THE MARK II AUTOMATIC DIFLUX

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ABSTRACT

We report here on the new realization of an automatic fluxgate theodolite able to perform unattended absolute geomagnetic declination and inclination measurements: the AUTODIF MKII. The main changes of this version compared with the former one are presented as well as the better specifications we expect now. We also explain the absolute orientation procedure by means of a laser beam and a corner cube and the method for leveling the fluxgate sensor, which is different from a conventional DIflux theodolite.

Keywords: Autodif, Geomagnetism, Magnetometer, Theodolite, DIFlux, Fluxgate

1 INTRODUCTION

The magnetic field of the Earth being a vector quantity, it requires evaluation of its modulus (total field F) and its direction (declination D and inclination I). The first is commonly measured absolutely and automatically with a proton magnetometer. The variations of the field direction are generally recorded automatically too, but its absolute determination must still be carried out manually, using a DIFlux theodolite magnetometer. If this last instrument could be automated, it would become possible to establish completely autonomous magnetic observatories, working without need for an operator.

The experience we had with the construction and operation of the first commercial automatic DIflux MKI has been useful. Concepts, hardware, and software solutions have been validated: laser pointing to a corner cube target, nonmagnetic optical angle encoders, the user interface, etc. The main weak point of the MKI was the unreliable operation and short lifetime (<1000 hours) of the ultrasonic motor selected in that design. Another source of problems originated in undesired torques from randomly twisted wires, passing the electronic signals from the lab reference to the rotating sensors (fluxgate, levels, photocells, etc.). They were negatively affecting the attitude of the alidade in the MKI.

2 PRESENTATION OF THE AUTODIF MKII

For the MKII, as presented on the schematics of Figure 2, the decision was taken to change to more reliable motors. We made a search for new nonmagnetic motors and another brand of ultrasonic nonmagnetic actuator was found (Figure 1). For this new motor device, the manufacturer claims a lifetime longer than 20000 hours and operation down to nanometer displacements. However, due to the tangential operation mode of this motor, the mechanical design of the theodolite had to be completely renewed, including the vertical and horizontal axes, where ceramic bearings were adopted.

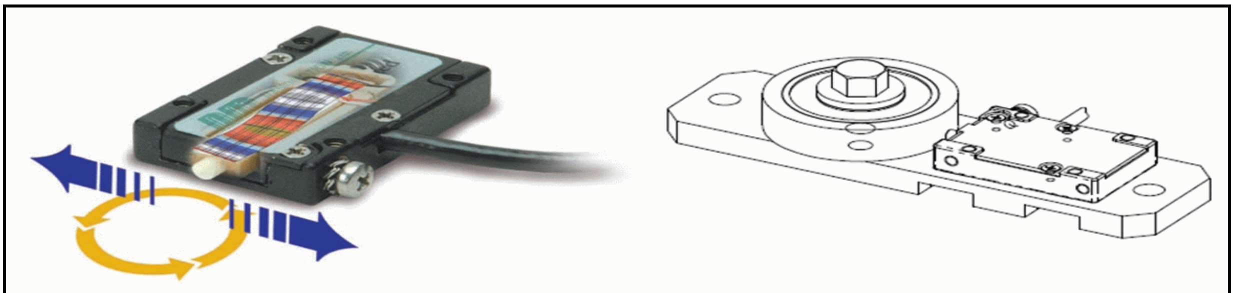


Figure 1. The newly adopted ultrasonic motor (left). The tangential motion of the tip is transformed to a rotation by driving a ceramic annulus (right).

3 INCREASED ACCURACY EXPECTED

The fact that the rotation axes are precisely defined by end-located precision bearings allows us to expect better control of the theodolite positioning and as a result a five-fold increased absolute accuracy over the MKI (which had an error budget of 0.1 minute of arc).

The passing of electronic signals from the lab reference to the rotating sensors (fluxgate, levels, photocells, etc.) is now done by a well controlled rotating contact system.

As in the previous designs, custom nonmagnetic optical encoders and chrome graduated glass disks are used for reading the orientation on both axes with accuracy not worse than 1 arc second. Two diagonally located reading stations are used on the disks so as to eliminate eccentricity errors.

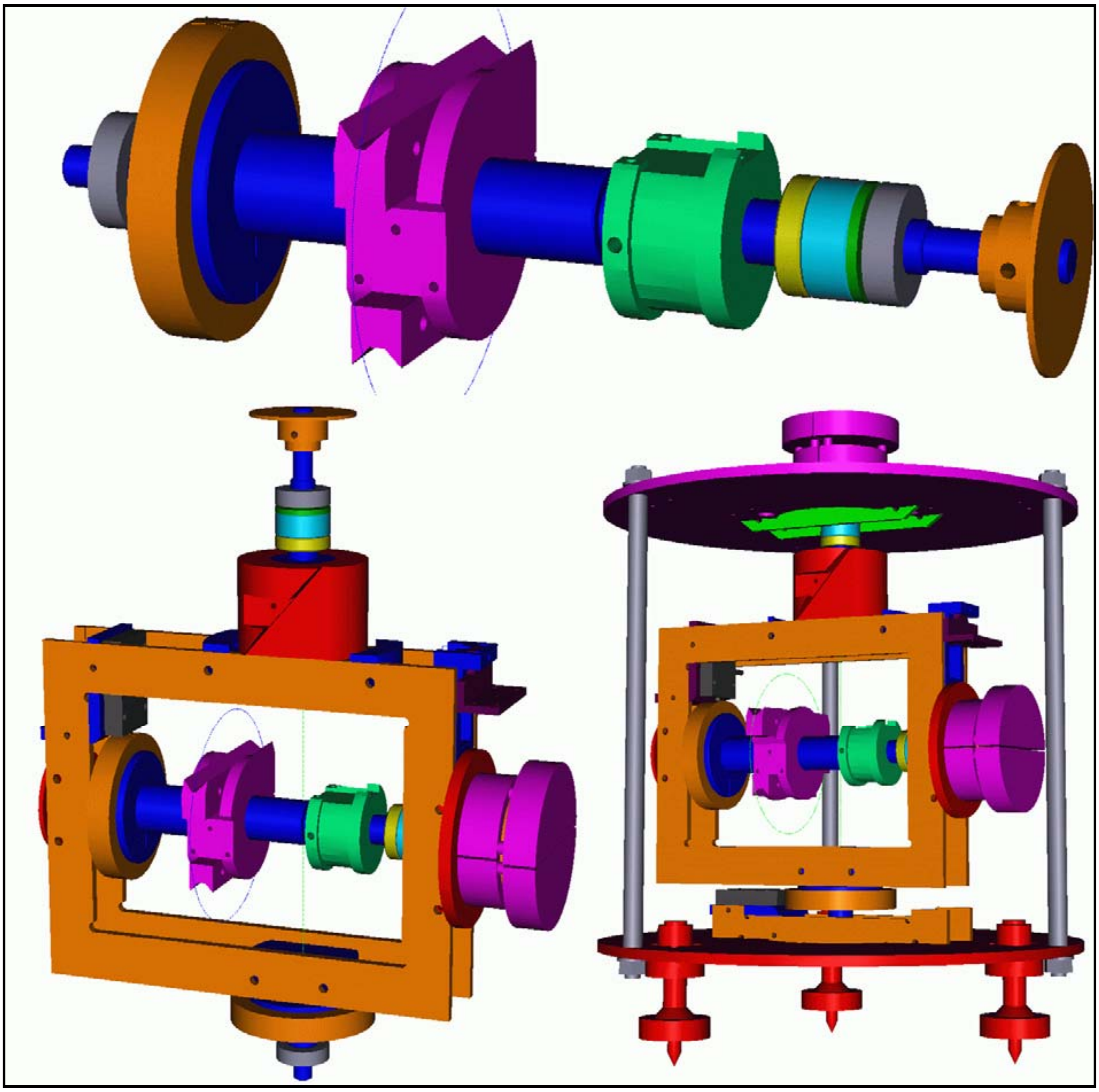


Figure 2. The mechanical design of AUTODIF MKII. Top drawing: the horizontal axis. On the axis left is the ceramic annulus for motor drive (brown) and the encoder disk is at the extremity to the right (also brown). The green cylinder takes up the rotating contact system. In grey, the ceramic bearings. Left drawing: the alidade with the vertical axis added. The violet bracket above the horizontal axis encoders is for mounting the electronic level. The black device is the ultrasonic motor. Right drawing: the complete instrument with the stator added. In red the leveling screws. The magenta parts are the fluxgate/laser holder and the dual optical angle encoders.

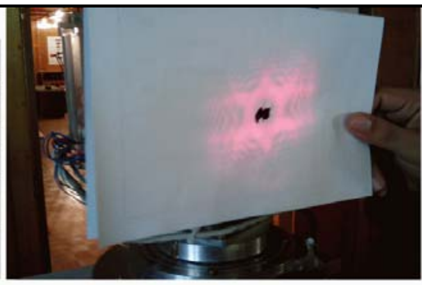
As has been demonstrated in a paper (Gilbert & Rasson, 1998), any element of a DIflux performing the same plungings as the fluxgate may be magnetic without affecting the DIflux measurement accuracy. The effect of these magnetic parts will be lumped into the "sensor magnetisation error" of the DIflux fluxgate sensor and eliminated by the DIflux measurement protocol. This allows us to use magnetic elements as long as they are an integral part of the horizontal axis and are following exactly the fluxgate in its motions. The magnetic parts on this axis are the sensor connectors for the rotating contact, laser and fluxgate as well as the graduated disk.

4 SPATIAL ORIENTATION: HOW TO?

The horizontal reference is provided by a nonmagnetic electronic level with adequate stability and sensitivity specifications (Figure 3). The level is mounted directly on the horizontal axis encoder so it can additionally monitor any deviation from the encoder index due to stator tilts (Figure 2, left).

SX-003D Specifications:

Specification	Data	Comments/units
Range	-3 to +3	arcdeg monotonous
Range	-0.5 to +0.5	arcdeg linear typical
Resolution	< 0.5	arcsec typical
Repeatability	< 0.0003	arcdeg typical
Linearity	< 10% @ 0.5	CCW & CW
Symmetry	< 15% @ 0.5	CCW & CW
Response time	< 15 msec	msec * #
Time constant	< 100 msec	msec ** #
Tot. settling time	< 500 msec	msec *** #
Temperature	-55 to +125	deg C operational
Temperature	-55 to +125	deg C storage
Construction	Flat mount	Advanced ceramics
Size	1.5"L x 0.5"W x 0.25"H	



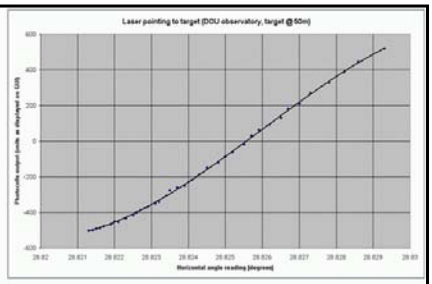


Figure 3. Spatial orientation of the AUTODIF MKII. Left: the specifications of the nonmagnetic electronic level monitoring the verticality. Middle: Orientation with respect of True North using the laser pointing device. The orientation with respect to the azimuth mark is done by a laser beam, reflected by a corner cube 50m distant and picked up by a set of differential photocells (a white screen has been inserted to show the reflection pattern at the DIflux). Right: Differential photocell voltage output of the pointing device versus the orientation of the laser (horizontal angle at a scale of 0.001°/div). The orientation sensitivity is clearly better than 1 arc second.

The orientation with respect to the geographic meridian (geographic north) is as usual via the use of a target with known azimuth. The sightings with a telescope are replaced by a laser beam shooting on a corner cube reflector (Figure 3). The reflected light is analyzed by a split photocell mounted around the laser. In order to eliminate ambient light fluctuations, the laser beam is modulated, and the reflected light is filtered by a synchronous detector.

How do we adjust the horizontality of the vertical circle index? We perform this adjustment by using the very direction of the geomagnetic field. By performing an inclination baseline measurement of our observatory variometer, following the DIflux protocol, we find the site error (epsilon) of the MKII. This error reflects the angle between the optical axis of a conventional theodolite (in our case the laser beam) and the magnetic axis of the fluxgate. It is then sufficient to zero epsilon simply by adjusting the index of the horizontal encoder. This can be done coarsely by a mechanical adjustment and finely by a software operation.

5 PACKAGING AND TRANSPORT

The AUTODIF MKII sensor has been designed as a self-contained cylinder of 260 mm diameter and 300 mm height. The cable connecting it to the electronics console is at minimum 10 m long. The electronics are housed in a custom box supplied by a 12V 7AH battery.

This console is connected to the controlling PC by a single USB connection. The console has been designed for easy access to the individual boards, by opening up like a book (Figure 4). This is a convenient aspect in the debugging and trial phase.

Both console and sensor are packaged for transport in an im2750 Storm Peli-Case. This robust set-up allowed us to transport the MKII without trouble from Belgium to Changchun and back so that it was possible to demonstrate it there (Figure 5).

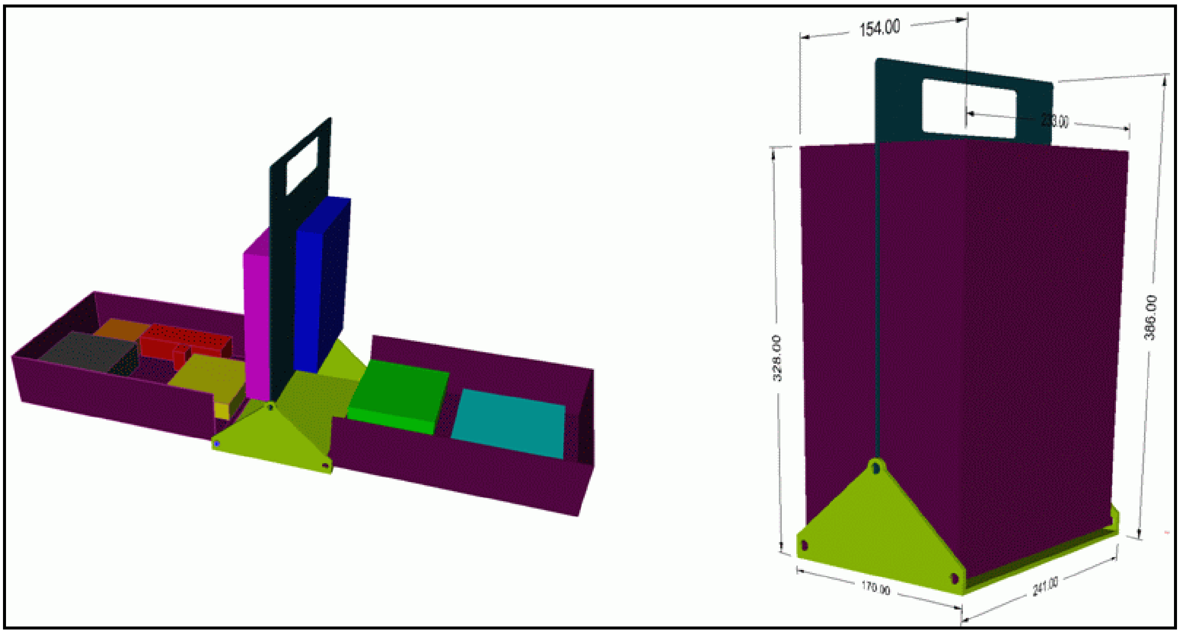


Figure 4. The electronics console is packaged like a book for easy access to the boards.

Figure 5. Demo of the AUTODIF MKII in the Changchun magnetic observatory absolute house.

6 ACKNOWLEDGMENTS

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