THE S.I.N. FAST MAGNETIC FIELD MEASURING SYSTEM

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Introduction

For automatic and fast magnetic field measurements and data collection on magnetic beam transport elements a computerized high precision measuring device was designed and constructed a few years ago.

Originally intended to perform point by point measurements - by using coil or Hall-probe as a field sensor - the positioning device is able to deliver the field date at moderate speeds. However, for precision magnets with different correction elements (shims, trimm-coils), it was necessary to produce numerous field maps, in which case the time factor became very critical. Therefore, efforts were made to speed up the measurement procedure.

Using a fast sampling DVM, the system was changed to perform measurements in so-called flying mode. The data collection at predetermined points during the measuring machine motion has shortened the overall measuring time by more than a factor three. Another factor four will be achieved by the use of a new gear box for the stepping motor with a lower gear ratio.

Measuring System

In order to perform field measurements with a resolution of 1 : 10^4 or better, special precautions must be taken in the construction of the mechanical as well as the electronic part of the system.

The mechanical part consists of a probe positioning device sliding on compressed air bearings without mechanical contact or hysteresis over a precisely flat machined granite block. This machine (Fig. 1) can move the measuring probe (Hall-probe or coil) with 5 degrees of freedom (3 cartesian, 2 circular) by means of stepping motors.

In order to avoid during the measurements unwanted displacements between the machine and the magnetic element, an iron reinforced concrete block serves as a common fundament for the granite block and the magnet.

The concrete fundament itself is supported by an automatic level regulating compressed air spring system by means of which the complete arrangement acts as a seismic block. Soil vibrations from the vicinity are sharply damped for frequencies higher than 1,5 Hz (mechanical low pass filter).

Furthermore, the spring system compensates for different loads of various magnets and/or for the measuring machine load displacements, keeping the device and the magnet always in horizontal position.

The electrical part consists of a position detecting and display unit, stepping motors (with motor driving units), mini computer with interface system and a DVM. In case of Hall-probe measurements, a constant current source and a water thermostat for coil measurements an electronic integrator is used.

Measuring Procedure

Originally, every point in a particular plane was individually positioned. In case that after a predetermined number of pulses from the computer an over- or under-shoot in respect to the wanted position resulted, a correcting subroutine was started. Once the exact position was achieved, the DVM (type SM215 with 1 µV resolution and 400 ms acquisition time was enabled and digitized data transferred to the computer (8421-BCD code).

The overall average measuring time thus obtained, i.e. the time required to move the machine from one point to the other, correction time as well as calculating, punching and printing time (in respect of one point) amounted to 10 sec. For large precision bending magnets with approx. 2500 mesh points per field map this added up to almost 7 hours measuring time.

The whole measuring procedure is controlled by a Hewlett-Packard HP 2114 B (8K-version) minicomputer in the ON-LINE mode, using the program MADAM (Magnetic Data Measurements). In the first part of this program the operator enters the measurement and control parameters and the comments. When the machine is ready to start, the second part of the program is called. There are two options of measurement:

1. one can take values of the magnetic field or gradients with an integrating coil. This coil is moved stepwise from one point to the other in any direction chosen before. In order to get better accuracy the coil can also oscillate several times around a certain measurement position. The average value is accepted and random errors are omitted.
2. For most of the bending magnets field maps in x, z-coordinates are measured with a Hall probe. Again, the computer drives the machine from one point to the

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other. At each position it stops the machine, checks the position and - if necessary - corrects it. It then reads the DVM value and after appropriate format conversions and calculations it stores the induction value in Gauss units into the memory. This procedure is repeated until the end of each z-path, where all value undergo a smooth check. If no errors are encountered, the values are transferred to a magnetic tape unit or a paper tape punch according to S.I.N. standard format specifications[1]. Afterwards, the machine has to go into the next x-position, where the measurements along the z-line continue. As an option, a plot of the induction vs. z-path can be made on the display (and hard copy) unit.

Improvements

Due to the unsatisfactory large time consumption, efforts were made to speed-up the measurements.

The first modification in the system was made by using a fast sampling DVM type Hewlett-Packard HP 3480 D (110 ns sampling time, 1 ms acquisition time, 10 μV resolution). This DVM enables to collect data during continuous drive of the machine ("flying mode") along a line. The points of a map are then covered by meander-like movement of the machine.

The obtained higher moving speed of the machine leads to a considerable time saving, while acceleration and deceleration take place only once per measuring line. The overall average measuring time per point amounts now only roughly 2,5 sec, totalling to one hour and 50 min. for a 2500 mesh point field map. This value is achieved with the maximum allowable speed of the stepping motor (3000 pps).

The Hall-probe (type SBV 579) sensitivity at 80 mA is approximately 10 μV/G, so 1 : 10^4 measurements at a level of 15 kG can be achieved with the above DVM The positioning error of ± 5 μm leads in gradient fields up to 1 KG/cm to an additional measuring error of 1 G or less.

For purposes of the new measuring system a part of the computer program had to be changed. The new program FAMA (Fast Magnetic Field Measurements) makes use of the 10 μm pulses, which are transmitted by the position detecting system ("Inductosyn"). These pulses act as interrupt signals, which interrupt the main program in order to call the pulse count subroutine. After a predetermined number of pulses (corresponding to the mesh distance) the computer triggers the DVM, which in turn reads the Hall-probe voltage and proceeds it back with an interrupt signal to the computer (from here the program remained generally unchanged).

Fig. 2 shows the logical scheme of the system. The position detecting system as well as digital voltmeters used to have a full scale resolution of six decades, i.e. 24 BCD lines. Because the HP 2114 uses 16-bit words, processing in two steps has to be made.

Future Prospects

The present speed limit is given by the gear ratio, which was designed to allow a sudden application of the maximum speed of the stepping motor. A new gear box with a lower gear ratio, which will exploit the maximum available stepping motor torque is under construction. The use of this gear box will imply that the acceleration of the machine must take place smoothly.

In spite of a certain time loss due to the latter effects, one can expect the overall average measuring time to be reduced to 0,7 sec, leading to less than 30 min. for a 2500 mesh points field map.

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References

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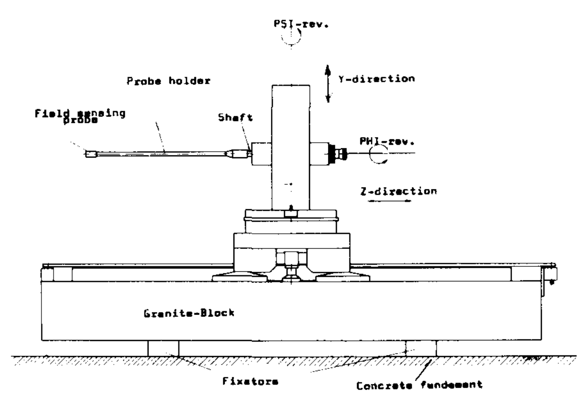

Fig. 1 The Measuring Machine

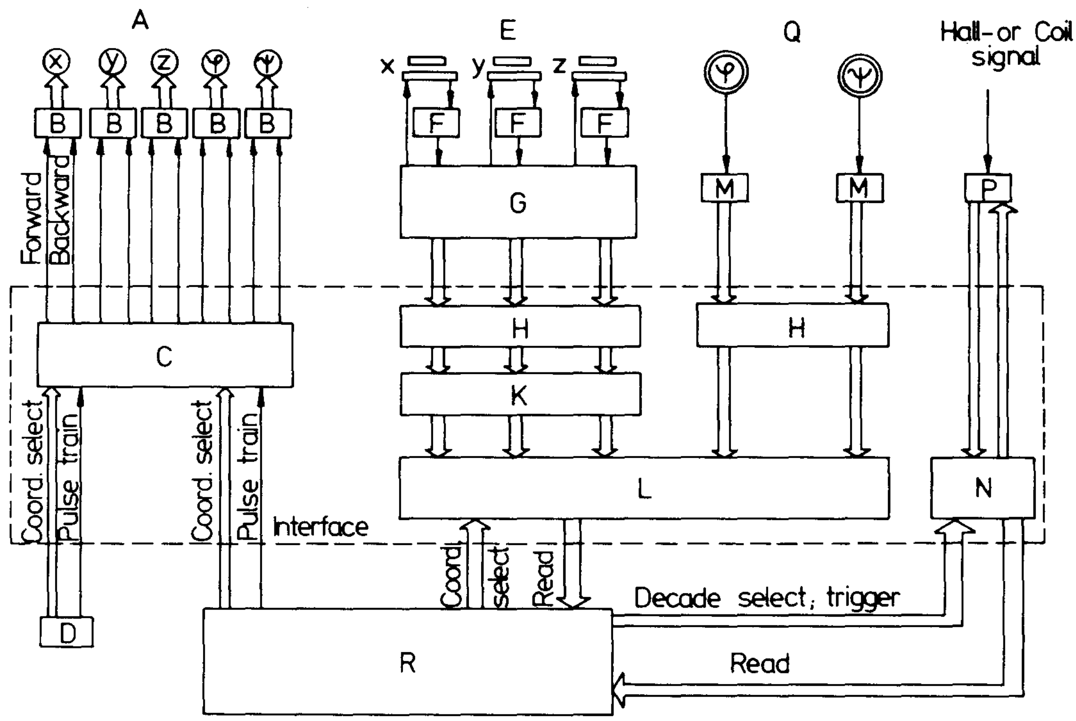

Fig. 2 The Logical Scheme

Figure Captions

A - 8-phase stepping motors for 5 axis

B - Motor drive units

C - Positioning multiplexer

D - Manual command unit

E - "Industosyn" position detecting sliders

F - Preamplifiers for position signals

G - Main position detecting and displaying unit

(The dotted line shows the interface unit)

H - Filter and matching

K - "1 out of 5" to BCD decoder

L - position detecting multiplexer

M - Scalers with display for rotational axis

N - Data multiplexer

P - DVM

R - Computer

Q - Shaft encoders