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PROCEEDINGS

Title: **Arthur Kill Lift Bridge – *Unique Trunnion Bearing Repair***

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On September 7, 2005, during a special inspection of the trunnion bearings of the Arthur Kill Lift Bridge, we found that all of the bolts of four sheave trunnion bearings holding the lock plate in place had failed. This allowed the lock plate to move freely within the bearings damaging the lock plates and also allowing the bearing inner races to move axially along the trunnion shafts. The loose lock plates also caused damage to the bearing caps. The bearings that were affected were the inboard and outboard bearings of the northernmost and southernmost sheaves shown in blue.

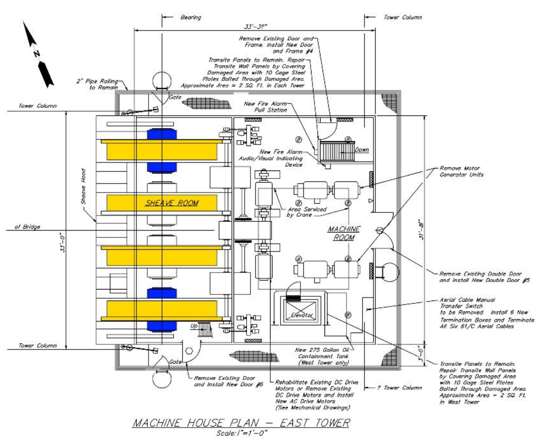

Figure 1: Sheave Location Plan

Each of the bolts retaining the lock plate contained three holes drilled through each of them crisscrossing through the head to facilitate installation of the lock wires. However, drilling these three holes removed so much section of the bolt head near the neck of the bolt that this loss of section created a weakness allowing the bolts to shear.

Since the lock plate was totally disengaged in each bearing, the inner races typically held in place by the lock plates moved outward from their normal positions allowing the rollers to be partially in contact and thus overstressing the loaded areas of the rollers. The amounts of movement in the races ranged from 15/16” to 1-9/16”. The movement of the inner races also pushed against the lock plate grinding the lock plates against the inside of the bearing end cover during bridge movements. Much of the bearing grease was contaminated with metal shavings from the ground metal of the lock plates and bearing covers.

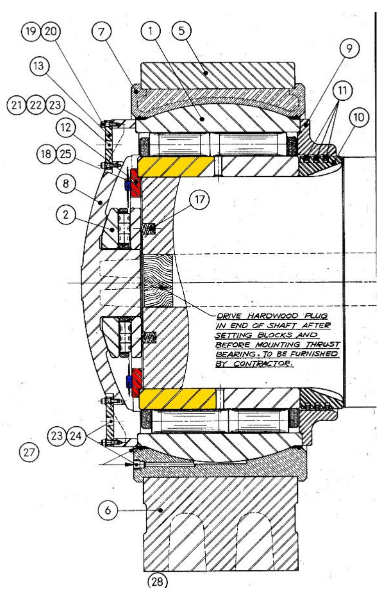

Figure 2: Trunnion Bearing Cross Section

The following observations were made in each of the bearings found to have damage.

South Sheave – Outboard Bearing

1. All eight lock plate bolts were broken off flush with the trunnion shaft end.
2. The lock plate holes and mounting surface were severely damaged. The outside edge of the lock plate was severely damaged from contact against the inside of the end cover.
3. The inner race had moved axially 1-9/16” off the end of the trunnion shaft.

4. The thrust bearings races and rollers had wear staining but no apparent scratches, pits, spalls or other destructive damage.

South Sheave – Inboard Bearing

1. All eight lock plate bolts were broken off at the heads and a portion of the bolts still protruded from the trunnion shaft end.
2. The lock plate holes and mounting surface had minor damage. The outside edge of the lock plate had minor damage from contact against the inside of the end cover.
3. The inner race had moved axially 1-1/4" off the end of the trunnion shaft.
4. The thrust bearings races and rollers had no wear staining or apparent scratches, pits, spalls or other destructive damage.

North Sheave – Inboard Bearing

1. All eight lock plate bolts were broken off at the heads and a portion of the bolts still protruded from the trunnion shaft end.
2. The lock plate holes and mounting surface had significant damage. The outside edge of the lock plate had significant damage from contact against the inside of the end cover.
3. The inner race had moved axially 15/16" off the end of the trunnion shaft.
4. The thrust bearings races each had about a 2 square inch area of pitting. The thrust bearing races and rollers had no wear staining or apparent scratches, pits, spalls or other destructive damage.

North Sheave – Outboard Bearing

1. Seven lock plate bolts were broken off at the heads and a portion of the bolts still protruded from the trunnion shaft end. One lock plate bolt was broken off flush with the trunnion end.
2. The lock plate holes and mounting surface had significant damage. The outside edge of the lock plate had significant damage from contact against the inside of the end cover.
3. The inner race had moved axially 1-7/16" off the end of the trunnion shaft.
4. The thrust bearing races and rollers had no wear staining or apparent scratches, pits, spalls or other destructive damage. Light rust was beginning to form on the races.

Photo 1: Southern Most Outboard Lock Plate. Note severe damage to hole and outside edge.

Since the bridge was due to go back into service in a short time after this condition was found, it was necessary to develop a repair solution that would shorten the time and cost of performing a typical trunnion bearing repair approach of jacking the sheaves up off of the bearings to relieve the load, thoroughly cleaning the bearings and resetting the inner races, a new method for repair was necessary. DMJM Harris along with

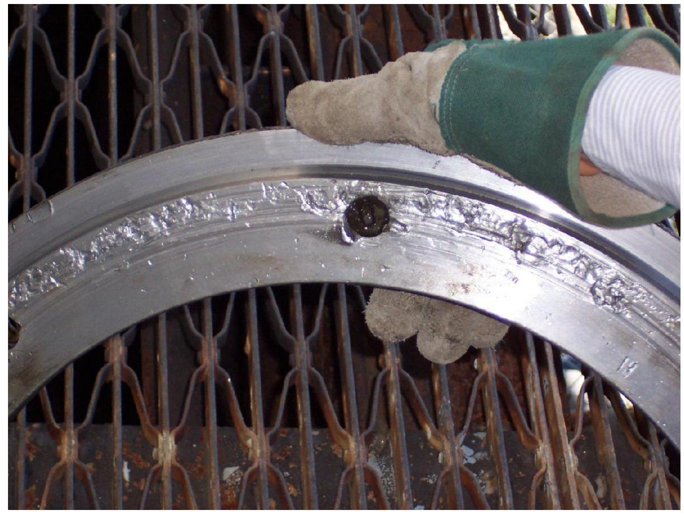

Photo 2: Southern Most Outboard Lock Plate Note severe damage to mounting face.

BRH Consulting and Timken designed a method where the inner races could be gently pushed back under load to their original position.

In order to perform repairs to these bearings, a repair procedure was developed that would eliminate the need to remove the trunnion bearing caps and jack up the sheaves, which would become a costly and potentially lengthy repair operation.

Prior to any repair operation, the bearings needed to be thoroughly cleaned. Each of the bearings was continuously flushed with mineral spirits to remove grease and metal shavings. The mineral spirits were applied using a special pressure gun and nozzle that was long and flexible enough to reach all**.** areas inside the bearing. This cleaning operation was repeated.

After every two cleaning iterations, the interior of each bearing was thoroughly inspected using a borescope to check for metal shavings remaining inside the bearing. If shavings or grease were found, more flushing operations were performed.

However, since the bridge was in the midst of a larger rehabilitation contract and the bridge operation was not tested, it was decided that custom made lock rings would be fabricated and installed that would account for the current position of the inner races. These lock rings were installed to prevent the inner races from moving further. Also, since the bearing cover holds the thrust bearings in place and would not fit over the temporary lock plate, extension rings and thrust bearing shim plates were manufactured and installed to fit the bearing cover and thrust bearings. The bearings were then fully greased.

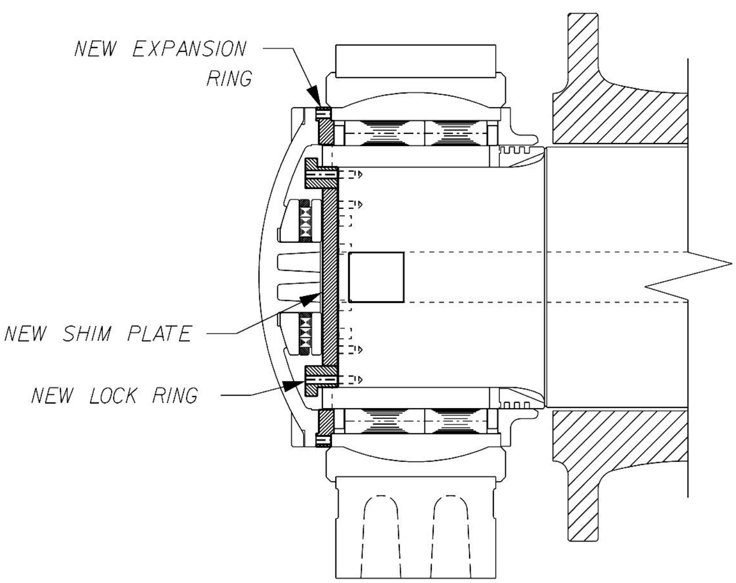

Figure 3: Temporary Lock Plate and Extension Rings

These custom lock rings were also fabricated in a way that once the permanent repair was accomplished and the races were reset in their original position, they could be re-machined to serve as the permanent lock rings.

After all bridge operations were tested, the bearing cover and temporary rings were removed. Luckily, the trunnions contained a 5½" diameter hole running down the center. An 8'-0" long, two inch diameter steel rod threaded at each end was inserted through each trunnion. Sections of the machinery house walls were cut open and several interior brace members were removed in order to fit the steel rods through. Specially fitted push plates and a

20 ton hydraulic center hole jack was installed onto rod. In order to reset all 4 bearing races simultaneously, this setup was installed on both outer sheaves at the same time.

The steel rods and jacks did not allow for the thrust bearings to be in place during the resetting operation. Special guide rollers were designed and installed to prevent the sheaves and trunnions from moving laterally as the bridge was operated during the resetting procedure was underway.

In order to start the resetting operation, the bridge was moved up and down while pressure was applied in very small increments from the jacks onto the inner races through the push plates. As the bridge was moved, the races were very slowly walked back into position. The entire operation required 15 half movements of the lift span to fully reset all of the inner races.

Photo 3: Two Inch Diameter Rod Installed Through Machinery House Wall

Once the resetting operation was complete, new measurements were taken to make sure all of the races were in their original location. The previously fabricated temporary lock plates were re-machined to become new final lock plates and the bearings were re-assembled and regreased.

Since this entire repair cost was approximately $75,000, it is stimated that this trunnion bearing repair as performed cost a fraction of the cost of jacking the sheaves and performing a typical bearing repair.

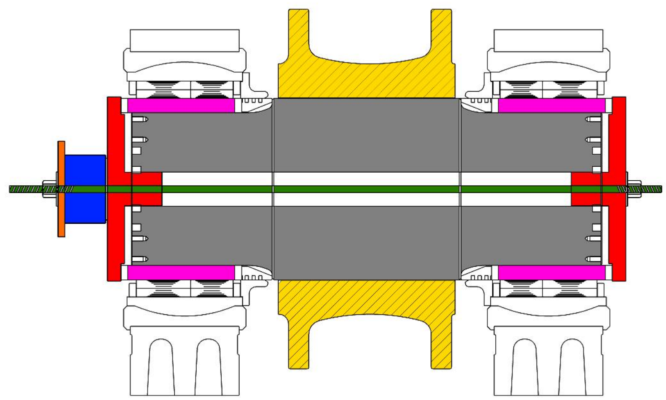

Figure 4: Schematic of Repair Set Up

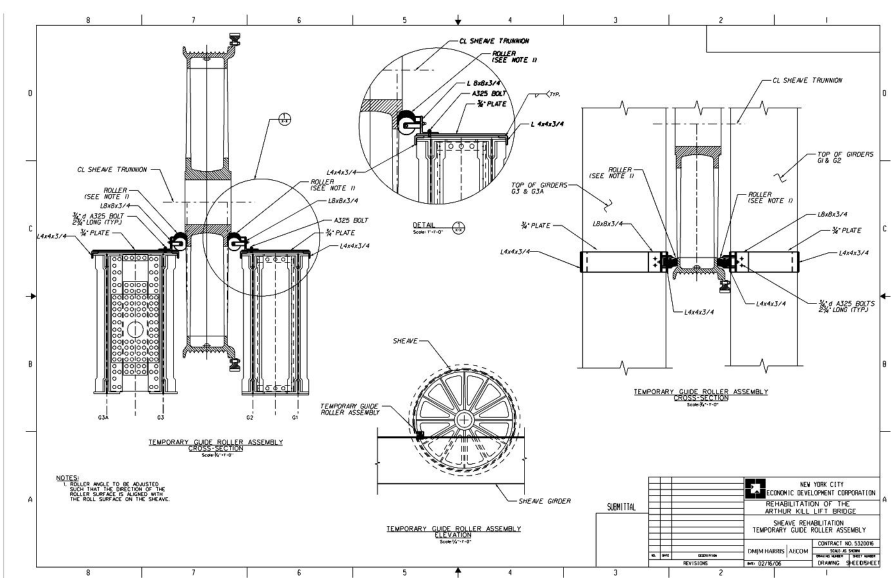

Figure 5: Special Sheave Guide Roller Assembly

Photo 4: Push Plate and Jack Assembly

Photo 5: Measurement of Races Prior to Repair Operations

Photo 6: Sheave Guide Roller