MDT WIRE TENSION MEASUREMENT USING AN ELECTROSTATIC METHOD

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Abstract

An automated system to measure wire tension in MDT tubes is presented. The method uses electrostatic forces between wire and tube to excite mechanical oscillation around the wire harmonic resonance. A LC oscillating circuit is used to measure capacitance variation due to wire oscillation. Wire tension is determined by the frequency at which the wire reaches the maximum oscillation amplitude. Both the excitation and measuring circuits are controlled by a computer.

1. Introduction

In order to reconstruct the wire position along the MDT tube, the wire tension must be known with a high accuracy [1]. The tube assembly specification requires a nominal tension of 350 *g* with a tolerance of ±7*g*. The proposed system, originally designed and used for the KLOE drift chamber stringing control [2], has been optimized to measure wire tension during MDT chambers production. An amount of 96 BML chambers of the Atlas muon spectrometer have to be produced at LNF. Each chamber is made of about 300 drift tubes, 3.6 *m* long; this means that ≈ 30000 tubes have to be produced and tested. As a consequence an automated system to test wire tension during tube production has to be foreseen. A prototype with one channel has been realized and in the following the preliminary results are reported.

2. Method and measurement set-up

To excite the wire into the fundamental mode oscillation, a frequency scanning using a high voltage square wave (about 1 kV amplitude) is performed; minimum wire sag is required to induce wire oscillation inside the tube. The block diagram of the single channel set-up is shown in fig.1. The amplitude of the oscillation is sensed by measuring the capacitance variation in the wire-tube system. The change of the wire capacitance modulates a LC oscillator (sensor) coupled to the wire. By measuring the LC oscillator frequency in coincidence with two gates opened (by the high voltage modulator) when the high voltage is ON and when is OFF is possible to determine the oscillation amplitude. A computer operates the full measurement and the program, which controls the frequencies scan and perform the analysis is realized in the Labview environment. The difference between these two frequencies, which depends on the variation of wire capacitance and then on the oscillation amplitude, is plotted as function of the high voltage modulating frequency. Changing the high voltage frequency in small steps, an excitation curve of mechanical resonance of the wire is obtained and the resonance frequency is determined by fit. In fig.2, a typical resonance curve is shown.

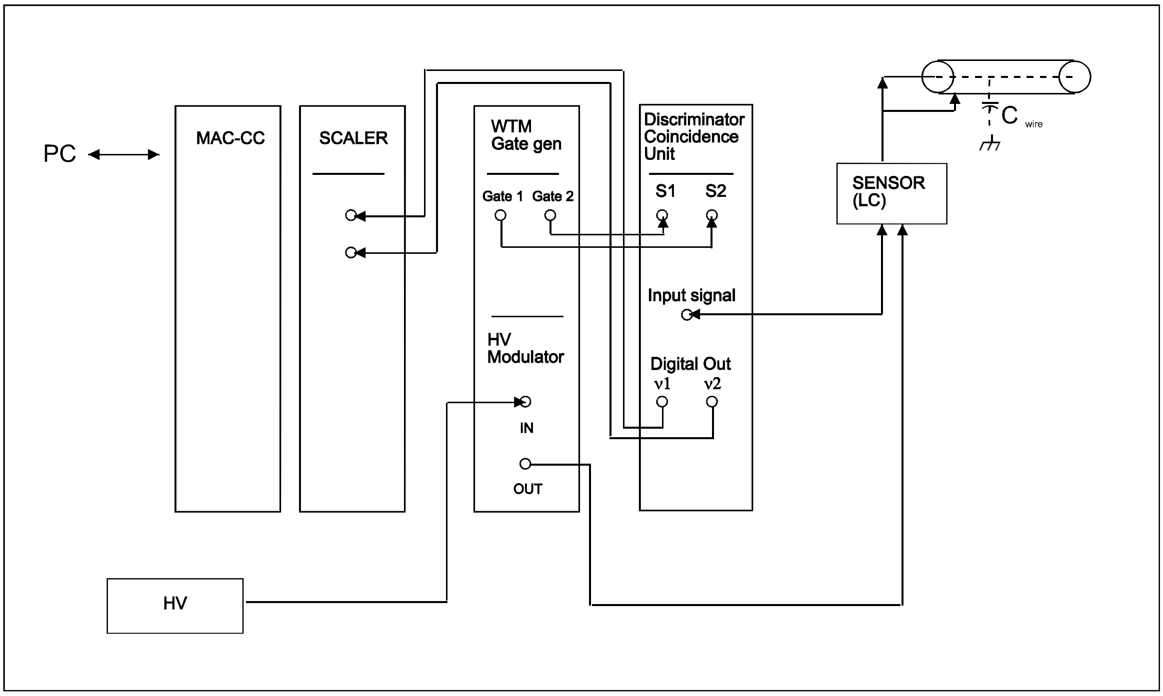
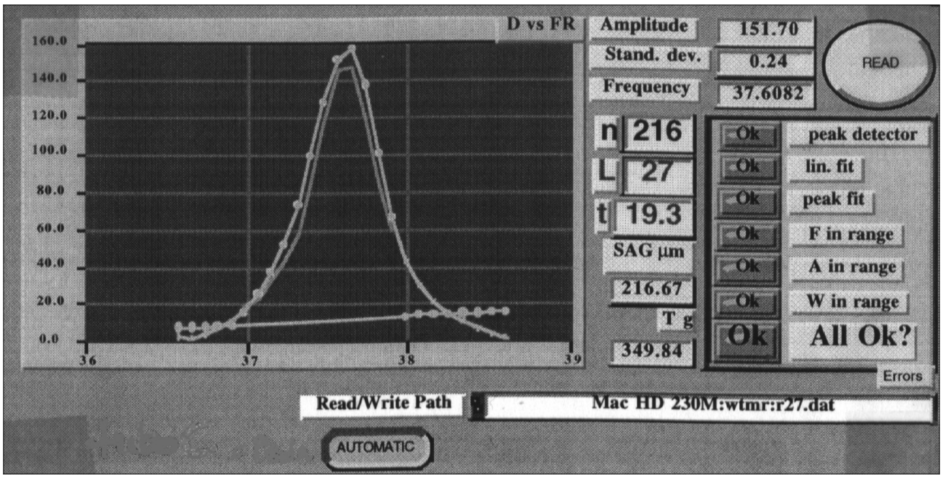


Fig.1 Single channel measurement set-up



Amplitude 151.70
Stand. dev. 0.24
Frequency 37.6082
n 216
L 27
t 19.3
SAG µm 216.67
T g 349.84
Read/Write Path Mac HD 230M:wtmr:r27.dat

Fig.2 Resonance curve for a single tube

The method has a high accuracy (0.1 %), a fast measuring time (30 sec per tube) and is completely controlled by computer. Moreover it does not require the use of magnetic field, so it can be used to measure wire tension of tubes assembled on MDT chambers.

3. Results

The relations between wire tension T (*g*), wire sag S (μm) and resonance frequency ν (*Hz*) are:

$$T = \frac{4\nu^2 L^2 \rho_{lin}}{9806.65}$$

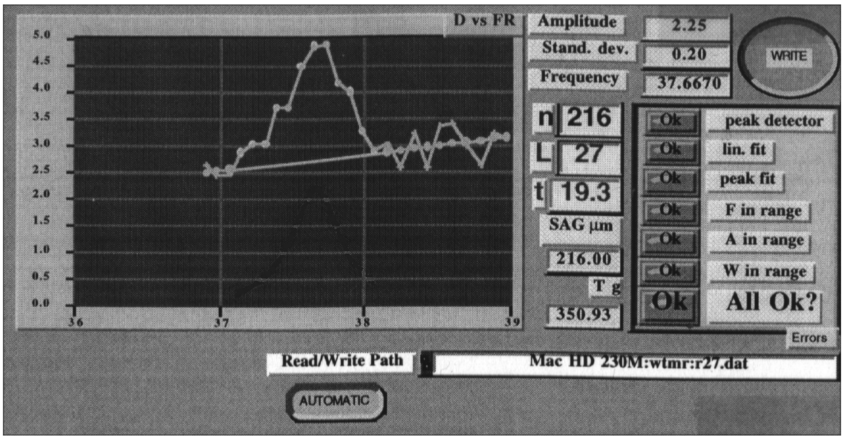
$$S = \frac{9806650}{32\nu^2}$$

where ρ_{lin} (*mg/m*) is the linear wire density and L (*m*) the wire length. The parameters used to calculate wire tension from the measured resonance frequency for the BML tubes are:

- L = wire length = 4.0 *m*
- wire diameter = 50 μm
- ρ = wire density (tungsten) = 19.34 g/cm^3
- ρ_{lin} = linear wire density = 37.9 *mg/m*

The nominal wire tension for the MDT tubes used in BML98 chamber prototype is 350 *g*, corresponding to a resonance frequency of 37.6 *Hz* and to a wire sag of 216.8 μm.

The wire tension meter has been tested to evaluate the overall measurement resolution in different conditions. First of all, tubes assembled on BML chambers have been measured when the chamber was on the jig. In this case the tubes are perfectly straight and the wire sag inside the tube is about 217 μm (@ 350 *g*). In fig.3, a typical resonance curve for a tube assembled on the BML chamber is shown.



Amplitude 2.25
Stand. dev. 0.20
Frequency 37.6670
n 216
L 27
t 19.3
SAG µm 216.00
T g 350.93
Read/Write Path: Mac HD 230M:wtmr:r27.dat

Fig.3 Resonance curve for a tube assembled on the BML chamber

Since we determine the wire tension from the resonance frequency, the absolute value of the frequency has to be known with high accuracy, then a crystal-based circuit is used to drive the HV modulator providing a very precise frequency setting.

The measurement resolution of the resonance frequency is 2×10^{-2} *Hz* (fig.4a), which corresponds to a resolution of 0.3 *g* on wire tension, as shown in the histogram of fig.4b, where a set of repeated measurements is reported. This value is well below the Atlas tube assembly specifications.

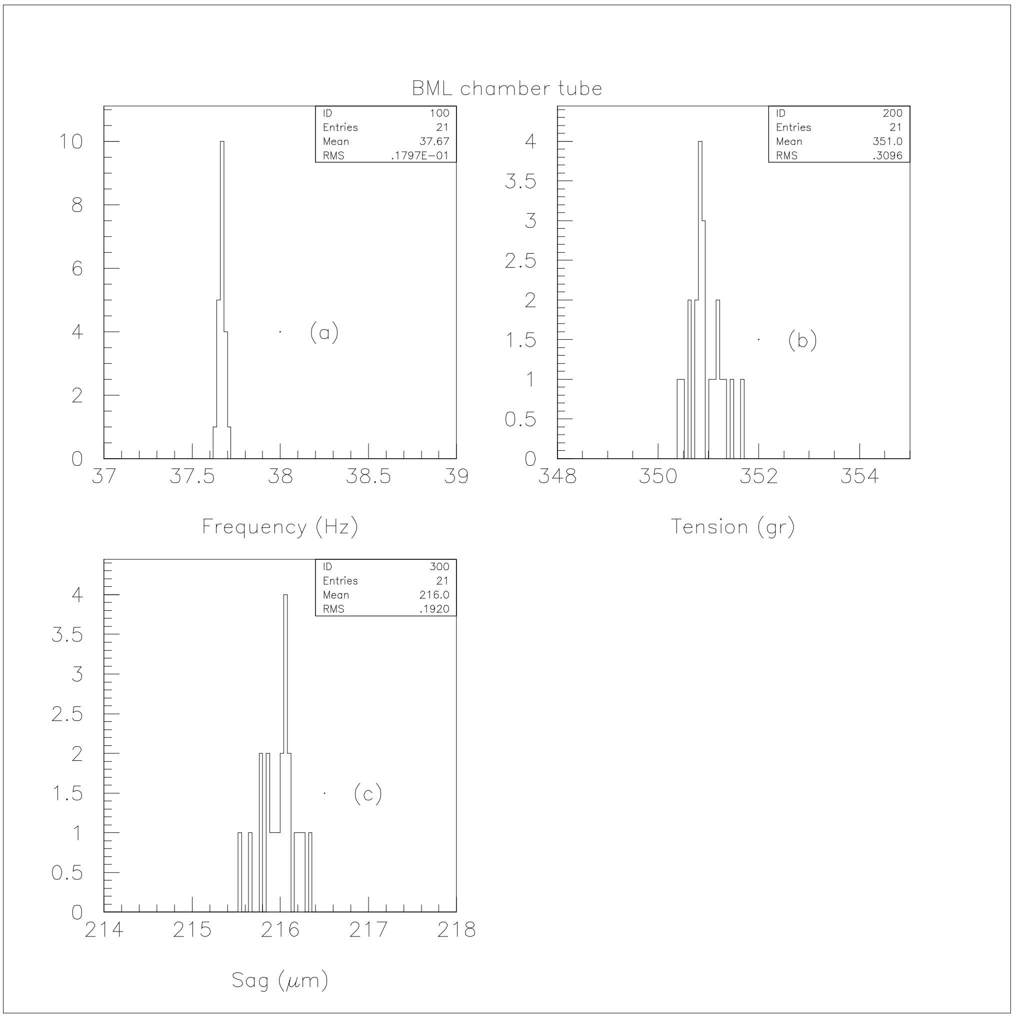
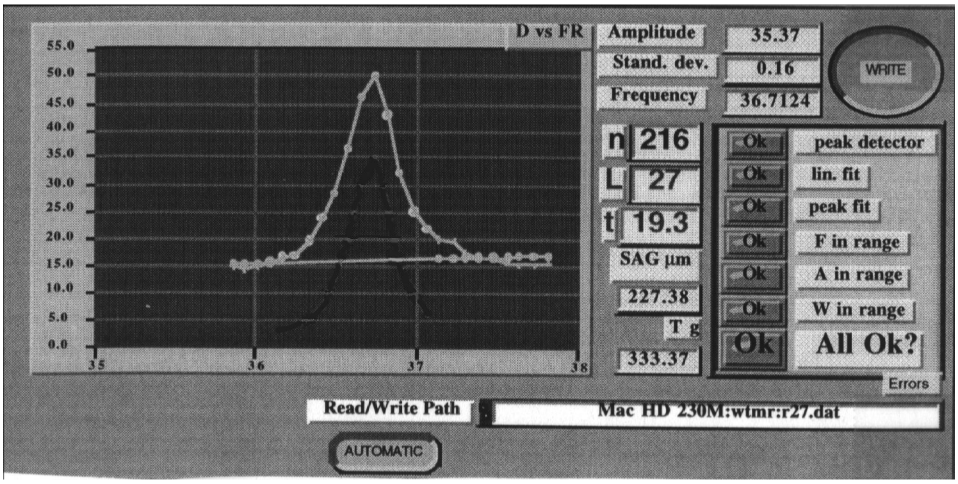


Fig.4 Resonance frequency (a), wire tension (b) and wire sag (c) for a BML tube

The previous results have been obtained for the BML tubes and in the specified measuring conditions. In different situation or for different tube lengths, a higher system resolution can be required. This can be obtained increasing the resonance curve amplitude, for example increasing the wire displacement respect to the center of the tube or rising the high voltage. To study the dependence on these parameters, measurements on single tube, 4 *m* long, have been performed.

The wire displacement can be obtained by mechanical handling of the tube. In fig.5 and fig.6 the resonance curves for a tube with and without a tube displacement of 500 μ*m* are reported.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Stand. dev. 0.16
Frequency 36.7124
n 216
L 27
t 19.3
SAG µm 227.38
T g 333.37
Read/Write Path Mac HD 230M:wtmr:r27.dat

Fig.5 Resonance curve with 500 μ*m* tube displacement

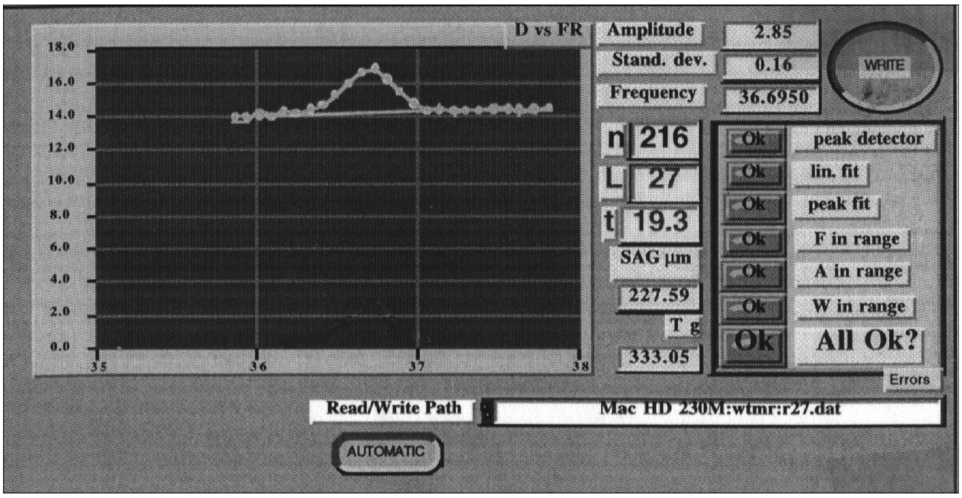
Amplitude 2.85
Stand. dev. 0.16
Frequency 36.6950
n 216
L 27
t 19.3
SAG µm 227.59
T g 333.05
Read/Write Path Mac HD 230M:wtmr:r27.dat

Fig.6 Resonance curve without (0 μ*m*) tube displacement

From these plots we can see that the resonance frequency is the same in both cases, but in the first one the amplitude of the resonance curve is greater giving a better resolution (fig.7 and fig.8) due to the higher signal to noise ratio.

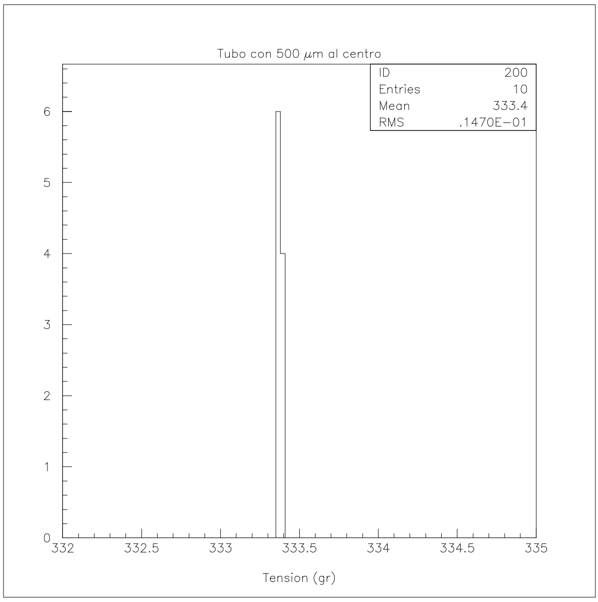

Fig.7 Resonance frequency with 500 μ*m* tube displacement

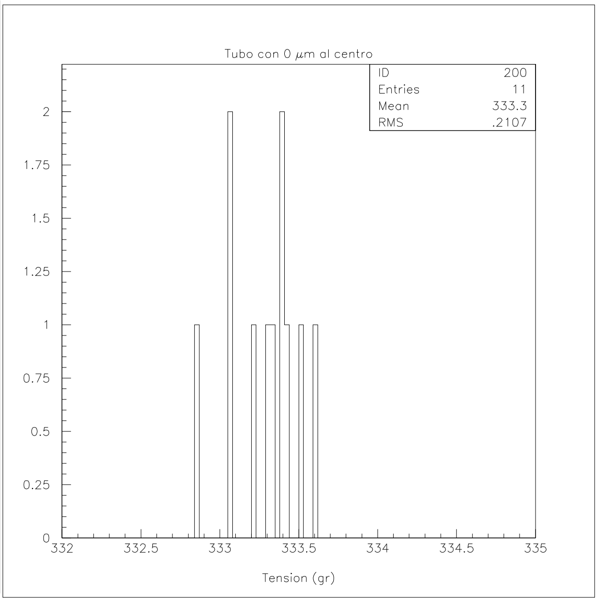

Fig.8 Resonance frequency without (0 μ*m*) tube displacement

The dependence on the high voltage modulating signal is shown in fig.9. As foreseen, the amplitude of the resonance curve increases with the high voltage, while the value of the resonance frequency is constant.

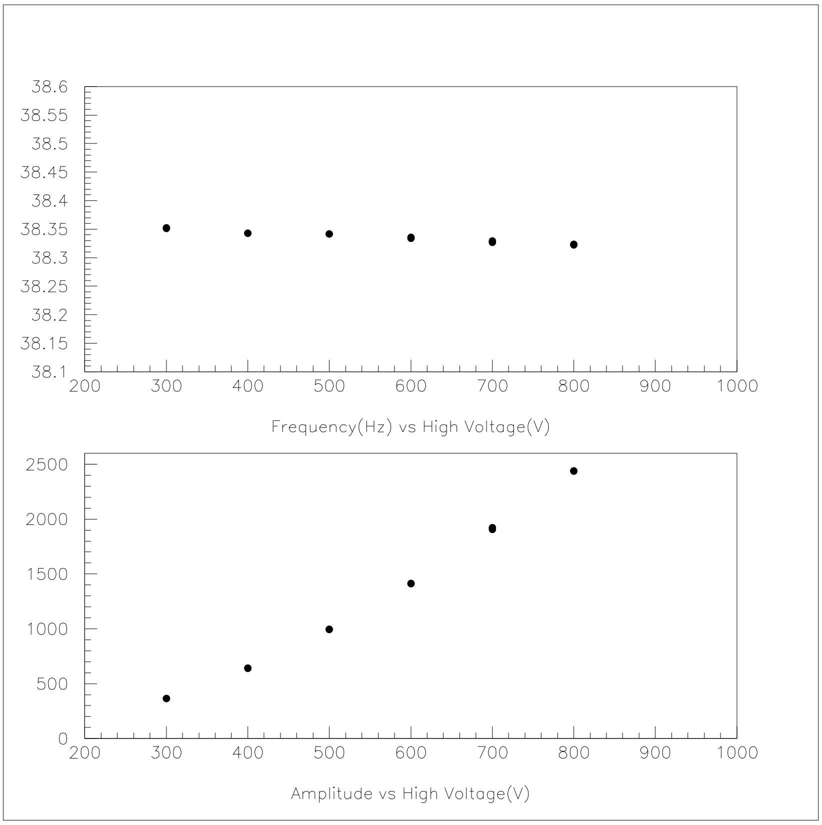

Fig.9 Resonance frequency and amplitude of resonance curve as function of the modulating high voltage

4. Conclusion

The proposed system, studied on the BML tubes, satisfies the requirements of the ATLAS quality control, providing a high accuracy measurement of the wire tension. Furthermore it does not require the use of magnetic field allowing measurements on assembled chambers. The system performance for others tube lengths has to be investigated.

5. Acknowledgements

We would like to tank M.Santoni, G.Paoluzzi and G.Papalino of the LNF “Servizio Elettronica” for their help with the construction of the wire tension meter prototype.

6. References

[1] ATLAS Collaboration, *ATLAS Muon Spectrometer Technical Design Report*, CERN/LHC/97-22 ATLAS TDR 10

[2] KLOE Drift Chamber Group, *Electrostatic digital method of wire tension measurement for the KLOE Drift Chamber*, KLOE internal note