A new method for in-situ calibration of rod extensometers

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Abstract

At the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences (GGRI) a new calibration apparatus was developed for in-situ calibration of extensometers. The calibrator contains a magnetostrictive actuator by means of which a known displacement can be produced as a reference pulse. Both this pulse and the displacement of the extensometer's end can be measured by the capacitive transducer of the calibrator. The sensitivity (scale factor) of the extensometer can be determined by comparison of the signals recorded by the calibrator and by the recorder of the extensometer.

1. Introduction

The measurement resolution of rod extensometers is better than 10^{-9} m. The in-situ calibration of these instruments represents a real problem since an absolute method by means of which such small displacements can be measured is not at our disposal. At the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences (GGRI) a calibration apparatus was developed in 1982. This instrument was planned for testing crapaudines and magnetostrictive actuators which serve as built-in calibration device for regular daily calibrations of quartz-tube extensometers. At the same time this apparatus is also suitable for the in-situ calibration of quartz-tube extensometers. The high resolution of the device was achieved by two differential condensers, placed at the ends of a rotating arm. Disadvantage of this calibration instrument is that the extensometer must be connected to the rotating arm which causes some problems: instability of the coupling to the extensometer, small, sometimes insufficient place for the calibration apparatus on the extensometer pillar, etc. (Mentes, 1995a, 1995b, 1998; Mentes and Brimich, 1996). The above described disadvantages were eliminated by the development of a new calibration device which does not have moving mechanical parts, e.g. rotating arm.

In this paper the construction and calibration of the new calibration apparatus is described and the results of the in-situ calibration of the extensometer at the Geodynamical Observatory in Sopronbánfalva are also given.

2. Construction of the new calibration apparatus

Figure 1 shows the principle of the new calibration apparatus. One end of the magnetostrictive actuator is fixed to a rigid and very stable base plate which is standing on three foot screws. The other end of the actuator holds the two outer plates of a capacitive transducer, while its middle plate is fastened to the quartz-tube of the extensometer. Thus, the magnetostrictive actuator can move the outer plates of the differential condenser relative to the middle plate and the displacement can be measured by the capacitive transducer. The characteristic curve of the magnetostrictive actuator was measured by means of a HP5508 laser interferometer. On the basis of the measurements the connection between the current of the coil and the displacement produced by the core of the magnetostrictive actuator can be described by the equation:

$$d = 20.4541 + 5.4540 \cdot I + 0.0051 \cdot I^2 ,$$

where d is displacement [nm] and I is current [mA].

The capacitive transducer was also calibrated by a laser interferometer. The calibration apparatus was placed onto the stage and the middle plate of the transducer was fixed to the stand of a microscope. The calibration apparatus was moved by the micrometer screw of the microscope. The displacement of the outer plates of the capacitive transducer relative to the fixed middle plate was measured by the laser interferometer and by the capacitive transducer simultaneously (Fig. 2). The scale factor of the calibration apparatus calculated from the measurements is: -1.206 ± 0.002 nm/mV.

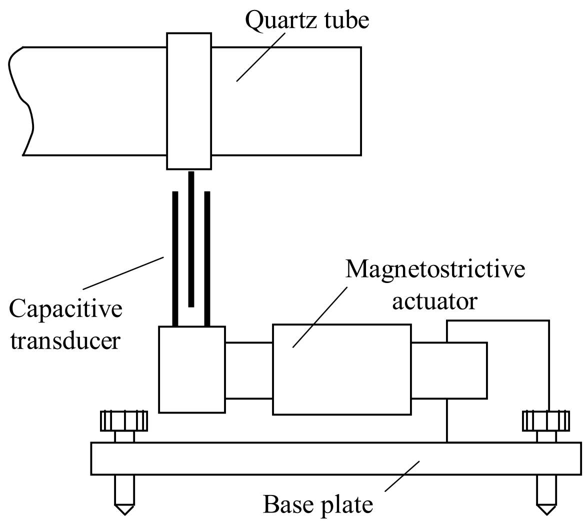

Fig.1. Principle of the calibration apparatus

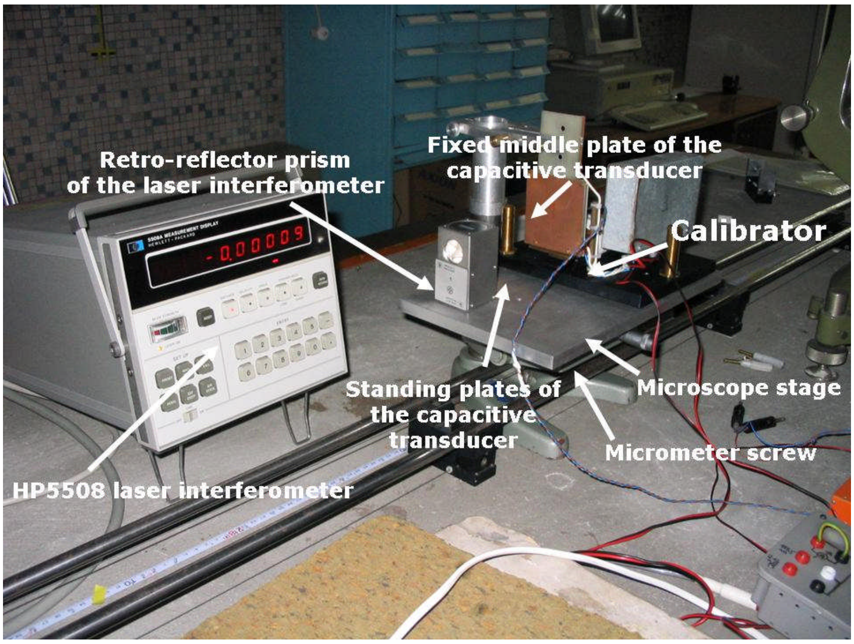

Fig. 2. Test of the calibration apparatus by means of the HP5508 laser interferometer

The scale factor of the calibration apparatus was also determined by another method as follows: the calibration apparatus was shifted to one end of the measuring range of the capacitive transducer by the micrometer screw. At this point a constant current ($I = 155.5$ mA) was periodically switched on and off to the coil of the magnetostrictive actuator. The magnitude of the displacement impulses was measured both electrically (c_i) – by the capacitive transducer – and by the laser interferometer (d_i). The average of both impulse series was calculated and the ratio of the average displacement measured by the interferometer ($\bar{d}_j$) and the average displacement measured by the capacitive transducer ($\bar{c}_j$) was calculated: ($s_j = \bar{d}_j / \bar{c}_j$). This value is the scale factor of the calibration apparatus at the given point of the measuring range. The scale factor was determined similarly at k ($j = 1...k$) points of the measuring range and an average scale factor ($\bar{s}_k$) was determined: -1.211 ± 0.021 nm/mV. The difference between the scale factors obtained by different measuring methods is within the error range of their determination. Since the error of the characteristic measurements is smaller than the impulse measurements, the scale factor: -1.206 ± 0.002 nm/mV was used for the calibration of extensometers.

3. Calibration of the extensometer at the Geodynamical Observatory in Sopronbánfalva

The principle of the calibration of rod extensometers is shown in Fig. 3. Displacement of the end of the extensometer is recorded both by the calibrator unit and the capacitive transducer of the extensometer. If the extensometer has a built-in magnetostrictive actuator for regular daily calibration, the sensitivity of the extensometer can be determined by means of parallel record of the calibration pulses produced by the built-in magnetostrictive actuator (Fig. 4). The sensitivity (scale factor) of the extensometer can be calculated by the comparing of the magnitudes of the recorded impulses. The scale factor of the extensometer is 2.093 ± 0.032 nm/mV.

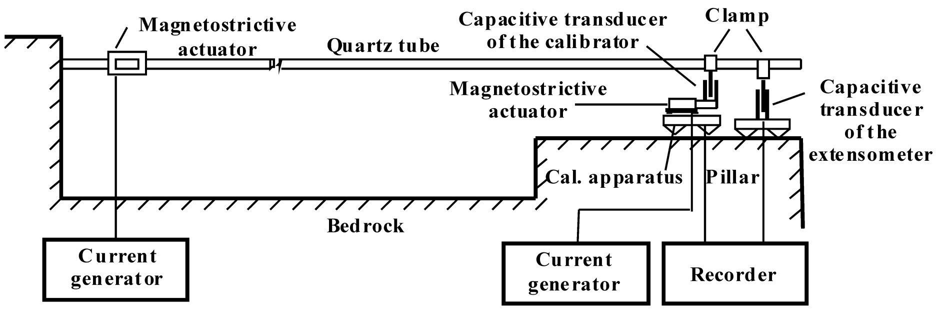

Fig. 3. Principle of the calibration of quartz-tube (rod) extensometers by means of the calibration apparatus

If the extensometer does not have a built-in magnetostrictive actuator, the comparison of the tidal curves recorded by the extensometer electronics and by the calibration apparatus (Fig. 5) can be used for the determination of the sensitivity of the extensometer. In this case the extensometer is calibrated by the magnetostrictive actuator of the calibration apparatus. The extensometer at the Sopronbánfalva Geodynamical Observatory was also calibrated by this method. The sensitivity of the extensometer is 2.119 ± 0.019 nm/mV. We can see that the difference of the scale factors measured by the two methods is within the error of their determination.

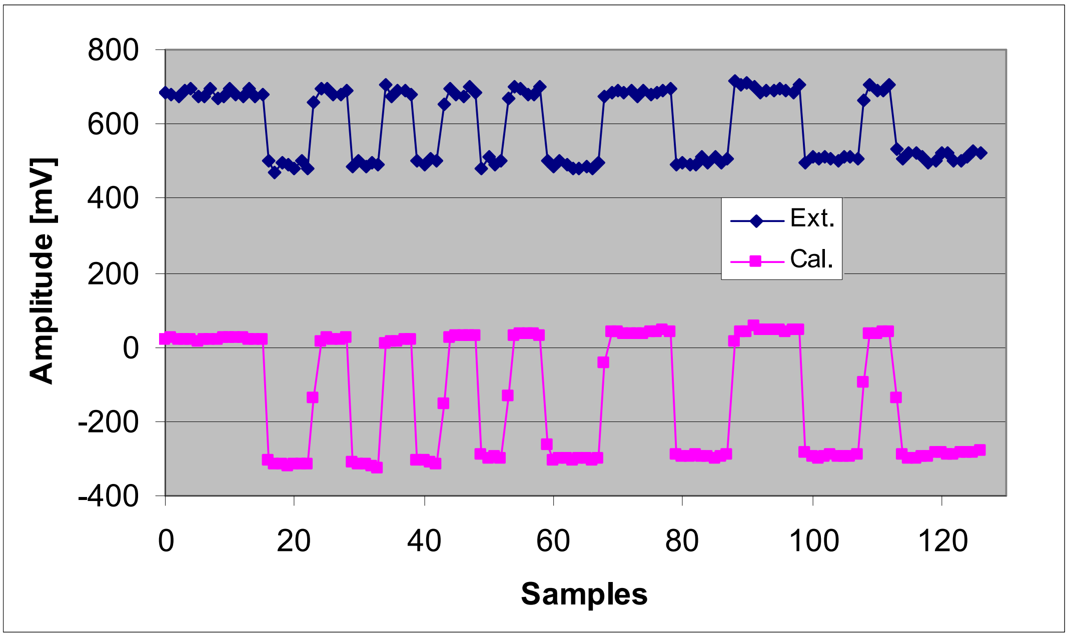

Fig. 4. Pulses of the built-in magnetostrictive actuator recorded by the extensometer electronics and by the calibrator apparatus

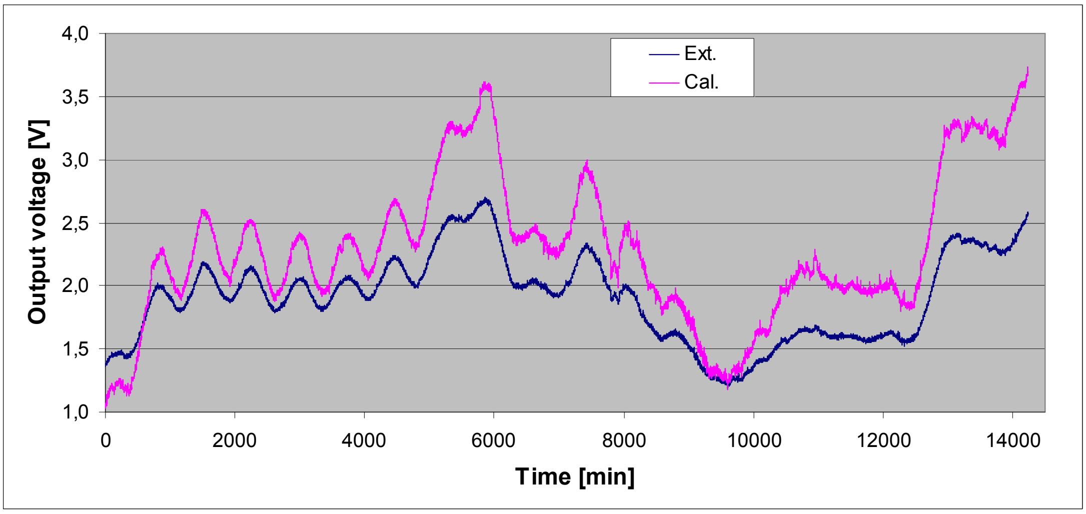

Fig. 5. Parallel tidal records made by the extensometer electronics and by the calibrator apparatus

Conclusions

As a result of instrumental development a calibration apparatus was constructed that has high accuracy owing to the fact that it does not contain moving mechanical parts. The installation of the new calibration apparatus is very easy and it is suitable for calibration of all types of extensometers including also invar wire extensometers.

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