The photogrammetric measurement of spherical tanks.

Abstract

Special tanks in the oil industry suggested the development of photogrammetric measuring techniques for non-topographic objects. A particular point was the determination of irregular surfaces, which could not economically be measured by traditional methods. The whole technique is a combination of geodetic distance and angle measurement and photogrammetric coordinate measurement in a stereoscopic model. A special variant of this general technology is the measurement of spherical tanks as used for the transport of natural gas on special tanker ships. The camera used with success was the UMK 10/1318 Universal Measuring Camera from Jena.
Bloms Oppmæling A/S in Oslo is an engineering bureau concerned with land surveying and photogrammetry since 1954. Recently it has extended its activities to data processing and cartography. Through its close relation with the oil industries of Norway and Libya it has become well experienced in underwater surveying of continental shelves which has won this firm numerous contracts abroad including a recent commission in the Republic of Cuba.

The idea to develop photogrammetric techniques of measuring non-topographic objects was prompted by special problems that had to be solved in the oil industry. One of the engineering teams had turned to industrial photogrammetry with growing success. Experiments were followed by pilot work, and these grew in several cases into working technologies which are now routinely applied at Bloms Oppmæling.

Over the last five years attention had been focused on extremely accurate coordinate measurements. These activities were born out of the need for digital descriptions as the basis for the application of electronic data processing methods. This concerned mainly coverage of irregular surfaces which, from an economic point of view, could not be covered by conventional methods. Bloms Oppmæling applied photogrammetry and solved the problem successively. The method is a combination of geodetic distance and angular measurements and photogrammetric coordinate measurements carried out in a stereoscopic model.

Measuring of spherical tanks as they are used for transporting natural gas on specially designed tankers is a special version of this general technology. The problem is to determine departures from the spherical form caused during assembly and the volume at different filling levels.

In developing a suitable procedure the engineers of Bloms Oppmæling were able to draw on fifteen years general experience in the calibration of oil storage tanks available with Norwegian refineries. Against this background a contract was signed with Rosenberg Verft A/S in Stavanger, Norway, which were building a series of gas tank vessels equipped with spherical tanks made by Kvaerner Burg A/S. These tanks have a diameter of roughly 37 m. The technique developed by Bloms Oppmæling in association with the Norwegian data processing firm of Datacom A/S guarantees an accuracy of volumetric determination of 0,1% under field conditions which fully meets the requirements made. The instruments used for recording the photograms included apart from a one-second theodolite and a precision stereoplotter, which are part of the standard equipment for land surveys carried out by Bloms Oppmæling, the UMK 10/1318 Universal
Measuring Camera made in JENA. This camera has proved highly efficient in pilot works and routine tank calibrations in Norway, the Federal Republic of Germany and Japan. The factors which mainly contributed to the great accuracy of the volumetric measurements were the large image scale and the favourable base-to-height ratio afforded by the wide aperture angle. Another extremely practical feature is the possibility of using films.

Bloms Oppmåling's method of measuring spherical tanks has been widely covered by a process patent.

The tank surface is described numerically by triaxial rectangular coordinate triples of about 1200 object points which were measured in photogrammetric stereomodels, with the exception of 85 geodetically determined control points. A closed ring polygon of 5 station points in a horizontal plane in the lower third of the tank, which are marked inside the sphere on an assembly scaffold (Figs. 1 and 2), forms the basic reference system for the subsequent determination of the coordinates of the surface points. These measurements are made with a one-second theodolite and a calibrated invar subtense bar. Closing error tolerance is 1 mm. Control measurements of the diagonals are also considered in adjusting this pentagon.

From these polygon points 17 control points each (of a total of 85) are determined in 5 horizontal planes (cf. Figs. 1 and 2) by intersection over the sides of the polygon and the diagonals of the pentagon. By redundancy in determination and subsequent adjustment the average coordinate error (as vector) is kept at ± 7 mm. Based on the coordinates of the 85 object points the first determination to ascertain the bearing of the centre of the sphere is made. From this the operator can tell where to take diameter measurements. Finally photographs are taken from the polygon points with a UMK 10/1318 universal measuring camera (Fig. 3).

The camera is stationed in such a way that the photographs obtained from the polygon points in different directions can be combined into stereopairs. This too is done with redundancy in determination so that the object points are contained in several stereograms. Maximum permissible tolerance of photogrammetric coordinate determination at the control points which have been intersected by theodolite is ± 10 mm.

Photogrammetric coordinate measurement is carried out in relatively and absolutely oriented models using a precision stereoplotter. Then the redundancy in determination is adjusted to a mean error of ± 6 mm. Taking into account the remaining parameters of the measuring setup an absolute mean error of ± 10 mm is obtained for the object points determined by photogrammetry.
Further processing of the data yields for each elevation of object points arranged at vertical intervals of 1 m a mean radius and the degree of departure of the surface from the intended spherical form with respect to the mean radius (Fig. 4). The volume is then calculated on the basis of this surface description, taking into account the installations inside the tank.

At a radius of 15.5 m the volume can be determined to an accuracy of ± 0.3 mm which by the laws of error propagation gives a theoretical error of the volume of the sphere of ± 0.05 \( \text{°/oo} \).

The measuring technique developed by Bloms Oppmåling is both very precise and highly economical to use.

Photogrammetric measuring of spherical tanks is an example illustrating that industrial metrology may well benefit from the application of photogrammetric techniques.

**Fig. 1:**
Measuring setup, elevation.
A = control points,
B = geodetically measured points.

**Fig. 2:**
Measuring setup, plan view.

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Fig. 3: Photogram taken with the UMK 10/1318.

Fig. 4: Departures of tank internal surface from the spherical form.