LABORATORY INVESTIGATION ON THE DISTANCE METER UNIT IN ELECTRONIC TACHEOMETERS

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Abstract

Consistency between the angular and distance measuring units of electronic tacheometers do not exist because the previous one is much more precise. Error in distance measurement is supposed to imply a systematic component too, but separating it from the error the accuracy in distance measurement can be improved. In the paper the layout of a laboratory investigation of electronic tacheometers phase meter unit has been introduced illustrating a method for determination of the residual function that eliminates the periodic systematic errors, besides, features of the baseline established in laboratory for checking the amending character of the residual function is also given.

Evaluation of precise networks in a relatively small extent (called micro-network) is in common practice in surveying, especially in engineering surveying. Generally speaking, angular measurements require "one second instrument" in the observation of interior angles. Several types of digitized theodolites are available having not less accuracy in measuring angles than those of the optical ones. However, automatization in observation and data processing permit the effects of systematic errors to be taken into account with the help of computation methods (Ref. [1]), thus importance of digitized theodolites in establishing controls in micro-networks is expected to be improved.

Strength of figures in primary nets can also be improved by measuring every length (or at least several) in the triangles. Employing the distance meter unit built in electronic tacheometers increasing of reliability in the survey nets seems to be possible.

Introducing distance measurements in surveying accuracy can be improved effectively just in case when reliability in angular and distance measurement is nearly equal. If reliabilities are being compared respectively it can be pointed out that no coincidence exists between them, because reliability in measuring distances up to 400—500 m will be far less than that in angular observations. It seems that accuracy can not be improved by using distance meters in establishing micro-networks.

Accuracy achieved by employing several types of electronic tacheometers in measuring distances and angles are being compared in Fig. 1. Whilst, reliability in measuring angles will be introduced by standard deviation of a single observed angle in two faces (m_α), the same for distance measurement is being

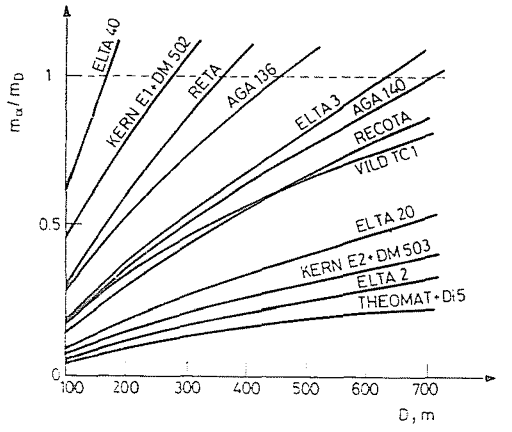

Fig. 1. Relation between Standard Error of Directional Observation and that of Distance Measurement in Function with the Measured Length on Different Electronic Tacheometers

illustrated by the standard deviation (m_D) that has been computed from the formula given by the manufacturer. The ratio $\left(\frac{m_\alpha}{m_D}\right)$ being in function with the measured distance is shown in Fig. 1.

It is supposed that the standard deviation for distance measurement given by the manufacturer may also involve systematic components. If these components are separated then errors in distance measurement will be decreased, thus the instruments can be employed for distance measurements in micro-networks. The final goal of our investigations is to check the assumptions on that principle.

Specially great care has been brought to bear upon testing the phase meter unit. Results from the phase measurement are also being affected by systematic errors occurring periodically as known from ([2], [3], [4], [5]), but these errors have more or less the same character at equal partial distances. In case of modern digital phase measuring units interference between the transmitter and receiver unit or the reflexion of a part of the measuring beam on the optical surfaces may be sources of error.

It is quite understandable that there is no information released by the manufacturers on the measure of interference and reflexion, for a systematic error occuring periodically may alter on different instruments of the same type even. Generally speaking, the error may be the smaller the more isolated the optical transmitter/receiver system from each other. Cyclic errors may also be decreased by leading the reference signal to the receiver utilizing modulated light instead of using current signal. When employing coaxial optical system we should always take into account the presence of cyclic error in practice.

Cyclic error may be in function with the distance to be measured while amplitude of the error originated from interference will be theoretically increasing according to the distance, because strength of the measuring signal is being inversely proportional to the distance while fault signal remains unchanged.

To determine relationship between the amplitude of error and the distance to be measured it is advised to investigate an extended range of phase measuring device widening the range of the fine measuring unit to three or four times of its initial capability. Obviously, investigations on the phase meter unit in the whole range of the distance corresponding to the preliminary planned field of application would give us the best result but it is unpracticable in laboratory.

Investigation on the phase meter unit is essentially measuring of known lengths and comparing the results with references. From the discrepancies obtained a function of the residuals will be set up. To produce reliable function of the residuals a large number of observations (about 25 . . . 30 within one phase of the fine measuring unit) are needed for the reference length. That will be achieved if the passive reflector is being moved along an optical bench equipped with a scale graduated in millimeter. In this case knowledge of the reference distance of a single prism position is only needed, but the optical bench must be removed occasionally to another position with a high precision.

Amending character of the residual function is to be checked. The most suitable method is to measure a set of reference distances with the help of the electronic tacheometer (selected in such a manner that partial distances would cover the fine measuring unit interval) so, that the whole range of the investigated lenghts should be involved, then the observed distances and the corrected ones would be compared with the reference lengths.

The baseline established in the Laboratory of the Institute of Surveying, Geodesy and Photogrammetry in the Technical University, Budapest, for test-

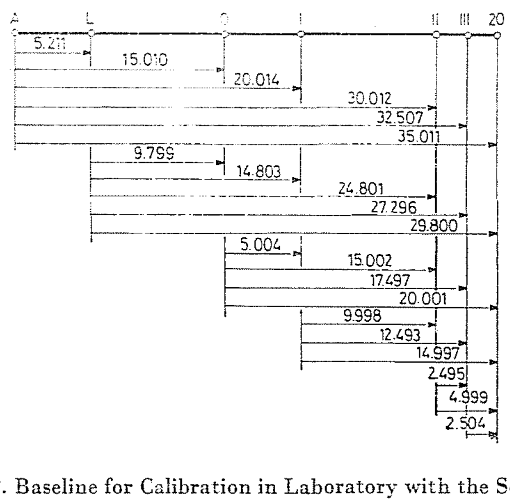

Fig. 2. Baseline for Calibration in Laboratory with the Sections

ing Electromagnetic Distance Measuring instruments had to satisfy the following requirements:

1. The baseline must be suitable for checking the phase meter unit in the distance of 35 . . . 40 m even (the fine measuring unit for both DI-4 and DI-4L models are equally 30.5 meter). The existing baseline (see Fig. 2) is 35.0 m long, but spreading the length of the optical bench investigation can be performed on the phase meter up to 36.5 meter.

2. Partial distances between intermediate stations should provide a set of lengths are being distributed equally in the range of adjustment. On the actual baseline the partial distances complete a set of lengths being the integer number of multiples of 2.5 m each except the 7.5 and 22.5 sections only.

3. Intermediate stations must be positioned onto concrete pillars. All the stations of the existing baseline has been situated on concrete pillars except A.

4. Lengths between intermediate stations should be measured by Mekometer ME 3000 directly or deduced from direct observations (20 m is the shortest distance that can be measured by ME 3000 correctly). Every length of the established baseline can be measured directly or deduced from direct observations carried out by Mekometer except 0—I section. Since the nominal length of the O—I distance is equal in length with that of the II—20 section, thus it can be determined by catenary taping transferring the length.

In course of baseline measurement the lengths being greater than 20 m have been measured fro and back by ME 3000 where the 0.2 mm difference in the two observations has never been exceeded. Computed lengths of the sections were rounded up to millimeter and no discrepancy was found in the results. Hence, the laboratory baseline has fulfilled our expectations in standardization in all aspects. However, testing of the phase meter unit can only be performed in two steps by transferring the instrument to be checked, still the layout of the measurements may have more advantages, like considerable overlaps in the sections (about 7—8 m).

Checks on the distance meter unit have been carried out for each model as follows:

1. Setting up the instrument over the station "O" a phase meter unit test has been in progress starting from the shortest length to the distance in 21.5 m and back.

2. Removing the tacheometer to the station "A" the test was being repeated in the interval between 14 m and 36.5 m.

3. Fro and back observation was made for partial distances between pillars in the baseline in all combination. Self centering device was used in observation, thus accuracy in setting up the instrument over the point has never exceeded ± 1 mm.

4. Values for the residual function has also been computed and represented in the whole range of the test. A periodic function obtained from graphical

adjustment was superimposed over the function values to determine the mathematical character of the function itself.

5. To check the amending character of the function of residuals reference distances were compared with observed lengths on one hand and corrected ones on the other hand. Considering discrepancies as true errors two quantities bearing average and standard errors' features were computed for both the corrected and non-corrected lengths. Amending character of the function is proved by the fact that the corrected error will be much smaller than that before adjustment. It was also investigated that performing adjustment how frequently the absolute value of the error decreased, remained unchanged or increased out of 21 measurements.

This chapter will discuss the conclusion of our investigation. Cyclic errors in the phase meter unit of every type of the electronic tacheometers to be tested were found individually. In most cases the shape of the residual function was found to be sinusoidal. Because of graphical adjustment no effort was made to express further harmonic components or slightly increasing amplitude of error being inversely proportional to the distance measured, however, sometimes the diagram on discrepancies indicates an existing component of such an error. If variation of the residual function is sinusoidal it can be expressed by the formula:

$$v(t) = A_0 + A_1 \cdot t + A_2 \cdot \sin 2\pi \frac{t - t_0}{L} \tag{1}$$

where

v = correction, involving linear (v_1) and periodical (v_2) components and relating to the measured distance,

A_0 = intersection point of the cyclic curve symmetry axis at the v axis,

A_1 = incline of the curve (the equation of the symmetry axis of the periodic component is being formed by the latest two),

A_2 = the amplitude of the periodic component,

t_0 = distance, respective to the first positive zero transit of the cyclic component,

L = full wavelength of a period being equal to the fine measuring unit (see Fig. 3).

The shape of the residual function was not always sinusoidal as shown in Eq. (1). In one case, when the ELTA 2 tacheometer was being tested the residual function was saw-tooth shaped. However, that can also be expressed as a sum of sinusoidal functions by means of Fourier's series, still the cyclic component of the residual function will be given as follows (see Fig. 3):

$$v_2 = A_2 \cdot \mathrm{frac} \frac{t - t_0}{L}, \tag{2}$$

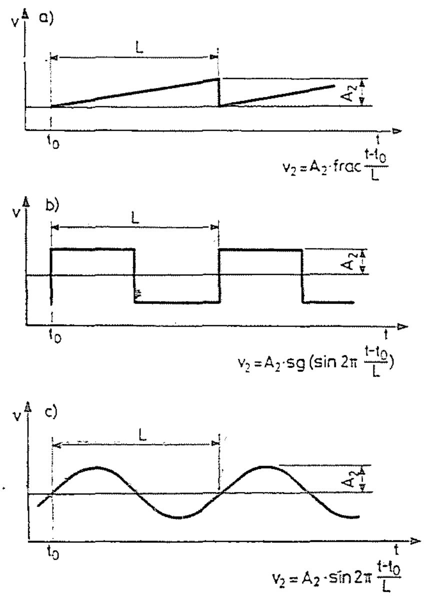

Fig. 3. Shapes of Periodic Components of the Residual Functions. a) Saw-Tooth Signal; b) Square Pulse; c) Sinusoidal Curve

where

$t \geq t_0$, that is, the residual function is defined to begin at t_0 distance from the starting point of the first saw-tooth signal. It can also be recognized that frac $(t - t_0)$ will be a partial distance from t_0.

The investigated specimen of RECOTA tacheometers shows clearly that cyclic component of the residual function varies between two discrete values, that is, the periodic component is square pulse shaped. However, the function can also be expanded in Fourier's series, cyclic component of the residual function will be given as follows (see Fig. 3):

$$v_2 = A_2 \operatorname{sg} \left(\sin 2\pi \frac{t - t_0}{L} \right), \tag{3}$$

where the periodic component in brackets determines the sign of A_2.

Both saw-tooth and square pulse shaped residual functions will give different solutions employing certain values for the function $t = t_0 + n \cdot L (n = 0, 1, 2 \ldots$ etc.) depending upon the direction of approximation (upwards or downwards). Practically, we have not been able to determine correct values for t, but experienced that in some spots (of which surroundings was investigated thoroughly having known the shape of the residual function) the difference between the measured and reference distance varied suddenly after the passive reflector having been removed within a few centimeters. Because of this, the

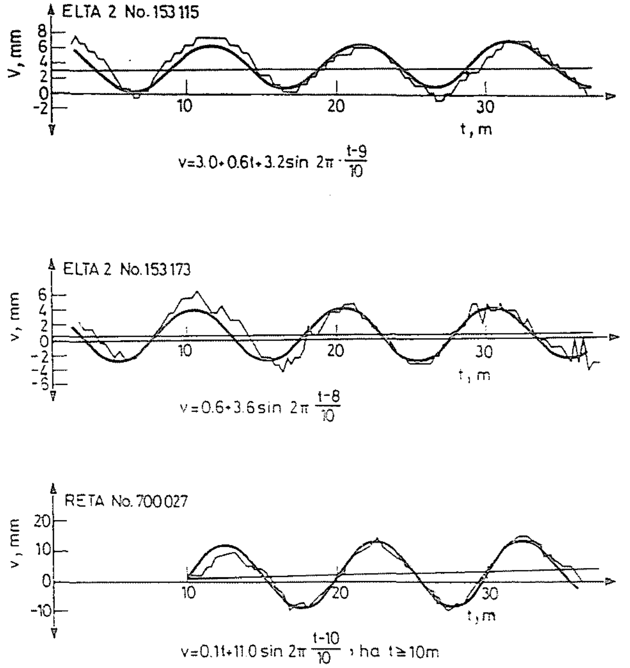

Fig. 4. Sinusoidal Residual Functions on Several Electronic Tacheometers to be Tested

fact that the residual function can not be explained in the surroundings of this critical spots (about 0.5 m apart) was also put in our records having compiled from the investigations. It was also noted that the instrument selected for testing was not suitable for measuring distances with a high accuracy.

Diagrams of residuals of further tacheometers and the graphical and numerical versions of the sinusoidal residual function are seen in Fig. 4.

Results obtained from checks on amending character of the residual function have been compiled in Table 1.

Comments for the figures in Table 1 will be given in the next paragraphs as below:

1. Two of ELTA 2 tacheometers have been recalibrated within about six months from the first test. During that time the manufacturer has performed slight modification on the instrument: the manually operated grey-wedge has been replaced to automatic one. This appeared in a slight (about 1 mm) removal of the cyclic component symmetry axis parallel to itself as far as the shape of the residual function concerned, but neither the amplitude nor the place of zero transits varied.

2. It is also clear from Table 1 that applying corrections the absolute value of the error has decreased with about 70—80 per cent, or remained un-

Table 1

Checking of amending character of the residual function

		Elta 2 N° 153115 calibration	Elta 2 N° 153115 re-calibration	Elta 2 N° 153173 calibration	Elta 2 N° 153173 re-calibration	RECOTA N° 101826	RETA N° 700027
average error mm before correction	before	2.4	2.0	3.3	3.3	9.7	3.5
	after	0.7	0.6	0.7	1.0	2.5	1.5
standard error mm before correction	before	±3.3	±2.4	±3.5	±3.6	±10.7	±5.9
	after	±1.0	±0.8	±1.0	±1.1	±3.1	±2.1
error after correction:	decrease	15	16	21	18	17	9
	unchanged	6	3	Ø	3	Ø	12
	increase	Ø	2	Ø	Ø	3	Ø
		in case	in case	in case	in case	in case	in case

changed in some cases, while increasing of the error occurred exceptionally (it is needed to say that increment of the error has never been in excess of 1 mm). In this respect, some more details on the RETA tacheometer may have importance. Applying correction the amplitude of error has remained unchanged in a large number of events (in twelve cases from the possible twenty-one) as shown in Table 1. The distance belonging to the first positive zero transit of the residual function's cyclic component is exactly 10 m for the instrument mentioned above (see Fig. 4). For lenghts having figures of zero or 5 in units the periodic residual function has no influence. It appears from Fig. 1. that fifteen reference lengths were ended to zero or 5 m (with a maximum decline of 0.2 m) out of the existing twenty-one, thus in this special case amending character of the residual function can hardly be pointed out (as far as favourable cases concerned). During investigation on RECOTA tacheometer one of the measured distances has been affected by mistake, hence the result was not taken into account.

3. Applying corrections for all the observations provided by the tacheometers both average and standard errors decreased significantly (to the one third of their initial values). It is also shown that in case of the investigated instruments the results on phase measurements are being affected by not only some significant systematic error, but also indicates that our method for testing the distance meter unit of electronic tacheometers hit its target: the systematic error could be separated from the observation and the instrument may become a useful tool in accurate distance measurement in micro-networks to be surveyed.

There can be doubt about the measure of variation of the residual function in time. Our investigation commenced about one and a half years ago, and only two instruments have been rechecked. This is poor enough to make decision. Apart from the fact, that periodical recalibration performed in every six month may be reasonable, extra calibration is also advised in case if the instrument has been despatched on a long road (e. g. abroad) or the transmitter/receiver system or the electronics in the phase meter unit has been changed over by the manufacturer.

Investigation on the phase meter unit and checking amending character of the residual function require handling of about 1500 . . . 1800 lines in data recording and processing. Hence, automatization (full or partial) in data collection and processing needed to the investigations are being planned utilizing the tacheometer's data collector or using outer facilities in data storage, computation and presentation of the final results.

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