Results of development of a stand for evaluation of the accuracy characteristics of absolute trackers

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Abstract. The paper analyzes the existing means of metrological support for absolute trackers, outlines the proposed solutions to the identified shortcomings of existing methods and means of metrological support for absolute trackers, and presents the results of the development of a stand layout for metrological support for absolute trackers.

1 Introduction

The Absolute Tracker is a high-precision coordinate measuring system. These measuring instruments have found applications in various industries from the world's largest infrastructure projects to leading scientific research.

The principle of operation of an absolute tracker is to measure the distance to the object under study and register the corresponding directions (vertical and horizontal angles) with the subsequent calculation of spatial coordinates. Depending on the manufacturer's firm and modification, absolute trackers structurally consist of an absolute rangefinder, an interferometer and goniometric decoders [1].

The suitability of absolute trackers for use is established by evaluating their metrological characteristics during the verification procedure. From the analysis of the metrological characteristics of existing and prospective absolute trackers, it follows that the error of the absolute rangefinder at the lower boundary is 10 μm, the error of the interferometer at the lower boundary is 0.5 μm, and the total error of volumetric measurements is 10 μm + 5 μm / m at the lower boundary.

2 Materials and methods

At present, the main means for verifying absolute trackers are measures for verifying laser coordinate measuring systems Leica Absolute Tracker AT401, Leica Absolute Tracker AT402, Leica Absolute Tracker AT901 (hereinafter referred to as the measure). The general view of the measure is shown in Fig. 1.

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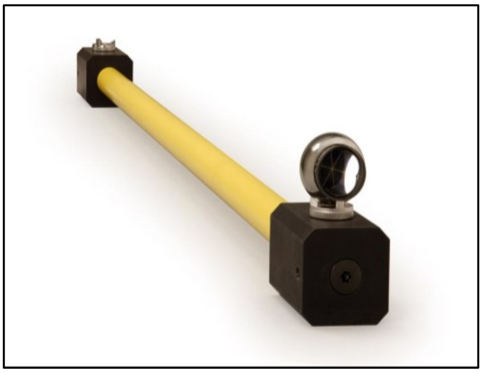

Fig. 1. Measure for verification of laser coordinate measuring systems.

A typical technique [2,3] for verifying absolute trackers using measures is as follows: the measure is sequentially located in four positions that are maximally different from each other (Fig. 2), at a distance of 1.7 to 6 m from the investigated device. According to the operational documentation of the absolute tracker, the spatial coordinates of the reflectors fixed at the ends of the measure are determined, the subsequent calculation of the distances between the centers of the reflectors and the determination of the deviations of the measured values from the actual values of the measure.

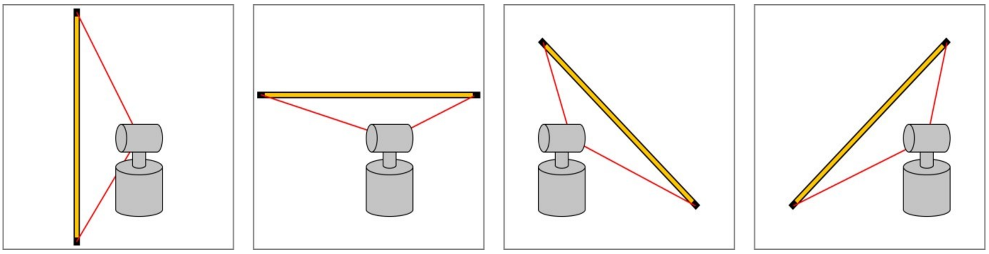

Fig. 2. Layout diagram of the measure relative to the investigated device.

The disadvantages of using the measure as the main means of verifying absolute trackers include:

- Limited measurement range - 2.5 m for prefabricated measures and 1 m for non-separable measures, which makes it possible to evaluate the error only in terms of measurements of spatial coordinates in a limited range of operation of the rangefinder and goniometric parts of the device;
- The limit of the absolute error of reproducing the length of the composite measure is ± 13 µm, which does not provide a margin of accuracy when assessing the metrological characteristics of most absolute trackers;
- The inability to assess the measurement error using interferometric systems that are part of the absolute trackers;
- Inability to estimate the absolute error of distance measurements by the rangefinder part of the device.

Taking into account the analysis of the existing standard base and the needs for metrological support of absolute trackers, it is proposed to develop a stand for metrological support of absolute trackers (hereinafter referred to as the stand) based on a reference measuring complex of length in the range of up to 60 m (hereinafter referred to as measuring complex of length) from The primary special standard of the unit of length (GET 199-2018) [4];

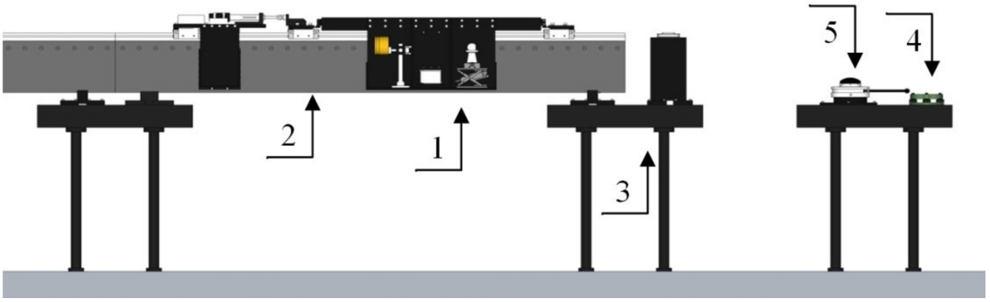

Fig. 3. Layout diagram of the stand. 1 - movable platform, 2 - rolling rail, 3 - optical table, 4 - slot for absolute trackers like Leica AT401-AT403; 5 - slot for absolute trackers like Faro Laser Tracker, Leica AT960 - AT930.

The developed model of the stand (Fig. 3) makes it possible to transfer the unit of length to absolute trackers (the main metrological characteristic) and to evaluate the error in determining the spatial coordinates in the entire working range, both with the use of an absolute range finder and with the use of interferometric systems that are part of the absolute tracker.

The principle of operation of the stand layout is based on the simultaneous measurement of the baseline lengths in the range up to 60 m by the interferometric system from the GET 199-2018 [5,6] (hereinafter referred to as the interferometric system) and the investigated device by the method of direct comparison, as well as by the method of indirect length measurements by coordinate increments.

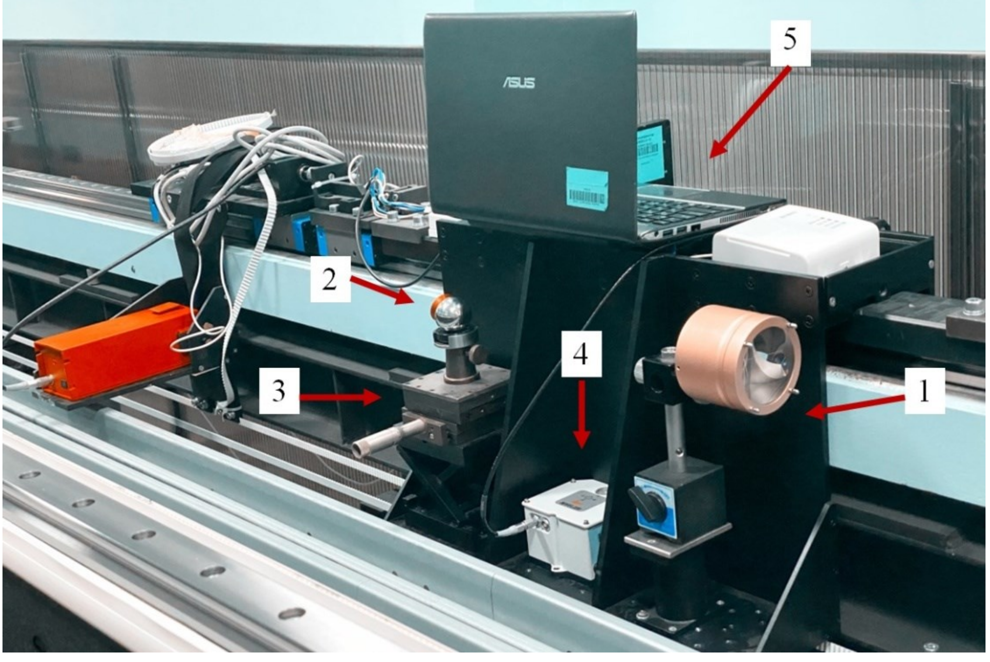

Fig. 4. The composition of the mobile platform. 1 - corner reflector of the interferometric system, 2 - corner reflector of the absolute tracker, 3 - adjustable turntable, 4 - Leica Nivel inclinometer, 5- PC for controlling the equipment of the moving platform.

A corner reflector of laser radiation of the interferometric system and a reflector from the delivery kit of the absolute tracker on an adjustable turntable are installed on the movable platform (Fig. 4). To compensate for the tilt of the movable platform, a high-precision Leica Nivel inclinometer is installed.

To transfer the unit of length, the investigated device is installed at the beginning of the measuring complex of length. The laser radiation of the investigated device and the interferometric system propagates towards each other along the measuring line to the reflectors installed on the movable platform.

The absolute error of length measurement by the direct comparison method is calculated as the difference between the obtained and actual values of the baseline lengths.

To determine the error of volumetric measurements, the investigated device is installed in the center of the measuring complex of length. The movable platform is installed in the extreme position of measuring complex of length. The determination of the spatial coordinates of the reflector of the absolute tracker installed on the moving platform is performed. The platform moves to an arbitrary length of the base. The displacement value is measured by an interferometric system. The spatial coordinates of the reflector are determined in the new position of the movable platform and the length value between the centers of the reflectors is calculated from the increments of coordinates in different positions of the platform.

The absolute error of volumetric measurements is calculated as the difference between the line lengths obtained from the coordinate increments and the actual values.

To implement the method for calculating the length by increments of coordinates in the entire range of measuring complex of length, it is necessary to maintain the aiming of the reflector at the instrument under study during measurements. This makes it possible to evaluate the measurement error using the interferometric systems that are part of the absolute trackers.

3 Results and Discussion

Experimental studies of the proposed method were carried out using a Leica AT401 laser coordinate measuring system. The limits of the permissible error in measuring the length and volumetric measurements were determined on the developed model of the stand, the measurement results are given in Tables 1 and 2.

Table 1. Results of studies of the error of rangefinder measurements.

Position of the movable platform, m	Length reference value, mm	Absolute tracker readings, mm	ΔL, μm	Allowable values, μm
5	5002,7141	5002,6966	-17,5	±45
10	10002,4511	10002,4328	-18,3	±75
15	15003,6181	15003,6228	4,7	±105
20	20002,8099	20002,7885	-21,4	±135
25	25002,3939	25002,3795	-14,4	±165
30	30001,7014	30001,6739	-27,5	±195
35	35001,9855	35001,9659	-19,6	±225
40	40000,7606	40000,7324	-28,2	±255
45	45000,0259	45000,0027	-23,2	±285
50	50002,5925	50002,5633	-29,2	±315
55	55003,7574	55003,7387	-18,7	±345

60	60005,6715	60005,6448	-26,7	±375

Table 2. Results of studies of the error of rangefinder measurements.

Position of the movable platform, m	Length reference value, mm	Absolute tracker readings, mm	ΔL, μm	Allowable values, μm
0-5	4996,9001	4996,9056	5,5	±255
5-10	5000,0855	5000,0977	12,2	±213
10-15	5001,0477	5001,0515	3,8	±171
15-20	5001,9800	5001,9914	11,4	±129
20-25	5000,1163	5000,1133	-3,0	±87
25-30	5000,1067	5000,1060	-0,7	±51
30-35	5000,8548	5000,8337	-21,1	±51
35-40	4999,7727	4999,7561	-16,6	±87
40-45	4999,7806	4999,7996	19,0	±129
45-50	4999,9104	4999,9220	11,6	±171
50-55	5000,1447	5000,1429	-1,8	±213
55-60 m	4999,8027	4999,8135	10,8	±255

4 Conclusions

Experimental studies have shown that the values of the absolute error in measuring the length and volumetric measurements, determined using the model of the stand, do not exceed the permissible values established when the type of the absolute tracker Leica AT401 was approved [7].

Thus, a model of a stand for metrological support of absolute trackers has been proposed and developed, a method for assessing the metrological characteristics of absolute trackers has been proposed and tested. The direction of further work will be the study of the metrological characteristics of the model of the stand, as well as its further development.

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