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FIELD INVESTIGATION OF BROKEN CUT SPIKES ON ELASTIC FASTENERS USING INSTRUMENTED SPIKES

SUMMARY

In 2019, the Federal Railroad Administration (FRA) and Transportation Technology Center, Inc. (TTCI) conducted field experiments to investigate the spike failure mechanism found on elastic fastener tie plates. These experiments took place at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO and at a revenue service site. The specific test locations were chosen from curves where broken spikes were common. To evaluate the real-time bending behavior of cut spikes, researchers developed and installed instrumented spikes in wood crossties (Figure 1). Rail force circuits measured the forces passing trains applied to the rails.

Figure 1. Instrumented spikes in a tie plate

Based on the test results, the following key observations were made:

- The bending strain caused by the train forces or by inserting or removing the spike from a tie could exceed the yield point of the steel. Exceeding the yield point permanently deformed the spike.
- The bending strains in spikes on the high rail were larger than those installed on the low rail.
- The bending strain for the spikes installed in new spike holes was higher than that of the spikes installed in existing spike holes.
- Spikes experienced the largest bending strains when a wheel load was directly over a tie plate. The spike loads were not evenly distributed among spikes in a plate, especially for the spikes on the high rails. In most cases, one or two spikes in a plate carried most of the applied load.

Future work will focus on in-track tests to evaluate how well potential solutions work.

BACKGROUND

Recent field inspections and observations (FRA, 2019) indicate that broken spikes (i.e., cut and drive/screw) result from the combination of elastic tie fastener plates and steep, high-degree curvature territories on North American Class I railroads. These broken spikes, in turn, contributed to recent derailments (Gao, et al., 2018; Kerchof, 2017). Spikes typically break within the spike hole, approximately 1 to 1.5 inches below the top surface of the tie, making it difficult to find the failures.

OBJECTIVES

In this project, researchers conducted field investigations designed to measure the loads applied to cut spikes on elastic fastener tie plates. The overall goal of the program is to determine the root cause of spike failures and recommend potential solutions.

METHODS

TTCI developed the instrumented spikes used in this study. All four surfaces of the spike shaft were instrumented with strain gages to measure the vertical, longitudinal, and lateral strains. Based on the varying thickness of a tie plate at different spike locations and the likelihood of spikes to break 1 to 1.5 inches below the tie surface, strain gages were placed at two distinct locations as shown in Figure 2 to differentiate between a rail spike and an anchor spike. The instrument calibration showed the strain gage layout successfully separated the lateral and longitudinal bending strains.

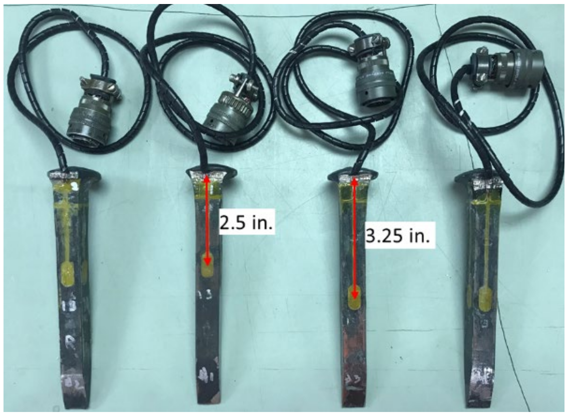

Figure 2. Instrumented locations of strain gages

The FAST and revenue service tests provided different test conditions for this research. The setup for each test was:

FAST

- 6-degree curve with 0.2 percent grade
- Single track; train runs both directions.
- Three consecutive ties were installed with instrumented spikes, both high and low rails. One tie was shifted to install new spikes.
- Three spikes per plate: all anchor spikes.

Revenue Service (Figure 3):

- 8.4-degree curve with 2 percent grade
- Main 1 and Main 3 were tested
- Trains descending the grade primarily used Main 1, which did not have rail anchors.
- Trains ascending the grade primarily used Main 3, which had rail anchors on the high rail.
- Due to limited track time, only one tie plate on the high rail of each track was tested with four instrumented spikes: two rail spikes and two anchor spikes.

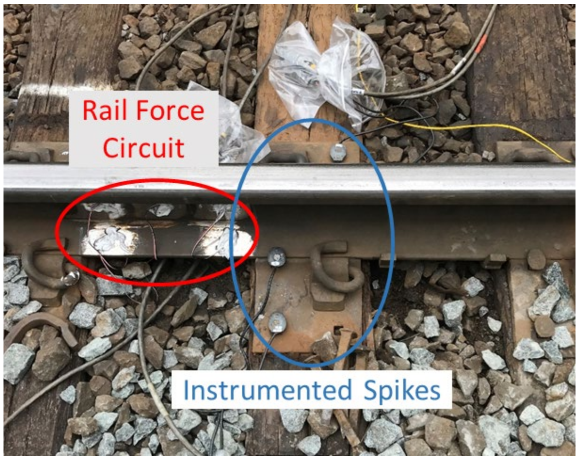

Figure 3. Instrumentation setup at the revenue service site

RESULTS

Researchers used the measured bending strains to quantify the loads applied to the spikes. Figure 4 shows an example of the bending strain data collected for the field-side rail spike on Main 1 track. For comparison, steel typically yields at a strain of 0.002. The fact the bending strain did not return to zero after the train passed indicated the spike deformed. Note that the spike deformed within the first few cycles, with a permanent strain of about 0.0005.

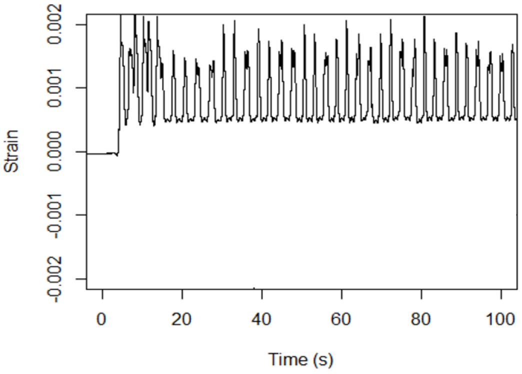

Figure 4. Example of bending strain in a spike, field side rail spike, Main 1 track, revenue service

The forces a spike experiences when inserted in or removed from a tie were evaluated during the FAST test. Spike were inserted with a sledgehammer and removed with a manual spike puller. The spike puller's pivot point was gradually raised using wood shims so the spikes pulled out vertically. The bending strain measured in the spikes during insertion in and removal from a tie was not as severe as that measured during a train passage. However, the residual strains after insertion were close to the highest values produced by the passing trains. The spikes retained the strains from by the insertion process after they were seated in the tie. Moreover, the strain on one spike exceeded its yield point during insertion.

Researchers also compared how the insertion conditions affected the resulting strains. One of the three ties in the FAST test was shifted so instrumented spikes could be driven into fresh wood. Instrumented spikes were also installed in the existing spike holes of this tie. The spikes driven in the fresh wood experienced higher bending strains than the spikes driven in the existing spike holes. This observation may explain why failures were most often found in new crossties (Kerchof, 2017).

The research team found the loads applied to each of the spikes in the same tie were not the same. Figure 5 shows the maximum lateral bending strain for all 6 spikes on the same tie after 10 train passes at FAST. The high-rail spikes (blue) carried a higher bending load than the low-rail spikes (black). In addition, the bending strains found in the high-rail spikes were not as evenly distributed as those in the low-rail spikes. The bending strain observed in one high-rail spike was substantially higher than that in the other two high-rail spikes. Other plates in the tests exhibited the same pattern of one or two spikes carrying a higher bending load.

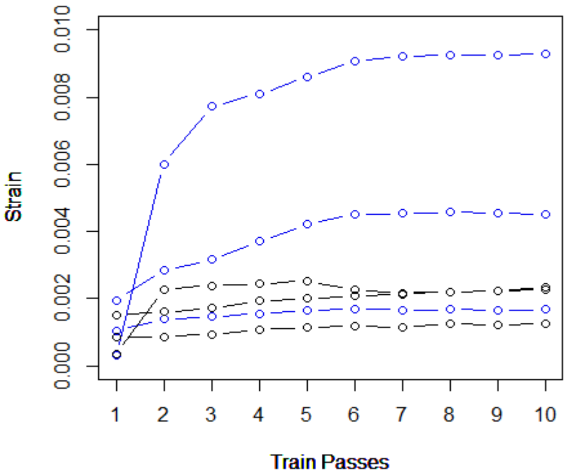

Figure 5. Maximum lateral bending strain for spikes on the same tie at FAST. High-rail spikes are shown in blue while low-rail spikes are shown in black.

The rail strain gage circuits measured the vertical, lateral, and longitudinal forces applied to the rails by passing trains. Figure 6 shows the spikes experienced the largest bending load when a wheel load was directly over that plate. The peaks in the spike bending strains were synced and aligned with the peaks of wheel loads. This indicates that vehicle body forces mainly caused the spike failures rather than train-induced track vibration.

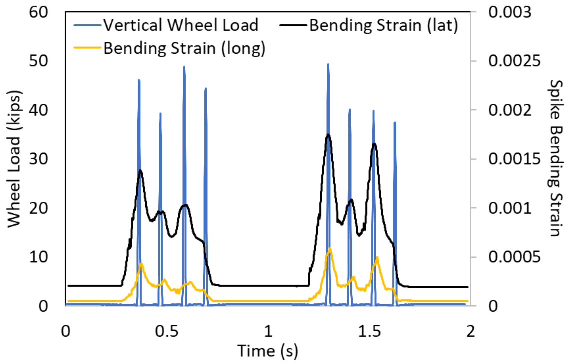

Figure 6. Wheel loads aligned with spike bending strains

CONCLUSIONS

Using instrumented spikes in these tests provided insight into the spike failure mechanism. The investigation proved the bending load in cut spikes used with elastic fastening systems could be high enough to cause permanent bending or even fatigue cracking in the spike material. This confirms the observations made during recent field inspections on a number of North American railroads (FRA, 2019).

FUTURE ACTION

Future work will focus on in-track testing of potential solutions for broken spikes. Potential solutions to be evaluated will include alternative rail fastening systems, improved fastener designs, and revised maintenance practices.

REFERENCES

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