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MEASUREMENT OF WIRETENSION IN DRIFT TUBES BY RESONANCE IN A MAGNETIC FIELD

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Measurement of Wiretension in Drift Tubes by Resonance in a Magnetic Field.

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Abstract:

Wiretension in drift chambers is commonly measured by observation of resonance frequency. In drift tubes, where the wire cannot be seen by eye, a vibration of the wire has to be detected in other ways. The method described here uses a simple bridge circuit for measuring the change in dc-resistance of the resonating wire. The decrease of the resistance (0.3 %) is due to self-cooling ($0.5^{\circ}C$) by convection when the wire starts swinging.

Introduction

The measurement of wire tension in proportional and drift chambers by observation of the resonance frequency has found a widespread use in detector construction for high energy experiments. The relation between resonance frequencies f_n of order n and wire tension F is given by

$$f_n = \frac{n}{2\ell} \cdot \sqrt{\frac{F}{\rho \cdot a}} \quad [\mathrm{Hz}] \ ,$$

where ℓ = wire length in cm
ρ = wire density in g/cm^3
$a = r^2$ = wire cross section in cm^2
F = wire tension in dyn = gcm/sec^2 .

If the wire stretching is done by hanging a weight of mass m in g on the wire end the formula reduces to

$$f_n = \frac{17.7 \cdot n}{\ell \cdot d} \sqrt{\frac{m}{\rho}} \quad [\mathrm{Hz}]$$

$d = 2r$ = wire diameter in cm.

For example, a 30 micron tungsten wire ($\rho = 19.3\ g/cm^3$) of 80 cm length streched by 200 g, has a basic resonance frequency $f_1 = 227$ Hz. In wire chambers, where the cathodes and anodes are both in form of wires, the observation of resonance can be done by eye. During construction, for example, a metal electrode is brought close to the wire and pulsed with high voltage (2 kV) of variable frequency. At the resonance frequency the swinging of the wire can be seen by eye. This method is in use at DESY during the construction of big drift chambers.

In drift and proportional tubes, nowever, the wire is electrically and mechaically shielded and cannot be seen by eye. The appropriate resonance measurement can be made in a magnetic field (a permanent magnet of 100 mT at the middle of the wire). The wire starts vibrating when the ac-current through the wire reaches the resonance frequency. Detection of the resonance can be done in different ways. One method, used at DESY by A. Krolzig and J. Swarsm determines the effect with an ac-bridge circuit by the generated induction voltage. A special amplifier for detection of the signal is needed.
In the following section we describe our method.

Measuring equipment and results

In Fig. 1 the bridge circuit for measuring the dc resistance of the wire is shown. The wire current has two components, a dc-current (30 mA) and an ac-current (30 mA) of variable frequency. Since both currents heat the wire by approximately 15^{0}C, the nulling of the dc-bridge has to be done with both currents turned on. For this procedure the permanent magnet (80 mT) is taken away, or the frequency of the ac-current is offset from the expected resonance frequency.
The temperature coefficient of the tungsten wire is $\alpha = 5\cdot 10^{-3}/{}^{0}C$, so that for a 15^{0}C rise the resistance of the wire is increased by 7.5 % = 6 Ω for a 80 Ω wire at room temperature. This does not change the wire tension appreciable, since the thermal expansion coefficient of tungsten is only $\lambda_{\text{tungsten}} = 4\cdot 10^{-6}/{}^{0}C$. It leads to a relative increase of the wire length of $\frac{\Delta\ell}{\ell} = 6\cdot 10^{-5}$ for 15^{0}C, which is 0.05 mm for a 800 mm long wire. This compares to the wire length increase of 5 mm due to the stretching, so that the resonance frequency is determined to 1 %.

The null instrument of the bridge circuit can be a simple ammeter or a chart recorder.
Fig. 2 shows a registration of the resonance with a chart recorder. The peak rise is approximately -12 mV or -0.2 Ω for the 80 Ω wire, which is equivalent to $\frac{\Delta R}{R} = 2.5\cdot 10^{-3} = \alpha \cdot \Delta T = 5\cdot 10^{-3}/{}^{0}C \cdot 0.5^{0}C$. The temperature of the hot wire decreases at resonance by about 0.5^{0}C, due to the better cooling of the swinging wire by heat convection in the surrounding air. It is also possible to register the first harmonic f_2, which gives a signal of comparable size, if the magnet is positioned at 1/4 of the wire length rather than in the middle. For a smaller current in the wire, the size of the resonance signal decreases, but the same

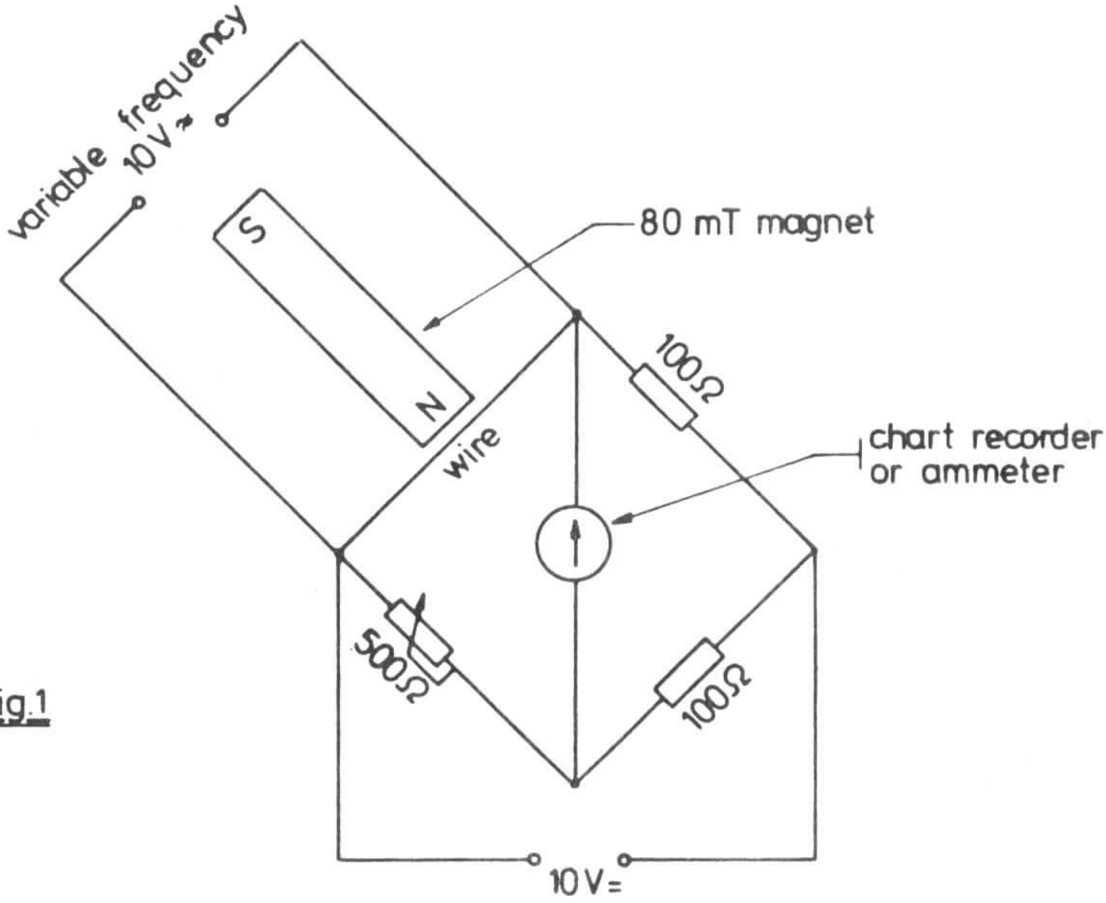
frequency within ±1 % is found.

The given explanation of the cause of the resonance signal can be proven by taking a stretched wire without surrounding tube. The signals in Fig. 3 have been produced by blowing air against the wire with the mouth or by waving the hand. The signals are of the same order in size. Fig. 3 also shows that this method is not practical for open wires, since any draught will disturb the resonance measurement. But for shielded wires this method is very simple, reliable and of high sensitivity.

Acknowledgements

We would like to thank A. Krolzig and J. Swars for bringing their method to our attention. We thank D. Hoppe and K.H. Wroblewski for setting up the measuring circuits and devices. Helpful discussion with P. Joos, W. Koch and K. Rehlich are acknowledged.

Fig.1



Bridge circuit for wire resonance measurement

Fig.2

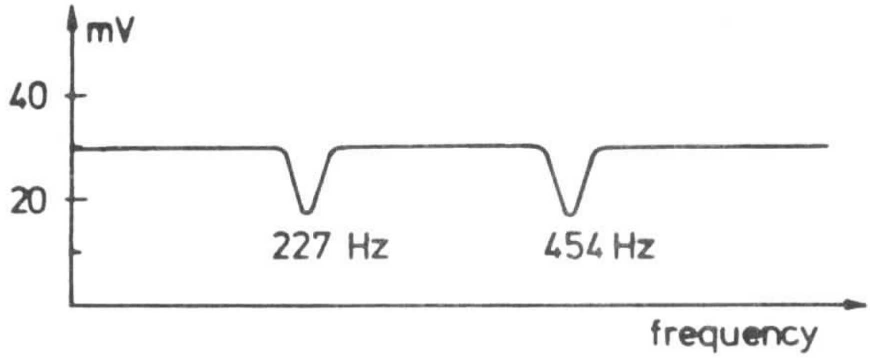


Fig.3