Trip Report – Hancock, NH VLBA Station

Dual Elevation Bearing Change and Failure Analysis

May 14-23, 2022

William Martin

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Trip Summary

A task force from the VLA and several site techs from VLBA sites traveled to the Hancock, NH VLBA station (HN) to replace both elevation bearings. Both the encoder side and synchro side bearing's grease samples showed significant metal particles and flakes. Initially only one bearing was to be replaced, but since the entire team would be there, it was elected to replace both bearings. The bearing replacement job took place between May 14th and May 23rd, 2022. The VLA staff that participated directly in the replacement are listed below:

William Martin
Jon Thunborg
Patrick Martinez
Sean Tracy
Scottin Platero
Jason Romero

Along with the VLA staff, there were VLBA site techs also visiting the HN site to help with the replacement and performing maintenance during the antenna downtime. The HN site techs were also available and helped in replacing the bearings. Those VLBA site techs were:

Dave Alderman (NL)
Juan De Guia (FD)
Tom Baldwin (HN)
Doug Whiton (HN)

Figure 1: The Hancock VLBA station antenna.

Plan Summary

Changing both elevation bearings in one trip had not previously been done, so the trip was carefully planned to save time, work, and money. Renting a crane and operator in the area cost over $2000 per day, so it was important to reduce the number of crane days to a minimum. The plan was to fully prepare both sides of the antenna before the crane arrived on site. The encoder side was focused first due to it having a hoist that could lift the 460lb jack support beam into place. Once the encoder elevation bearing was changed, the crane was planned to remove the jack support beam and lift it into place on the synchro side. After

the synchro side was replaced, the crane could lower the jack support beam and then the crane could be dismissed. This was planned to take place within three days.

Trip Details

Saturday, May 14th 2022

Jon Thunborg, William Martin, Jason Romero arrived by airline into Manchester NH in the afternoon and traveled to Keene NH. Patrick Martinez and Sean Tracy arrived the previous evening and used this day to get tools and equipment organized and out of the container at the HN site.

Sunday, May 15th 2022

The mechanics began preparing the antenna for the bearing change. The platform was cleared of electrical cables and connections and marked for drilling. A new hole template was built for this trip which removed the possibility of using the template upside down as has happened in previous bearing changes. The structural lugs were also tacked into place on the encoder side. The elevation locking pin was welded into place.

Figure 2: Scottin, Jason, and Patrick using the newly built template for marking the platform for drilling. Note that it is impossible to use it upside down.

Monday, May 16th 2022

The platforms were drilled and tapped to accept the jack support beam. The structural support lugs on the encoder side were fully welded and the beams bolted into place.

Figure 3: The encoder platform being drilled in preparation for installing the jack support beam.

Tuesday, May 17th 2022

The final preparations for the encoder side bearing change were completed, including cutting away the pillow block welds and placing the jacks. Welding on the synchro side structural support lugs started.

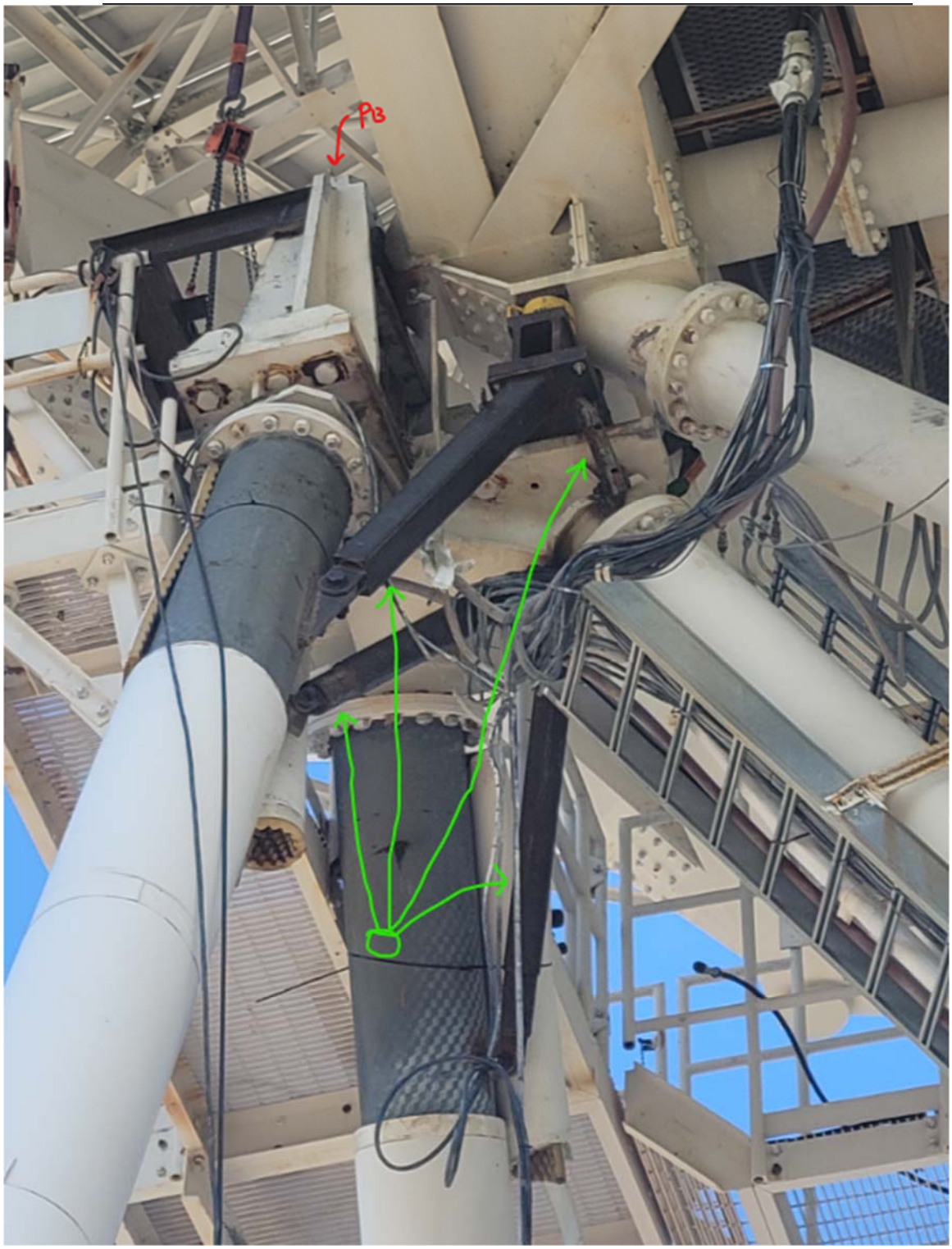

Figure 4: An annotated picture highlighting the pillow block, structural supports, jacks, and bearing puller fully installed.

The dish was lifted by the end of this day in attempt to break the taper coupling free. The pillow block lifted from the platform at approximately 6500 psi on the jacks. With the pillow block fully freed from the platform, the bearing puller was used to apply pressure to the taper coupling. Pressure on the bearing puller was pumped up to 8000 psi however there was not a 'pop' sound to indicate the coupling had broken free. One of the mechanics noticed that the rear cover had not been removed from the pillow block, so the taper coupling was being pushed against the cover. After the cover was removed, the taper coupling easily pushed free from the bearing. It was assumed that pushing on the coupling with the cover in place probably loosened it slightly, so there was no 'pop' heard. The dish was set down again and three bolts reinstalled into the pillow block.

Wednesday, May 18th, 2022

The size of the boom tip and distance from the hook to the top of the boom were the biggest concern when planning for and reserving the crane. The distance from the center of the axle to the overhanging dish structure is approximately 10 ft and the dish structure protrudes horizontally from the axle's face approximately 10 ft.

Figure 5: The crane without the jib installed. The hook and boom tip have been highlighted in red. The minimum height of the hook/boom tip are shown in green. This dimension was the greatest concern when renting an appropriately sized crane.

Figure 6: A comparison of the boom tip with or without the jib installed. With the jib installed, the height was much lower and allowed for extra maneuverability of the crane.

The dish was jacked up, pillow block unbolted, and removed from the antenna. The bearing was pulled from the block, it pressed out with relative ease. The bearing races were intact although one of the rollers had rotated sideways relative to the others. This block had spacers installed in front of and behind the bearing. The new bearing was pressed into place to rest against the rear spacer and the pillow block reinstalled on the platform. The reduction in clearance (RIC) was started late in the afternoon but was paused to finish the next morning.

Figure 7: Mechanics work with the crane operator to hoist the pillow block up and out of the antenna.

Figure 8: The pillow block being lowered from the platform. The crane operator showed 2700 lbs on the hook when the block was fully freed from the antenna.

Figure 9: The bearing being pressed out of the block. The jack and pressure plate are used on the other side when pressing the new bearing into the block.

Thursday, May 19th, 2022

The dish was jacked up again in the morning. This time the dish was only jacked up until the rollers on all sides of the bearing were loose (the weight of the pillow block still rested on the elevation platform.) The RIC was completed while the synchro side's platform was prepared for the next day's lift. The crane was used to move the jack support beam over to the synchro side platform after the dish was set back down. The synchro side was fully prepared and the dish was lifted (on the synchro side.) The synchro side's taper coupling was loosened before the end of the day. The rear cover was removed this time and the coupling broke free at approximately 8000 psi and with a resounding 'pop'. Although it took extra time that afternoon/evening, it was a decision that most likely saved an extra day of crane rental.

Friday, May 20th, 2022

After jacking up the dish, the pillow block was lifted out of the antenna and the bearing was removed. The bearing's outer race was split in half around its perimeter and this breakage made it difficult to press the bearing out. Eventually the broken outer race had to be cut in

several places and hammered out of the block. The broken outer race caused significant gouging in the pillow block's bearing surface. These gouges were sanded and care was taken to not over sand the surface of the pillow block.

Figure 10: The broken outer race of the old bearing left large gouges in the bearing surface.

Figure 11: The outer race of the old bearing had to be cut and hammered out. The broken edges where it split around the perimeter caused the gouges in the pillow block.

As the new bearing was being pressed in, it became lopsided. This couldn't be corrected by hammering or pressing on one side. The new bearing was pushed out and installation reattempted. The bearing once again became badly lopsided before it was fully in place. This time the bearing was incredibly difficult to remove. It required nearly 10000 psi on the jack to get it out of the pillow block. The bearing surface in the pillow block was sanded further to reduce the gouges. Due to the incredible forces applied to the new bearing when pushing it out for the second time, it was elected to use the spare new bearing. The spare pressed in much more easily. The struggles with the new bearings took much longer than expected, the pillow block was not replaced on the antenna until later in the afternoon. If the taper coupling had not been broken free the night before, the crane may have been needed for another day. The pillow block was replaced on the antenna and RIC was started before the end of the day.

Saturday, May 21st, 2022

The dish was lifted in the morning just enough that the rollers on all sides of the bearing were loose and the RIC process was completed. After completing the RIC process, the dish was

lowered and the pillow block bolted into place. After prepping the bearings, the antenna was tilted as far as some cryo hoses would allow (they were installed incorrectly, this has been fixed already.) A set of dial indicators on the axle showed approximately 1/100th of an inch of horizontal movement as the dish tilted. This movement was observed several times in the same places as the dish elevation was moved up and down. There were no erratic movements as shown by the dial indicators.

Figure 12: A newly installed bearing on the synchro side (before it had been greased.)

Sunday, May 22nd, 2022

The dish was tilted several times in both directions after the cryo lines had been moved by the site techs. Everything seemed to be functioning normally. The site was cleaned, tools put away, and the mechanics left the site.

Figure 13: The dish was rocked back and forth repeatedly to ensure it was not making unusual sounds or movements.

Monday, May 23rd, 2022

Patrick and Sean began driving the truck/trailer back to the VLA. Jon, Jason, and William returned to NM via airline.

Trip Conclusion

Both encoder side and synchro side elevation bearings were replaced on the Hancock VLBA station. Preparation took approximately three days, in which time both platforms were completely prepared and the structural supports were mostly installed on both. The structural support welds were completed concurrently with the first day of crane work. The crane was used for three days to remove and replace the pillow blocks on both sides as well as move the jack support beam. The site was left clean and the antenna has returned to normal operation.

Appendix A: Planned Schedule of Work vs Actual Work

Sunday	Planned	Actual
	Unpack Truck	Unpack happened previous day.
	Lift beam to encoder side	
	Mark hole locations	
	Drive antenna to 90	
	Remove Encover	
Monday		
	Drill encoder side holes	
	Elevation lock pin	
	Encoder support structure	
	Drill synchro side	
Tuesday		
	Synchro support structure	
	Encoder lift prep	
Wednesday		
	Encoder bearing change	
Thursday		
	Synchro lift prep	
	Encoder side finish work	Encoder side RIC finished this day.
Friday		
	Synchro bearing change	
Saturday		
	Synchro finish work	Synchro RIC finished this day.
	Remove support structure	
Sunday		
	Pack container, clean site	

Figure 14: The spreadsheet of planned activities for each day.

As mentioned in the body of the report, the trip was meticulously planned by engineering. The goal was to maximize the use and efficiency of each work day to reduce the amount of days the crane was needed and number of days six people were on travel. Aside from the RIC process taking slightly longer than expected, the work went as planned. Engineers on site were able to finish the RIC for each bearing while other work was being completed, so overall the team stayed on schedule for the entire trip.

Appendix B: Bearing Failure Analysis

The bearing failure analyses have been attached to this report. When referring to an axial crack, it is a crack that runs parallel to the centerline of the axle. A radial crack runs along the perimeter of the bearing race. The reference of outer means the side of the bearing further away from the center of the antenna, inner the opposite.

- **Synchro Bearing Failure Analysis**

  The synchro side elevation bearing was uncovered on Sunday, May 15th. The grease around the bearing contained significant amounts of large metal flakes and glitter, indicating the bearing was at least approaching failure. Further inspection while the bearing was installed revealed the outer race was split into two pieces around the perimeter. The depth of the bearing was measured relative to the face of the pillow block while it was still installed. The outer section was sitting approximately 88.3 degrees tilted upwards with respect to the axle.

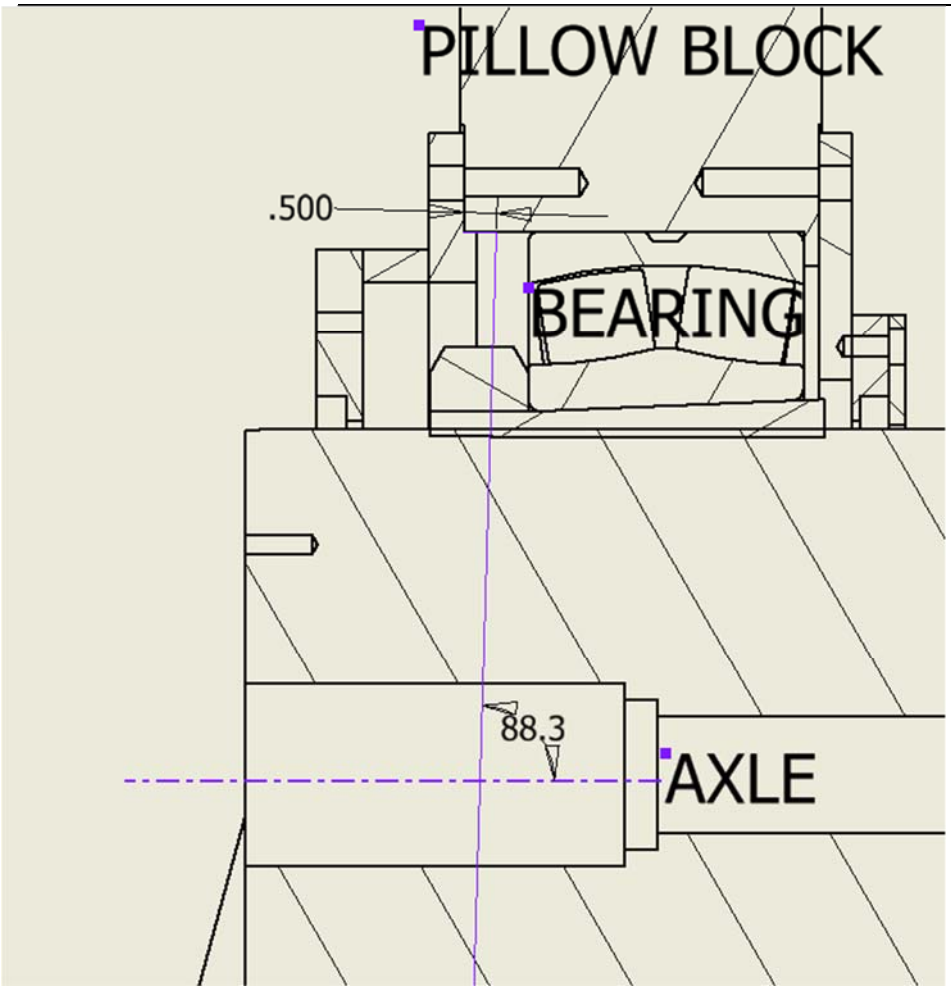

Figure 15: A drawing showing the relative angle between the face of the synchro bearing and the face of the pillow block.

The outer half of the bearing's outer race pressed out of the block without much issue. The rollers, cages, and inner race were removed from the pillow block as a single assembly after carefully beating them out with a hammer. The inboard portion of the outer race proved much more difficult to remove. It became bound on one side and only pushed out partially. It was decided to cut the most narrow part of the race and push it out with a punch and hammer.

The bearing was taken to the VLA site where it was cleaned and disassembled for further inspection. The inner race showed severe spalling, fragmentation denting, and cracks, both radially and axially. A piece of the roller guide between the two roller surfaces was also broken off. All of the major damage to the inner race existed near the cracking.

Typically, an axial crack on the inner race would form from an excessively tight interference fit, such as a taper coupling being tightened too much. There is fragmentation denting on both rolling surfaces of the race which indicates that the rollers were rolling over metal chips inside of the bearing. As the rollers pass over a metal chip, the loads are concentrated into one small area and the race material begins to fail. The failure shows up as spalling, which in turn produces more metal chips, more concentrated loads, and more spalling.

Figure 16: The bearing's inner race. The finger is representative of the antenna's axle, pointing away from the center of the antenna.

Figure 17: The inner race's roller surfaces were severely spalled and cracked in several places. The cracks are highlighted with the red dotted lines. Also, a part of the roller guide that divides the roller sections broke free.

The outer race was found with a radial crack that ran around the entire perimeter. In a typical situation, this type of cracking forms from a faulty fit in the bearing housing, such as debris between the housing and race or a misshapen housing. This also could have occurred as a result of the inner race's failure. The spalling on this race was found on one side of the crack, likely because the outer part of the race moved away from the rollers and the load was concentrated on what remained in place. The area around the spalling on the broken edge was rounded off, likely from the rollers rounding the sharp broken edge as they pressed down onto it.

Figure 18: The spalling on the outer race. Note the rounded broken edge and fragmentation denting.

Figure 19: The outer race and rollers. The radial crack is visible and the axial cracks came from cutting the race out of the block.

The rollers were found in equally bad condition. All of them showed fragmentation denting, spalling, or both. A few of the rollers showed that they were supporting an uneven load as evidenced by significant spalling on one side but not the other. Some of the rollers had large flat dents on the inside corners. These rollers were possibly being pushed up against the roller guide in the middle of the inner race.

Figure 20: The rollers were dented and spalled. Note the tops of the upper rollers have spalling on one side. These rollers were likely subjected to all of their load being concentrated on that side.

The taper coupling had some damage where the cracked pieces of the inner race were lodged. The roller cages didn't show any damage.

Figure 21: The marks on the taper coupling match up with the axial cracks on the inner race.

The synchro bearing was probably damaged by a taper coupling being excessively tightened during installation. This crack may not have developed any further damage for a long time, but once it began developing it became a chain reaction that caused more and more damage.

- **Encoder Bearing Failure Analysis**

The Encoder bearing was not as damaged as the synchro bearing. The inner race of the bearing had a similar axial crack. The inside faces of the crack showed signs of fretting, where the two faces were rubbing against each other. The rolling surfaces had fragmentation denting but was not spalled yet. The major damage to the inner race was the roller guide, which had a pattern of approximately 1" chunks that were broken off. These chunks appear to have broken off one after the other in series.

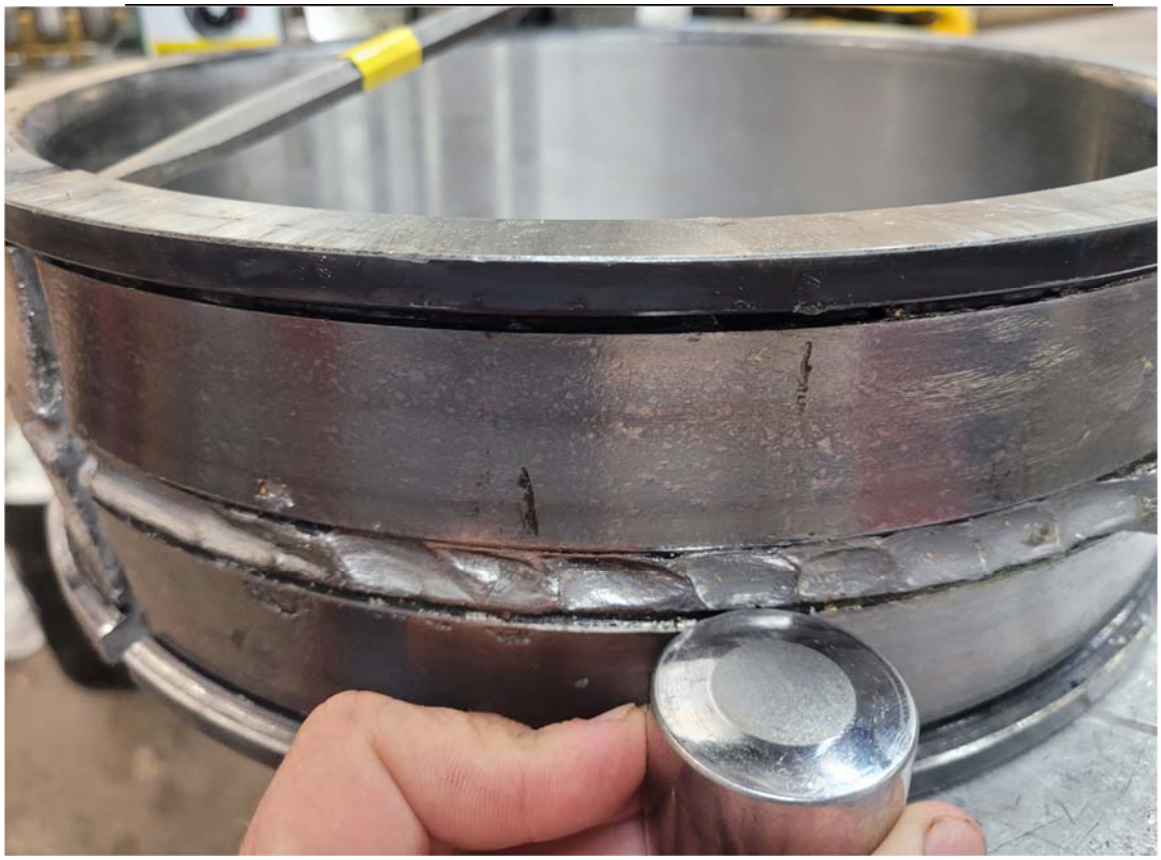

Figure 22: The rolling surface of the inner race. The broken chunks of the roller guide were found inside of the bearing.

The outer race was found in decent condition. It had some minor fragmentation denting where the rollers contacted the surface. The rollers were in similar condition, with minor fragmentation dents but nothing otherwise notable.

Figure 23: The outer race and rollers. Neither of these components showed any major damage. Also pictures are the fragments of the roller guide that broke free from the inner race.

The roller cages both had similarly sized sections broken free. One broken section broke into smaller pieces. These broken sections allowed one roller to rotate sideways so it was no longer rolling along the rolling surface. Besides being dragged along, the roller didn't seem to do any major damage.

Figure 24: The fragments of the broken roller cages.

Figure 25: The roller cages with their missing sections removed. Both roller cages were missing similarly sized sections.

The fragments of the inner race roller guide and the roller cages were likely causing more chips which would have eventually lead to spalling on the roller surfaces like what was seen in the synchro bearing. The damage was likely a chain reaction stemming from the axial crack in the inner race. The axial crack could have formed from the taper coupling being excessively tightened during installation.