

Possible Impact of the Long-term Variation of the Length of Precise Levelling Rods on the Results of Precise Levelling

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1. Introduction

Different errors of precise levelling instruments and precise rods are tested and investigated but the problem of the long-term length variation of precise levelling rods is considered very seldom. The length of precise levelling invar rods may subject to considerably big changes caused by different influences from which as the most frequently factors are regarded the temperature and changes of tension force of the invar tape. But the invar itself is a very whimsical and fastidious material, so the invar tape could be a seedbed of many unexpected errors. The most probable violent changes of the length of invar rods can be caused by chocks due to improper transport and maintenance of rods. Of course there is very difficult to formulate general indications how to calculate the relevant corrections since the behaviour of particular levelling rods must be tested and considered individually.

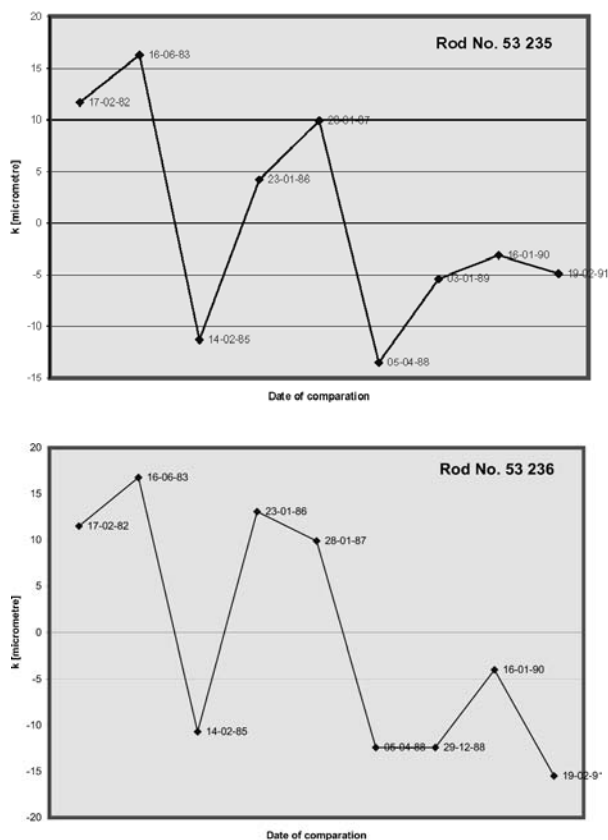


Fig.1. Periodic variations of a sinusoidal type

2. Concise Outline of the Programme of Levelling Rod Comparison Carried out at the IG&GA WUT

The research works on the precise levelling rod comparison were begun at the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology (IG&GA WUT) in 1971. The first stage, 1971-1973, consisted in building a precise horizontal-vertical optical comparator and in developing a method of the comparison that fulfil the recent accuracy requirements. The next step was to develop a method of investigation of the graduation errors. The routine comparison service for all geodetic and surveying enterprises in Poland was initiated in 1973.

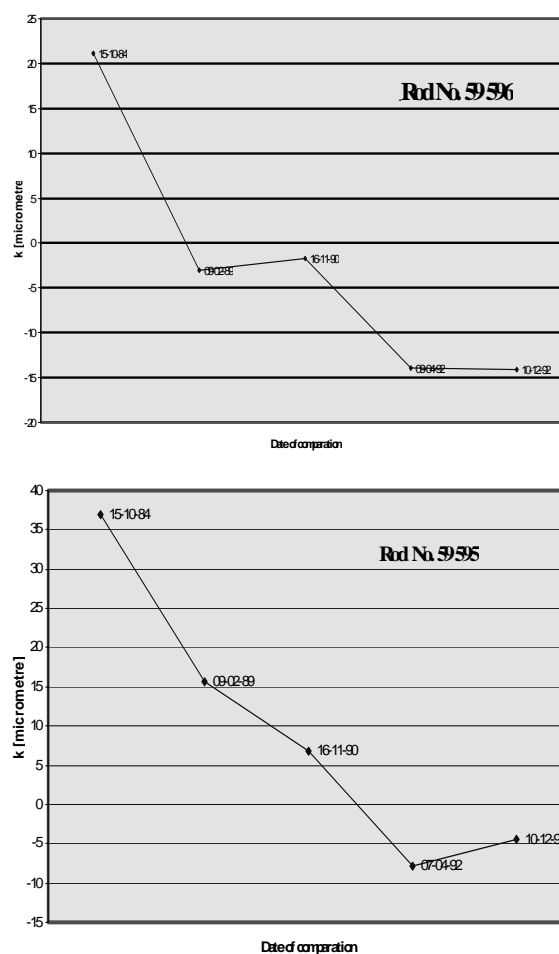


Fig. 2. Length variations of a decreasing tendency

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The extensive research programme included a number of investigations, which had to be carried out in order to develop a modern method of comparison and examination of graduation errors. These were the following investigations: (a) variations in the length of the rod depending on the method of its support, (b) determination of the length difference between the rod length in its horizontal and vertical positions, (c) influence of the rod strip tension force upon the length of the average rod metre and others. Results of investigations and experiences gained by the Institute's metrological team have been reported several times (see References). This paper deals particularly with analysis of results of multiple comparisons of the same levelling rods performed in the years 1973-2002. In the archives of the Institute's metrological laboratory there are materials of comparison of about 3000 levelling rods (about 1500 sets). There are probably only few metrological laboratories in the world that possess such immense great source of information data.

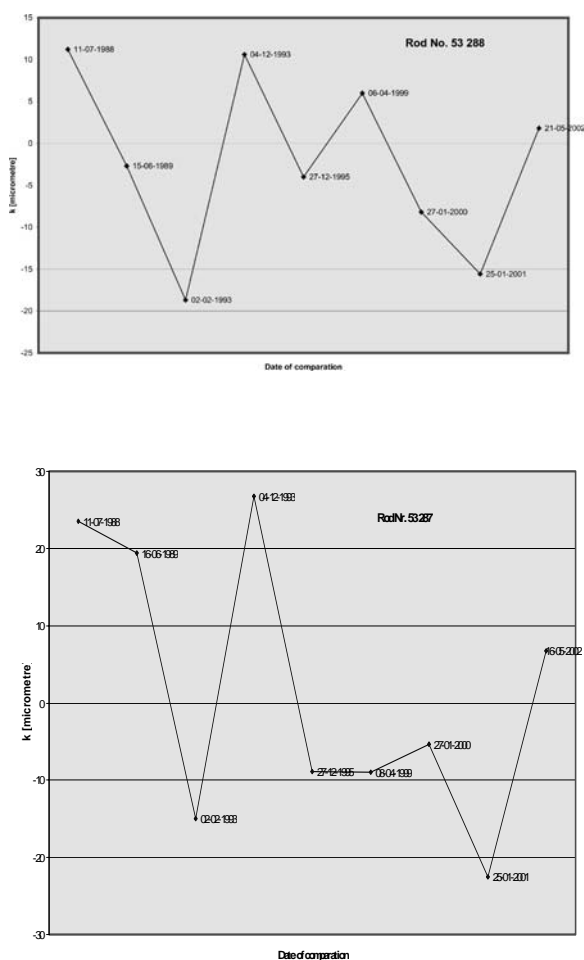


Fig. 3. Abrupt length changes

Results of multiple comparison of some selected levelling rods reduced to the temperature $+20^{\circ}\text{C}$

Nr of the rod	Date of comparison	k [: m]
53 235	17.02.1982	+11.7
	16.06.1983	+16.3
	14.02.1985	-11.3
	23.01.1986	+ 4.2
	28.01.1987	+ 9.9
	05.04.1988	-13.5
	03.01.1989	- 5.4
	16.01.1990	- 3.1
	19.02.1991	- 4.9
53 236	17.02.1982	+11.5
	16.06.1983	+16.8
	14.02.1985	- 10.7
	23.01.1986	+13.1
	28.01.1987	+ 9.9
	05.04.1988	-12.4
	29.12.1988	-12.4
	16.01.1990	- 4.0
	19.02.1991	-15.5
59 595	15.10.1984	+37.0
	09.02.1989	+15.6
	16.11.1990	+ 6.8
	07.04.1992	- 7.9
	10.12.1992	- 4.5
	15.10.1984	+21.1
	9.02.1989	- 3.0
	16.11.1990	- 1.7
	9.04.1992	-13.9
59 596	10.12.1992	-14.1
	15.10.1984	+21.1
	9.02.1989	- 3.0
	16.11.1990	- 1.7
	9.04.1992	-13.9
	10.12.1992	-14.1
53 288	11.07.1988	+11.2
	15.06.1989	- 2.7
	2.02.1993	-18.7
	4.12.1993	+10.6
	27.12.1995	- 4.0
	6.04.1999	+ 6.0
	27.01.2000	- 8.2
	25.01.2001	-15.6
	21.05.2002	+ 1.8
53 287	11.07.1988	+23.5
	16.06.1989	+19.4
	2.02.1993	-15.0
	4.12.1993	+26.8
	27.12.1995	- 8.9
	8.04.1999	- 9.0
	27.01.2000	- 5.4
	25.01.2001	-22.5
	16.05.2002	+ 6.7

3. Time Variations of the Length of Invar Levelling Rods and Their Possible Impact on the Results of the Precise Levelling

About sixty levelling rods compared several times within the period of the last few years were taken for detailed analyses. Twelve rods were compared 7-12 times, for forty three rods results of 6-9 comparisons are available. Results of some selected multiple comparisons reduced to the temperature 20°C are shown in Table 1. This Table contains number of the rod, date of comparison and the length of the mean metre of the rod ($1\text{ m} + k$: m). Changes of k for some selected levelling rods are also shown in Fig 1 – Fig. 3.

The detailed analyses lead to the following conclusions:

- The distinct diminution of the mean metre was found out in 19 cases,
- Relatively not significant variations of the mean rod metre, but with a decreasing tendency was stated for 20 staves,
- Periodic variations of a sinusoidal type were detected in 10 cases,
- 6 levelling rods indicate abrupt sudden changes of the mean rod metre.

A decreasing tendency of time changes of the rod length was stated for about forty levelling rods. This fact is rather inconsistent with the known tendency of lengthening of invar standards and tapes resulting from time structural changes of the invar alloy. A comment on this fact may be that the time variations of the length of rods depend to a greater extent on changes and warping of the wooden body of the rod than on changes of its invar tape itself. The analyses indicate decreasing changes rate of -4.3 : m per year.

Periodic changes of the rod length indicate the necessity of periodic comparison of the levelling rods used for practical works. These comparisons performed before and after the field work season allow us to determine proper correction that should be introduced to improve the results of field levelling data.

Abrupt length changes may indicate improper maintenance and treatment of precise levelling rods (tumbling, inappropriate transport, etc.).

4. Some General Conclusions

- The performed analyses may have simply statistical character. More exhaustive chronicle of the use and maintenance of rods could give records in rod certificates; they could clarify some detected length changes.
- Since the time changes of the mean rod metre can amount to 4-5: m per year, the resulting error of precise levelling could be of about 0.5 mm for the 100m of the height difference. So, the imposed requirement to compare the rods before and after the field works must be absolutely kept in order to give possibility - if necessary - even to interpolate the appropriate comparison correction for the time of field works.
- The abrupt sudden changes (chocks) of the mean rod metre that may indicate improper maintenance and treat-

ment of precise levelling rods (tumbling, inappropriate transport, etc.) may amount even to about 40: m, so the e.g. 100m-height differences may be incorrect by about 4 mm. These sudden changes can be found by repeated comparison process. Since we usually do not exactly know when these chocks occur these errors seem to be very dangerous and the results of precise levelling should be particularly carefully considered in such cases.

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