

3D Measurement of Water Turbines



The company TOPOMATIKA successfully performed 3D digitizing of turbines in several hydroelectric power plants in order to assess the condition and the efficiency of these turbines, to check their shape, to create copies or to prepare new ones ...

ATOS, the optical 3D digitizing system, allows for exact and detailed scanning of the shapes of complex objects. Together with the photogrammetry system TRITOP, you can precisely digitize objects up to a size of ten meters and, when using bigger reference points, even larger objects can be scanned. Both measuring systems are easy to transport and allow for on-site 3D scanning (e.g. in factories, workshops, etc.). Thus, it is no longer necessary to take the object to a measuring laboratory.



Fig. 1 The measuring systems ATOS and TRITOP are passed through a small opening into the turbine of a hydroelectric power plant. This allows for measuring and assessing the installed turbine rotor.

The Croatian company TOPOMATIKA, who created this report, successfully cooperates with the Croatian Institute of Civil Engineering (IGH) and the Croatian Electric Power Industry (HEP). So far, 3D scanning of turbines was performed successfully in several hydroelectric power plants in order to assess the condition and the efficiency of these turbines, to check their shape, to create copies or to prepare new ones.

3D Digitizing of the Rotor of a Pelton Turbine

Pelton turbines are used in hydroelectric power plants with high water pressure and a low amount of water (fig. 2). As these water turbines run at a great speed, the rotor's geometry and a steady rotation are of great importance. 3D scanning of the rotor starts with photogrammetric shots (TRITOP) using a professional digital camera (fig. 3). The TRITOP software then processes these images and calculates the exact position of the reference points applied to the turbine's rotor and blades.



Fig. 2 Rotor of a Pelton turbine



Fig. 3 Photogrammetric image recording

The ATOS system projects a dense fringe pattern on the surface of the blades and scans the visible part by means of two calibrated stereo mounted digital cameras. During this process, the system also exactly measures the reference points visible in the measuring area. Based on the recorded reference points, the scan data are automatically transformed into the mesh of the predefined reference points (object coordinate system). Each scan takes about 2 seconds and – depending on the ATOS system used – generates up to 4 million 3D measuring points. Thus, the shape of the scanned blade segment can be determined precisely. The scan process was repeated until the turbine blades were recorded from all sides. The common coordinate system of the individual scans is defined by the TRITOP measurement but can be adapted to current requirements at any time.

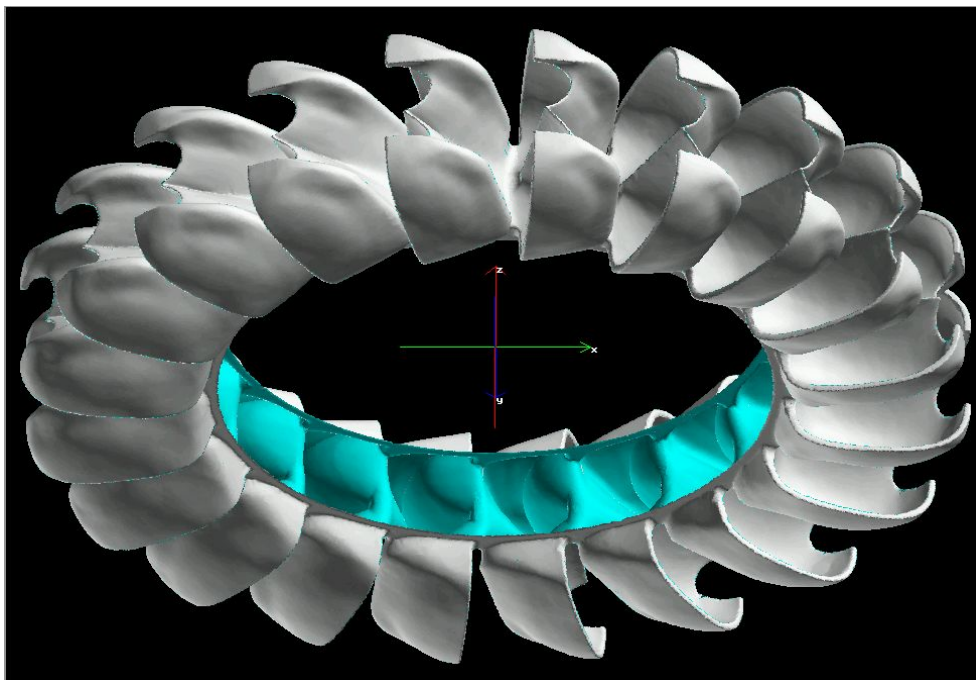


Fig. 4 3D scan result of the Pelton turbine's rotor, created with the ATOS and TRITOP systems

Fig. 4 shows the 3D measuring data of the rotor digitizing. The resulting data file consists of millions of 3D points describing in detail the shape of each blade. The normal point density for such measurements is 10 points per mm, corresponding to a measuring point distance of approx. 0,3 mm. If required, the ATOS system can easily be adjusted to scan much more or fewer measuring points.

Such a detailed 3D model detects the slightest deviations from the ideal geometry of the rotor. The data of the scanned turbine blades can be compared with the CAD model (if available), with the data of other blades or with the mirrored data of the same blade (for symmetry checks), see fig. 5.

The deviations in the shape are represented in different colors corresponding to the scale on the right side in the picture. Areas in which the shape of the turbine blades deviates up to 2 mm are clearly visible (red and blue). It is also possible to display and export the result with fewer measuring points (thinned data set) or as section data so that, depending on the task to be performed, the measuring data can be loaded into less powerful CAD systems (fig. 6).

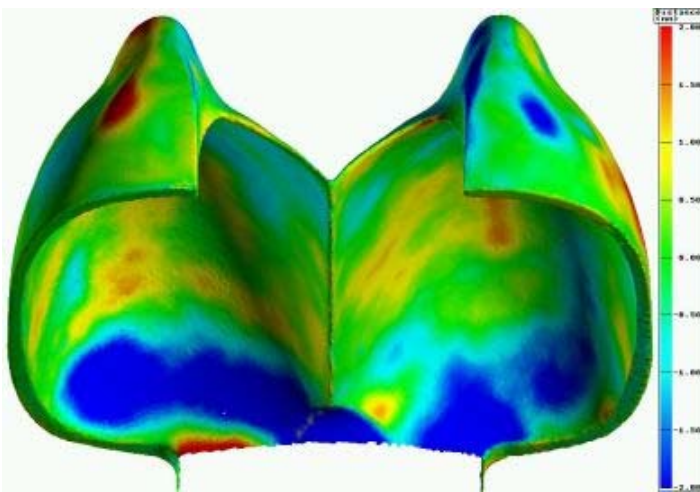


Fig. 5 Deviation of the shape of two blades

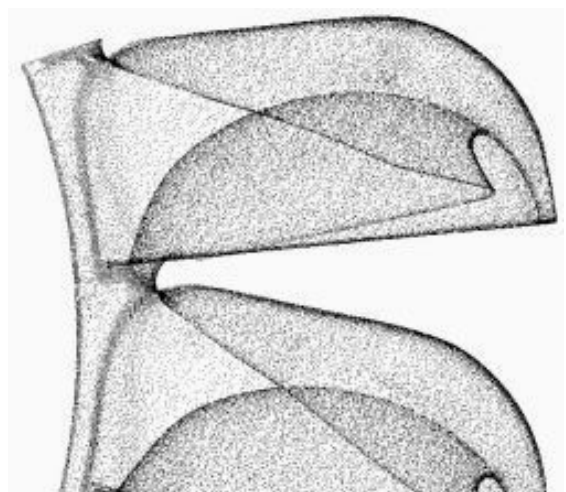


Fig. 6 Segment of the turbine rotor, displayed as thinned data set

3D Digitizing of the Rotor of a Francis Turbine

Francis turbines are widely used in hydroelectric power plants (fig. 7). They are used for medium water pressure (drop height) and medium amount of water and excel by their high efficiency in various operating conditions.

The blades of the Francis turbine are very curved and installed quite densely. At the end of the manufacturing process, they are manually ground and polished. It is difficult to access the water inlet channels. Therefore, manufacturing of these turbines is complicated and expensive, and it is very difficult and time-consuming to record and assess the shape of the blades using traditional measuring methods.



Fig. 7 Segment of the turbine rotor, displayed as thinned data set



Fig. 8 Preparing the rotor for 3D scanning

As for the Pelton turbine, 3D scanning of the Francis turbine's rotor was performed with ATOS and TRITOP. The result is a scanned 3D model with millions of measuring points (fig. 9). ATOS efficiently and exactly scans the complete surface of the blades in 3D as shown in figures 9 and 10 despite the inaccessibility because of which traditional measuring methods can hardly be used.



Fig. 9 3D scan of the rotor of a Francis turbine

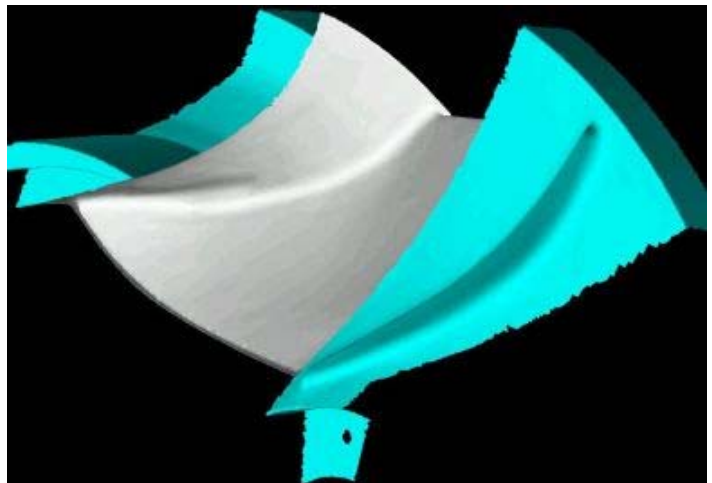


Fig. 10 Display of an individual turbine blade, part of the scanned data of the entire rotor

3D scanning allows for checking the shape of the rotor, for assessing the dimensions necessary to reconstruct the turbine, for manufacturing a substitute rotor or smaller copies for test purposes, for creating a CAD model or for various other applications. If required, the shape can be represented with a reduced amount of points (fig. 11) or with parallel sections (fig. 12).

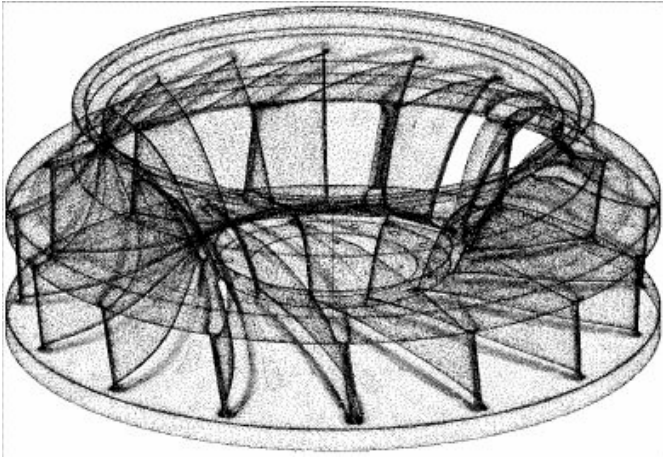


Fig. 11 Reduced scan model

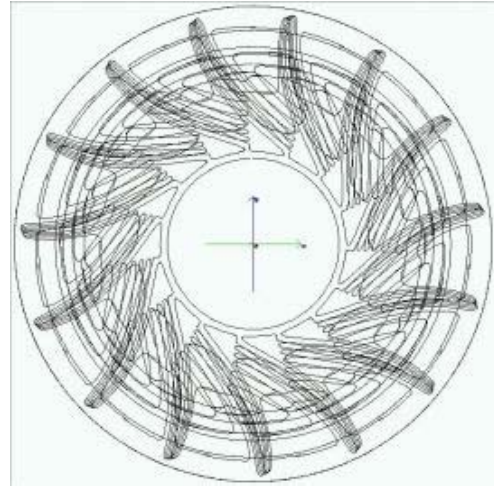


Fig. 12 Representation with parallel sections

Checking the Geometry of a Kaplan Pipe Turbine

Two Kaplan pipe turbines in the hydroelectric power plant Dubrava located on the river Drava generated cyclical vibrations detrimental to the operation. These vibrations were particularly noticeable in generator A1 while generator A2 rotated much smoother. In order to understand and, if possible, correct this condition, the shape and position of the blades of both wheels were scanned and evaluated (fig. 13). For this purpose it was necessary to determine the exact distance to the adjacent blades (angle position), the shape tolerance of the blades and the alignment of the blades with respect to the centerline of the turbine's rotor. Using the GOM systems ATOS and TRITOP, detailed 3D scanning of the blades of both rotors in different positions and rotation angles was carried out.



Fig. 13 Preparation of the turbine wheel (5.4 m diameter) for 3D scanning

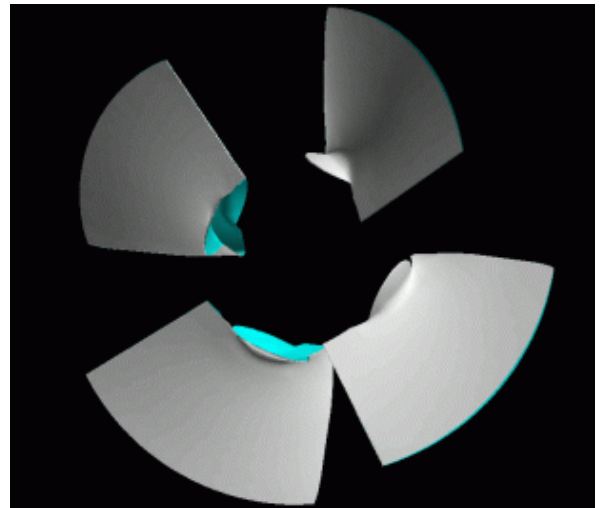


Fig. 14 3D scan data of the blades created with ATOS and TRITOP

The 3D scan results (fig. 14) allow for a detailed comparison of the blade shapes. Figure 15 shows a cross section of the leading edge of the four blades of rotor A1. A considerable deviation is particularly noticeable

in the section A-A at the wheel hub. Rotating the rotor made it possible to scan all blades in the same position and to determine the irregularities in the installation of the blades on the shaft.

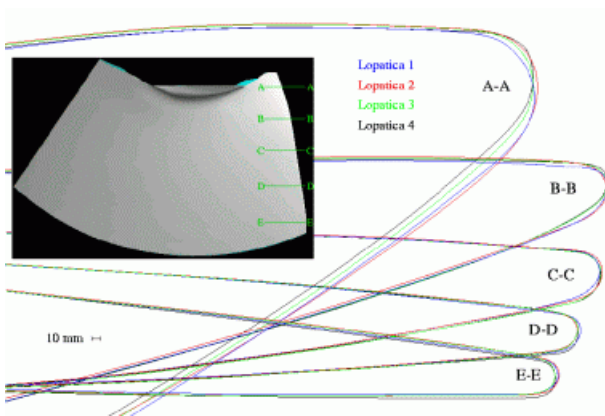


Fig. 15 Shape of the blades along the section in the area of the leading edge

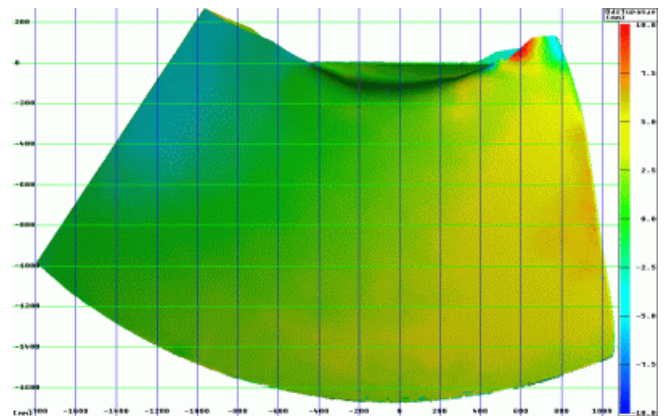


Fig. 16 Surface deviation of the first and fourth blade of generator A1, caused by the differences in shape and irregularities of installation on the shaft

Table 1: Deviations of the inlet angle (slope) of the first blade and the remaining blades of generators A1 and A2

Blade	2	3	4	Largest deviation of two blades
Generator A1	-0,06°	-0,21°	-0,17°	0,21°
Generator A2	-0,06°	-0,07°	+0,01°	0,08°

Table 1 shows the different values of the blade angles of generators A1 and A2. The blades 3 and 4 of generator A1 are considerably more closed than blades 1 and 2 (negative angle), while blades 2 and 3 of generator A2 are more closed than blades 1 and 4. However, the deviation is never larger than 0.08°. It is obvious that the largest deviation of the inlet angle of the blades of generator A1 is almost three times as high as the largest deviation measured for generator A2.

Despite the difficult measuring conditions in the flow duct of the turbine, the reliability of the position assessment was approx. 0.1 mm and of the angle assessment 0.01°. These values were verified by selective comparative measurements using conventional measuring systems and repeated scanning of one blade.

We would like to thank IGH and HEP for their confidence in our measuring technology and for the longstanding good cooperation.