Monitoring of the Sunrise Movable Bridge

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ABSTRACT: Movable bridges experience major deterioration as compared to regular fixed bridges due to their complex structural, mechanical and electrical systems [1] and even a minor malfunction of any component can cause an unexpected failure of bridge operation. The implemented system is able to monitor the structural mechanical and electrical systems of the bridge. For the sake of brevity, sample results from one study for monitoring of open gear using video cameras are presented.

Test Structure and Measured Data

In this section, the design and implementation of a monitoring system on the Sunrise Movable Bridge in Ft. Lauderdale (Figure 1) is presented. The selected representative movable span (constructed in 1989) is the west-bound span of two parallel spans on Sunrise Boulevard in Ft. Lauderdale (Catbas et al. 2009) [3]. It has double bascule leaves, with a total length of 117 ft, width of 53.5 ft each 70-ft long, and 40-ft wide, carrying three traffic lanes. The bridge opens every 30 minutes when requested and about 10 times a day.

Figure 1. Sunrise Bridge in Ft. Lauderdale, FL

The data acquisition system (DAS) is a critical component of a structural health monitoring system that includes sensors, data acquisition systems, signal processing, synchronization, and storage of the data. In this real-life bridge monitoring application, the data acquisition equipment is installed in permanent protective and temperature-humidity-controlled-enclosures located in both machinery rooms at each side of the bridge. The sensors are connected by weatherproof cables and specially designed connectors. Since the two leaves of the movable bridge are physically separated from each other, wireless communication is provided to ensure the data transmission between the leaves of the bridge, and two GPS units are used for synchronization. The instrumentation plan is designed to monitor the most critical electrical, mechanical, and structural components. The original sensor installation consists of an array of 162 sensors (adding up to more than 200 channels). These sensors are installed to monitor structural, mechanical, and electrical components of the bridge. In addition, a weather station to monitor the environmental factors is also installed. A summary of the sensors used in the study is shown in Table 1.

Table 1. Summary of the installed sensors

Sensor type	Structural	Mech. and Elect.	Total
High-speed Strain Gage	36	0	36
Vibrating Wire Strain Gage	36	0	36
Strain Rosette	6	16	22
Tiltmeter	4	4	8
Accelerometer	16	24	40
Pressure Gage	4	0	4
Microphone	0	6	6
Infrared Temperature	0	2	2
Video Camera	1	2	2
Ampmeter	0	6	6
Total	103	60	163

SHM Methodology and Results

Due to the extensive nature of this project, several studies were conducted using the monitoring data collected from this bridge. The following is a brief list of such studies but interested readers are referred to several papers and reports related to this project (all the references, e.g. papers and reports, could not be included in this short report and more references can be obtained from the websites of the authors of this text). For the sake of brevity, only the lubrication monitoring of open gear using vision based methods and related results were presented in this report.

1. Monitoring of structural elements using strain data [2]
2. Monitoring of structural elements using video and strain data [3]
3. Monitoring of gear boxes using vibration data [4]
4. Monitoring of open gears using video data [5]

Monitoring of the Open Gears using Computer Vision Techniques:

The open gears are the main gears, which are parts of the leaf main girder, receiving the torque from the rack and pinion assembly. Excessive strain, out-of-plane rotation, and misalignment are common problems for open gears. Another concern is loading sequence problems, which mean that the drive shafts begin their rotation in a delayed sequence. This has an adverse effect on the condition of the open gears, usually by causing impact loading. To mitigate all these and related problems, routine maintenance is required on the gear teeth. Unless they are kept properly lubricated at all times, wear and corrosion due to grinding of the rack and pinion will occur. One of the open gears of the movable bridge and the camera used for monitoring are shown in Figure 2.

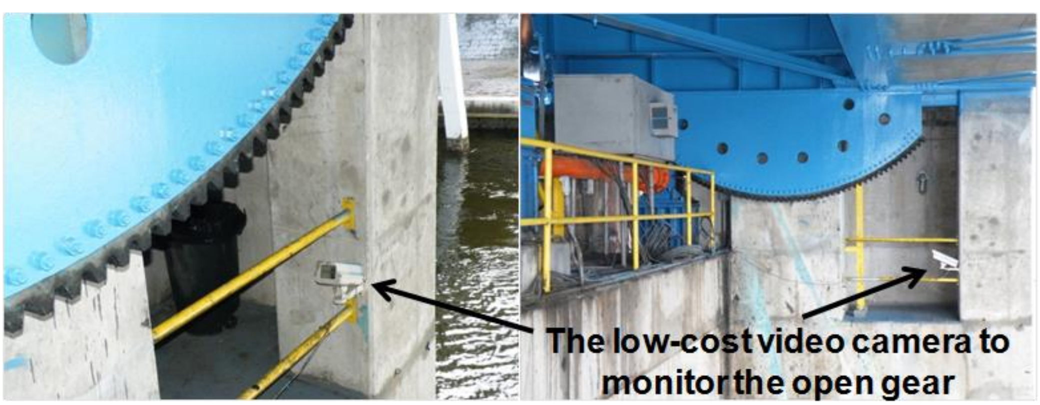

Figure 2. The open gear of the movable bridge and the video camera for lubrication monitoring

For the open gear tests, the lubrication of the open gear was removed and it was not maintained intentionally for about 6 weeks. The image data from regular operation as well as from low lubrication operation was collected. The 6-week low lubrication period was not enough to have corrosion on the gears however regular lubrication was started after 6 weeks due to safety reasons. However, a set of valuable monitoring data for the evaluation of the proposed methods could still be collected from the this monitoring period: 1) baseline well-maintained condition 2) removal of grease and no maintenance for 6 weeks, and 3) finally after the maintenance of the open gear. Finally, a second data set was also collected for verification purposes. During this period (approximately two months), the open gear was properly lubricated. Preliminary review of several recorded images showed that the grease chunks in the properly lubricated open gear were visually detectable whereas the low lubrication cases did not show these grease chunks. Therefore, it was proposed by the authors that an edge detection methodology would identify more edges for the proper lubrication cases because of the grease chunks. More details about the methodology can be found in [5].

Figure 3 shows the LI results for these three periods that are obtained by the edge detection–based algorithm. The results clearly show that the LI values drop after the grease is removed from the open gear. The low value for the LI is consistent throughout the no lubrication period (except one outlier point). This was a significant finding that showed the promise of the approach for lubrication monitoring of an open gear using image processing–based methods. Furthermore, the same plot shows that the LI starts increasing after the lubrication operations went back to normal, with a few false positives.

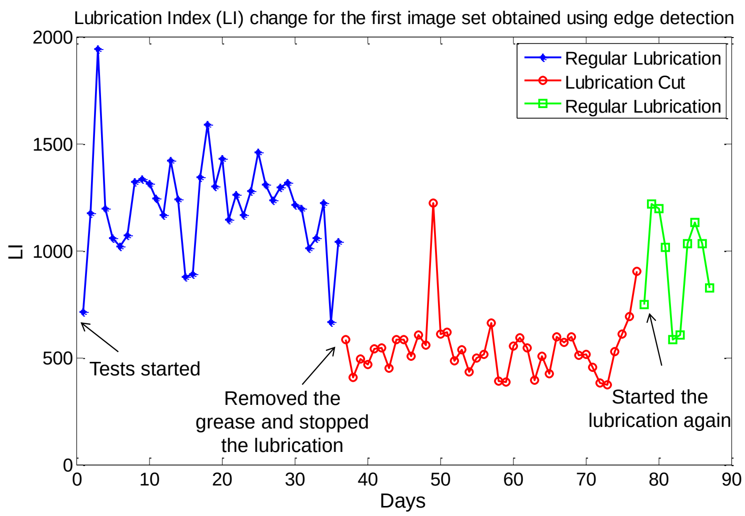

Figure 3. LI for the first image set obtained using edge detection [regular lubrication (baseline), lubrication cut, and regular lubrication (repaired)]

Lessons Learned

The project presented in this case-study report yielded several important results for the bridge owner that was successfully used for improving the maintenance operations of the movable bridge. Since the movable bridge under consideration included several different structural, mechanical and electrical components to be monitored, we had to use several different sensors and data analysis methodologies to interpret the data. Therefore, this was a very challenging application that needed a significant effort for coordination and project management with involvement of several people with different backgrounds. At the end, the project turned out to be very rewarding considering the success of the project from both academic and practical points of view. For example, the LI results presented in this report showed that the level of lubrication of the open gear can be successfully assessed using the proposed monitoring system, which was an important finding for the infrastructure owner for their maintenance planning and scheduling offering significant cost savings.

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