BEARING MALFUNCTION IDENTIFICATION OF STEEL BEARINGS FROM RESPONSE MEASUREMENT

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INTRODUCTION

Steel bearings are relatively more susceptible to corrosion and malfunctioning because of water ingress and debris growth. Environmental disintegration, maintenance shortages and ageing are the main reasons. Malfunctioned bearing primarily restricts its movements and effects the bridge performance in both operational and extreme conditions, ranging from local stress concentrations and cracking in sole plates under the repetitive traffic and temperature induced actions; and pounding, unseating or damage to supporting piers during seismic activity. In the past, notable attempts have been made to elaborate the severity of the situation and addressing the issue. Most of the studies were either based on laboratory experiments [1] on representative bearing samples or based on numerical analysis results [2], mainly focusing the seismic behavior of the bearings. This study focuses on response based bearing malfunction identification approach considering the traffic and temperature effects. Moreover, a real structure with the samples of both functioning and malfunctioned bearings was considered which distinguishes this study from other laboratory experiments and numerical analysis oriented approaches.

EXPERIMENTAL ARRANGEMENTS

Simply supported span of one steel girder bridge in Yokohama city was considered. One of the pin-roller bearing was found damaged with partial unseating because of earthquake. The bearing was temporarily retrofitted which restricted the bearing movement in longitudinal direction and caused the sliding malfunction (figure 1). The malfunctioned and good condition bearings located side by side were instrumented with laser displacement sensors and wireless acceleration sensors, with sampling frequency of 1000 Hz and 100 Hz, respectively. Figure 2 shows the instrumental setup of laser displacement sensors and reference axis adopted for discussion. Two sets of wireless acceleration sensors were firmly attached with double sided tapes at above the bearings on the girder flanges and on the piers. Measurements were carried out for about 6 hours to record possible effect of temperature also. Bridge span comprises of two lanes namely the slow lane and fast lane. Malfunctioned bearing was located at slow lane end and good condition bearings was located at the fast lane end. For the sack of comparison the input to the bearings should be identical and for this reason a test vehicle was ran in either lane close to each bearing to impose the same input actions. During the test vehicle movement over the bridge, there were no other vehicles present and if any vehicle appeared on the bridge the response information was not taken into account. Results of experiments are presented in the following section.

Fig .1. Retrofitted bearing on site

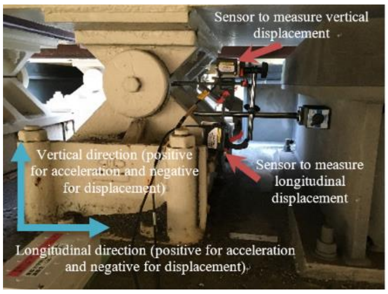

Fig. 2. Sensor layout at bearing

RESULTS AND DISCUSSIONS

Laser displacement sensor response recorded both the traffic and temperature effects in terms of visible peaks and nonlinear response, respectively. Thermal effects were isolated by low pass filtering with cutoff frequency of 1×10^{-3} Hz. Temperature and isolated thermal displacement response of bearings in longitudinal direction are plotted in figure 3(a) and bearing with good condition is appeared to be following the temperature change. Laser displacement response under the test vehicle driven near the bearing is shown in figure 3(b) and 3(c).

Keywords: Structural health monitoring, Steel bearings, Bearing malfunctioning, Traffic loading, Thermal effects.
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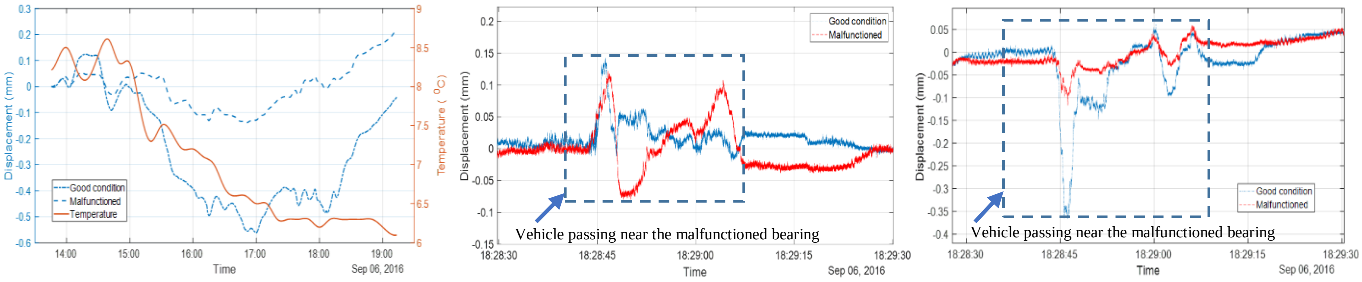

Fig. 3 (a). Temperature and longitudinal response plot (b). Vertical displacement response (c). Longitudinal displacement response

Bridge girder at malfunctioned bearing location had upward and downward vertical displacements while the girder at other location has only downward vertical displacement (figure 3(b)). This behavior is linked with the rotational capability of girder and difference is actually due to the sliding restrictions as can be seen in figure 3(c) that is the longitudinal displacement of malfunctioned bearing is close to zero. Normally when vehicle passes over the bridge, bearing slides in longitudinal direction and girder rotates which is reflected as downward displacement response and then finally equilibrium is attained. Whereas in case of malfunctioned bearing under the input action it does not slide and energy is dissipated via rotation only which is reflected as both upward and downward displacement response and it continues until the equilibrium is attained. Similar phenomenon was observed when vehicle was passed closer to the good conditioned bearing. Observation of restricted longitudinal displacement is compatible with actual site condition and increased bearing rotational demand is perceived from response that is due to difference of sliding mechanisms of both bearings.

From the aforementioned discussion, difference in vertical acceleration response of girders and longitudinal acceleration response of pier under the same input could be expected and hence simultaneously considered. Acceleration data was high pass filtered to eliminate the very low frequency components. Vertical acceleration response of girders at good condition bearing location was found to be higher (figure 4(a)) than the response at malfunctioned bearings (figure 4(b)). This is because the vertical displacement of girder at properly functioning bearing was only in downward direction which continue to increase or decrease whereas vertical displacement of girder at malfunctioned bearing had upward and downward movement which changes more frequently and result in lower acceleration response. Additionally, longitudinal acceleration response of pier at malfunctioned bearing location was also found to be larger in value (figure 4(b)) which is mainly due to its virtue of attracting greater share of imposed actions from superstructure as a result of longitudinal restrained condition of bearing.

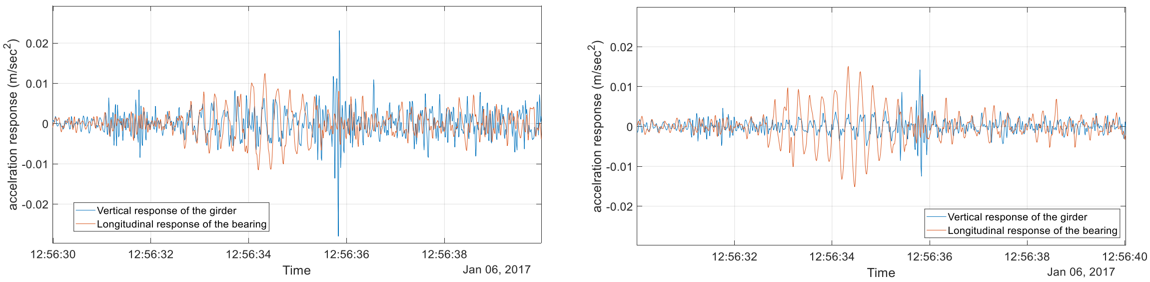

Fig. 4 (a). Response at good condition bearing (b). Response at malfunctioned bearing

CONCLUSION

Bearing malfunction identification approach via response measurement was discussed by comparing response of both good condition and malfunctioned bearings. Thermal analysis disclosed the different sliding performance of these bearings. Deep insight of displacement response revealed that bearing sliding restraint could alter the vertical response of the girder. Wireless acceleration sensor response of the bearing vicinity was subsequently investigated under the same input excitation. Comparatively smaller vertical acceleration response of girder and larger longitudinal response of pier at malfunctioned bearing was observed. More investigation is requisite to quantitatively examine the damage extent and its associated effects.

ACKNOWLEDGEMENT

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