3D Model Creation of Hydro-Technical Structures

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Key words: modeling of hydro-technical structures, data acquisition by classical methods and by TLS, model visualization

SUMMARY

Hydro-technical structures of hydro-electric stations (HS) belong to industry structures whit hard loading. According this are these structures regular controlled by methods which includes geodetic methods too. Last years are increasing the number of projects which aim is the reconstruction of these structures, focused to the better operating parameters and the higher effectiveness of the operation of the stations.

The designers are use the data to made your work in CAD software. Also is required to have the data prepared for the designers in digital form, not in the form of numbers (list of point co-ordinates) only, but complete whit graphical presentations and visualizations. In the case of complicate 3D form (shapes) is needed to create a model of measured structure using the adequate CAD software.

The paper present the way of the 3D model creation of two different structures at the HS Ladce and Cunovo in Slovakia. The time shift between these projects (10 years) determined, the fully different data acquisition technology given by the actually level of the instrumentation. For all that are the results, the 3D models and their accuracy, of both projects comparable.

The HS Ladce build in 1936, is the oldest HS in Slovakia and belong to the small HS at the Vag river cascade. The power and flow volume of this HS is limiting for the HS´s situated above and below them. To find a solution of this problem was concluded to correct the existing turbine parameters (to achieve more effective operation) or to design the new turbine into the existing structure of the HS. According this was the 3D model of existing structures around the turbine required.

The HS Cunovo builds the part, of the last constructed and well known HS complex, build at the Danube. In the frame of international co-operation were made the measurements by terrestrial laser scanners (TLS) on these HS, whit the aim to confirm the possibility of TLS usage for data collection for modeling of special industry structures. The turbine of HS, whit their complicated 3D form (shape) and geometry which is know whit high accuracy, is the best object for realization of the test. The horizontal positioned Kaplan turbine of the HS Cunovo, was out of operation, which give the possibility to made scans from different positions. The 3D model was made by the software offered by the producers.

ZUSAMMENFASSUNG

Objekte der Hydro-elektrischen Kraftwerken (HEK) behören zu den Industrieobjekten mit starker Belastung. Auf Grund der sind diese Objekte regelmäßig kontrolliert mit Methoden zu dem auch die geodätische Methoden gehören. Letzte Jahre ist die Anzahl von Projekten die mit Rekonstruktion der alte HEK widmen vergrößert. Viele von diesen sind auf die Verbesserung den Parametern der HEK orientiert.

Die Projektleiter brauchen die Daten in Form geeignet für verschiedene CAD Software. So ist erwartet die Daten nicht nur in Form der Liste von Nummern abzugeben aber parallel mit ihrer Visualisierung. Im Fall der relative kompliziert 3D Form der gemessene Objekte sind im adäquate CAD Programm das 3D Model von Objekten aufgebaut.

Im Artikel sind die 3D Modelbildung von zwei unterschiedlichen Objekten von HEK Ladce und HEK Cunovo beschrieben. Die Zeitverschiebung zwischen beiden Projekten (10 Jahre) bestimmt die verwendeten Messmethoden, die durch den aktuellen Stand der Technology sind determiniert. Trotzdem sind die Ergebnisse, 3D Model den Objekten und ihrer Genauigkeit, vergleichbar.

Die im 1936 gebaute HEK Ladce ist die älteste HEK der Vag Kaskade und auch in Slowakei. Die Leistungskapazität and die Wassermenge dieser HEK ist zu klein und begrenzt die Leistung den HEK die über und unter Ladce sind. Eine Lösung zu finden, wurde entscheidet die Parameter der existierende Turbine verbessern oder eine neue Turbine in existierenden Bau der HEK aufzusetzen. Für diese ist das 3D Model den Objekten außer der Turbine notwendig.

Die HEK Cunovo bildet das Teil der letzte HEK Komplex, die an Donau gebaut wurde. Die Messungen der Turbine von HEK Cunovo wurde in Rahmen eine internationale Kooperation durchgeführt. Das Ziel dieser wurde die Einsatzbereitschaft für Industriemessungen der neuer Technology der terrestrischen Laserscanner (TLS) zu überprüfen. Die horizontal lagerte Kaplan-Turbine, mit seiner komplizierte 3D Form und bekannte Geometrie (mit hoher Genauigkeit bestimmt), ist die beste Möglichkeit dieses Tests durchzuführen. Die Turbine wurde abgestellt, so könnten die Messungen auch von der Turbinenröhre realisiert werden. Das 3D Model wurde mit TLS gelieferte Software gemacht.

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1. INTRODUCTION

Hydro-technical structures of hydro-electric stations (HS) belong to industry structures with hard loading. According this are these structures regular controlled by methods which includes geodetic methods too. Last years are increasing the number of projects which aim is the reconstruction of these structures, focused to the better operating parameters and the higher effectiveness of the operation of the stations.

The designers are use the data to made your work in CAD software. Also is required to have the data prepared for the designers in digital form, not in the form of numbers (list of point co-ordinates) only, but complete whit graphical presentations and visualisations. In the case of complicate 3D form (shapes) is needed to create a model of measured structure using the adequate CAD software.

The paper present the way of the 3D model creation of two different structures at the HS Ladce and Cunovo in Slovakia. The time shift between these projects (10 years) determined, the fully different data acquisition technology given by the actually level of the instrumentation. For all that are the results, the 3D models and their accuracy, of both projects comparable.

2. MEASUREMENT OF THE HS LADCE

The HS Ladce built in 1936 is the oldest HS in Slovakia and belong to the small HS at the Vag river cascade. The power and flow volume of this HS is limiting for the HS´s situated above and below them. To find a solution of this problem was concluded to correct the existing turbine parameters (to achieve more effective operation) or to design the new turbine into the existing structure of the HS. According this was the 3D model of existing structures around the turbine required.

The task of the objects over and under the turbine is a regulation of leak water that ensure the maximum possible utilisation of their potential energy for the power production. This task determines the form and size of both objects. There are created with many reciprocal connected circle arc´s and minimum number of plane surfaces. The parts situated over the turbine have the form of space spiral (spiral) and they have to obtain the rotation of the leak water. The parts under the turbine have the form of irregular paraboloid, and have the task a rapid outgoing of the leak water (sack). For data acquisition (measurement) was the turbine out from operation, the objects are without water, with entrance through the service opening of cyclic form with 1,0 m diameter.

The concrete surface inside the objects (structures) is relative sleek, with a little number of small cracks. Daily lighting inside of objects is very slack, non-sufficient for the moving of workers and measurement. These conditions determine the advanced methods and equipment (Staněk et al, 1996).

2.1 Data Acquisition

Before starting the measurements were the objects and the turbine recognize. During the recognisation are designed the frame of measurement - the set of base points (Fig. 1). The position of these points must be designed so that they enable the pointing of greater parts of the measured objects. The narrowed and bounded objects enable to have a geodetic frame of the form of free polynomial only. Parts of objects do not observable from polynomial points

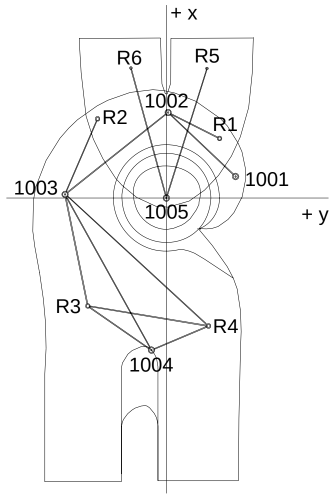


Fig. 1 Network of the control points

are observed from station which is determined by bi-directional polar method. The differences of bi-directional measured distances are less than 2 mm. The accuracy of base points can be given by standard deviation of co-ordinates $\sigma_{x,y}$ = 3 mm. The co-ordinates of base points located on the object under the turbine are determined by mining measurement methods with three plumbs positioned to the lines. The accuracy of points determined by this method is describe by standard deviation of co-ordinates $\sigma_{x,y}$ = 5 mm (Staněk et al, 1996).

For high determination it was used the method of trigonometric heights. The heights of base points positioned under the turbine were determined by vertically suspended tape with mm-indexing. The accuracy of heights is given by standard deviation of σ_H = 5 mm (Staněk et al, 1996).

Considering the complicated form of both objects it was elected for measurement the method of profiles and sections. The set out and direction of single sections was elected so that they could describe the characteristic spots of object's surface. From 32 measured sections are positioned vertically sections from 0 to 22 and from 28 to 32. The sections under the turbine from 23 to 27 are positioned horizontally (Fig.2).

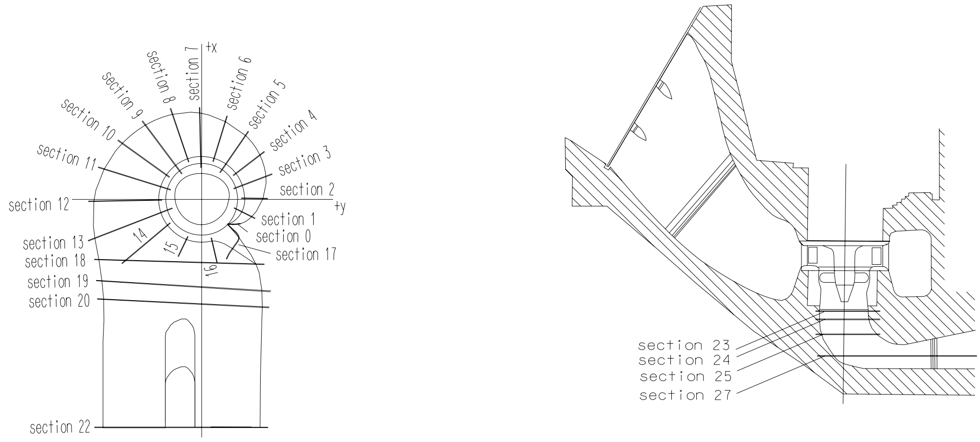


Fig. 2 Horizontal and vertical sections (profiles)

The slack day lighting, the narrowed and bounded objects determine the using of special equipment. For the angle measurement was used the theodolite THEO020B from Zeiss Jena (Germany) with lighting equipment and zenith ocular. For the distance measurement was used the Leica DISTO (Switzerland) laser distance meter, the once distance meter which enables the distance measurement without reflecting prismas in this time. The apriory characteristics of used equipment is:

- standard deviation of the angle measurement $\sigma_{\omega} \leq 10$ mgon,
- standard deviation of the distance measurement $\sigma_{S} \leq 3$ mm.

The measured points are pointed by second laser type LASERFIX 2 (Germany). The diameter of the laser beam is less than 8 mm to 15 m distance.

The local frame used for the measurement was defined by turbine centre:

- centre of turbine, with co-ordinates:

x_{1005}= 100,000 m,

y_{1005}= 100,000 m,

- x axis oriented parallel to the flow,
- y axis oriented perpendicular to the flow.

The centre of turbine was pointed by plumb suspended from turned fixture, fixed to the turbine axis. The x axis is defined by section "26-10" on the original drawing No.TvE 11.560a - concrete spiral, designed in 1936. This section is identical with the axis of the centre wall and is identify with accuracy of 2-3 mm under the turbine in the suck (Staněk et al, 1996).

The heights are determined in the local system of heights used in WPS Ladce. It was possible to determine these measurement of structural elements marked on the original drawing (decking of the corridor, ground of the suck, centre of dividing vanes of the spiral, etc.) (Staněk et al, 1996).

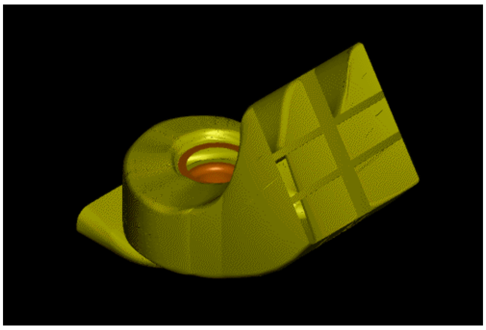
The standard deviations of co-ordinates are from interval 8-10 mm, depended on the configuration. The measured points situated over the stations (base points) are determined with greater accuracy (steep collimating). The standard deviation of heights determined by trigonometric method are from interval of 8-15 mm.

2.2 Creation of the Model

3D model of the object enables the effective presentation of measurement results. During the solution it was formulated the requirement to create the 3D model by AutoCAD from AUTODESK, Ltd.®. Because the MicroStation from Bentley System, Incorporated® has more facilities it was used for the creation of the 3D model. The resulting product was created by transformation to the format that is readable for AutoCAD. The information loss caused by transformation is smaller as by using the software with smaller facilities.

Resulting the 60th years usage was surface of objects dressed by water. According this was the form of these changed. The form of objects has ben changed in size and can not be reconstruct the object's sizes and parameters from the original drawing. The surfaces can not be approximate by the primary designed surfaces (cylindrical or spherical surfaces) and must be approximate by surface with alternating curvature (B-spline). The using of B-spline coating surfaces is not allowed by AutoCAD.

It is possible to work arbitrary with the created model in MicroStation or in AutoCAD. The 3D model of objects can be arbitrary rotated, can be created the complete or particularly drawing from the model (Staněk et al, 1997). On the model can be realised the various computations (distance of two points, angle of two lines or planes, etc.), graphical measurements and edition. The model can be viewed by some of the named methods. It is possible to create some views of the model, from various points, different directions and lighting using of different objectives (Fig. 3). The part of the rich offer of MicroStation is the possibility to choose the materials which are used in the surface presentation (steel, concrete of different granularity, etc.) resultant to the presentation (picture) of photo realistic quality.



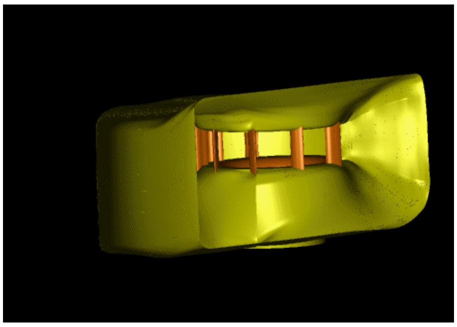


Fig. 3 Different view of the 3D model

The quality of the model is given by the quality of data which are used for the model creation. The measurements in terrain as resource of direct data collection assure the data of higher quality. The accuracy of co-ordinates obtained is $\sigma_{X,Y}$ = 8-10 mm and enables required tolerance of 10 mm of the surface creation. The really accuracy of the created surfaces is given by 10 to 20 mm, on the connection of two surfaces by 30 mm. Higher model accuracy can be obtained by higher quality of data used for model creation, today achieved by terrestrial laser scanning.

3. MODELING THE TURBINE IN CUNOVO

The HS Cunovo builds the part, of the last constructed and well known HS complex, build at the Danube. In the frame of international co-operation were made the measurements by terrestrial laser scanners (TLS) on these HS, whit the aim to confirm the possibility of TLS usage for data collection for modelling of special industry structures. The turbine of HS, whit their complicated 3D form (shape) and geometry which is know whit high accuracy, is the best object for realisation of the test. The horizontal positioned Kaplan turbine of the HS Cunovo, was out of operation, which give the possibility to made scans from different positions. The 3D model was made by the software offered by the producers.

The water running through the turbine and strike the maximal surface of the turbine vane, according this can be used for small rivers or rivers with small water overflow. The turbine had three vanes and the rotation velocity can be two times higher as the velocity of the overflowed water (Tab.1).

Tab. 1

Type of turbine	Kaplan turbine, 3 – vanes
Diameter	3710 mm
Turbine suck – designed, (max.)	92,0 $m^3. s^{-1}$, (100,0 $m^3. s^{-1}$)
Power – installed	6,27 MW

3.1 Data Acquisition by TLS

In the frame of international co-operation with the Department of Surveying of the TU Munich have the collective of the Department of Surveying at SUT Bratislava the possibility to measure the turbine in the HS Cunovo by terrestrial laser scanner (TLS). Technology of TLS enables parallel to the high velocity of data acquisition very simply and quickly visualisation of the measured structures.

The data acquisition is influenced by many facts, which could be considered before the measurement – the structure form and volume, configuration of the instrument stations, control points, scanning parameters. For scanning of the turbine was 5 different stations used with configuration determined by the small space and bad entrance to the turbine. The turbine is positioned under the floor of the machine hall, the entrance to this was enables through the opening only. The instrument stations were chosen on the floor, the last SW5 station was positioned directly in the turbine tube (Fig. 4).

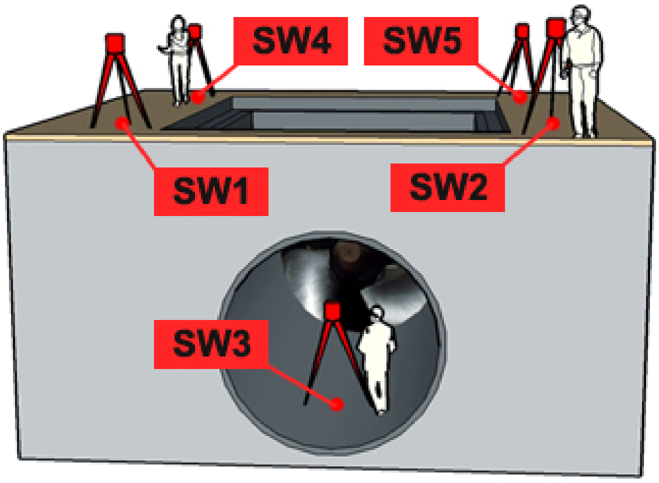


Fig. 4 TLS scanning positions

For control points were used points with natural marks (targets). For these were used exactly identifiable points on the turbine and their surrounding. For higher accuracy is better to have measuring target in the surrounding of the measured structure. For measurement the HDS 2500 from Leica Geosystems was used. The accuracy of the scanned surface is given by the producers with 2 mm for scanning of structures in maximum distance 50 m.

3.2 Model Creation

For transformation of the scans made by TLS on the different stations the system of requirements, given for two equivalent objects included to the both scans was used. Connection of the scans is made by 3D transform process applied for all point clouds. For all transformation are used minimum 4 equivalent points positioned equally in the scanned scene. The transformation quality is defined by the software with standard deviation of model points, which could be not exceed the value 10 mm. In our case are these values from the interval 7 mm to 10 mm.

After the transformation of scans to the reference system can be started creation of the 3D model. The software Cyclone from Cyrax enables two different way of model creation:

- using defined geometrical entities (cylinder, sphere, cone, etc.),
- using triangle network of points – MESH.
-

Using the geometrical entities are first defined the geometrical shapes (forms), which build the model. The next step is to define the parameters of these shapes using regression statistic. In last step are the defined shapes included to one reference system.

The triangle network is used for model creation of complicate structures (forms), which can not be modelled by geometrical entities. In this case is by the measured points build the triangle structure of different level – BASIC, COMPLEX and TIN. The triangles create the coherent surface. For visualisation of the Kaplan turbine of the HS in Cunovo was used the TIN structure. Resulting are created the model of turbine with continuous surface and sharp limited borders (Fig. 5).

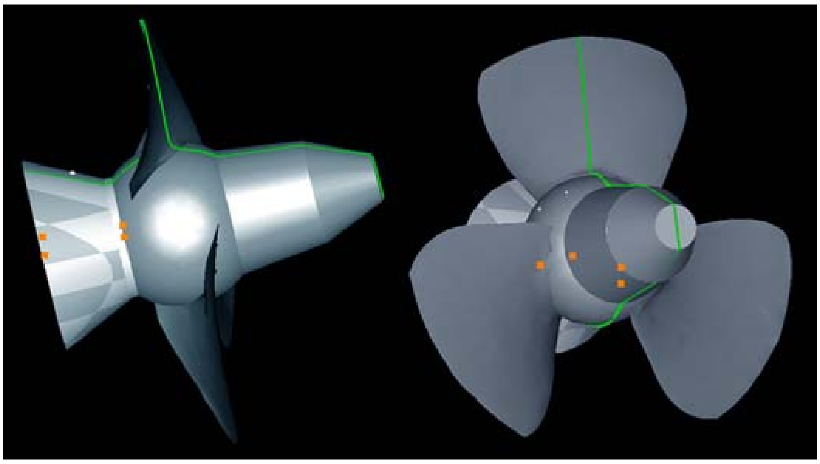


Fig. 5 3D model of the turbine in Cunovo

On the created model can be realised the measurement (quantification) of different parameters. This can be made directly by Cyclone or after the transportation of the model by any CAD software (Fig. 5).

4. CONCLUSION

The paper summarizes the author's skills in the field of 3D model creation of hydro-technical structures. There are presented results of two different way of data acquisition determined by the level of the technology because the more than 8 years time-shift. In the first case (HS Ladce) the classical methodology and instrumentation was used, which was complete by lasers for signalization of the measured points and profiles. In the case of the turbine in Cunovo the newest technology of laser scanning was used for data acquisition. In the time was made the measurement in Cunovo was not possible to have TLS in Slovakia, also the measurements were made in the frame of international co-operation between the TU Munich and SUT Bratislava.

Creation of the models are mades in different software. The model of the structures in Ladce was made in MicroStation, for creation of the turbine model in Cunovo the Cyclon from Leica Geosystems was used. Because the specially aim and development of this software their usage was more comfortable. Time needed for the model creation was shorter in the case of the model in Cunovo.

The usage of modern technology is much more effective in terrain and in office too. The natural signalization (control points) is not enough for industry applications. Usage of spherical targets positioned in the scene enables to achieve higher accuracy in the dataset and in the resulting model too. According the model quality and accuracy characteristics can be concluded, that the TLS is very appropriate technology for data acquisition of complicate industry structures. Software given by producers is fully compatible with CAD software used in the filed of design and have many functionalities their make easier the work with them. After transformation of the model to the appropriate software for visualization can be create different animations of the model.

REFERENCES

Kopáčik, A. et al, (1998) Geodetic measurement and modelling of the hydro-technical profile of a water power-station. Slovak Journal of Civil Engineering, Volume VI, 1998, No. 1-2, p. 26-32.

Sleziak, T., (2005) Digital model of the turbine in Cunovo. Diploma thesis. Bratislava, Department of Surveying of the SUT Bratislava, 2005, 58 p. (Slovak).

Staněk, V. et al, (1996) Determination of the hydro-technical profile of the turbine in Ladce. Technical report. Bratislava, Department of Surveying of the SUT Bratislava, 1996, 43 p. (Slovak).

Staněk, V. et al, (1997) 3D model of the hydro-technical profile of HS Ladce. Technical report. Bratislava, Department of Surveying of the SUT Bratislava, 1997, 14 p. (Slovak).

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