Cloud platform-based real-time supervision to safety inspection of hydraulic engineering metallic structures and equipments

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Abstract: The safety inspection network of hydraulic engineering metallic structures and equipments was developed based on the Cloud platform technology. The experimental inspections of metallic structures in terms of the coating thickness, metal substrate thickness, welding defect and the structure stress were conducted in the under-constructed hydraulic projects in Shenzhen City. The results showed that the manual inspection data of the coating and metal thickness and the non-destructive testing scenes photos and results can be transmitted to the cloud platform in real time through semi-automatic mode. Differently, the dynamic variation value of structure stress is automatically collected by the intelligent acquisition module and then wirelessly transmitted to the Cloud platform. By granting access rights to relevant personnel of quality and safety supervision department, they can ensure real-time supervision of safety inspection results and receive alarm information.

1. Introduction

Hydraulic engineering metallic structures and equipments (e.g. the steel gate, the hoist and the pump) have been widely used in water conservancy projects and they may suffer from malfunctions and even accidents during the operating process, giving rise to grave damages to the project itself and its downstream regions. Therefore, periodical inspections are required in many security inspection criterions, with respect to the corrosion, the stress, the vibration, et al., to look out the hidden defections and troubles [1, 2].

Actually, a great proportion of safety inspections on metallic structures and equipments are focused on the service stage of the hydraulic project, especially the exposure of some operation faults. In the construction stage, the inspections of outgoing and installation qualities are mainly conducted on basis of the contract documents and product standards; however, the safety inspection of metallic structures and equipments is not systematic before the accomplishment of the whole project. In addition, the health of hydraulic metallic structures and equipments involves various indexes and a comprehensive inspection is needed [3]. It is important to note that there are different sensors, time interval, collected
rules and allowable boundaries for the inspected data of different safety indexes [4]. As a rule, several types of inspections in terms of multi-factors and multi-standards are conducted to evaluate the safety grades of metallic structures and equipments, which lead to a fact that a large number of un-related documents (data, images, videos etc.) are collected. For the quality and safety supervision department, the supervision and inspection to hydraulic projects are usually accomplished by sampling the inspection data and documents provided by the construction unit, the supervision unit and the inspection organization. On one hand, the collection and analyses of massive inspection documents occupy great personnel and financial pressure with the continuous increase in the construction of water conservancy projects [5]. On the other hand, the provided documents and data lack of real-time quality, giving rise to the fact that the accuracy and reliability of the inspection data may be influenced by various external factors. The two aspects make it difficult to understand the hidden problems in real time and comprehensively judge the quality of the under-constructed hydraulic project.

Ideally, all inspection information should be in aggregated. The development of modern information technology (e.g. Cloud platform, big data) makes it possible in combining the separated databases [6]. In present work, a safety inspection network of hydraulic engineering metallic structures and equipments was built on basis of the Cloud platform. The problem of real-time transmission of data streams such as photos, static detection data and dynamic detection data to the cloud platform has been overcome, which provides support for the quality and safety supervision department for real-time quality control of water conservancy projects under construction.

2. Technical solution of the safety inspection network

2.1. Key points of Cloud platform of the safety inspection network

As shown in Fig.1, four common types of metallic structures and equipment used in hydraulic projects are selected, including the steel gate, the hoist, the penstock and the pump. In the Cloud platform, the inspection parameters of each metallic structure and equipment are classified as semi-/automatic ones. For the automatic inspection, the collected data (e.g. stress, temperature, electric parameters) is converted to electrical or magnetic signals which can be directly transmit to the Cloud platform and provide great convenience for real-time analyses of the dynamic variation. In general, the used sensors include four types, namely the strain sensor, the vibration sensor, the displacement sensor and the environment sensor. Differently, the accuracy of partial inspection parameters are easily influenced by the environment and the experience of the inspection personnel, such as the appearance description, the thickness of coating and metallic substrate, the welding defect etc. Therefore, a kind of semi-automatic inspection is set in terms of a fact that the manual check and evaluation are required before the transmission to the Cloud platform.

2.2. Overall frame of Cloud platform-based safety inspection

The collection and transmission of the inspected data, pictures and documents are accomplished through automatic and semi-automatic styles, constructing the basic module of the safety inspection
network based on Cloud platform. The combination modules of system permission, visitor access, project management, data management, alarm management and daily record center make up the overall frame of Cloud platform, wherein the safety inspection personnel are required to set up the data manipulation and alarm criterion in advance and record the detailed inspection information in real time, including the inspection value, the inspection and the check personnel, et al. The staffs of the quality and safety supervision department are given relevant permissions to access the allowed fields by means of the website or the mini program of mobile-phone at any moment, which ensures the real time control to the safety inspection information and results.

Figure 2. Schematic diagram of Cloud platform-based real-time supervision of the safety inspection.

3. Experiment of the safety inspection network
Two types of metallic structures (steel gate and penstock) are selected from the under-constructed hydraulic projects in Shenzhen City to test the real time of the safety inspection network. The locating information of the selected metallic structure and equipment are shown in Fig.3. It is convenient for the quality and safety supervision department to supervise the safety inspection process with respect to the inspection parameter and its detailed inspection information in real time through directly clicking the location mark.

Figure 3. The real-time supervision of the safety inspection information, wherein ① position information, ② inspection parameter lists and ③ the detailed inspection information.
3.1. Semi-automatic inspection

The inspection information of appearance, coating and substrate thickness as well as the welding defects is submitted to the Cloud platform via the style of on-site photos or data importation. The coating thickness of steel gates and the metal thickness of penstocks are listed in the Table 1 and Table 2, respectively. The inspection information such as instrument, start and end time, inspection environment, inspection and check personnel are real-time input in the Cloud platform. The inspection work is accomplished by the personnel having related inspection license according to the inspection criterions and the check of inspection data is required before inputting to the Cloud platform. The average value is automatically calculated and compared with the pre-set design value and minimum allowable one. In final, the evaluation of the inspected structures is supplied to the quality and safety supervision department.

The nondestructive inspection results of welding defect are displayed in Fig.4. Three curves are drawn in the ultrasonic flaw detector in advance, namely evaluation line (EL), scale line (SL) and rejection line (RL) from bottom to up. As shown in Fig.4, the maximum echo amplitude exceeds the rejection line, reflecting a fact that a defect position needs to be recorded. It is important to note that the defect is not allowed to exist in the grade I welding line. Therefore, the welding line on the penstock is recognized as disqualification by the inspection personnel. The detailed inspection information and on-site photos can be examined by the quality and safety supervision department in real time.

Figure 4. The nondestructive inspection of welding defect of the penstock.

3.2. Automatic inspection

The static stress acted as an important parameter involving the safety of the steel gate is inspected by fixing strain sensors on the representative positions such as the middle and quarter parts of girders as well as support arms of a horizontal steel gate. It can be seen that the dynamic variation of the static stress during the opening and closing process is collected by an intelligent acquisition module and automatically transmit to the Cloud platform (see Fig.5). In addition, the alarm threshold value is set in the Cloud platform on basis of the allowable stress of steel. In the case of the inspected stress exceeding the threshold value, an alarm message will be real-time sent to the specified mobile phone number of the quality and safety supervision department through the cloud platform service.
Figure 5. The variation of static stress of the horizontal steel gate, wherein the strain sensors are fixed at (a) the middle of longeron, (b) and (c) the middle and quarter of main transverse girder, (d) the support arm.

Table 1. The inspection information of coating thickness of steel gates in pump stations, wherein Q-qualification and DQ-disqualification.

| Structure position | Inspection time | Submission time | Environment | Instrument | Inspection person nel | Measured value/μm | Average value/μm | Design value/μm | Minimum value/μm | Evaluation |
|--------------------|-----------------|-----------------|-------------|------------|----------------------|------------------|------------------|-----------------|-----------------|------------|
| TC-girder          | 2019-1 2-05 15:35:0 | 2019-12 0 0 | exterior | Positec or 6000 | *** *** | 4 4 3 4 4 | 424.0 0 | 350 297.50 | Q            |
| TC-longeron web    | 2019-1 2-05 15:31:0 | 2019-12 0 6 | exterior | Positec or 6000 | *** *** | 3 3 4 3 3 | 394.4 0 | 350 297.50 | Q            |
| TC-longeron        | 2019-1 2-05 15:28:0 | 2019-12 0 5 | exterior | Positec or 6000 | *** *** | 4 4 4 4 4 | 475.2 0 | 350 297.50 | Q            |
| TC-panel           | 2019-1 2-05 15:12:0 | 2019-12 0 7 | exterior | Positec or 6000 | *** *** | 4 4 4 4 4 | 478.0 0 | 350 297.50 | Q            |

Table 2. The inspection information of metal thickness of penstocks in pump stations, wherein Q-qualification and DQ-disqualification.

| Structure position | Inspection time | Submission time | Environment | Instrument | Inspection person nel | Measured value/mm | Average value/mm | Allowable value/mm | Evaluation |
|--------------------|-----------------|-----------------|-------------|------------|----------------------|------------------|-----------------|-------------------|------------|
| TC-1               | 2019-1 2-05 14:22:0 | 2019-1 2-05 14:26:4 | interior | Zonotip | *** *** | 12. 44 12. 14 12. 45 12. 46 11. 90 | 12.28 0 | 12±0.4 | Q            |
| TC-2               | 2019-1 2-05 14:16:0 | 2019-1 2-05 14:22:4 | interior | Zonotip | *** *** | 12. 09 12. 06 11. 99 11. 91 11. 73 | 11.96 0 | 12±0.4 | Q            |
| PLH-1              | 2019-1 2-03 10:58:0 | 2019-1 2-03 11:03:4 | exterior | Zonotip | *** *** | 11. 00 11. 05 11. 08 11. 02 11. 25 | 11.08 0 | 12±0.5 | DQ           |
4. Conclusions
The application of Cloud platform technology in the safety inspection of hydraulic engineering metallic structures and equipments makes it convenient for the quality and safety supervision department to real-time control and intelligently manage the construction quality in the initial construction stage. The combination of semi-automatic and automatic inspections based on the features of different safety parameters provides a feasible way to comprehensively collect and analyze the inspection data, image and document. However, the Cloud platform-based safety inspection network with respect to the technical properties of the automatic acquisition module needs to be optimized in order to fulfil the very high collection and transmission frequency of cannot fulfil dynamic data (e.g. dynamic stress, vibration).

Acknowledgments
This work is financially supported by Program of Research and application demonstration of real-time inspection technology for metal structure and equipment in under-constructed water conservancy projects (no. SZGX2019037-SCZJ).

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