Monitoring of petroleum pipelines using aerial laser scanning and digital aerial photography

A. Voitenko, Kadastrsyomka, Irkutsk, Russia

Monitoring of petroleum pipelines is one of the important tasks affecting operational safety of trunk oil and gas pipelines.

For these purposes, JSC "Kadastrsyomka" has developed a monitoring technology based on aerial laser scanning and digital aerial photography technology, which has been tested at a pilot section of a trunk oil pipeline.

This development pursued the following goals:

1. to determine the tolerance of object points coordinates and error in measurement of geometric parameters of structural elements based on aerial laser scanning

2. to identify the capability of detecting terrain forms caused by exogenic processes. To set the minimum dimensions of laser reflection forms reliably identifiable with all points at preset scanning altitude;

3. to identify the capability to trace changes in terrain shape based on prior monitoring observations;

4. to determine the capability of controlling elevation position of the subsurface part of pipeline by measuring the height of elevation markers of underground oil pipelines and surveying the surface portion of protective berm.

5. to determine whether it is possible to detect vertical deviation of power transmission line posts and communication masts.

Requirements to accuracy of coordinates measurement and terrain form dimensions measurement were set prior to the start of pilot work.

1. Maximum elevation discrepancy – not more than 0.05 m;

2. Error in detection of mutual position – not more than 0.05 m;

3. Average point density - 16 points/m^2;

At the first stage, we performed geodetic survey of the surface to establish and set equal level of the two base stations distanced at 30 km. Then we marked a rectangular site composed of 25 points with spacing of 1 m from each other and conducted measurement of vertical deviation angles of power transmission line towers and communication masts in two mutually perpendicular planes. Using the method of ground geodetic survey, we determined the areas with terrain microforms, oil pipeline elements (inspection hole covers) and elevation detection devices. The works were performed by specialists of the pipeline operator organization (Fig. 1).

Fig. 1.

At the second stage, we performed aerial laser scanning and digital aerial photography using special equipment by Swiss manufacturer Leica, which undergoes annual calibration. Aerial laser scanning and digital aerial photography parameters were chosen so as to match particular requirements (Appendix 1). Survey was performed from a MI-8 helicopter, following pre-calibration of equipment.

Appendix 1

Laser survey parameters

Flight speed	120 km/h
Flight height	250 m
Scanning angle, scanning rate	56°, 190000 Hz
Average point density per 1 sq.m. of surface	22 points
Accuracy of plan point position	0.03 cm
Elevation scanning accuracy	0.04 cm

Key technical parameters of aerial photo camera and survey mode:

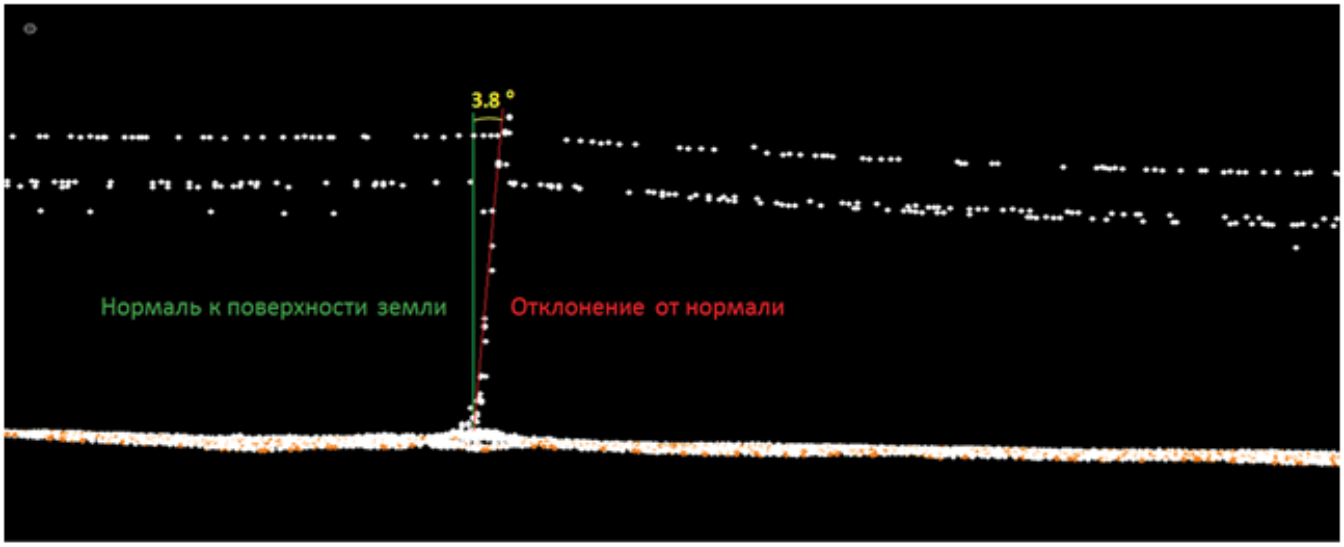
Flight height	250 m
Image size	8956px*6708px
Lens focal distance	52 mm
Camera pixel size	6 μm
Acquisition interval	2.32 sec
Calibration	RCD30 incorporates photogrammetric calibration data
Average pixel size on terrain (GSD)	0.03 m

At the third stage, we adjusted the level of flight trajectory from two base stations, downloaded laser reflection points, performed image decoding and calibration of recorded laser reflection points, verified digital camera parameters, classification of laser reflection points, plotted digital orthophotomaps and digital terrain models (Fig. 2).

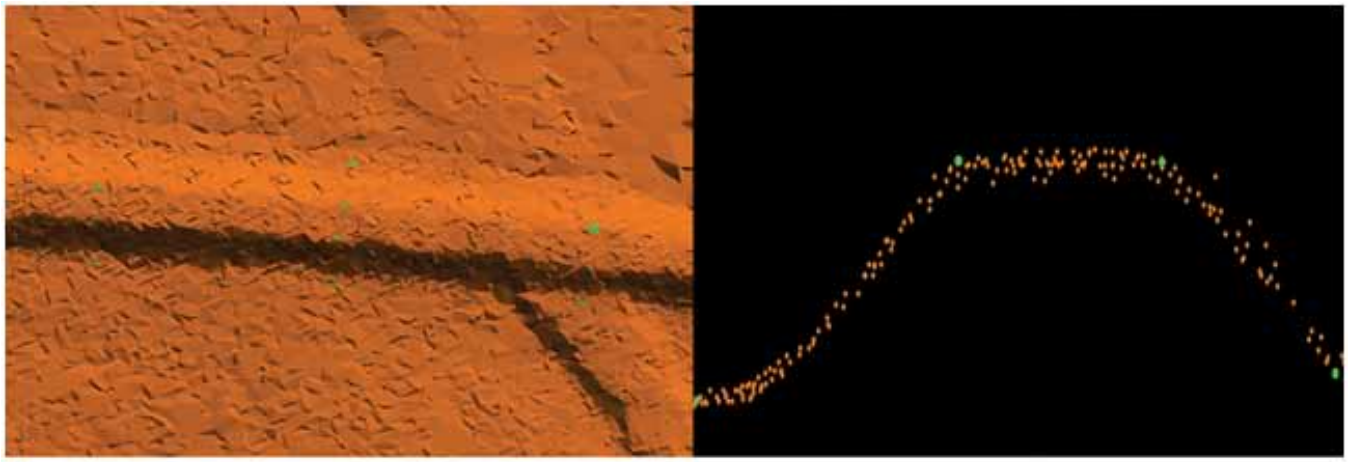
At the fourth stage, together with representatives of the pipeline operator organization, we performed joint evaluation of the collected data represented in Appendix 2.

Fig. 2.

Item No	Form	Dimensions according to ground measurements (L x W x D), m	Dimensions according to ALS (L x W x D), m	Difference, m
1	2	3	4	5
1	Shape 13	0.25 x 0.50 x 0.10	0.25 x 0.50 x 0.13	0.0 x 0.0 x 0.03
2	Shape 11	0.50 x 0.75 x 0.20	0.45 x 0.70 x 0.22	0.05 x 0.05 x 0.02
3	Shape 12	0.75 x 1.00 x 0.30	0.70 x 1.00 x 0.27	0.05 x 0.0 x 0.03
4	Shape 15	0.50 x 0.10	0.50 x 0.21	0.0 x 0.11
5	Shape 10	0.75 x 0.15	0.80 x 0.20	0.05 x 0.05
6	Shape 14	1.00 x 0.30	1.00 x 0.34	0.0 x 0.04
7	Shape 4	0.25 x 0.50 x 0.10	0.25 x 0.50 x 0.08	0.0 x 0.0 x 0.02
8	Shape 1	0.50 x 0.75 x 0.20	0.50 x 0.65 x 0.17	0.0 x 0.10 x 0.03
9	Shape 3	0.75 x 1.00 x 0.30	0.80 x 1.00 x 0.37	0.05 x 0.0 x 0.07
10	Shape 2	0.50 x 0.10	0.50 x 0.11	0.0 x 0.01
11	Shape 5	0.75 x 0.15	0.70 x 0.18	0.05 x 0.03
12	Shape 7	1.00 x 0.30	1.00 x 0.33	0.0 x 0.03
13	Additional shapes			
14	Shape 6	0.70	0.68	0.02
15	Shape 8	1.90 x 0.50 x 0.40	2.00 x 0.50 x 0.42	0.10 x 0.0 x 0.02
16	Shape 9	2.10 x 0.60 x 0.40	2.00 x 0.60 x 0.40	0.10 x 0.0 x 0.0
17	Wood log	2.40 x 0.13	2.40 x 0.10	0.0 x 0.03
18	Employee1	+	+	–
19	Employee2	+	+	–
20	Employee3	+	+	–
21	Shape	4.85 x 0.92	4.95 x 0.95	0.10 x 0.03
22	elevation markers	0.5x0.5	0.5x0.5	0.0x0.0



Tower No.	Vertical deviation angle based on tacheometrical survey, degrees	ALS-based tower deviation angle, degrees	Difference, degrees
1223	4.2 (направление крена – 324)	3.8	0.4



Point determined by field survey

Point determined by laser scanner

Mean height, m	0,000
Minimum height, m	-0,010
Maximum height, m	0,070
Standard deviation, m	0,048

Resulting from the study, we have come to conclusion that minimum dimensions of reliably identifiable terrain forms must be at least 28 x 40 cm for aerial survey height of 250 m. In this case, accuracy of pipeline elements geometry measurements remained under 3 cm. Elevation dimensions (depth, height) were detected with mean error of under 4 cm.

The following results were obtained for dimension measurement of modified elevation markers and surface of protective berm:

Maximum measurement error for elevation markers amounted to 6 cm, RMS error – 1 cm;

For surface of protective berm, the maximum error was 8 cm, RMS error – 6 cm;

For surface of water drainage berm, the maximum error was 7 cm, RMS error – 5 cm;

Inferences:

Aerial laser scanning and digital aerial photography technology enables identification of terrain forms, which are created by exogenic processes, along the oil pipeline route and beyond, including those covered by vegetation.

Aerial laser scanning and digital aerial photography technology allows controlling the elevation of the subsurface portion of an oil pipeline using measurement of elevations of modified elevation markers and surface of protective berm, with the accuracy specified in the program of not more than 4 cm.

Aerial laser scanning and digital aerial photography technology allows monitoring of vertical deviation of power transmission line towers and communication masts;

It also enables to measure geometric parameters of pipeline elements with error under 3 cm.

The company is prepared to use the experience gained in this project for monitoring of other trunk oil and gas pipelines in operation.