Application Example: Quality Control

Mobile Optical Coordinate Measuring Technology Used in Offshore Wind Turbines Setup

Measuring Systems: TRITOP^{CMM}
Keywords: Quality Control / Turbines / Wind Turbines / Large-scale CMM Measurement / Offshore / Inspection of Connection and Mounting Surfaces

Because of their size, wind turbines are transported in individual parts to their offshore setup destination. Due to different production sites, the individual components are often put together for the first time at the mounting site on the high seas. Therefore, it is necessary to control the connections and mounting surfaces of tower and foundation independently before mounting.

To guarantee a smooth setup of the offshore wind turbines, the optical TRITOP^{CMM} measuring system is used for checking the mounting surfaces and bolts.

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Optical 3D Coordinate Measuring System

TRITOP^{CMM} is a portable optical measuring system that precisely determines 3D coordinates of specified object points (Fig. 1). The gauging points are easily marked with self-adhesive or magnetic markers before the measuring process (Fig. 2).

Fig. 1: TRITOP^{CMM} measuring system, photogrammetric camera with accessories

Fig. 2: TRITOP^{CMM} consumables, self-adhesive and magnetic markers

The measuring object is then captured with the TRITOP^{CMM} photogrammetric camera from different viewing angles. Based on all captured 2D images the computer automatically calculates the 3D coordinates of the gauge markers by means of bundle adjustment (Fig. 3, 4). Two certified scale bars guarantee the accuracy and process security of the measurement result.

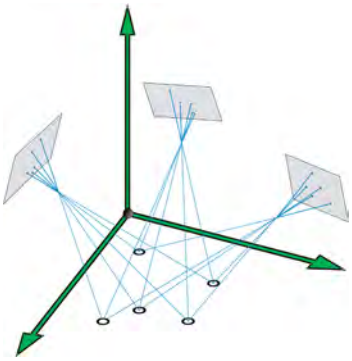

Fig. 3: Scheme of bundle adjustment of three camera positions

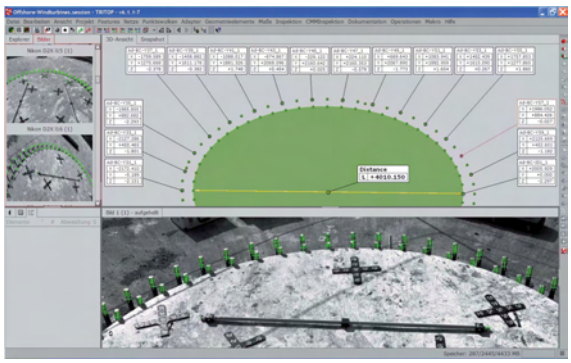

Fig. 4: 3D coordinates in the TRITOP^{CMM} software measured from a 2D image set

Primitives such as cylinders, holes, spheres, border lines, etc. can be measured by using corresponding adapters (Fig. 5, 6, 7). For special requirements, custom adapters may be created.
The TRITOP^{CMM} System is very mobile and flexible. The entire equipment consisting of camera case, laptop and scale bar case can easily be carried by one person. The measuring process as well requires one operator only. Since data acquisition is carried out with a camera and data evaluation takes place on a laptop, measurement projects can be recorded and inspected without the need of an external power supply.

Fig. 5: GOM adapter to measure various primitives

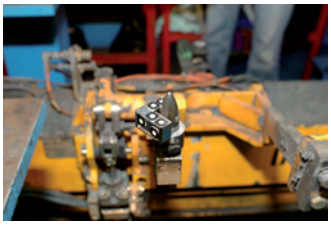

Fig. 6: TRITOP^{CMM} cylinder adapter

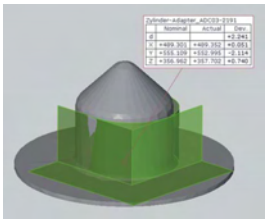

Fig. 7: Primitive (cylinder) measured with a GOM adapter

Inspection of Mounting Bolts and Offshore Foundations

For the setup of offshore wind turbines special concrete foundations are built on land. They are more than 20 meters high and have a diameter of approx. 10 meters on the upper platform. After completion, the foundations are tugged to their destination ashore and anchored to the sea bed so that the upper edge of the platform rises 2-4 meters from the water surface (Fig. 8). Because of the height of the wind turbine, the tower consists of several segments. These parts are also transported by boat to their offshore destination. The tower is then constructed on site using a special floating crane for heavy loads. For mounting the lowest tower segment, 120 steel bolts are recessed in the concrete foundation. These mounting bolts are positioned in two circles with a diameter of approx. 4 meters (Fig. 9).

Fig. 8: Offshore anchored concrete foundation

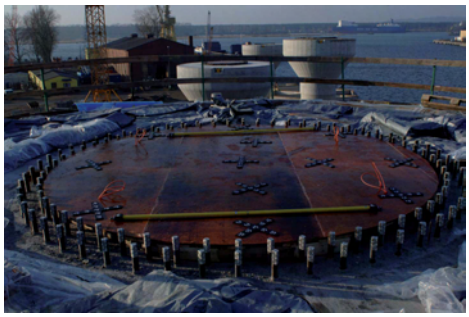

Fig. 9: Position of the mounting bolts in the concrete foundation and preparations for the measurement

Since foundations and tower parts are produced at different places, a test setup ashore is not always possible. If the position of the mounting bolts in the foundation does not fit to the hole pattern in the lowest tower segment, time-consuming adjustments have to be made on site. In this case the tower mounting on high seas is extremely difficult if not impossible. As the floating crane is very expensive, such a situation causes extremely high additional costs and a large time lag.
To avoid such problems, the position of the mounting bolts in the concrete foundation has to be verified to the required accuracy of 1/10 millimeter. The TRITOP^{CMM} measuring system enables the verification of the bolts directly after the completion of the foundations ashore as well as after the anchoring on high seas (Fig. 10).

Fig. 10: Measurement and inspection of 120 mounting bolts with the TRITOP^{CMM} system on high seas

Harsh conditions such as the limited space and measuring distance on the concrete foundations, strong wind or the lack of power supply are no obstacles at all for reliable measuring with the mobile and compact TRITOP^{CMM} system.
False positioned or tilted mounting bolts in the foundation can be identified fast and clearly with the required accuracy. Thus, it is possible to eliminate problems before starting the mounting process.

Measuring Procedure

For the measuring process, gauging markers and scale bars are placed on the foundation. Customized adapters, which were made from angle profiles, are used for inspection of the 120 bolts (Fig. 11).

Fig. 11: User defined TRITOP^{CMM} adapters for measuring the mounting bolts

The measuring area is then captured by several pictures taken from different directions and viewing angles (Fig. 12). During the measuring process the images are automatically transferred to the laptop. Immediately after the image transfer, the 3D coordinates of all 120 mounting bolts are calculated within a few minutes on the basis of the unique dot pattern on the adapters. As the project is already evaluated on site, it can be immediately checked for success or missing data (Fig. 13).

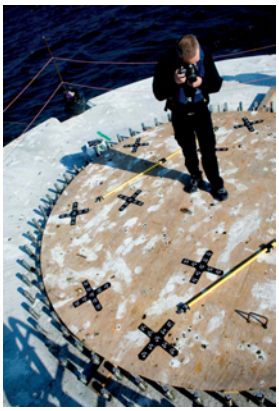

Fig. 12: Measurement with TRITOP^{CMM} photogrammetric camera

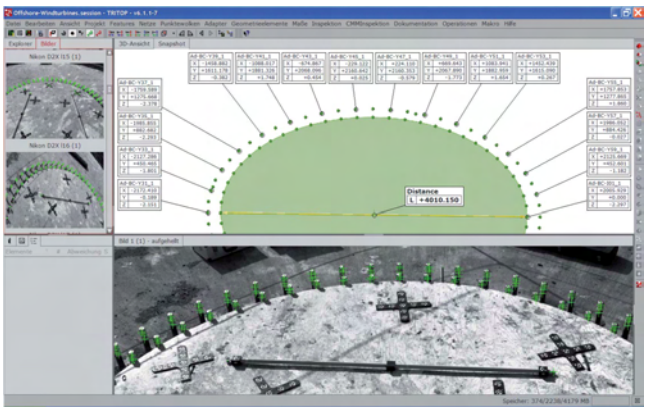

Fig. 13: Measured positions of the mounting bolts in the TRITOP^{CMM} software

Depending on the definition of the adapters, single points or the axis of a mounting bolt can be calculated to determine the position or the direction of each single mounting bolt. The TRITOP^{CMM} software allows the creation of measuring reports as well as the export of measuring data into tables (Fig. 14, 15).

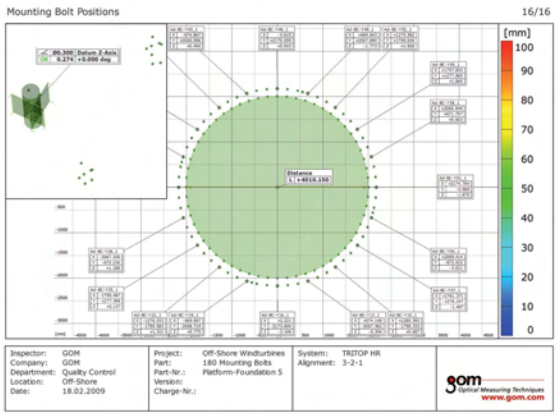

Fig. 14: Measuring report from TRITOP^{CMM} software with position of mounting bolts and detail of Geometric Dimensioning and Tolerancing (GD&T)

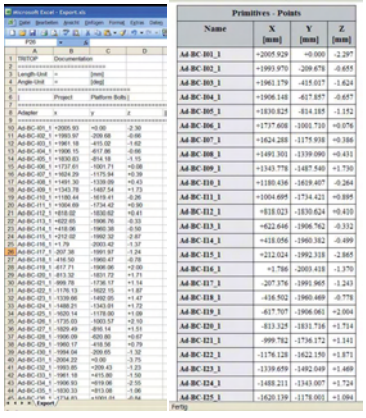

Fig. 15: Report as tables (Excel, HTML)

The preparations for the measurement take less than 30 minutes, the measurement itself approx. 10 minutes. Thus, inclusive the transport by boat to the next platform, about one hour is required for each foundation.

Conclusion

The easily portable optical TRITOP^{CMM} measuring system allows precise measurement and verification of mounting bolts and surfaces using CMM inspection. By this method, possible problems caused by false positioned or tilted mounting bolts can be identified and eliminated before assembly.
Due to the simple measuring process, the inspection of over 120 mounting bolts per platform can be accomplished by a single person. The data evaluation directly on-site, guarantees that all features were captured completely and correct.
Using optical measuring technology for inspecting mounting surfaces ensures a smooth setup of offshore wind turbines preventing high additional costs and saving time.

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