STRETCHED WIRE METHOD FOR MAGNET ALIGNMENT WITH MEDIUM FREQUENCY CURRENT

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Abstract

The stretched wire method is one of magnet alignment techniques. In alignment of the straight section, this stretched wire method is simple and even better in precision than modern instruments such as a laser tracker[1]. There are two ways to detect wire position. One is capacitance measuring method using semi-conductive wires, and the other is to pickup electric signals using metallic wires.

We are investigating simple and cheap hand-made stretched wire technique, in which we just stretch a thin metallic wire and feed alternating current of medium frequency. Signals are picked up by handmade pickup coils. Our aiming alignment precision is 0.1 mm.

Frequency dependence of resolution and precision is reported as well as effect of an ion plate placed nearby.

INTRODUCTION

The stretched wire method is one of magnet alignment techniques. There are two ways to detect wire position. One is to stretch a semi-conductive wire, and detect capacitance between two electrodes, between which the wire passes through. Change of the capacitance is converted to wire position. This kind of instrument has good precision of several tens of micro-meters, and can be purchased commercially. But the price is comparatively expensive.

The other way is to stretch a thin metallic wire and feed alternating current of some frequency to the wire. Signal is picked up by electrodes between which the wire passes through. Higher frequency gives us better resolution and better precision. But high frequency current requires co-axial structure in the stretched wire. By this reason, this technique is hard to be used in magnet alignment, but used only in monitoring the change of position.

We are investigating a magnet alignment method, in which we stretched a thin metallic wire without coaxial structure, and feed alternating current of some medium frequency. With higher frequency, better resolution and better precision can be obtained, but it becomes harder for a long wire to propagate current. With lower frequency, situation is vice versa. Signals are picked up by handmade pickup coils. This system can be made cheaply. Our aiming precision is 0.1 mm, which is enough for usual magnet alignment in the accelerator.

In the following, frequency dependence of resolution and precision, and effect of an ion plate placed nearby are reported.

EXPERIMENTAL SETUP

Fig.1 shows the setup of the experiment.

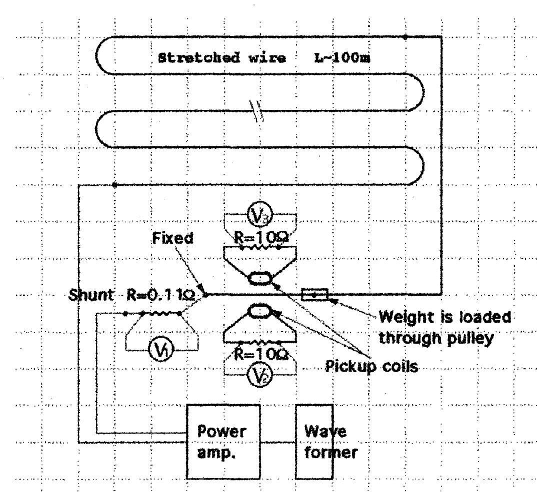

Fig.1: Schematic drawing for the experimental setup

A brass wire, which had diameter of 0.3 mm and length of 100 m, was stretched. A brass wire was selected due to its low volume resistivity of 7.0×10^{-8} Ωm and large tensile strength of 52-77 kg/mm^2. A 0.8 m long part of the wire was stretched strongly by loading weight of 2 kg. One end of this part is fixed to the base of the wire support rod and the other end is connected to the weight through pulley. The fixed end is connected to the power supply through a shunt resistor. The rest part of the wire was stretched rather loosely between two plastics fences standing 10 m apart each other. One end is connected to the power supply, and the other end to one end of the 0.8 m wire part. Total length of the wire is about 100 m.

In pickup coils, copper wire of 0.4 mm diameter was wound 300 turns around bobbins of 82.83 mm circumference. Two pickup coils are fixed 40 mm apart each other on a movable support. Position of the support in the direction perpendicular to the wire is measured by a micro-meter.

A wave former, AFG 310 of Sony-Tektronix, produces alternating current with arbitrary frequency, which is fed to a power amplifier, BSW 60-5 of Takasago Ltd. Both ends of the wire are connected to the output terminals of the power amplifier. The current in the wire is observed by measuring voltage, V1, between both ends of a shunt resistor of 0.11 Ω. Output from pickup coils is observed by measuring voltage, V2 and V3, between both ends of resistors of 10 Ω, which terminate pickup coils. Voltage is measured by a digital multimeter 2000 of Keithley, and sometimes observed by a digital oscilloscope, TDS 380P of Sony-Tektronix.

EXPERIMENTAL RESULTS

Resolution

Observing the multimeter display, we found the stability of output is ±1 μV (the least digit). This value can be converted to corresponding space resolution using a calibration constant described in the following. Obtained space resolution is shown in Fig. 2 as a function of frequency of alternating current fed to the wire.

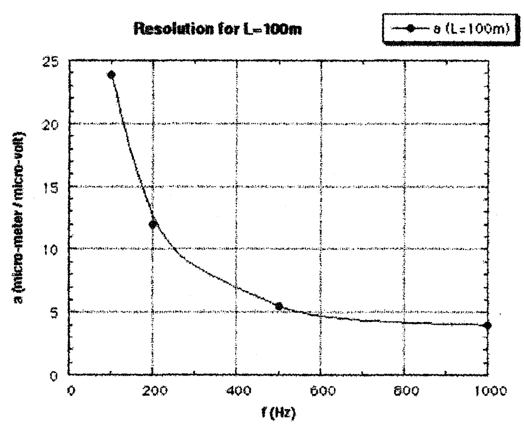

Fig.2: Resolution for L=100m

Precision

Fig. 3 shows some example of analysis results of data. Difference between output from two pickup coils (V2-V3), and deviations of each data points from a fitted line are shown as a function of the position (X) of the coil support. Fig. 3(a) is for the frequency 100Hz of alternative current fed to the wire, and (b) for 1kHz. Measurement was executed for the frequency, 100Hz, 200Hz, 500Hz and 1kHz. Each plot was fitted to the linear form Y = M0 + M1 ·X. The same measurement was executed with an ion plate, 4 mm thick and 910x1090 mm^2 wide, placed above the pickup coils at various height.

Standard deviation in linear fitting is shown in Fig.4 as a function of frequency, where the blue solid triangles show results with the ion plate placed as far as 700 mm above the wire, and solid red circles show results with the

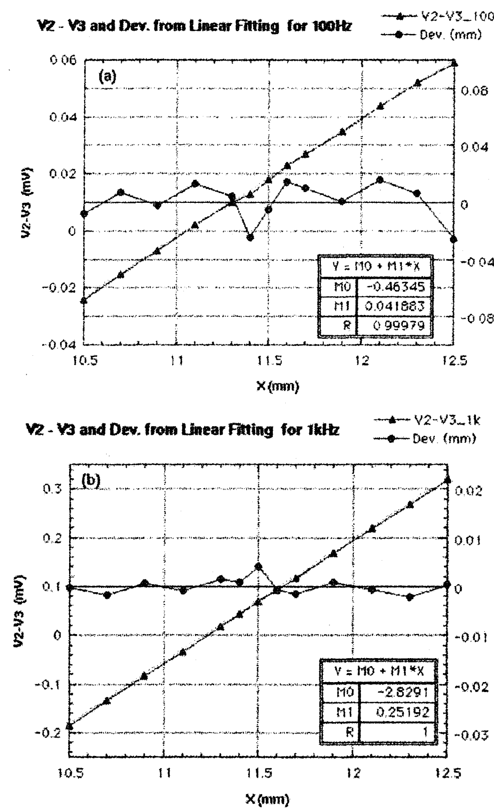

Fig.3: Difference between output from two pickup coils, V2-V3, (blue triangles), and deviations of each data point from linear fitting (red circles); (a) for the frequency 100Hz and (b) for 1kHz.

ion plate placed 50 mm above. Higher frequency gives better standard deviation. The standard deviation is better than 5 μm for the frequency higher than 500Hz. But improvement with frequency higher than 500Hz is small.

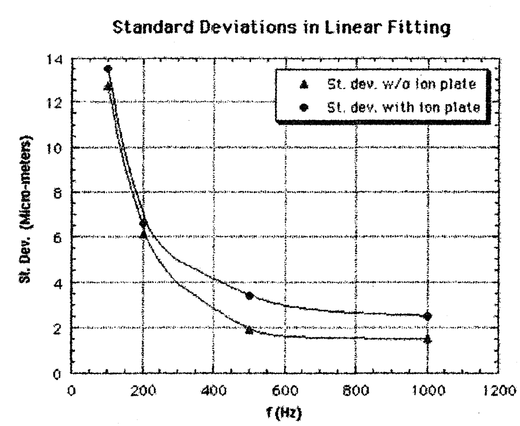

Fig.4: Standard deviations in linear fitting. Blue triangles show those without an ion plate, and read circles with an ion plate placed 50 mm above the wire.

An ion plate placed above the pickup coils does not degrade the standard deviation much.

Fig.5 shows the variation of zero-cross point as a function of wire current frequency. The zero-cross point, X_0, is defined as X-position where the output from two pickup coils are balanced.

$$X_0 = -M0/M1$$

This variation might be caused by ion material used in the base part of the coil support.

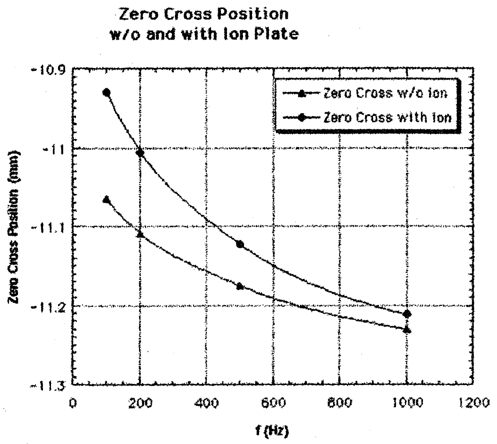

Fig.5: Variation of zero cross point as a function of wire current frequency. Definition of markers is the same to that in Fig.4.

Effect of ion plate

Change of coil output was measured with various height of an ion plate. Fig. 6 shows the change of (V2-V3), which is converted to the spatial unit by the formula

$$X = (Y - M0)/M1,$$

where Y=V2-V3, and M0 and M1 are coefficients in linear fitting. Wire current frequency was changed from 100Hz to 1kHz. X-position of the coil support was fixed. If the height of an ion plate is larger than 200 mm, change is less than 0.07 mm.

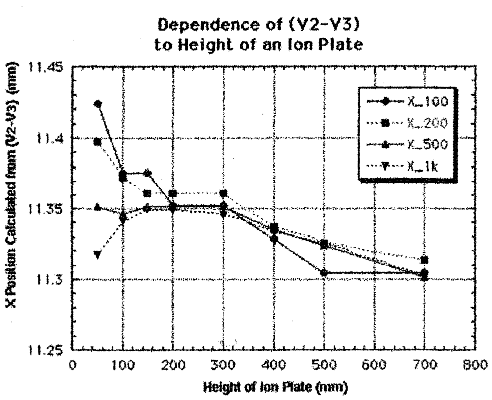

Fig.6: Change of X-position calculated from (V2-V3) with variation of height of an ion plate. Four curves show those for wire current frequency of 100Hz (circles), 200Hz (squares), 500Hz (triangles) and 1kHz (reversed triangles), respectively.

SUMMARY

Cheap stretched wire technique without coaxial structure was studied as a magnet alignment method with precision of 0.1 mm. A thin brass wire of 0.3 mm diameter was stretched over distance of 100 m. Alternating current of various frequency from 100Hz to 1kHz was fed to the wire, and the frequency dependence of the pickup signal was measured, because it is conceivable that high frequency alternating current might be hard to propagate long non-coaxial cable. And it is also conceivable that the system night be affected by ion material, such as magnets, placed nearby. So the effect of an ion plate was also studied.

Attenuation of alternating current due to high frequency is only about 10% in case of 1kHz for the wire length of 100m. The resolution is about 24, 12 and 6 μm for 100Hz, 200Hz and 500Hz, respectively. Frequency higher than 500Hz does not improve resolution much. Change of zero-cross point of about 0.2-0.3 mm is observed when the frequency is changed from 100Hz to 1kHz. Although this change might be caused by ion material in the pickup coil support, further investigation is required. Dependence of X-position, calculated from (V2-V3), to height of an ion plate is less than 60 μm for the height larger than 200 mm.

It is found from this experiment that our aiming precision 0.1 mm is achievable with a stretched wire technique of non-coaxial structure for the length of 100 m

ACKNOWLEDGEMENT

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REFERENCES

[1] K. Egawa et. al., "Magnet system for the KEKB main ring", Nucl. Instrum. & Methods in Phys. Research A 499 (2003) P24-44.