Application of ground laser scanner in surveying and mapping field

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Abstract—With the continuous development of measurement demand, the market of single point measurement mode is shrinking, 3D measurement is more and more appearing in the field of surveying and mapping, ground laser scanner as a portable 3D measurement tool, its use is more and more important. This paper takes substation measurement, cadastral measurement, facade measurement and oil tank measurement as typical cases, and introduces the case of oil tank measurement in detail.

1. INTRODUCTION

With the development of society, we have entered a three-dimensional digital era. The P40 is a new Leica scanner, which makes it used in an unprecedented range of applications, such as dam monitoring, open pit mining, building survey, topographic mapping, and so on [1]. This paper takes substation measurement, cadastral measurement, wall facade measurement and oil tank measurement as typical cases, and introduces the case of oil tank measurement in detail.

The ground scanner is mainly composed of laser ranging system, laser scanning system, control system, power supply system and accessories, etc. It can quickly and extensively collect spatial point cloud information, establish point cloud model, and provide early services for the later establishment of data model [2]. In the process of measurement, the scanner uses the spherical coordinate system. It can accurately control the fast movement of the multi-surface reflection prism through the internal servomotor system, so that the laser beam can carry out linear array or planar array scanning along the horizontal and vertical directions. It measures the transverse scanning Angle and longitudinal scanning Angle of each laser beam through the precision clock control encoder, as well as the distance observation value along the measuring axis, and finally converts the coordinates into three-dimensional coordinates under Cartesian coordinates.

2. APPLICATION CASES

2.1. Substation scanning

As a big power output country, China is very rigorous in the construction of substation, but the structure of substation and power transmission system is very complex. The daily maintenance of the substation is related to the normal supply of the power system. Traditional measurement method is difficult to...
collect complete basic data, unable to accurately monitor the substation, it is easy to appear problems. When the substation equipment is updated, the general plane drawings can not be macro three-dimensional display of it. The design of the substation itself is very complex, among which the details are especially important. If there is any mistake, the consequences are very serious. This requires substation measurement and equipment update, must have high-precision measuring equipment, and in the case of not interfering with the normal work of other substation equipment to measure the entire substation.

The emergence of 3D scanning technology has solved this problem. As an emerging technology, 3D scanning technology avoids the danger faced by manual operation through the contact-less scanning measurement of 3D scanner. Moreover, 3D laser scanning technology can better guarantee the accuracy of data, and the equipment can work continuously, faster and more efficiently [3]. This is not achieved by traditional measurement methods.

Substation 3D scanning steps: 3D laser scanner is used to carry out 3D scanning on the internal equipment and external structure of the substation. Since the structure of the substation is very complex, multiple scanners are used to scan from multiple angles to get the 3D point cloud data of the substation. At the same time, pictures are taken by camera for post-processing. The point cloud data were de-noised and spliced. The point cloud data scanned by several previous devices from different angles were screened and spliced to obtain complete point cloud data outside and inside the substation. Through the point cloud data and pictures taken, 3D modeling is carried out with 3DMAX to obtain the 3D model of the external structure and internal equipment of the substation, and then the material is padded to obtain the 3D visualization information of the substation. Fig. 1 shows the site map of the substation scan.

![Figure 1 Substation scan](image)

2.2. Cadastral survey
Ownership -- Ownership work of the third land survey, including investigation, confirmation, registration and certification of collective land ownership, collective construction land use right and homestead use right (hereinafter referred to as "three rights" registration and certification), centering on cadastral survey, remote sensing monitoring, land right confirmation, dispute mediation, registration and certification. According to the scope delineated by ownership, mapping scheme is formulated. First, control points are delineated by GNSS measurement technology, and then dot with total stations (5-10 total stations are estimated) or point cloud map is assembled by scanning with P40. There is a big difference between the two methods. Total station is a field measurement process is more on the late drawings faster, program is dot - processing - a figure, P40 scanning - together - drawing, if it is P40 scan that is joining together with the cologne software, total station is in the south, the figure with the southern CASS9.2 regional figure, is the acceptance of party a, after the error is within 20 mm. Figure 2 shows a schematic diagram of cadastral surveys using a terrestrial laser scanner.
2.3. **Curtain wall measurement**

Contemporary architecture for profound attainments, has long break traditional rules construction sash and march to the art form, so the general drawing management, information transmission become the difficulty of construction measurement problem. BIM (building information model) to produce make everything possible, BIM is also a hot spot of the construction industry in recent years, introduced to China, installation is particularly crucial step in building construction. Large-scale curved curtain wall installation has become the pursuit of modern architectural art, but at the same time for the construction has increased a lot of difficulty, in order to save the waste of materials and manpower, production units generally in the processing of curtain wall factory for pre-installation, the method is: 1, field scanning building entity; 2. Obtain factory curtain wall information; 3, in the software for pre-installation; 4. Verify the installation effect to determine whether the factory curtain wall is qualified. In this way, the curtain wall is avoided to be directly lifted to the installation site for installation, and if any discrepancy is found, it will have to be returned to the factory for processing. The large-scale installation may waste hundreds of millions of direct economic losses.

Leica P40 has high scanning accuracy and is compatible with 3D software Cyclone, which guarantees installation efficiency: 1. The regular curtain wall directly uses the total station function to measure feature points, and constructs entities based on feature points in Cyclone; 2. Curved curtain wall uses scanner function to scan the whole curtain wall, and constructs the entity in 3D MAX; Finally, the physical model is connected with Revit and compared with the design values to obtain the installation effect. Of course, the installation of the curtain wall is a part of the application of P40, which is also satisfied by the traditional architectural measurement P40. The measurement data can be easily obtained with the measurement function of the total station instrument, which is efficient and convenient. In the process of construction, single point measurement and scanning can also be combined to improve the work efficiency and the utilization efficiency of the instrument. The traditional measurement methods are quite mature and will not be repeated here. Fig. 3 is a schematic diagram of obtaining curtain wall data by field scanning.
Not only field data collection P40 provides convenience for BIM, but also software post-processing provides an open platform for BIM. Leica 3D post-processing software Cyclone not only supports 3D browsing, measurement, modeling and other functions, but also supports CAD, 3D Max, Maya and other commonly used architectural software. The most critical is Revit, which supports BIM construction. 3D data provides the basis for BIM visualization. The traditional two-dimensional diagram cannot directly reflect the error conflict in building construction, but the visualization effect of BIM provides real-time feedback for the collision error in the construction process, making the construction more smooth.

2.4. Tank measurement
Tank storage tank due to the particularity of its utility and part of the tank with the traditional measurement methods the inconvenience, so the general average total station theodolite is difficult to solve the precision of measurement, entirety station type scanner make everything possible, the advent of tank testing is also the hot spot of the oil industry in recent years, safety is the oil storage and key step [4][5]. The color point cloud is used to replace the general total station level to reflect the overall settlement or deformation of the oil tank from a three-dimensional perspective from scientific data. The main operating methods are as follows: 1. Obtain the shape data of the storage tank; 2. Analyze in Cyclone; 3. Verify whether the storage tank is qualified. In this way, the accident of leaking tanks caused by repairing tanks without a theoretical basis is avoided, resulting in hundreds of millions of direct economic losses. Fig. 4 shows the point cloud map of the oil tank scanned by a scanner.

![Figure 4 Oil tank point cloud scanned by P40 scanner](image)

3. ANALYSIS OF CONCRETE EXAMPLE OF TANK MEASUREMENT
Data analysis of the oil tank as shown in Fig. 5 is conducted mainly from the aspects of elevation data, the height of each layer of the measured ring plate, the diameter of the fitted standard circle of the ring plate, and the ellipticity. 30 relative elevation measurement points were selected counterclockwise from north to south for measurement [6][7]. The first point started from the stair below the tank nameplate "1". The relative elevation points of the storage tanks are shown in Figure 3 and Table 1.
It can be seen from Fig.5 and Table 1 that the maximum relative elevation of the storage tank is -0.525m, the minimum relative elevation is -0.684m, and the maximum relative elevation deviation is 0.159m.

**TABLE 1 ELEVATION DATA OF TANK FOUNDATION TABLE**

| serial | unit (m) | serial | unit (m) |
|--------|----------|--------|----------|
| 1      | -0.560   | 16     | -0.620   |
| 2      | -0.547   | 17     | -0.561   |
| 3      | -0.547   | 18     | -0.545   |
| 4      | -0.538   | 19     | -0.526   |
| 5      | -0.541   | 20     | -0.528   |
| 6      | -0.552   | 21     | -0.527   |
| 7      | -0.561   | 22     | -0.525   |
| 8      | -0.573   | 23     | -0.539   |
| 9      | -0.600   | 24     | -0.559   |
| 10     | -0.630   | 25     | -0.554   |
| 11     | -0.651   | 26     | -0.551   |
| 12     | -0.674   | 27     | -0.555   |
| 13     | **-0.684** | 28     | -0.555   |
| 14     | -0.656   | 29     | -0.556   |
| 15     | -0.638   | 30     | -0.576   |

**TABLE 2 THE HEIGHT OF EACH LAYER OF RING PLATE MEASURED**

| Circle plate layers | 1/4 height of ring plate (mm) | 3/4 height of ring plate |
|---------------------|-------------------------------|--------------------------|
| 1                   | 215.2                         | 1110.3                   |
| 2                   | 2005.3                        | 2900.3                   |
| 3                   | 3720.3                        | 4465.3                   |
| 4                   | 5212.3                        | 5960.3                   |
| 5                   | 6710.3                        | 7464.3                   |
| 6                   | 8215.3                        | 8966.3                   |
| 7                   | 9625.3                        | 10193.3                  |
| 8                   | 10859.3                       | 11622.3                  |
Table 2 shows the height of each layer of the ring plate measured. The height of the ring plate at 1/4 of the point and 3/4 of the ring plate are calculated.

**TABLE 3 RING PLATE FITTING STANDARD CIRCLE DIAMETER**

| Circle plate layers | 1/4 diameter of ring plate (mm) | 1/4 diameter of ring plate (mm) |
|---------------------|---------------------------------|---------------------------------|
| 1                   | 28457.8                         | 28443.4                         |
| 2                   | 28391.9                         | 28382.9                         |
| 3                   | 28388.6                         | 28392.6                         |
| 4                   | 28359.0                         | 28328.1                         |
| 5                   | 28318.4                         | 28296.7                         |
| 6                   | 28330.7                         | 28316.8                         |
| 7                   | 28247.3                         | 28185.5                         |
| 8                   | 28218.2                         | 28202.6                         |

Table 3 shows the diameter of the standard circle fitted by the ring plate. As can be seen from the data, the bottom execution is generally higher than the diameter of the top.

**TABLE 4 MAXIMUM DEVIATION BETWEEN THE FITTED DIAMETER OF THE MEASURING POINT OF THE RING PLATE AND THE STANDARD CIRCLE**

| Circle plate layers | 1/4 diameter of ring plate (mm) | 3/4 diameter of ring plate (mm) |
|---------------------|---------------------------------|---------------------------------|
|                     | The largest deviation           | The minimum deviation           | The largest deviation           | The minimum deviation           |
| 1                   | 179.8                           | -81.6                           | 195.2                           | -87.8                           |
| 2                   | 295.3                           | 19.4                            | 266.0                           | -47.9                           |
| 3                   | 286.5                           | -94.7                           | 414.7                           | -57.0                           |
| 4                   | 368.1                           | 97.8                            | 525.6                           | -59.3                           |
| 5                   | 468.6                           | -115.8                          | 542.9                           | -136.2                          |
| 6                   | 514.7                           | -106.7                          | 731.0                           | -50.5                           |
| 7                   | 667.3                           | -87.0                           | 769.4                           | -103.8                          |

According to the data in Table 4, it is found that the diameter of 1/4 and 3/4 of the ring plate shows an increasing trend, and the minimum deviation is irregular.

**TABLE 5 OVALITY OF EACH LAYER OF RING PLATE**

| Circle plate layers | 1/4 diameter of ring plate (%) | 1/4 diameter of ring plate (%) |
|---------------------|---------------------------------|---------------------------------|
| 1                   | 0.919                           | 0.995                           |
| 2                   | 0.971                           | 1.106                           |
| 3                   | 1.292                           | 1.357                           |
| 4                   | 1.632                           | 1.665                           |
| 5                   | 2.000                           | 2.067                           |
| 6                   | 2.226                           | 2.399                           |
| 7                   | 2.740                           | 2.773                           |
| 8                   | 2.759                           | 3.066                           |
Table 5 shows the data values of the ovality of each layer of the coil plate. Through the data, it is found that the ovality has an increasing trend with the increase of the number of layers of the coil plate.

![Figure 6 Comparisons of tank relative elevation data](image)

Figure 6 Comparisons of tank relative elevation data

![Figure 7 Comparison diagram of ellipticity data of tank inner wall](image)

Figure 7 Comparison diagram of ellipticity data of tank inner wall

Through data analysis, it can be concluded that crude oil storage tank No.1 is inclined to settlement along the southwest direction (the maximum elevation deviation of the southwest is 0.159m), resulting in the deformation of the inner wall of the tank ring plate in this direction, and the direction of deformation is almost the same as the direction of settlement. The verticality of the overall storage tank is 78.88mm.

4. CONCLUSIONS
With the continuous development of surveying and mapping technology, the application of ground laser scanner is increasing gradually [8]. The paper briefly analyzes the application of ground laser scanner through substation measurement, cadastral measurement, curtain wall facade measurement, and analyzes the application case of ground laser scanner in detail with the typical case of oil tank measurement.

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