APPLICATION NOTE

Using the 3D-Rotator with Multifunction Kappabridge MFK1

1 Introduction

New 3D-Rotator (Fig. 1) was developed by AGICO company to increase the speed and comfort of anisotropy of magnetic susceptibility (AMS) measurements. The 3D-Rotator rotates the specimen simultaneously about two axes with different velocities. The 2-axis rotation enables to determine 320 directional susceptibilities during a single anisotropy measurement. These directions are very well distributed on a sphere which makes the measuring design almost rotatable. Calculation of the anisotropy tensor and respective error analysis is based on the principles described by Jelinek (1977)[1].

The actual measurement is fully automated in such a way that, once the specimen is mounted into the rotator, it requires no additional manipulation to measure the full AMS tensor. The approximate duration of one anisotropy measurement including bulk susceptibility is 1.5 min, compared to more than 3 minutes when the classical (3-plane) rotator is used.

Figure 1: New 3D-Rotator for Agico Multifunction Kappabridges

[1] *The Statistical Theory of Measuring Anisotropy of Magnetic Susceptibility of Rocks and Its Interpretation.* This publication can be downloaded from http://www.agico.com pages in the section Customers Support/User manuals and AGICO prints.

2 Requirements

The 3D-Rotator is compatible with Agico Kappabridges in versions MFK1-A and MFK1-FA. The Electronic Unit must be equipped with the latest processor (release date 12-12-2012). The measurement with 3D-Rotator is controlled by new Safyr5 software. Both the processor and the software are supplied together with the 3D-Rotator. Instructions for exchanging the processor inside the MFK Electronic Unit are attached.

3 Software

3.1 Introduction and installation

Safyr5 was designed for Microsoft Windows© (Windows 98 up to Windows 10).

Safyr5 retains all the functions of the previous version (Safyr4W) and adds new features for controlling the 3D-Rotator. In addition, a simple data browser, based on Anisoft42, is included. Installation of the software is straightforward: double click on the `Safyr5-Setup.exe` and follow the instructions of the installation wizard. The software will be installed into the directory `C:\Agico\Safyr5` and a default data directory `C:\MFKData` will be created.

3.2 Instrument settings

Make sure that the 3D-Rotator is connected to the MFK Pick-Up Unit. Start the software, go to the *Instrument settings* and select Anisotropy measurement with 3D-Rotator (see Fig. 2). The *Instrument settings* window is accessible via *Settings* in the main menu (shortcut `F12`). Measuring parameters such as Measurement mode, Field intensity, Operating frequency, and specimen volume can be set using this window.

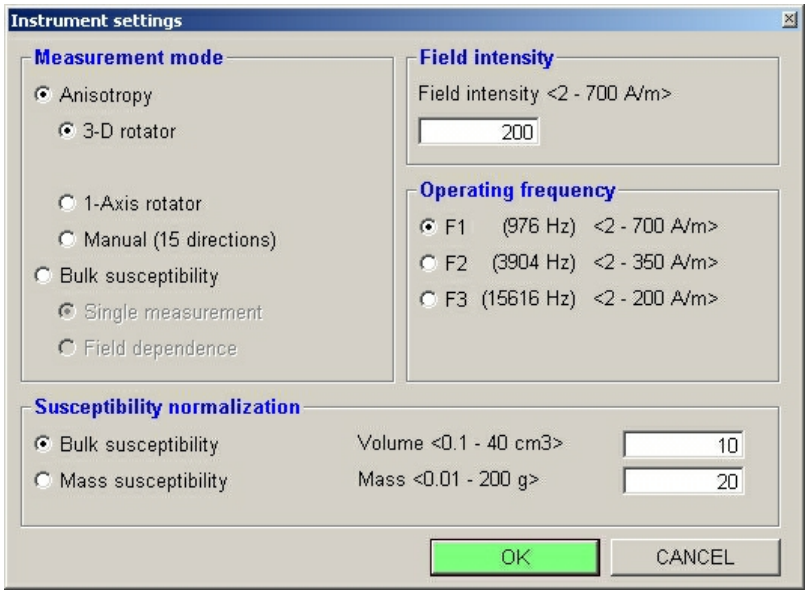

Figure 2: Instrument settings window

3.3 Initialization

Press the *Initialize* button on main screen to start the initialization procedure. Results of such routine are shown on Fig. 3. The software automatically recognizes whether the 3D-Rotator is connected, it sets voltage for appropriate speed of rotation (voltage is in the AD converter units and its value should be in the range from 1450 up to 1650), and it measures the speed (duration of one revolution which should be close to the 2750 ms). Then initial position of the 3D-Rotator is set. After a successful initialization, you are prompted to wait 10 minutes until the instrument is stabilized. The stabilization helps to eliminate the coil drift and it is especially necessary in case of the low-susceptibility specimens with low degree of anisotropy. After initialization, you are prompted to wait 10 minutes until the instrument is stabilized. The stabilization helps to eliminate the coil drift and it is especially necessary in case of the low-susceptibility specimens with low degree of anisotropy.

Figure 3: Initialization screen, 3D-Rotator informations are highlighted in red frame.

4 Measuring procedure

4.1 Specimen mounting

It should be noted that, due to the design of the 3D-Rotator, the specimen tightening screw is accessible only when the inner shell of the rotator is turned off the initial position (Fig. 4a). The mounting position of the shell is automatically set after the initialization routine or whenever the measurement is finished. The specimen has to be inserted into the shell with the specimen arrow (*x-axis*) pointing down and matching with the arrow drawn on the shell and fixed using the screw as shown on Fig. 4b. This screw has to be tightened gently to prevent damage of the shell. Be carefull during the loosening of the fixing screw as well.

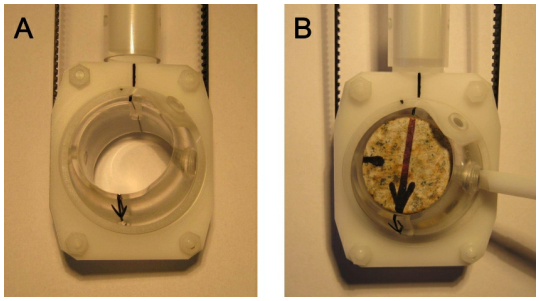

Figure 4: A - position for specimen insertion , B - inserting and fixing.

4.2 Calibration

Calibration routine consists of two steps: measurement of bulk susceptibility of the calibration standard for determination of the gain and anisotropy measurement for obtaining Delta (phase shift) value.

To perform the calibration:

1. Open the *Calibration* window (Fig. 5, main menu *Execution/Calibration*, shortcut F3).
2. Mount calibration standard into the 3D-Rotator (see Fig. 6)
3. Compare the Calibration standard values with those written on the calibration standard. If they do not match, close the Calibration window and input the correct calibration standard susceptibility values using the main menu *Settings/Calibration standard value(s)*.
4. Start the calibration by pressing the *Start* button.

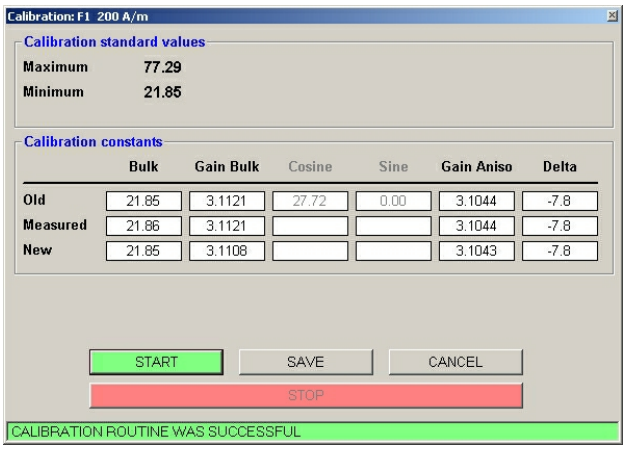

Figure 5: Calibration window

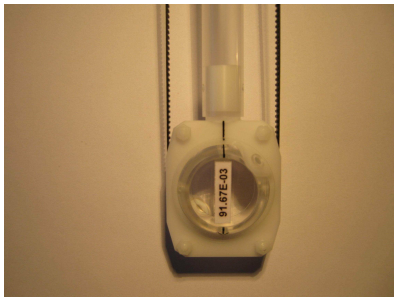

Figure 6: Position of the calibration standard for calibration routine

5. Successful calibration can be saved by pressing the *Save* button.
6. If the calibration is unsuccessful (due to various reasons), then use the *Cancel* button to retain the old calibration value.

Correct values of the calibration constants must fall within the following limits (Table 1).

Constant	Value range
Gain, Frequency 1	1.82 ÷ 3.75
Gain, Frequency 2	0.16 ÷ 0.33
Gain, Frequency 3	0.43 ÷ 0.87
Delta, all Frequencies	-15 ÷ -5

Table 1: Calibration values ranges

4.3 Holder correction

Performing the holder correction routine is crucial for the correct measurement of weak specimens with low degree of anisotropy. It is recommended to perform calibration as well as holder correction everyday to achieve the best measuring results. To perform the holder correction routine:

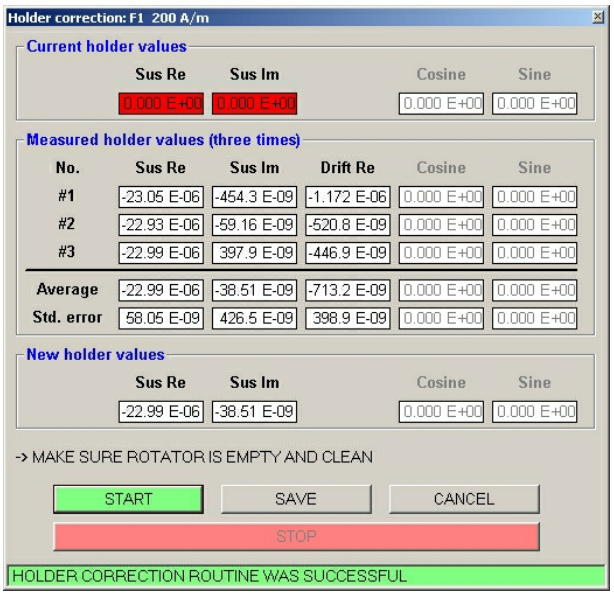

Figure 7: Holder correction window

1. Open the *Holder correction* window (Fig. 7, main menu *Execution/Holder correction*, shortcut F4).
2. Make sure that the holder is clean and empty.
3. Start the holder correction by pressing the *Start* button.
4. Three anisotropy and three bulk measurements of empty 3D-Rotator are made. Average values are calculated.
5. Holder correction can be saved by pressing the *Save* button.

4.4 Specimen measurement

Main screen of Safyr5 for the measurements with the 3D-Rotator is shown on Fig. 8. Specimen measurement consists of following steps:

1. Mount the specimen into the rotator as shown on Fig.4b;
2. Press the *New specimen* button to input the specimen name, orientation, foliations and lineations.
3. Press the *Aniso* button to start anisotropy measurement.
4. Press the *Bulk* button to start bulk susceptibility measurement. If the *Auto bulk* is checked, the bulk susceptibility is measured automatically right after the anisotropy measurement is finished.
5. Results are automatically calculated whenever all necessary data are available.
6. Press the *Save* button to save current measurement into the file.
7. Press the *Cancel* button if you want to reject current measurement for some reason.
8. Start another specimen.

Stop button immediately stops the current operation in case of emergency (hotkey: `Spacebar`).

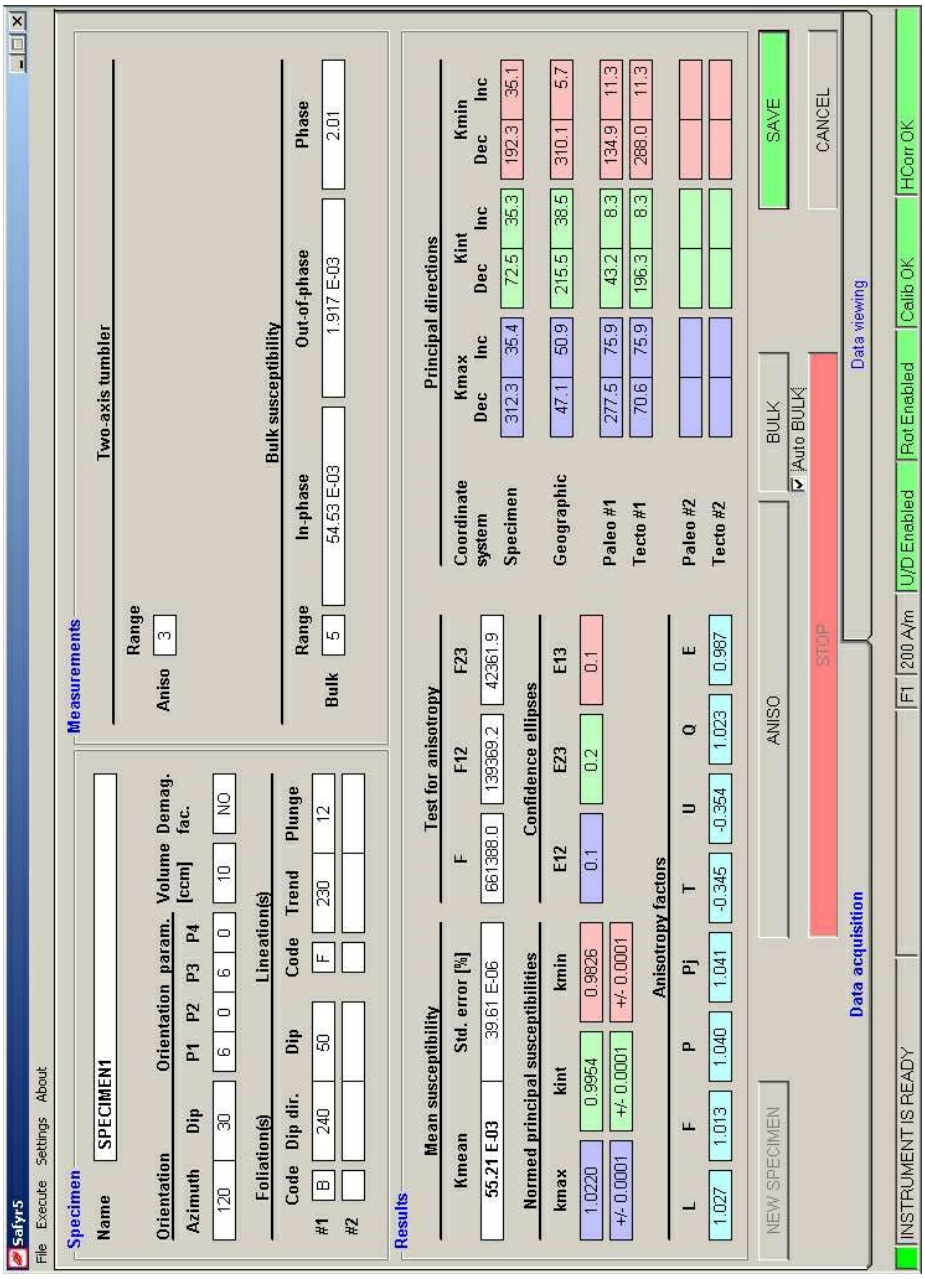

Figure 8: Data acquisition window

5 Limitations

The 3D-Rotator can be used only for the standard paleomagnetic cylindrical specimens (25.4 mm in diameter, 22 mm in height). It is not possible to measure cubic specimens or soft sediments in boxes (unless the boxes mimic the shape and size of the standard paleomagnetic specimen).

The 3D-Rotator is quite massive compared to the classical rotator or manual holder; its bulk susceptibility is approximately -30$\times 10^{-6}$ SI on Frequency 1; this value is much higher on Frequencies 2 and 3. Consequently, the specimens with bulk susceptibility below 100 $\times 10^{-6}$ SI and/or with low degree of anisotropy may be measured less precisely compared to the classical rotator or the manual holder. Always check the confidence angles as well as the F-tests values. The F value should be higher then 3 to be sure that specimen is anisotropic, F12 and F23 must be higher then 3.5 to be sure that there is a significant difference between the principal susceptibilities.

Another limitation may be faced while measuring very strong specimens (bulk susceptibility over 1×10^{-3} SI) with anisotropy higher then 300 % and direction of the maximum susceptibility parallel to z-axis of the specimen; (specimens similar to the calibration standard). The anisotropy of this kind of specimens should be preferably measured using the classical rotator or 15-position design with manual holder. Please note that the actual process of calibration is not affected.

6 Maintenance and repairs

Important note: Please keep your specimens as clean as possible. Any dust particles that fall from your specimens can increase friction in between 3D-Rotator parts, so the voltage for correct speed of rotator will increase. Higher voltage shortens the life-time of rotator motor. If the contamination of the rotator is too high, then the rotation may be not so smooth or it can stop to rotate at all.

6.1 Cleaning and setting up the rotator

If the motor driving voltage exceeds 1700 units (as mentioned in section 3.3), then it is necessary to clean your 3D-Rotator or decrease tension on the driving belt.

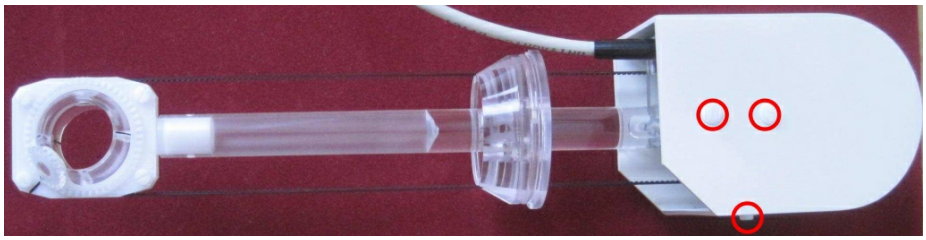

Figure 9: Removing of the top cover of the rotator

1. Make sure that your Kappabridge is switched off, unplug the rotator.
2. Unscrew plastic screws marked by red circles on Fig. 9 and remove the top cover of the rotator.
3. Loose two metal screws (just a little bit, half-turn is enough) marked by big red circle on Fig. 10, but do not unscrew them. Unscrew two plastic screws marked by the green circles on Fig. 10.
4. Remove the plastic ring as shown on Fig. 11A. Do not loose the small rubber piece which works like a spacer. It is marked by blue rectangle on Fig. 11|A. Its correct position with respect to the plastic ring is on Fig. 11B.
5. Remove the belt and clean it with toothbrush (or similar tool) and warm water. Little bit of detergent can be used as well. **Do not use any solvents such as alcohol, toluene and similar chemicals.**
6. Unscrew two plastic screws marked by the blue circles on Fig. 10 and dismantle the bottom part of rotator as seen on Fig. 12.

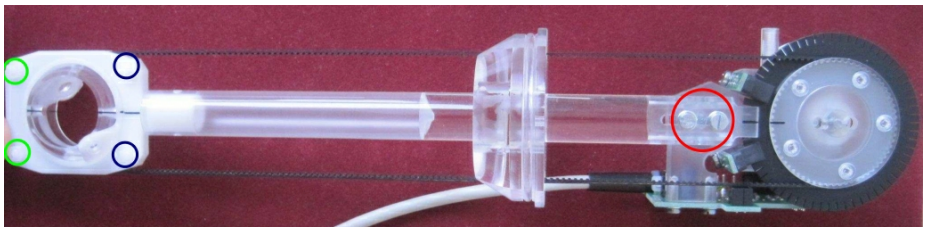

Figure 10: Position of the screws on rotator

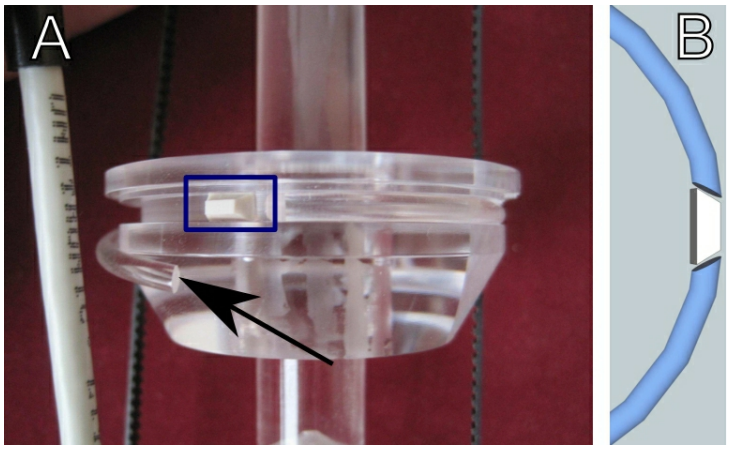

Figure 11: A - Plastic ring and white rubber spacer, B - correct position of the spacer with respect to the plastic ring

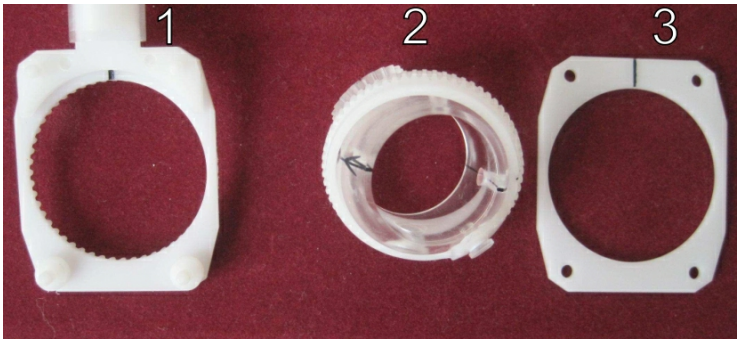

Figure 12: Dismantled rotator

7. Clean all the parts with a piece of cloth (soft toothbrush) and warm water with little bit of detergent. **Do not use** any solvents, it may causes some serious damage of the 3D-Rotator. Then clean all parts with clear water and dry them as good as possible.

8. Insert the rotator shell (No. 2 on Fig. 12) into the its holder (No. 1 on Fig. 12). Make sure that the marks shown on Fig. 13 A and B are simultaneously aligned as on the picture. Then cover it with rectangular plate (No. 3 on Fig. 12) and carefully screw two plastic screws marked on Fig. 10 by blue circles.

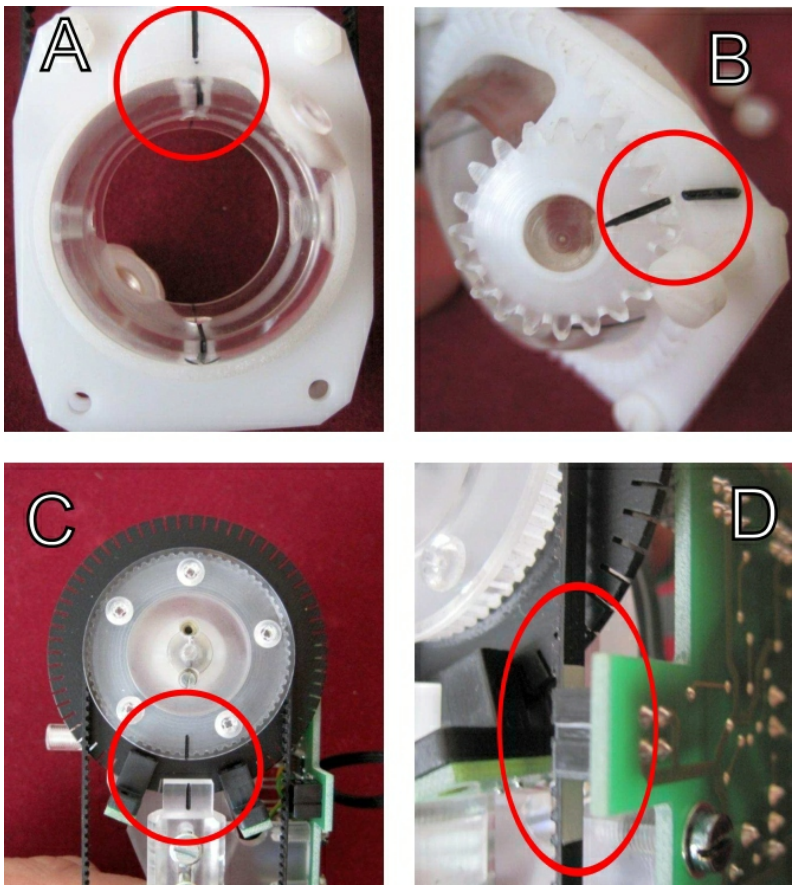

Figure 13: Aligning marks on rotator and white mark on belt

9. Put on the driving belt and make sure that all the marks shown on Fig. 13 A, B, C and D are simultaneously aligned as on picture.
10. Gently screw two plastic screws marked on Fig. 10 by green circles. Do not forget to use pads to keep entire system in correct position.
11. Apply some tension on belt and tighten the metal screws marked on Fig. 10 by red circle. Do not put on the top cover of rotator, yet.
12. Connect rotator to the Kappabridge, switch on the MFK and run the initialization routine.

13. Open the *Auxiliary commands* (menu *Execute/Auxiliary commands*). Click on the *Initial position* button, wait until this procedure is finished and check the position of the marks as shown on Fig. 13 A, B, C and D.

14. If previous step was successful then press *Set Supply* button and check resulting value of the driving voltage. It is in the instrument units and it should be in the range 1450-1650. If the value is lower then try to increase the tension on belt little bit, if it is higher then try to loose the belt somewhat. It is better to reach lower values in the range from 1450 up to 1550. If the voltage is in the desired range, put on the top cover, use three plastic screws for fixing it (screw them with care) and your rotator is ready for use.

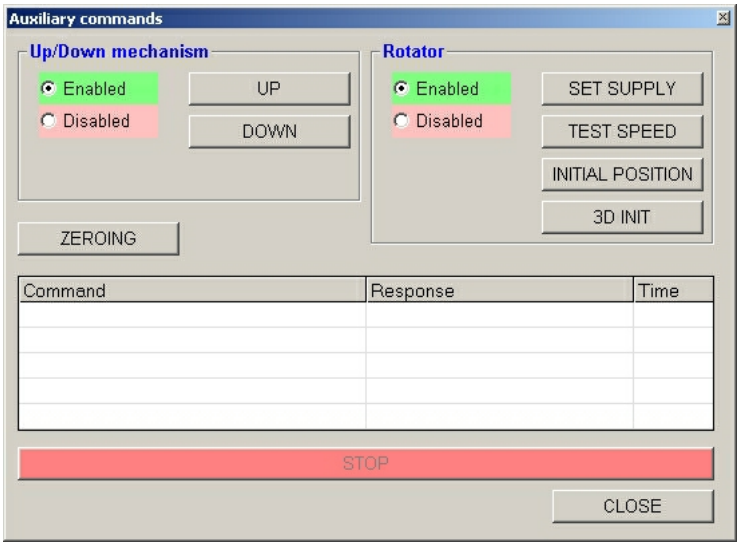

Figure 14: Auxiliary commands window