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A COMPUTER-AIDED SYSTEM FOR MWPC WIRE TENSION CONTROL

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ABSTRACT

We report here on a semi-automatic system for the control and measurement of the wire tension in a large detector (23,000 wires) to be used by the UA1 Collaboration in an experiment at the CERN $\bar{p}p$ collider. The method consists in feeding an alternating current of variable frequency to the wire in the presence of a small magnetic field. The wire resonance frequency, which is simply related to the mechanical tension, is found by requiring a 90° phase shift between the driving current and the oscillation of the wire. The control procedure is computer controlled and can be applied to any large system of wire chambers where a precise ($< 1\%$) and fast measurement is needed.

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1. INTRODUCTION

For the experiment being prepared by the UAl Collaboration¹⁾ at the CERN $\bar{p}p$ collider, a set of drift chambers with image read-out is currently under construction. Figure 1 shows the chamber assembly, which consists of a self-supporting cylinder with a diameter of 2.3 m and a total length of 6 m. The cylinder is split in the horizontal plane and along the beam pipe into six half-moon sections. The arrangement and characteristics of the wires are represented in Fig. 2. For holding the assembly of almost 23,000 wires, a technique based on crimp connection of the wires has been used²⁾. The sense wires are held at a tension of about 80 g, already near the elastic limit (100 g), while all other wires are stretched to 230 g.

One of the most striking features of the system is the cylindrical shell of the chambers supporting the wires. It is a prestressed structure made of honeycomb (5 cm) sandwiched between two vetronite layers, each 1.5 mm thick. The amount of prestressing, which, after wiring, is entirely counterbalanced by the tension given to the wires, is such that in the median plane the distance between the chamber edges is reduced by about 80 mm. The construction procedure initially implies an external load (about 600 kg total) before and during the wiring. The final cylindrical shape, after the wires have been mounted and the load removed, depends on the equilibrium between the tension given to the wires and the stresses in the structure. This peculiarity obviously requires a strict control of the tension during the wiring and periodically afterwards.

2. TENSION CONTROL SYSTEM

2.1 Preliminary remarks

The methods used to control the wire tension³⁾ are generally based on the mechanical excitation of the wire [using, for instance, electromagnetic force (emf), loud speaker, gas jets, etc.], and the subsequent measurement of its natural oscillation frequency through either the emf induced in the wire vibrating in a magnetic field or the varying capacitance between the oscillating wire and a fixed electrode.

The above-mentioned systems are difficult to apply to wire arrangements not having a simple planar structure, since a short distance between the magnets or the electrodes and the wires is necessary. For our detector we have developed a method which, being sensitive to very small oscillation amplitudes (20-30 μm), involves little power and no high-voltage hazards, while it enables us to measure the natural frequency of the wires without the need of elements near them.

2.2 Description of the method

The mechanical oscillation frequency of a wire, fixed at both ends with a total tension τ , depends on its mass and length through the relation

$$T = 2L/n \sqrt{\mu/\tau} , \quad (1)$$

where

T = period of oscillation (s)

L = length of the wire (cm)

μ = linear mass density (g/cm)

τ = mechanical tension (dyne)

$n = n^{\text{th}}$ mode of the oscillation frequency.

A schematic representation of the set-up we use is shown in Fig. 3. The wires are excited by means of an alternating current in the presence of the magnetic field of a permanent magnet. As in any resonant system, the phase difference between the wire oscillation and the driving current goes through 90° at the resonance. To measure the phase we then use a laser beam associated with a photodiode so that a modulation in the photodiode response is produced when the excited wire starts to oscillate and moves away from the shadow of the neighbouring wires. Driving an oscilloscope in the x-y mode, with a signal from the current generator on the x-input and the photodiode response on the y-input, it is easy to follow the interference pattern (Lissajous figures) and hence to monitor the phase (Figs. 4 and 5). Since the method is sensitive to oscillation amplitudes of the order of the wire diameter, only a very low magnetic field is needed.

The oscillation amplitude A (cm) at the fundamental resonance frequency is given by⁴⁾:

$$A = \frac{2IB \Delta \ell Q}{\mu L c \omega_0^2}, \quad (2)$$

where

I = current (CGS units)

B = magnetic field (gauss)

$\Delta \ell$ = length (cm) of the wire central region where $B \neq 0$

μ = linear mass density (g/cm)

L = length of the wire (cm)

ω_0 = resonant angular frequency

c = velocity of the light (cm/s)

Q = Q-value of the resonance.

From Eq. (2) it turns out that for low-resistivity wires in which a relatively high current can flow (about 50 mA), the presence of the earth magnetic field alone (about 0.5 G) is able to produce detectable oscillations. This feature has been exploited to follow the tension behaviour of the whole chamber structure once new planes were added. However, as far as the control of the sense wires is concerned, because of their high resistivity (about 2 k Ω /m), a string of small magnets at a distance of about 10 cm is employed.

The block diagram of the electronics is represented in Fig. 6. To speed up the control procedure, a set of connectors and a multiplexing unit allow the current to flow into one wire at a time. A sine wave generator, controlled by a CAVIAR computer⁵), first produces a signal with the frequency equal to the expected resonance value; a frequency scan can then be started until the resonance conditions appear on the oscilloscope. At this stage the computer reads the frequency value and calculates the mechanical tension. The electrical resistance is also measured for the sense wires. In normal conditions about 350 wires/hour can be controlled.

An auxiliary software package gives the possibility of an over-all control of the tensioning operation through the display of plots, graphs, etc. (Fig. 7).

The over-all precision of the method is much better than 1%: actually a relative accuracy $\sigma = 1.5 \times 10^{-4}$ is achieved in the frequency measurement, as can be seen from Fig. 8 where the results of 100 consecutive measurements on the same wire are presented.

3. CONCLUSIONS

The system we have built allows a fast control of the wire tension with a precision much greater than the one obtained at the wiring, so that any anomaly can be detected immediately. Furthermore, the method is very sensitive, does not require any cumbersome apparatus, and offers an easy adaptability to many types of geometry.

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Figure captions

- Fig. 1 : Cut-away diagram of the central detector.
- Fig. 2 : Orientation and structure of the wires in the central and forward chambers.
- Fig. 3 : Schematic representation of the set-up.
- Fig. 4 : Time relation between the diode response and the driving voltage at the resonance. The picture refers to a sense wire ($R \approx 2.5 \text{ k}\Omega$, $\emptyset - 30 \text{ }\mu\text{m}$, length 1.5 m) in a plane of 350 wires.
- Fig. 5 : Lissajous figures showing the frequency scan of the driving emf around the resonance (central picture).
- Fig. 6 : Schematic block diagram of the electronics.
- Fig. 7 : Typical distribution of the tension for all sense wires (1000 wires).
- Fig. 8 : Distribution of 100 consecutive frequencies measurements at the resonance for the same wire.

Fig. 1

a) CENTRAL CHAMBER

b) FORWARD CHAMBER

Fig. 2

Fig. 3

← diode 0.5 V/cm

← driving voltage 5V/cm

→ 5 msec /cm

Fig. 4

$f_1 = 80.45 \text{ Hz}$

$f_0 = 79.65 \text{ Hz}$

$f_2 = 79.02 \text{ Hz}$

diode

↑ 0.5 V/cm

Voltage → 5 V/cm

Fig. 5

Fig. 6

Fig. 7

Fig. 8