TTCI TECHNOLOGY DIGEST

June 2020 TD20-013

The research described was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Field Investigation of Broken Cut Spikes on Elastic Fastener Plates: Revenue Service

Yin Gao, Mitch Miller, and David Williams

Key Findings:

- Test results show that the loading environment on cut spikes installed with elastic fastener tie plates exceeded the yield point of spike material (strain > 0.002).
- Spikes had more severe loading environment on the high rail of curves than on the low rail.

Transportation Technology Center, Inc. (TTCI) has conducted comprehensive field testing to investigate the occurrence of broken spikes in revenue service. Metallurgical investigation and modeling work showed that metallic fatigue was the failure mechanism, and that the bending stress in spikes can exceed the fatigue limit of spike material.[1, 2] For the current study, TTCI engineers designed, assembled, and calibrated instrumented cut spikes. Prior to use in the revenue service tests described in this *Technology Digest*, the instrumented spikes were evaluated successfully in a 6-degree curve at the Facility for Accelerated Service Testing (FAST) near Pueblo, CO.[1]

FIELD SURVEY OF BROKEN SPIKE ISSUE

A Class I railroad performed a field survey of broken cut spikes on elastic fastener tie plates collecting data from walking inspections and from automated inspections by track geometry cars. The survey confirmed the following:

- Broken spikes were found in over 70 different curves.
- Curves with broken spikes are all over 6 degrees and have a timetable speed of less than 35 mph. Broken spikes are found on the high rail, on gage and field sides, and in rail spike and anchor spike positions.
- Fretting and wear were found on the spike shaft where it contacts the inside edges of the tie plate spike hole. Fatigue failure surfaces were consistently about 1.5 inches below the top surface of the tie.
- Some curves were on a substantial grade, suggesting that high longitudinal forces may be a factor. Longitudinal forces can be generated by heavy braking (air or dynamic), or by high tractive effort.
- Broken spikes are often associated with non-uniform alignment in the high rail, which is known to contribute to higher wheel-rail lateral forces.

These field survey observations were used to guide the parameters of the field testing conducted.

TEST DESCRIPTION

The test location was at an 8.4-degree curve with a 2 percent grade on a Class I railroad (Figure 1). Main 1 and Main 3 tracks of this curve were instrumented with strain-gaged spikes (A detailed design of the strain-gaged spikes can be found in Reference 1). Downhill traffic with loaded cars was mostly on Main 1 (non-anchored), and uphill traffic with empty cars was mostly on Main 3 (high rail anchored). Elastic fasteners were used on high and low rails on Main 1 and on high rail on Main 3. Conventional cut spike plates were used on the low rail of Main 1.

Figure 1. Test Curve

Since most broken spikes were found on the high rail of curves, instrumented spikes were installed on the high rails of Main 1 and Main 3. The low rail of Main 1 was also instrumented. Figure 2a shows the spiking pattern on each plate; the spike locations on a plate are identified by field or gage side and anchor or rail spikes. For example, "AF" stands for anchor spikes on the field side. The existing spikes were pulled out and replaced with instrumented spikes without wood plugs. The four instrumented spikes installed on the Main 1 high rail were later moved to the low rail to collect the spike loading environment. Also, at each instrumented location, rail circuits to measure the vertical and lateral wheel-rail forces and a thermocouple to measure the rail temperature were installed, as shown in Figure 2b.

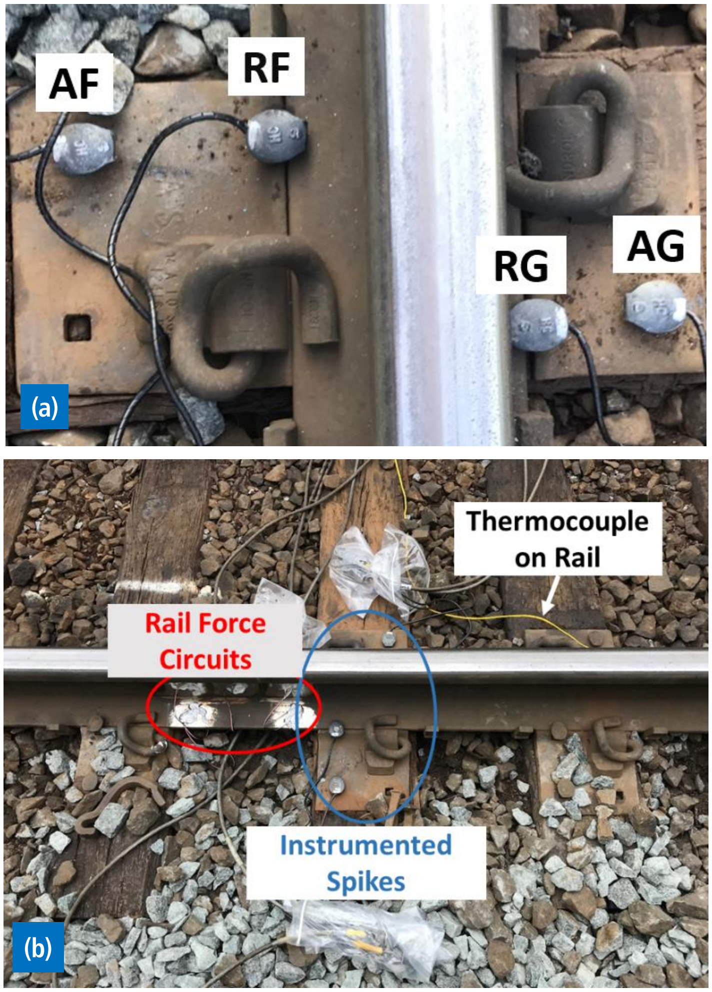

Figure 2. Instrumentation layout (a) and spiking pattern (b) on each plate

A total of 30 train passes were collected in two days: 15 from Main 1 and 15 from Main 3. The following parameters were investigated in this test:

- General observation on spike loading environment (bending strain values).
- Bending strain values of an anchored track versus a non-anchored track.
- Bending strain values of high rail versus low rail.
- Bending strain values after reducing the number of spikes on a single plate.

TEST RESULTS

Spike Loading Environment

Bending strain values were measured to quantify the loading environment of a spike. A bending strain exceeding 0.002 indicates that steel material has yielded. Figure 3 shows an example of the bending strain data collected for the field side rail spike on Main 1 track. The bending strain in this spike indicates potential yielding of the spike material. Moreover, the bending strain in some spikes did not return to zero after a train had passed, indicating that the steel had yielded, and that residual bending strain existed in spikes without experiencing any direct train loads. Figure 3 indicates the yielding happened in the first few cycles. Permanent strain is about 0.0005.

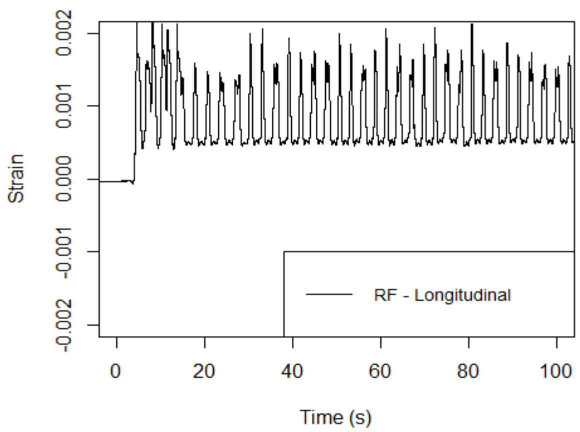

Figure 3. Example of bending strain in a spike, field side rail spike, Main 1

Figure 4 shows the plate movement of the two instrumented plates (Main 1 and Main 3). As a result, the spikes were loaded by their plates in the direction of the train movement in the longitudinal direction and toward the field side of the track in the lateral direction.

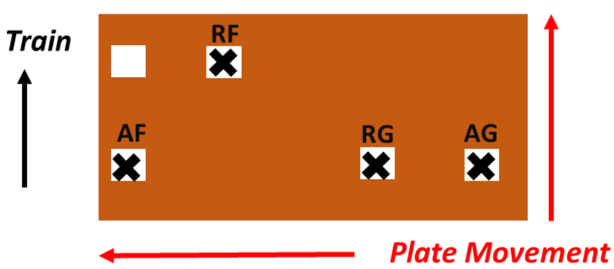

Figure 4. Plate movement/Spike loading direction

Low Rail versus High Rail

The spike loading environment on a high rail and on a low rail was investigated on Main 1 track. The instrumented spikes were used to collect the bending strains on the high rail and were moved to the same tie on the low rail. Figure 5 shows a comparison of the bending strains on the high rail and on the low rail. The bending strains on the low rail were much less than the values on the high rail, which could explain why most of the broken spikes were found on high rails. It may also suggest that the loading environment of low rails was not enough to generate broken spikes, which may help in understanding the fatigue limit for a cut spike.

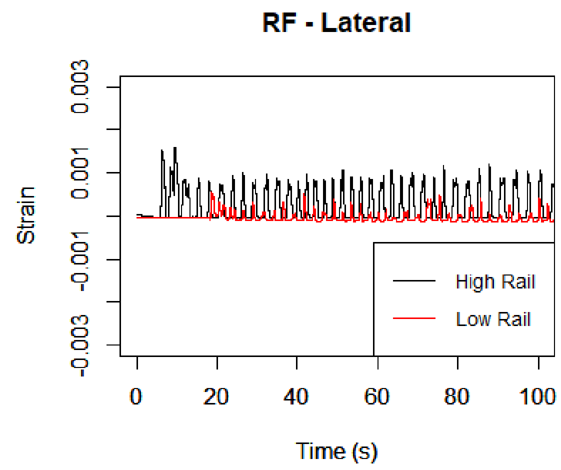

Figure 5. Bending strain on high rail versus low rail

Fewer Spikes on a Single Plate

One test parameter was to reduce the number of spikes on a single plate to determine if there was a change in the spike loading environment. The tie plate on the high rail of Main 1 was selected to perform the test. The spikes that had the highest bending strains were removed one by one until only one spike was left. The bending strain data of one train pass was collected after each spike removal. Figure 6 shows a comparison of the bending strains of a four-spike pattern versus a three-spike pattern (RG was removed, flat line in the plot) in the longitudinal direction.

The field side rail spike had an increase in bending strain from 0.0003 to over 0.002, a seven-time increase; the other two remaining spikes showed little change in bending strain.

This test aimed to investigate if the spike loading environment can be shifted among the spikes on a single plate. The removed spike can be considered as a spike that broke first on that plate. Thereafter, the forces that were taken by the broken spike may be transferred to other spikes on that plate and caused a bending strain higher than the yield point of spike material (>0.002).

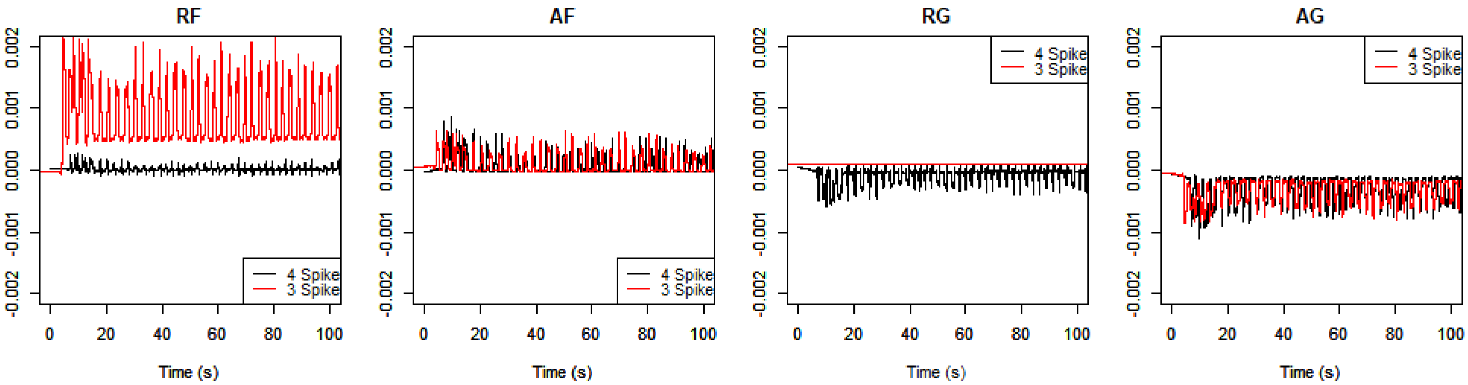

Figure 6. Comparison of spike loading environment after one spike removal on the tie plate on the high rail of Main 1

CONCLUSIONS

The following are findings from this field investigation:

- The bending strain shows that the loading environment on spikes exceeded the yield point of spike material (strain > 0.002).
- Spikes had more severe loading environment on high rail than on low rail.
- Removing spikes on the same plate could result in a loading environment change for the other spikes on that plate.

Acknowledgement

This research is funded collaboratively by the Federal Railroad Administration and the Association of American Railroads' Strategic Research Initiative on Improved Tie and Fastener System Performance.

References

1. Gao, Yin and M. McHenry. 2019. "Modeling and field investigation of spike breakage on elastic fastener tie plates." 2019 International Heavy Haul Association Conference. Narvik, Norway.
2. Gao, Yin, M. McHenry, and B. Kerchof. 2018. "Investigation of Broken Cut Spikes on Elastic Fastener Tie Plates Using an Integrated Simulation Method." Proceedings, 2018 ASME/IEEE Joint Railroad Conference. Pittsburgh, PA.

For comments or questions about this publication, contact Yin_Gao@aar.com