tube measurements at NICA.

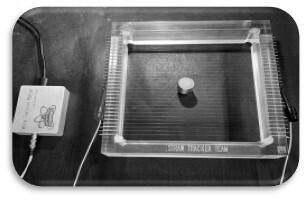
DISCUSSION

The developed complex offers several advantages over existing methods, including its non-contact approach, ease of calibration, and adaptability to different tube geometries. The use of a permanent magnet enhances sensitivity by enabling precise control over the wire's vibrations. Comparisons with similar methods in the literature, such as those employed in the VENUS and CDF experiments, highlight the improved accuracy and efficiency of the proposed solution. This system also simplifies the assembly process by integrating measurement steps into production.

CONCLUSION

In conclusion, a hardware-software complex for measuring the tension of anode wires in drift tubes has been successfully developed and tested. The system achieves high precision, meets the demands of mass production, and represents a significant advancement in the technology of wire detectors.

Future improvements may include extending the system's capabilities for longer tubes and refining the software for even higher measurement accuracy.

FIGURES

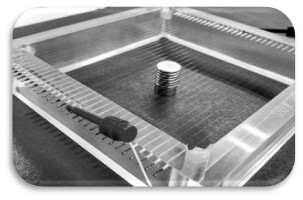


Fig.1.The process of measuring tension Fig.2.The appearance of the experimental

camera

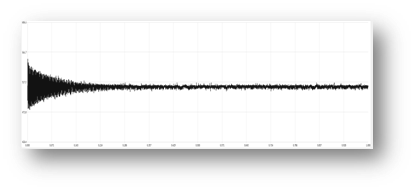
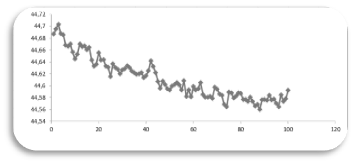


Fig.3. Tension meter Fig.4. Pulse attenuation graph



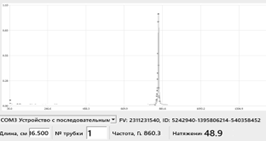


Fig.5. Graph frequency of oscillation of the thread Fig.6. The result of repeated

measurement of thread tension

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