Demonstration of the mechanism driving the GBT track movement

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1 Introduction

In August, 2000, a significant number of 1 inch bolts holding the 2.25 inch wear strip to the 9 inch base plate on the GBT track were discovered to be broken. Subsequent measurements, by COMSAT and the GBT Antenna Metrology group, showed relative movements of about 0.140 inches in the direction of travel of the wheels. Moreover, significant movement was detected between the base plate and the concrete foundation–also in the direction of travel of the wheels. A number of measurements were made and the results were reported in references[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12].

The most puzzling aspect was the consistent movement in the direction of travel of the wheels. This seemed to violate Newton's third law! The motion integrated smoothly (no jumps) as the wheels moved over a segment, and, for the most part, the motion was in phase at both ends. The motion was the same for both driven and idler wheels, although there were some differences in the trailing wheels.

A number of theories were proposed[13], but none were consistent with the measurements. Lee King pointed out some references to work by McGinness at JPL [14, 15], which reported the same phenomena, even though the wheels were driven in a different manner. McGinness also corresponded with Mark McKinnon about some additional ideas[16].

2 Delamination between the wear strip and base plate

In March 2001, the GBT Antenna Metrology group bonded strain gages on the wear strip to test a popular plastic deformation theory. The theory predicted that the wheels were "rolling" the metal in the wear strip "like dough under a rolling pin". By measuring the horizontal strain as the wheels rolled over the array of gages between the top and bottom of the wear strip, it was hoped the theory could be verified or dismissed.

Much to our surprise, we discovered that, under the wheel the strain was in compression at the top of the wear strip, and in *tension* at the bottom of the wear strip. The attached plot, taken from report A0234, looks like the strain pattern for a bending beam. Everyone was expecting the wear strip and base plate to act together as a laminated beam–which should have produced strain in compression down to about the middle of the assembly, i.e., about 5-6 inches. Subsequent measurements on the base plate confirmed that it too was in compression at the top.

So, given that the strain on the bottom of the wear strip was 180 degrees out of phase with the top of the base plate, a mechanism for relative movement at the interface was clear. This is demonstrated by a simple experiment.

Figure A shows two strips of wood. The upper strip is about 1/4 inch thick and the lower strip is about 7/16 inch thick. Figure B shows a clamp holding the right end of the assembly. Note that the assembly is free to slide, except at the clamp, and thus the beams are delaminated and act independently. Figure C illustrates the assembly bending under a load. Under this bending condition, Figure D clearly shows that, at the interface, the bottom of the upper beam is longer than the top of the lower beam.

3 Preferred direction of movement

Assuming that the movement was due to deflection of the foundation, and insufficient clamping force between the wear strip and base plate to force the assembly to act as a single laminated beam, the question remained about the preferred direction of movement in the direction of travel of the wheel.

Each wheel carries over 1,000,000 lbf. The handbook value for the coefficient of friction for hard steel is around 0.78. So, directly under a wheel there is a propagating line of static friction force of around 780,000 lbf. Under this condition, the relative movement between the wear strip and base plate would be zero—directly under the wheel. Of course this line propagates forward with the wheel.

Lee King and Dennis Egan estimated the force developed by each 1 inch bolt to be around 49,000 lbf at 800 ft-lbf, or about 535,000 lbf absolute maximum for 14 bolts (assuming the same coefficient of friction). The strain gage measurements also showed that the direction of the strain reversed between a pair of wheels as though the foundation sinks directly under a wheel and bulges up between a pair of wheels. This would imply that the direction of the forces on the bolts changed within the length of one-two pairs of bolts, and the forces developed against the bolts were localized to a small number of bolts. Therefore, it seems plausible that the forces developed by the deflection of the foundation would result in motions in front and behind the wheel.

Figure E shows the two strips resting on two keyboard wrist pads. By applying pressure, starting at the right side and stepping across as shown in figures F-I, a load migrates across the beam. A wheel can be thought of as the same process where the incremental steps become smaller. Figure J shows the characteristic motion in the direction of travel.

4 Conclusion

This illustrates one mechanism for movement of the wear strip. Following the strain gage measurements, COMSAT increased the bolt size from 1 to 1 1/2 inches, and the number from 14 to 36 per segment, for an increase in clamping force of about 5-6 times the original design. Early measurements indicate this was sufficient to laminate the wear strip/base plate assembly. A follow-up report on the problem by Lockheed Martin[17] made no mention of calculations of the bolt sizes or influence of the foundation deflections. NRAO has contracted with VertexRSI to do a detailed model of the problem, and a more quantitative explanation is expected soon. In any case, it is clear that future designs (or repairs) should calculate (or measure) the foundation deflections and resulting strains in the wear strip/base plate assembly.

References

[1] Report on 12/12/00 track experiment, David H. Parker, 12/21/00, report A0200.

[2] Report on 12/20/00 track experiment, David H. Parker, 1/11/01, report A0201.

[3] 1/17/2001 welded track measurements, David H. Parker, 1/23/01, report A0218

[4] Welded vs un-welded track measurements, David H. Parker, 1/31/01, report A0226.

[5] Notes on COMSAT wear strip experiment, David H. Parker, 2/16/01, report A0230.

[6] Track temperature measurements, David H. Parker, 2/22/01, report A0231.

[7] Doweled track measurements, David H. Parker, 3/13/01, report A0232.

[8] March 15 measurements of GBT wear strips, David H. Parker, 3/28/01, report A0233.

[9] Notes on GBT wear strip strain gage measurements, David H. Parker, 4/12/01, report A0234.

[10] Notes on rev I track measurements, David H. Parker, 4/25/01, report A0235.

[11] Notes on track strain gage measurements, David H. Parker, 5/9/01, report A0236.

[12] Revisions J and K, and strain gage track measurements, David H. Parker, 7/18/01, report A0252.

[13] GBT track movement, Jack Gurney, 12/5/00, report A0199.

[14] Antenna azimuth bearing model experiment, H. McGinness, DSN progress report 42-53, July and August, 1979, in report A0221.

[15] Antenna azimuth bearing model report, H. McGinness, TDA progress report 42-66, September and October, 1981, in report A0221.

[16] Comments for Mark McKinnon of NRAO re the JPL azimuth bearing model test, H. McGinness, 3/28/01, report A0237.

[17] Technical report GBT 100 m telescope track design analysis review, David Enterline, Lockheed Martin, Management & data systems–western region, 5/01, report A0248.

Wheel On MicroStrain - Wheel Off MicroStrain   vs   Strain Gauge Number

File : Track_Strain _040301_4.xls   Disk : B417

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