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ATLAS AUTOMATED MEASURING SYSTEM FOR GEOMETRIC RECORDING OF RAIL TRACK SITES IN MINES

The article describes the industrial test and the test data of an automated measuring system designed for geometric recording of rail track sites in mines. The profile of an underground opening and the parameters of a rail track are measured in the course of underground mineral mining.

The industrial tests of the automated measuring system for recording geometric parameters in sections of the railway track were carried out in the Yakovlevsky Mine, and the methodology of the track deformation and geometrics recording using the ATLAS automated measuring system was developed and evaluated. The method proposed for the track gauge measurement used an unmanned automated device. The results of the ATLAS automated measuring system are compared with the check measurements taken using the traditional method and an electronic tachometer. The use of the system makes it possible to significantly improve the quality, speed and safety of measurements for determining deformation of rail track and geometric parameters of mine openings.

Keywords: *automated measuring system, track gauge, mine opening profile, railway gradient, remote technologies, Lidar, point cloud*
DOI: *10.17580/em.2025.02.18*

Introduction

The key methods of profile leveling and track alignment in mine openings are survey measurements, including reflectionless performance [1–4]. These methods have some disadvantages connected with the presence of a miners' crew in the zone of possible deformation of rock mass, the manual operation speed not higher than 3 km/h, and the measurement accuracy totally dependent on the personnel skill level. During execution of obligatory survey measurements, mining operations are interrupted, which leads to economic losses.

Aimed at minimizing risks and economic loss in surveying in profile leveling and track alignment in mine openings, scientists of the Institute of Earth Sciences within the Belgorod State National Research University jointly with experts from Industrial Electronic Systems LLC developed an unmanned automated measuring system for taking and recording geometrical measurements of railway tracks in mines.

This article describes the survey measurement procedure using the ATLAS automated measuring system and the testing results of the latter in the Yakovlevsky Mine.

Research procedure and results

The ATLAS automated measuring system is designed for measuring geometrical parameters: track gauge, rail cant—actual gradient, configuration and dimension of a mine openings [4, 5].

The system moves independently along a rail track inside a mine and automatically records geometrical parameters, and also saves the results in on-board memory.

The system is a special automated device for geometric measurements to be taken in railway underground openings.

An operator carries out remotely controlled tour along a mine opening with automated measurement of track gauge and gradient. Built-in Lidar scans the mine opening profile while the system moves along the rail track [6–8]. The measurement data are recorded in the on-board memory in the form of files and are later sent to a PC for the further processing.

The system has a dedicated software program which scans sensors, records measurements, controls the system travel, protects the system and exchanges information with the remote control (**Fig. 1**).

Specifications of the system are given below:

Roof height measurement accuracy, mm	±4
Edge clearance measurement accuracy, mm	±25
Travel velocity, km/h	6
Self-sustained travel distance, km	2
Track gauge measurement error, mm	1
Angular data measurement error, deg	1
Outline dimensions, mm	440x1060x270
Allowable ambient temperature range, °C	From –10 to +30
Equipment protection level	IP55
Battery recharging-free active time, h	2
Control	Wifi via Web interface
Geometric measurements:	
Track gauge, mm	730–790
Cant, mm	± 63

An operator manually, using an iPad (smartphone) application, commands the system to start the tour along a mine opening. The track gauge is measured automatically together with the deviation of the upper surface of rails from zero datum, and Lidar performs continuous scanning of surfaces in the mine opening to build its profile later on.

The track gauge is measured using a magnetic linear encoder. The operation of magnetic linear encoders involves the reader and magnetic tape interaction [9–13]. The maximum working range is governed by the length of the magnetic tape.

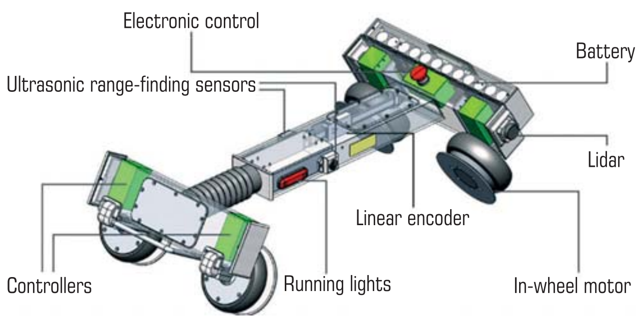


Fig. 1. Measuring system

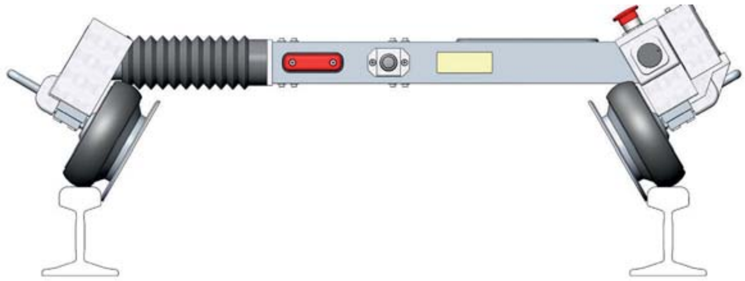


Fig. 2. Arrangement of measuring system on rails

Design of a magnetic linear encoder allows using it with equipment exposed to dust, oils and other aggressive environments.

The body of the system has movable and immovable parts with in-wheel motors. These parts are spring-assisted so that the wheel disks are pressed to the inner vertical surfaces of rails (**Fig. 2**).

As the system travels and the track gauge changes, the mechanical displacement is transferred from the in-wheel motors to the movable parts of the system body and, then, to the magnetic linear encoder. During displacement, the encoder gets digital pulses which code the distance of the displacement of the reader relative to the magnetic tape.

The pulses are decoded by microcontroller STM32F103VET6 arranged on the board of the electronic control to the value of the track gauge at a pitch of 0.01 mm. The track gauge values are recorded together with the information on the distance covered by the measuring system relative to a start point.

The rail track gradient is measured by the system using an angular orientation subsystem based on chip MPU-9250. The chip is a universal sensor integrating capacities of a gyro, acceleration meter and a magnetometer.

The distance travelled by the system is determined using three Hall-effect sensors set on each in-wheel motor. The Hall-effect sensors generate 45 impulses per one revolution of an in-wheel motor. During measurement of a travel distance, the instantaneous speeds and accelerations of the system are additionally calculated.

When the measurement process is finished, the system makes a report in the form of a set of the time-oriented and covered distance-oriented results. The measurement data are saved in USB memory in the form of an e-table. Later on, the data are processed using cloud analytics and report preparation.

The system software is downloaded to the electronic control. The functions of the software are accessed via web interface.

Being energized (connected to the battery), the robot automatically connects using Wi-Fi networks to the remote control (cell phone or iPad). An IP address of the system is assigned by an operating system of the cell phone.

As the IP address is entered, the main browser window shows the master form depicted in **Fig. 3**.

A mode of motion is set as follows:

Distance—sets the distance to be covered by the system in meters;

Return—sets the system, after it has passed the preset distance, to return automatically to a starting point;

Motion—sets the direction of the system travel;

Start button—starts the system travel at the preset parameters;

Reset button—zeroes the critical errors and resets the system to standby mode until the Start command;

Stop button—stops the system travel.

During the travel, position angles of the unit are measured (pitching motion, inclination). In addition, the covered distance and the track gauge are measured at a discretization of one meter. The Lidar data are also recorded during the travel.

In case of an emergency, using the mushroom knob, it is possible to cut off the circuit feeders of the in-wheels. In case that an obstacle or an equipment fault appears during the travel of the system, it displays the information on the screen.

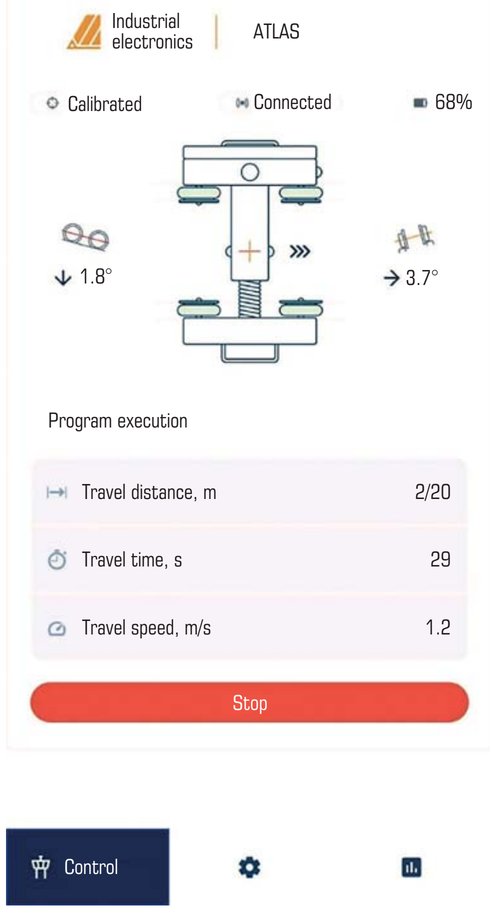


Fig. 3. Master form of measuring system application

The ATLAS automated measuring system was tested in the Yakovlevsky Mine between October 1, 2024 and June 1, 2024. To that effect, a testing site 120 m long was created on the Level of – 425 m. For the covered distance measurement accuracy assessment, the test way interval was split into station distances of 10 m by survey marks. For the accuracy assessment of the gradient measurement, the spatial coordinates were determined for each station distance using an electronic tachometer. The reference measurements of distances between the rail head and the mine opening roof in each station distance were obtained by the tachometer-based scanning in the reflectionless mode [14, 15].

The test of the automated measuring system involved two modes of behavior:

• continuous survey along the whole route, with automatic return to a starting point;

• continuous survey in short (10–30 m) sections, with automatic return to a starting point.

The profile of the mine opening was built in a special program and using the obtained 3D model of the opening (**Fig. 4**) [16].

The actual/design profile deviation in a mine opening was determined based on the distances between the rail edge and the sidewalls and between the rail head and the roof. It is important that during operation, the automated measuring system performs continuous acquisition of data and preparation of a report as against traditional manual measurements taken every 10 meters. In the latter case, the working team may miss a section with deformation of a rail track and may fail to determine visually the conformity of the mine opening profile to the design dimensions (**Fig. 5**).

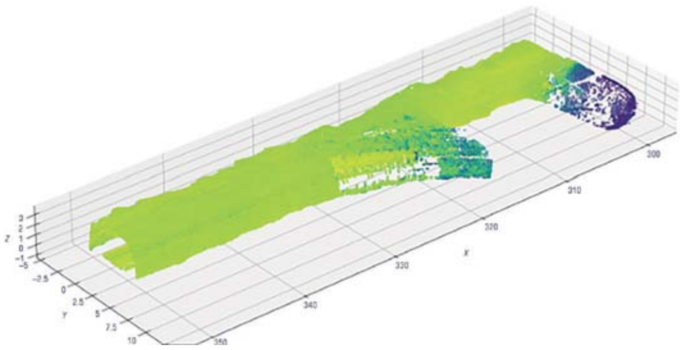


Fig. 4. 3D model of mine opening surface

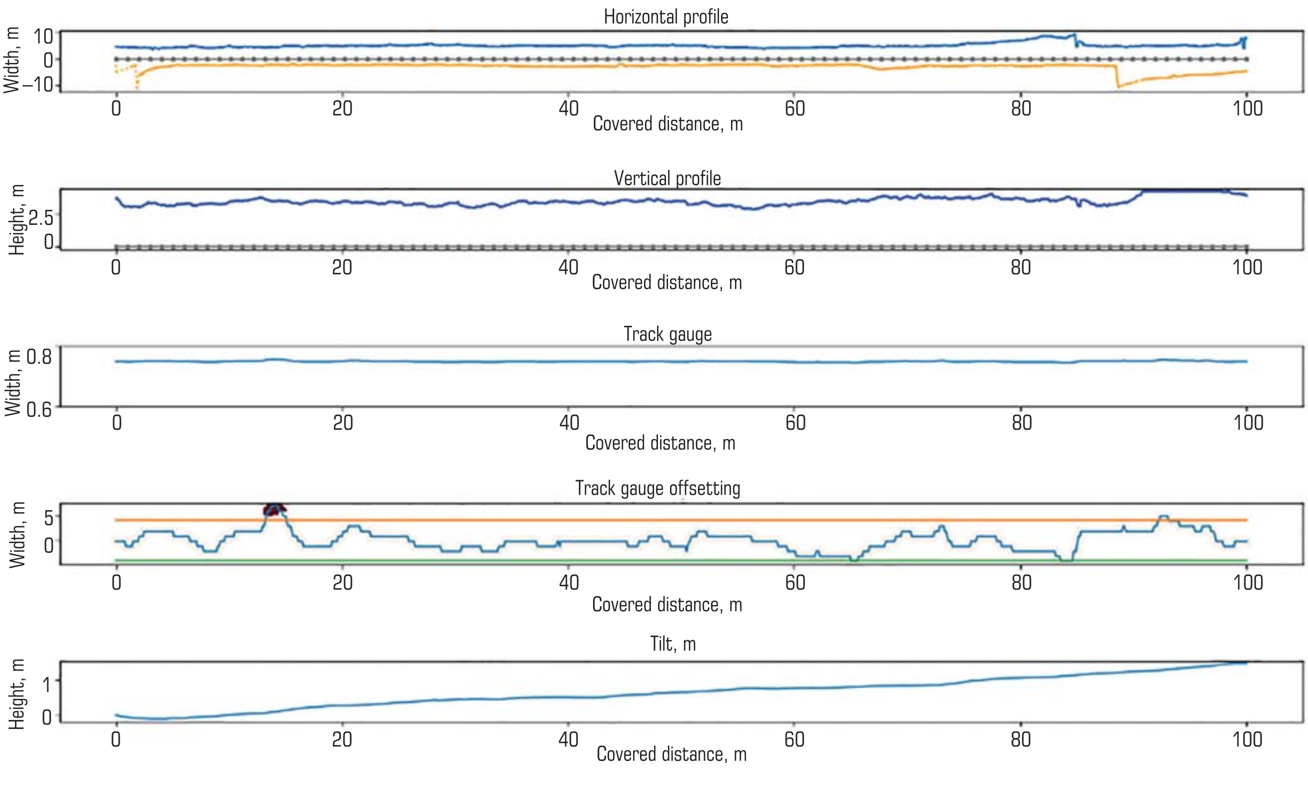
The measurement results obtained using the automated measuring system (AMS) and a traditional tachometer (reference) are compared in the **Table**.

The comparison of the measurement results shows that the deviation of the track gauge measured by the automated measuring system from the reference manual measurement using a laser meter is not more than 1 mm. The deviation of the distances from the rail side surfaces to the mine opening sidewalls ranges from 1 to 18 mm. The maximal deviation of the roof heights obtained using the automatic measuring system and the laser meter is 4 mm.

It is worthy of mentioning that some errors of measurements are governed by that fact that during the full-scale test of the automated measuring system, it was impossible to ensure complete coincidence of the contact area of the laser beam of the Lidar with the point where the manual measurements were taken. Considering that the sidewalls of the mine opening had extremely uneven surfaces, that added to the measurement error. The error was additionally estimated via measurement taken in an enclosed space of a regular geometrical configuration.

Conclusions

1. The measurement procedure of geometrical parameters of rail tracks and mine opening profiles using the ATLAS automated measuring system is improved and tested in the Yakovlevsky Mine.



Distance, m	0.0	10.427	21.222	31.029	41.456	51.137	60.733	70.635	80.431	91.31	99.919
Left-side clearance, m	2.388	2.423	2.436	2.508	2.891	2.49	2.645	3.284	2.784	7.682	4.701
Right-side clearance, m	4.462	4.376	4.741	4.973	5.081	4.862	4.096	4.517	6.981	4.842	7.93
Width, m	0.749	0.75	0.752	0.748	0.749	0.75	0.746	0.75	0.747	0.751	0.749
Height, m	3.542	3.353	3.258	2.883	3.256	3.083	3.16	3.596	3.455	4.296	3.811
Tilt, m	0.0	0.02	0.28	0.45	0.51	0.66	0.76	0.84	1.06	1.25	1.45
Gradient, ‰	0.0	0.00192	0.02409	0.01733	0.00575	0.01549	0.01042	0.00808	0.02246	0.01746	1.45
Ruling gradient	0.01451										

Fig. 5. ATLAS measurement report

Comparison of measurement results

Parameter	Approach	Survey marks												
		0	10	20	30	40	50	60	70	80	90	100	110	120
Track gauge, mm	AMS	754	757	766	776	768	766	766	764	762	769	766	770	760
	Reference	755	757	765	777	769	766	767	764	763	770	766	771	760
	Difference	1	0	1	1	1	0	1	0	1	1	0	1	0
Distance to the left sidewall, mm	AMS	140	138	167	150	156	280	430	160	160	175	153	170	170
	Reference	146	139	176	154	166	287	438	158	152	190	140	152	184
	Difference	6	1	9	4	10	7	18	2	8	15	13	18	14
Distance to the right sidewall, mm	AMS	191	133	168	144	168	157	168	147	144	138	142	151	156
	Reference	190	130	172	152	171	159	166	161	143	146	153	143	164
	Difference	1	3	4	8	3	2	2	14	1	8	11	8	8
Distance to the roof of mine opening, mm	AMS	335	333	315	338	378	297	315	316	313	323	295	296	336
	Reference	336	329	317	339	378	296	317	317	315	324	297	300	334
	Difference	1	4	2	1	0	1	2	1	2	1	2	4	2
Railway gradient, ‰	AMS	0.025	0.019	0.012	0.018	0.008	0.019	0.013	0.010	0.013	0.014	0.010	0.016	0.013
	Reference	0.019	0.012	0.007	0.014	0.002	0.015	0.008	0.005	0,009	0.010	0.006	0.012	0.008

2. The full-scale tests of the automated measuring system are performed in the form of recording of geometrical parameters in a section of a rail track in the mine. All in all, 35 000 measurements are taken.

3. As against traditional manual measurement taken at survey marks installed every 10 m in the mine, the automated measuring system carries out continuous measurement along the whole length of a test mine opening. Thus, the data of the ATLAS AMS are usable for the continuous technology and geomechanics monitoring.

4. The automated measuring system is totally neutral ecologically (electric operation), which improves the working environment in the mine.

5. The use of the ATLAS unmanned measuring system improves efficiency by 3 times and enhances safety of operations, both in mines and along open-air rail tracks owing to the remote measurement technologies applied.

Acknowledgement

The study was supported by the Ministry of Science and Higher Education of the Russian Federation in the framework of State Contract No. FZWG-2025-0006.

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