Reading and Registering of Directions by Electronic Theodolites and Electronic Tacheometers Leica

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Abstract: *In this work, reading and registering of directions in modern electronic theodolites and electronic tacheometers Leica is described, and a simple way to achieve very high accuracy by using them. Besides, it is described how a simple two-axis compensator was constructed, which occupies little space and can be ideally centrically set in vertical axis of the instrument. This is why the liquid deviates very little from its horizontal position even during a fast rotation of alidade, which is very favourable and enables high accuracy.*

Keywords: *electronic theodolites, registering of directions*

1 Introduction

In references, both ours and foreign, the way of reading electronic theodolites and electronic tacheometers (measurement stations) Leica has not been described in detail. Since that approach is very interesting, we decided to analyse some information that were published on the subject and to write an article about it.

2 Absolute Way of Reading Horizontal and Vertical Angle in the Leica Instruments

The Leica Corporation has been using an absolute way of reading horizontal and vertical limb with all electronic theodolites and electronic tacheometers (measurement stations) (for example, T1000, T1600, TPS1100 and other) since approximately 1999. This absolute way of reading limbs uses only one coded concentric track (trail – division) with cracks. The usual way of coding for reading limb with measurement uncertainty of 1 mgon would require 19 concentric tracks (Joekel, Stober 1991), which would be expensive and hard to achieve from the technical point of view. This is why constructors, in construction of electronic theodolites T1000 and T1600 and measurement stations TPS1100, decided to divide measurement to "rough" and "fine" measurement. They decided for the measurement (by patented solution) to be uncertain approximately 0.3 mgon. According to this solution, a division of limb (concentric track) consists of 1024 light cracks at *equal distances*, with different thickness, which lets light through (Fig 1). Each eighth crack has width of 180 μm, and 128 intervals of "rough" divisions are separated by them. Seven cracks of different widths 60 and 120 μm are inside of one interval of "rough" limb division, which in coded form determine what the number of intervals of rough division is. A thin crack is interpreted as number 1, and a thicker crack as 0. In this manner 7 cracks within one interval of "rough" division define the number of intervals of "rough" division in the decimal system (0 to 127) or the number of intervals of rough division (0000000 to 1111111) in the binary system.

The horizontal and the vertical limb have equal divisions, but the horizontal limb is firmly attached to the base of theodolites, and the vertical limb is firmly attached to the spyglass. Approximately 1% of the limb division, i.e. somewhat more than one interval of "rough" division is illuminated with a luminescent diode and is projected to linear CCD[1] (128 pixels[2] aligned in one row) (Fig 2). During this, one interval of rough division is projected to approximately 100 pixels. One pixel has active area of 25×15 μm^2 and the space between pixels' centres is 25 μm.

[1] CCD (charge coupled device), charge bounded (connected) device, which converts light signal (image) to the electric signal.

[2] Pixel – smallest unit of the mosaic picture on the screen, which can be stored, shown or addressed. Abbreviation of English word *picture cell*, picture on the screen divided into rows and columns, made of small squares, and each of them represents one pixel.

Očitavanje i registracija pravaca elektroničkim teodolitima i elektroničkim tahimetrima Leica

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Sažetak: *U radu je opisano očitavanje i registriranje pravaca modernim elektroničkim teodolitima i elektroničkim tahimetrima Leica i kako se s pomoću njih na jednostavan način postiže vrlo visoka točnost. Opisano je kako je konstruiran jednostavni dvoosni kompenzator, koji zauzima malo prostora te se može postaviti idealno centrično u vertikalnoj osovini instrumenta. Zato se tekućina u kompenzatoru i pri brzom okretanju alhidade vrlo malo otklanja od njezina horizontalnog položaja, što je vrlo povoljno i omogućava vrlo visoku točnost.*

Ključne riječi: *elektronički teodoliti, registracija pravaca*

1. Uvod

U literaturi, u nas i u svijetu, još nije detaljno opisan način očitavanja elektroničkih teodolita i elektroničkih tahimetara (mjernih stanica) Leica. Budući da je taj način vrlo zanimljiv, odlučili smo analizirati podatke koji su o tom objavljeni te o tome napisati članak.

2. Apsolutni način očitavanja horizontalnog i vertikalnoga kuta instrumentima Leica

Tvrtka Leica od približno 1999. godine upotrebljava elektroničke teodolite i elektroničke tahimetre (mjerne stanice) s apsolutnim načinom očitavanja horizontalnog i vertikalnog limba (npr. T1000, T1600, TPS1100 i drugi). Pri apsolutnom načinu očitavanja limbova koristi se samo jedna kodirana koncentrična pruga (trag-podjela) s pukotinama. Uobičajenim načinom kodiranja za očitanje limba s mjernom nesigurnošću 1 mgon trebalo bi 19 koncentričnih pruga (Joekel, Stober 1991), a to bi s tehničke strane bilo teško i skupo postići. Zato su konstruktori pri konstrukciji elektroničkih teodolita T1000 i T1600 i mjernih stanica TPS1100 odlučili rastaviti mjerenje na "grubo" i "fino". Za mjerenje odlučili su (prema patentiranom rješenju) da bude nesigurnost približno 0,3 mgon. Prema tom rješenju podjela limba (koncentrična pruga) sastoji se od 1024 svjetlosna proreza na *jednakom razmaku*, različitih debljina, koji propuštaju svjetlost (sl. 1). Svaki osmi prorez širine je 180 μm, a s njima je odvojeno 128 intervala "grubih" podjela. Sedam proreza različite širine 60 i 120 μm nalazi se unutar jednog intervala "grube" podjele limba, koji u kodiranom obliku određuju koji je to broj intervala "grube" podjele. Tanki prorez interpretira se kao broj 1, a deblji prorez kao 0. Tako 7 pukotina unutar jednog intervala "grube" podjele definira broj intervala "grube" podjele u decimalnom sustavu (0 do 127) ili u binarnom sustavu broj intervala "grube" podjele (0000000 do 1111111).

Horizontalni i vertikalni limb imaju jednake podjele, ali je horizontalni limb čvrsto vezan uz postolje teodolita, a vertikalni je limb čvrsto vezan uz dalekozor. Približno 1% podjele limba, tj. nešto više od jednog intervala "grube" podjele, osvijetljeno je luminiscentnom diodom i preslikava se na linearni CCD[1] (128 piksela[2] poredanih u jednom redu) (sl. 2). Pritom se jedan interval "grube" podjele projicira na približno 100 piksela. Jedan piksel ima aktivnu površinu 25 × 15 μm^2, a razmak je između centara piksela 25 μm.

[1] CCD (engleski charge coupled device), nabojski vezan (spojen) uređaj koji svjetlosni signal (sliku) pretvara u električni signal.

[2] piksel (engleski pixel), najmanja jedinica mozaične slike na zaslonu koja se može spremiti, prikazati ili adresirati. Kratica engleskih riječi *picture cell*, slika na zaslonu podijeljena na retke i stupce, sastavljena od sitnih kvadratića, a svaki od njih predočuje jedan piksel.

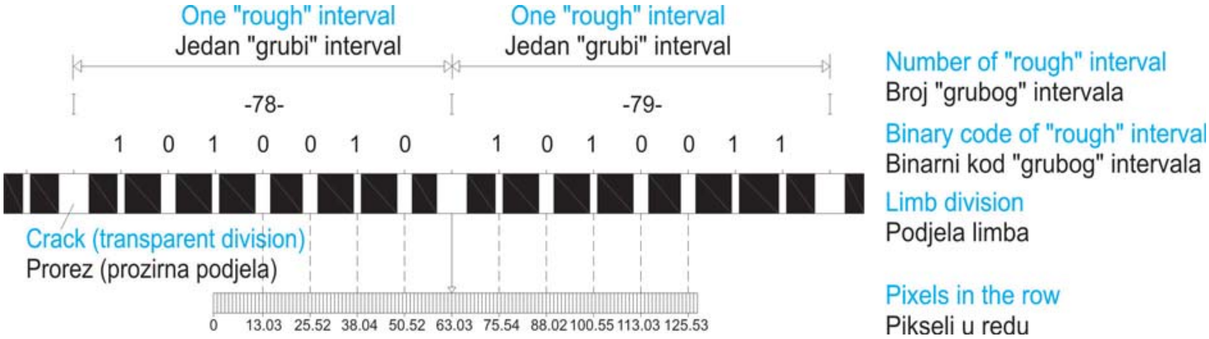


Fig 1. Absolute coding on one concentric track (trail) (Benčić, Solarić 2007)

Slika 1. Apsolutno kodiranje na jednoj koncentričnoj pruzi (tragu) (Benčić, Solarić 2007)

Light falling through a certain crack falls on several pixels. Voltages on the pixels of the linear CCD are read with the use of multiplexer and A/D[3] converter, and based on these voltages the amount of light which fell on them can be calculated. This enables to determine how big part of the pixels light falls, and exact determination the centre of crack through which light falls.

Determining the centre of the crack

From the measured values of voltage on pixels, as it is represented in Fig 3, the centre of the crack can be determined with the measurement uncertainty of 0.01 pixels.

Limb reading is defined as a point of limb division that falls on the first pixel in the row. Measurement value of limb reading consists of "rough" component G and "fine" measurement F. In the part of "rough" measurement, the number of intervals of "rough" (G) limb division is determined from the binary code, whose start is projected to the pixels first (in Fig 1, first is the start of 79th interval of "rough" division). Since 1% of the limb is projected to the linear CCD, at least one "rough" interval falls on the CCD. During the "fine" measurement, deviation of start of the "rough" interval from the first pixel (63.03 pixels in the Fig 1) is determined. For example: One interval of "rough" division has size of exactly 400 gons / 128 "rough" intervals = 3.125 gon/(rough interval). If one "rough" interval is projected to 100 pixels, theodolites reading in a direction R will be:

$$G = 79 \qquad F = \frac{63.031}{100} = 0.63031$$

$$R = (G - F) \times 3.125\,gon$$
$$= 78.36969 \times 3.125\,gon = 244.9053\,gon$$

[3] Multiplexer – a device for multiple data transfers. A/D converter (Analog/Digital converter), converts analog value of voltage to digital, i.e. binary numbers.

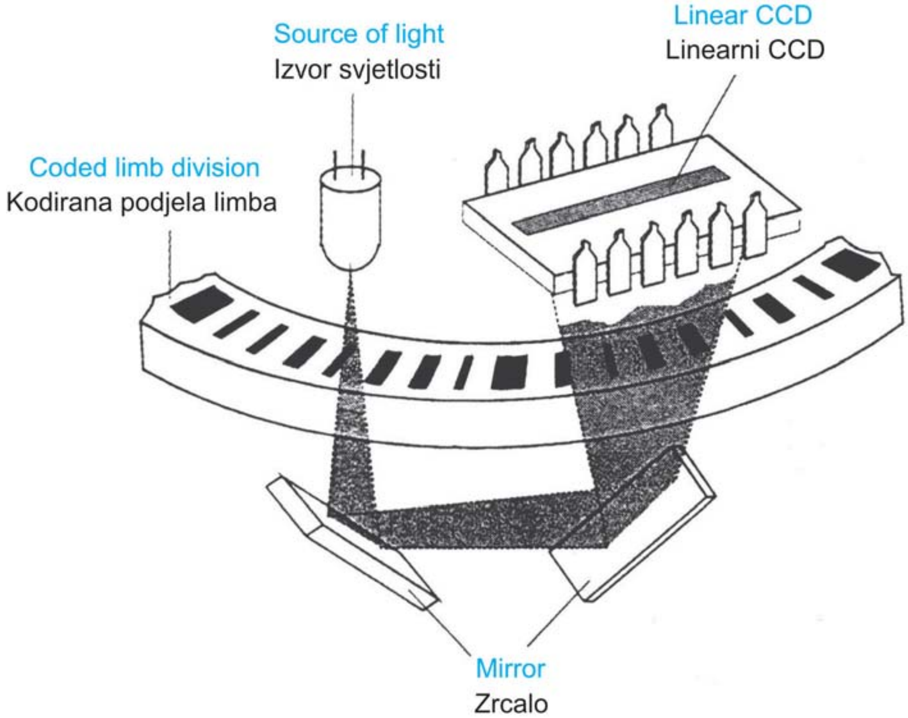


Fig 2. Reading of limb in Leica TPS1100 measurement stations (Deumlich, Staiger 2002)

Slika 2. Očitavanje limba u mjernim stanicama Leica TPS 1100 (Deumlich, Staiger 2002)

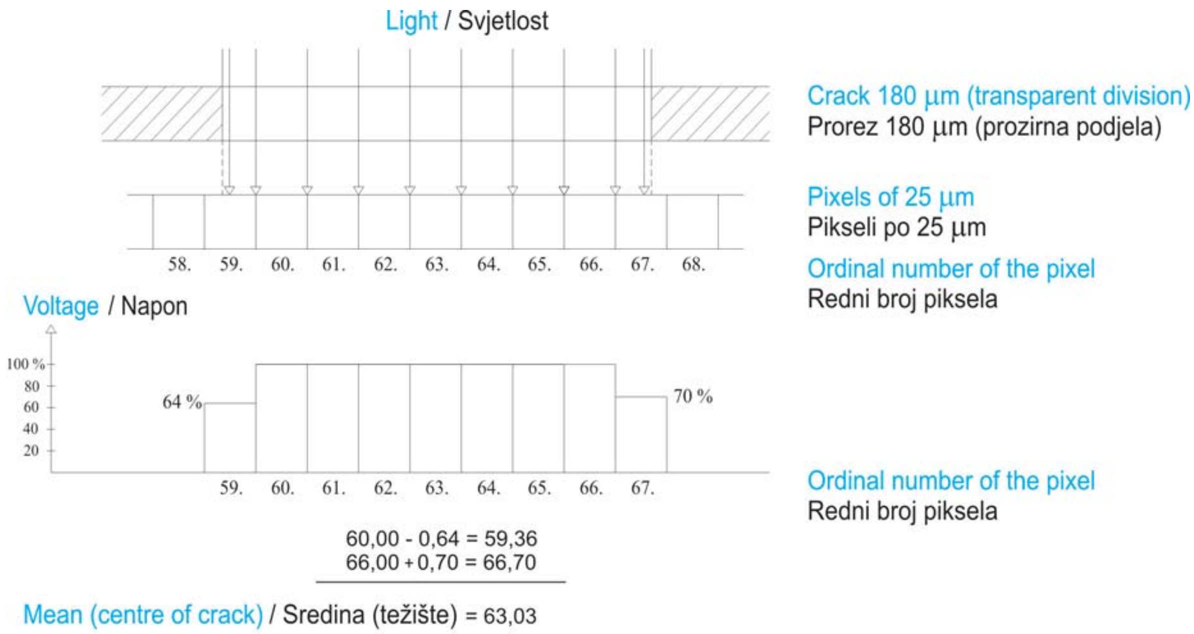


Fig 3. Determination of the centre of the crack (Benčić, Solarić 2007)

Slika 3. Prikaz određivanja težišta proreza (Benčić, Solarić 2007)

Svjetlost koja pada kroz pojedini prorez pada na više piksela. Naponi na pikselima linearnoga CCD-a očitavaju se serijski s pomoću multipleksera i A/D[3] pretvarača, te se na temelju tih napona može izračunati kolika je količina svjetlosti pala na njih. Tako se može odrediti na koliki dio piksela pada svjetlost i točno odrediti težište proreza kroz koji pada svjetlost.

Određivanje težišta proreza

Iz izmjerenih veličina napona na pikselima, kao što se vidi na slici 3, može se odrediti težište proreza s mjernom nesigurnošću od približno 0,01 piksela.

[3] Multiplekser- uređaj za višestruko prenošenje podataka. A/D pretvarač - pretvara analognu veličinu napona u digitalnu, tj. binarne brojeve.

Očitavanje limba definirano je kao točka podjele limba koja pada na prvi piksel u redu. Mjerena vrijednost očitanja limba sastoji se od "grube" sastavnice G i "finog" mjerenja F. U dijelu "grubога" mjerenja određuje se iz binarnoga koda broj intervala "grube" podjele limba G, čiji se početak prvi preslikava na piksele (na sl.1 prvi je početak 79. intervala "grube" podjele). Budući da se preslikava 1% limba na linearni CCD, na CCD pada najmanje jedan "grubi" interval. Za "finog" mjerenja određuje se odstupanje početka "grubog" intervala od prvog piksela (na sl. 1: 63,03 piksela).

Na primjer: jedan interval "grube" podjele predstavlja točno 400 gona/128 grubih intervala = 3,125 gon/grubi interval. Ako se jedan "grubi" interval preslikava na 100 piksela, očitanje teodolita u nekom smjeru R bit će:

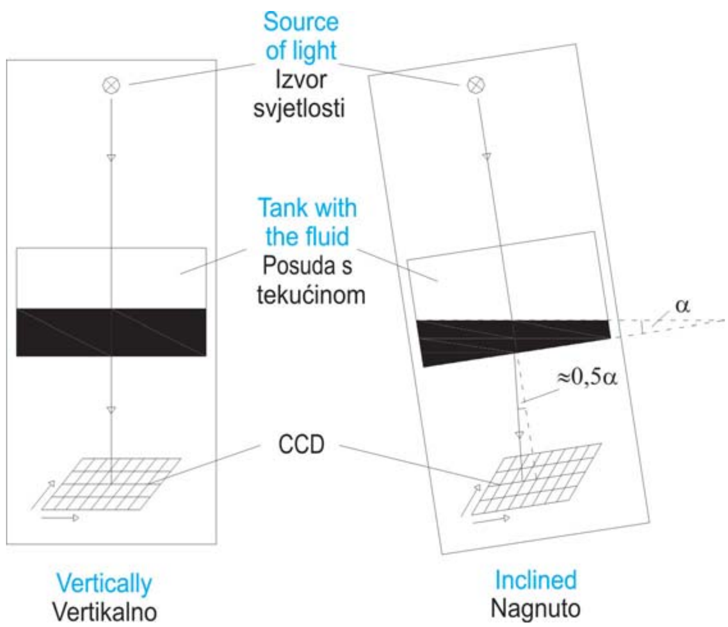


Fig 4. Light passes through the fluid (Deumlich, Staiger 2002)

Slika 4. Svjetlost prolazi kroz tekućinu kompenzatora (Deumlich, Staiger 2002)

With the goal of further accuracy enhancement and in order for limb division mistakes to have as small influence as possible, not only certain lines of divisions (cracks) are used, but also centre of all other projected cracks. In order for the resolution of 1 mgon to be achieved, positions of individual divisions have to be interpolated with the accuracy of 3/100 pixels.

Usually, for the "fine" measurements, 10 divisions (cracks) are used. In this way, focuses of projected cracks in Fig 1 fall on pixels and pixels' parts: 13.03; 25.52; 38.04; 50.52; 63.03; 75.54; 88.02; 10055; 113.03; 125.53 (Fig 1 and Table 1). On the ordinal number of the pixel and the part of pixel on which the centre of individual crack falls, 12.5 pixels[4] multiplied by the number of cracks to the first crack of the interval of the "rough" division is added (Table 1). Theoretically, in this way we get (according to individual division) the pixel on which falls the centre of start of the "rough" interval. By taking their average value, higher accuracy is obtained for the "fine" measurement (63.031 in Table 1).

Calculated value of limb reading before displaying on the display and before memorizing is fixed by corrections. Reading of horizontal limb is fixed by stored collimation error and by the error in inclination of horizontal axis, as well as by the component of horizontal axis' inclination vertically on viewing axis in dependence of vertical angle. Reading of vertical limb is fixed for the stored error of vertical circle index and current component of vertical axis in the direction of the spy glass (target).

[4] On the space between two cracks come (100 pixels) / (8 cracks) = 12.50 pixels/crack.

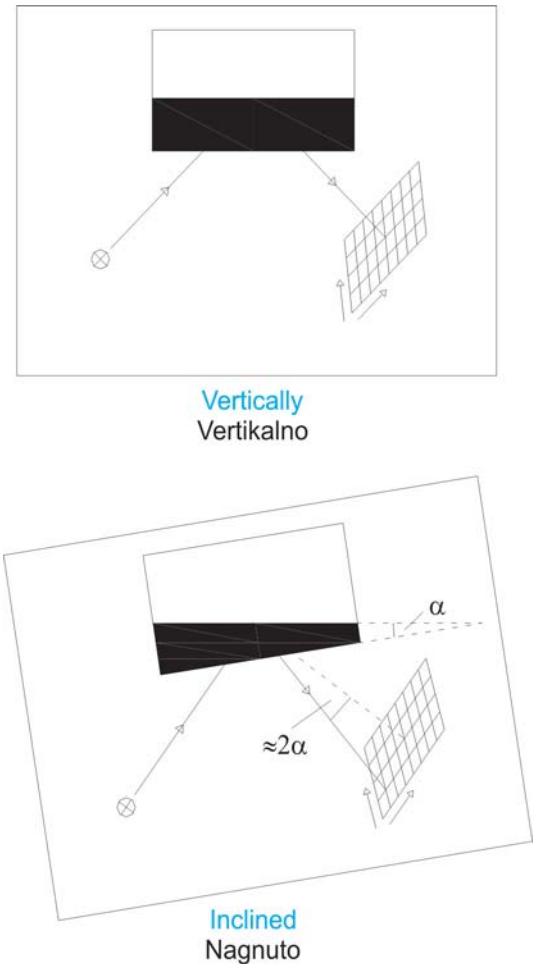


Fig 5. Light comes from the bottom side (Deumlich, Staiger 2002)

Slika 5. Svjetlost dolazi s donje strane tekućine kompenzatora (Deumlich, Staiger 2002)

3 Double Axis Compensator

Compensators in electronic theodolites and tacheometers measure the inclination of instrument's vertical axis. With optical theodolites and tacheometers, compensators really have the role to immediately compensate (correct) the influence of the inclination of vertical axis on the reading of vertical circle, and corrected reading of vertical circle is immediately received. With electronic theodolites and tacheometers it would be more proper for the compensators to bear the name of vertical axis inclination meters, but with them, as well as with optical theodolites, the name compensators became common in references. Vertical axis inclination in the direction of telescope measured by compensator is arithmetically taken into consideration when calculating the vertical circle.

If the compensator is also set in the direction of horizontal axis of tacheometer, with the help of that compensator, influence of inclination of the instrument's vertical axis on the reading of horizontal circle can also be taken into consideration, which is extremely important in steep line of sights. These compensators which measure inclination of vertical axis in the direction of telescope and in the direction of horizontal axis are called double-axis compensators, while single-axis compensators measure only the inclination of vertical axis in the direction of the telescope. Today, almost all electronic tachometers have double-axis compensators (vertical axis' inclination meters), and Leica compensator excels in simplicity and idea of construction.

After approximate horizontal positioning of tacheometer with dose plumb or alidade plumb, thanks to compensators, reading of horizontal and vertical circle is obtained almost as if the instrument were exactly horizontally positioned. This is why it does not take as much time to position the instrument horizontally as before, and received measurement is more accurate, especially if the views are steep.

In the compensators, fluid level is positioned horizontally, i.e. vertically on the direction of vertical (plumb bob), independently of the instrument's setting. When the instrument is not horizontally positioned, light goes through fluid as through a pin, and fractures (Fig 4). It is even better if light comes from below the fluid, and there is total reflection on the upper horizontal surface (Fig 5). Then the shift of light-ray is bigger, approximately four times, than when light comes from above. This enables more accurate determining of tachometers' vertical axis' inclination. This is why constructors in Leica Corporation have chosen the kind of position in which light comes from the bottom side of the fluid.

$$G = 79 \qquad F = \frac{63.031}{100} = 0.63031$$

$$R = (G - F) \times 3.125\, gon$$
$$= 78.36969 \times 3.125\, gon = 244.9053\, gon$$

Radi daljnjeg povećanja točnosti i da bi pogreške podjele limba utjecale što manje, ne primjenjuju se samo pojedine crtice podjele (prorezi), nego također i težišta svih ostalih preslikanih pukotina. Kako bi se postiglo razlučivanje od 1 mgon, pozicija pojedine podjele mora biti interpolirana s točnošću od 3/100 piksela.

Za "fino" mjerenje obično se koristi najmanje 10 podjela (proreza). Tako težišta preslikanih proreza na slici 1 padaju na piksele i dijelove piksela: 13,03; 25,52; 38,04; 50,52; 63,03; 75,54; 88,02; 100,55; 113,03; 125,53 (sl. 1 i tablica 1). Na redni broj piksela i dio piksela na koje pada težište pojedinog proreza dodaje se 12,5 piksela[4] puta broj proreza do prvog proreza početka intervala "grube" podjele (tablica 1). Na taj se način dobiva teorijski (prema pojedinoj podjeli) na koji piksel pada težište početka "grubog"intervala. Uzimanjem njihove srednje vrijednosti dobiva se za "fino" mjerenje veća točnost (u tablici 1: 63,031).

Izračunana vrijednost očitanja limba prije prikazivanja na zaslonu i memoriranja popravlja se korekcijama. Očitanje horizontalnog limba popravlja se pohranjenom kolimacijskom pogreškom i pogreškom nagiba horizontalne osi kao i aktualnom sastavnicom nagiba vertikalne osi okomito na vizurnu os u ovisnosti o vertikalnom kutu. Očitanje vertikalnog limba popravlja se za pohranjenu pogrešku indeksa vertikalnoga kruga i trenutačne sastavnice vertikalne osi u smjeru dalekozora (cilja).

3. Dvoosni kompenzator

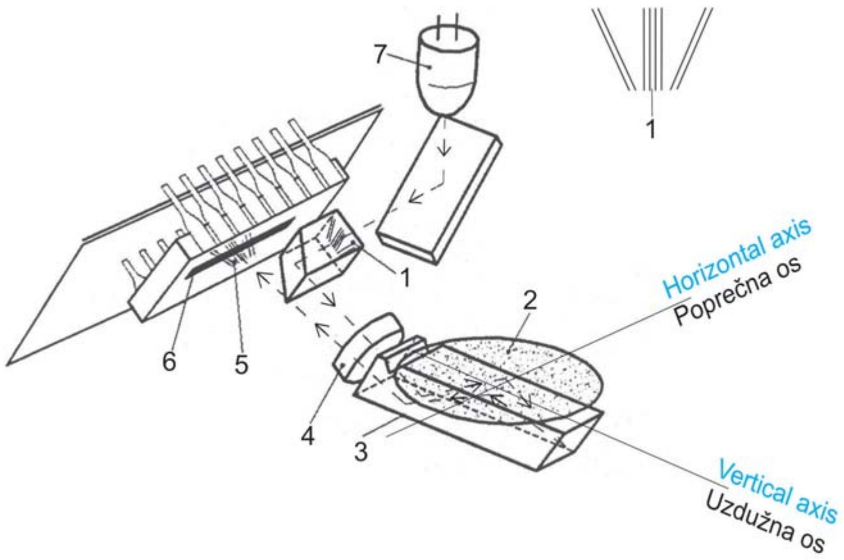
Kompenzatori u elektroničkim teodolitima i tahimetrima mjere nagib vertikalne osi instrumenta. U optičkim teodolitima i tahimetrima kompenzatori stvarno imaju ulogu da odmah kompenziraju (isprave) utjecaj nagiba vertikalne osi na očitanje vertikalnoga kruga, te se odmah dobiva ispravljeno očitanje vertikalnoga kruga. U elektroničkim teodolitima i tahimetrima bilo bi pravilnije da kompenzatori imaju naziv mjerači nagiba vertikalne osi, ali se u literaturi uobičajio naziv kompenzatori. Kompenzatorom izmjereni nagib vertikalne osi u smjeru

[4] Na razmak između težišta dvaju proreza dolazi (100 piksela) / (8 proreza) = 12,50 piksela/prorez.

Table 1. Calculating on which pixel and part of the pixel the centre of the first crack of start of the "rough" division interval falls, from centre of other cracks

Tablica 1. Računanje na koji piksel i dio piksela pada težište prvog proreza početka intervala "grube" podjele, iz težišta ostalih proreza

Pixel and part of the pixel on which the centre of certain cracks falls Piksel i dio piksela na koji padaju težišta pojedinog proreza	*n* number of cracks from the first pixel to the first cracks of start of the "rough" division interval *n* broj proreza od prvog piksela do prvog proreza početka intervala "grube" podjele	*n*×12.5 pixels *n*×12.5 piksela	Centre of the first cracks of start of the "rough" interval, calculated by the centre of other cracks 1+3 Težište prvog proreza početka "grubog" intervala, izračunano prema težištima ostalih proreza 1+3
1	2	3	4
13.03	4	50.00	63.03
25.52	3	37.50	63.02
38.04	2	25.00	63.04
50.52	1	12.50	63.02
63.03	0	0	63.03
75.54	–1	–12.50	63.04
88.02	–2	–25.00	63.02
100.55	–3	–37.50	63.05
113.03	–4	–50.00	63.03
125.53	–5	–62.50	63.03
			Mean / Sredina: 63,031



1 – Lines on the prism
2 – Upper surface of oil
3 – Prism for rotating of light rays on the other side
4 – Lens for projection of lines from prism (1) to linear CCD
5 – Image of line from prism (1) on linear CCD
6 – Linear CCD
7 – Luminescent diode for illumination

1 – Crtice na prizmi
2 – Gornja površina ulja
3 – Prizma za okretanje snopa svjetlosti na drugu stranu
4 – Leća za preslikavanje crtica s prizme (1) na linearni CCD
5 – Slika crtica s prizme (1) na linearnom CCD-u
6 – Linearni CCD
7 – Luminiscentna dioda za osvjetljenje

Fig 6 – Double-axis compensator (Deumlich, Staiger 2002)

Slika 6. Dvoosni kompenzator (Deumlich, Staiger 2002)

In the instruments Leica, both components of vertical axis' inclination are measured with the continuous double-axis compensators (Fig 6). In this Figure, composition of compensator is given schematically, in which upper reflecting surface of the fluid (on the bottom side) represents the horizon.

Luminescent diode (7) illuminates lines on the prism (1). Over the projecting lens (4) and double reflection on the upper surface of oil (2), lines from the prism are projected to linear CCD (pixels arranged in one line). With the help of lines (1) on the prism that have some angle between them (Fig 6), it is possible to determine both components of vertical axis' inclination with the use of linear CCD. This enables determination of both components, vertical and horizontal, with one compensator. In the horizontal inclination on linear CCD (6) the difference between images of lines of different lengths changes, while in the vertical inclination centre of whole picture (figure) of the lines on the linear CCD changes. More lines on the prism (1) are set up in order for measurement accuracy to be improved.

With this successful construction, a double-axis compensator of very small dimensions was created, and it can be ideally centrically set on the vertical axis. This is why even during fast rotation of alidade, fluid deviates very little from its horizontal position, which is very convenient and enables high accuracy.

4 Conclusion

This absolute way of limb reading has its advantages to incremental way because the theodolite might be put out of operation (electricity) and reengaged. If the stature doesn't move in the meantime, it continues measurement. This enables saving of power from the accumulator. On the other hand, this absolute way of reading is much cheaper compared to dynamic reading of theodolites. Since approximately 1999, the Leica Corporation has been producing electronic theodolites and absolute measurement stations with only this absolute way of reading limbs with one coded concentric track.

This double-axis compensator of very small dimensions was created in one part and is very interesting. With its use, simultaneous determination of theodolite's vertical axis' inclination in vertical and horizontal direction is achieved. And then, by electronic arithmetic way, influence of theodolite's vertical axis' inclination on the reading of horizontal and vertical circle is calculated.

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dalekozora tahimetra računski se uzima u obzir pri računanju očitanja vertikalnoga kruga.

Ako je kompenzator postavljen i u smjeru horizontalne osi tahimetra, s pomoću toga kompenzatora može se uzeti u obzir i utjecaj nagiba vertikalne osi instrumenta u smjeru horizontalne osi na očitanje horizontalnoga kruga, što je osobito važno kod strmih vizura. Takvi kompenzatori koji mjere nagib vertikalne osi u smjeru dalekozora i u smjeru horizontalne osi nazivaju se dvoosni kompenzatori, a jednoosni kompenzatori mjere samo nagib vertikalne osi u smjeru dalekozora. Danas gotovo svi elektronički tahimetri imaju dvoosne kompenzatore (mjerače nagiba vertikalne osi), a kompenzator Leice ističe se jednostavnošću zamisli izvedbe.

Nakon približnoga horizontiranja tahimetra doznom ili alhidadnom libelom, zahvaljujući kompenzatorima dobiva se očitanje horizontalnog i vertikalnoga kruga kao da je instrument gotovo točno horizontiran. Zato ne treba mnogo vremena trošiti na horizontiranje instrumenta kao prije, a dobiva se i točnije mjerenje, osobito ako su vizure strme.

U kompenzatorima se razina tekućine postavlja horizontalno, tj. okomito na smjer vertikale (viska), neovisno o postavu instrumenta. Kad instrument nije horizontiran, svjetlost prolazi kroz tekućinu kao kroz klin i lomi se (sl. 4). Još je bolje ako svjetlost dolazi s donje strane tekućine, a na gornjoj horizontalnoj plohi dolazi do totalne refleksije (sl. 5). Tada je pomak zrake svjetlosti približno četiri puta veći nego kada svjetlost dolazi odozgo. To omogućava točnije određivanje nagiba vertikalne osi tahimetra. Zato su konstruktori u tvrtki Leica izabrali takav položaj u kojem svjetlost dolazi s donje strane tekućine.

U instrumentima Leica obadvije sastavnice nagiba vertikalne osi mjere se kontinuirano dvoosnim kompenzatorom (sl. 6). Na toj slici shematski je prikazana građa kompenzatora kod kojega gornja reflektirajuća površina tekućine (s donje strane) predstavlja horizont.

Luminiscentna dioda (7) osvjetljava crtice na prizmi (1). Preko leće za preslikavanje (4) i dvostruke refleksije na gornjoj površini ulja (2) crtice s prizme (1) preslikavaju se na linearni CCD (6) (pikseli poredani u jednom redu). S pomoću crtica (1) na prizmi, koje su međusobno pod nekim kutom (sl. 6) moguće je linearnim CCD-om odrediti obadvije sastavnice nagiba vertikalne osi. To omogućava da se jednim kompenzatorom određuju obadvije sastavnice – uzdužna i poprečna. Pri uzdužnom nagibu na linearnom CCD-u (6) mijenja se razmak između slika crtica različitog nagiba, a pri poprečnom nagibu mijenja se težište ukupne slike (figure) crtica. Više crtica na prizmi (1) postavljeno je zato, da bi se povećala točnost mjerenja.

Takvom uspjelom konstrukcijom napravljen je dvoosni kompenzator vrlo malih dimenzija, te se može postaviti idealno centrično u vertikalnoj osovini. Zato se i pri brzom okretanju alhidade tekućina vrlo malo otklanja od njezina horizontalnog položaja, što je vrlo povoljno i omogućava visoku točnost.

4. Zaključak

Prednost je apsolutnog načina očitavanja limba pred inkrementalnim načinom u tome, što se teodolit smije isključiti iz rada (struje) i opet uključiti i nastaviti mjerenje, ako se stativ u međuvremenu nije pomaknuo. To omogućava uštedu struje iz akumulatora. S obzirom na dinamički način očitavanja teodolita, apsolutni način očitavanja znatno je jeftiniji. Od približno 1999. godine tvrtka Leica proizvodi elektroničke teodolite i mjerne stanice samo s tim apsolutnim načinom očitavanja limbova s pomoću jedne kodirane koncentrične pruge.

Dvoosnim kompenzatorom vrlo malih dimenzija, izrađenim u jednom dijelu, na vrlo zanimljiv način postiže se istodobno određivanje nagiba vertikalne osi teodolita u poprečnom i uzdužnom smjeru, a zatim se elektronički računskim putem obračunava utjecaj nagiba vertikalne osi teodolita na očitanje horizontalnog i vertikalnoga kruga.

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