U.S. Department of Transportation
Federal Railroad Administration

RESEARCH RESULTS
FRA OFFICE OF RESEARCH, DEVELOPMENT & TECHNOLOGY

RR 20-25 | **November** 2020

TIMBER CROSSTIE SPIKE FASTENER FAILURE INVESTIGATION: FIELD EVALUATION OF AN ALTERNATIVE FASTENER

SUMMARY

The Federal Railroad Administration has sponsored the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign's (Illinois) to conduct a comprehensive investigation into timber crosstie spike fastener failures on North American railroads. As a part of this project, researchers conducted a field evaluation of fastening systems and an accompanied modelling effort between September 2019 and June 2020. The field evaluation subjected control and alternative fastening systems to 170 million gross tons (MGT) of Heavy Axle Load (HAL) freight traffic at the Transportation Technology Center (TTC). The alternative system exhibited no component failures while the control system suffered multiple broken spikes. The results from this evaluation were compared with data from a finite element analysis (FEA) providing insight into the key fastener characteristic (i.e., tie-plate to crosstie clamping force) that likely lead to reduced spike stress and improved performance with the alternative fastening system.

BACKGROUND

RailTEC has been investigating the mechanics of broken spikes in timber crosstie elastic fastening systems under an FRA contract since April 2018 [3] [4]. Preliminary findings from the project were reported in greater detail in an FRA report published in May 2019 [1]. Key takeaways from this prior research included: 1) longitudinal loads are more detrimental to the spike health than an equivalent lateral load; 2) elastic fastening systems transfer additional longitudinal load through the spikes compared to anchored systems; 3) spike fatigue failures occur approximately 1.5 inches below the top of the crosstie; and 4) fatigue failures in track are difficult to detect without manual inspections.

RailTEC continued this research by leveraging field and laboratory experimentation as well as analytical modelling. Field experimentation was deployed on a Class I HAL railroad to quantify the loading environment (i.e., vertical, lateral, and longitudinal) and fastening system displacements under revenue service traffic at a location that has experienced broken spikes. Laboratory experimentation was developed to quantify the effect of key variables (e.g., fastener type, etc.) on spike stress and fastener stiffness. FEA was used to quantify the effectiveness of mitigation methods (e.g., increased spike cross-sectional area, clamping force between tie-plate and crosstie, etc.). Finally, a field evaluation of an alternative timber crosstie elastic fastening system was executed at the Facility for Accelerated Service Testing (FAST) at the TTC, which is the subject of this report.

OBJECTIVE

The primary objective of this field evaluation at the TTC was to compare the performance of a traditional and alternative elastic fastening systems under identical loading conditions.

METHODS

The evaluation of fastening systems at the TTC consisted of a control zone and a test zone in the same track segment. The track is curved (6-degress) with 5-inches of superelevation and a 40-mph operating speed. Designated as

Section 25, this track segment has a history of spike failures. The control zone fastener type is commonly found in North American heavy haul track and consisted of 20 crossties, e-clips, and cut spikes. The test zone consisted of an alternative fastening system with 30 crossties, tension clamps, and screw spikes with spring washers. The test setup included installing new ties at every third tie location. All other ties were in good, used condition. Table 1 provides select details of each fastening system, while Figure 1 shows the installed systems. Each spring washer is expected to apply between 4,000 and 7,000 lb. of preload.

Table 1. Select fastener characteristics

Zone	Spike Type	Spike Qty	Spring Washer	Tie-Plate Length *(in.)*	Toe Load *(lb./rail seat)*
Control	Cut	5	n/a	18	4,800
Test	Screw	4	1 / spike	14	4,800

Figure 1. Transition between control fastener (left) and alternative fastener (right) at TTC's FAST

Head and base gage were quantified at every third crosstie after 57 and 170 MGT. A lateral load of 9 kips was applied using a portable track loading frame (PTLF). Ten measurements were obtained in the test zone and 7 measurements in the control zone.

To compliment the field tests at FAST, FEA was used to evaluate methods to mitigate spike stress. One mitigation method considered was the use of spring washers. The FEA model consisted of a timber block, plate, and spikes and considered the spring washers as distributed forces at the area of the springs.

RESULTS

Experimental field results are summarized in Table 2.

Table 2. Overview of general inspection findings

	Control	Test
Plate Cutting	minimal	none
Broken Components	6 broken spikes	none
Loosened Components	spike uplift	3 (1.3%) spikes (at 60 MGT)
Plate Movement	some evident	none visible
Skewed Crossties	significant	two ties, minimal

The control zone experienced six broken spikes while the test zone experienced none. While the control zone showed evidence of plate movement and spike uplift—which can lead to additional transfer of load to the spikes—the test zone had no indication of plate movement.

Three spikes in the test zone loosened by less than 1/16th of an inch after 60 MGT. Loosening of 1/16th of an inch is still within the working range of the spring washer, and thus the pre-load was not lost. The spring washers hold the plate tightly to the tie, ensuring that some of the train forces (lateral and longitudinal) are carried by friction. Additional screw loosening was found after 170 MGT, though the exact amount of loosening and number of spikes was not quantified. This indicates the possible need for periodic screw maintenance with this fastener type.

The control section showed higher gage widening and variability compared to the test zone, shown in Figure 2 and Figure 3. The lower magnitude of head and base widening for the alternative fastening system indicates improved rail rotational restraint and a tighter system, respectively. Additionally, the reduced variability in the test zone indicates more uniform distribution of forces.

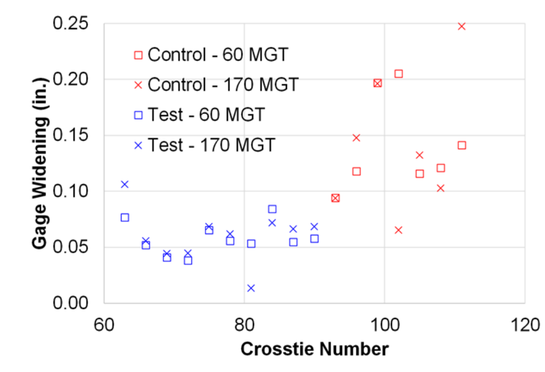

Figure 2. Rail head gauge widening at 9 kips of lateral load

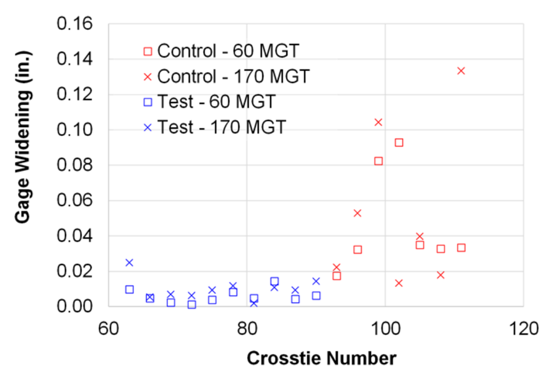

Figure 3. Rail base widening at 9 kips of lateral load

The finite element model, based on a validated model previously used for quantifying the effect of longitudinal and lateral loads on spike stress [5], consisted of a timber block, tie-plate, and four spikes. The FEA was run with spring washer preloads (i.e., normal clamping force) of 0 (control case), 1,000, and 3,400 lbs. per spike. A total longitudinal load of 2,500 lbs. was applied to the plate at the location of the tie-plate shoulders and Figure 4 shows the predicted spike stresses.

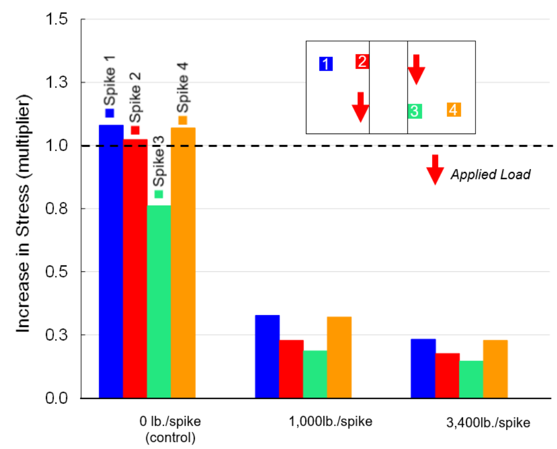

Figure 4. Effect of normal clamping force on maximum spike stress at 2,500 lb. longitudinal load

The analysis reveals that there is a 70 percent reduction in spike stress (on average) when spring washers apply 1,000 lb., and 80 percent with 3,400 lb. This reduction occurs because the applied load is transferred through friction as well as bearing on the spike. Developing friction at this interface aligns with design fundamentals for bolted shear joints and direct fixation fastening systems that are expected to transfer load through a combination of friction and bearing. Therefore, stress can be reduced substantially with relatively low levels of preloading. The analysis also indicates that the applied load is not uniformly transferred to the individual spikes. This is consistent with the observed field performance, and is likely due to the non-symmetrical spike placement relative to the applied load.

CONCLUSIONS

Field performance at FAST as well as results from the FEA indicated the alternative fastening system consisting of spring washers had improved the performance compared to the control system.

There were no failures within the test zone compared to six broken spikes within the control zone during the 170 MGT FAST test. Gauge widening demonstrated that the tension clamp-spring washer system provides lower magnitude and more consistent gauge widening (at both the rail head and base) than the control system.

The FEA analysis indicated that spring washers substantially reduced the magnitude of spike stress, likely due to the friction maintained between the tie plate and the crosstie.

FUTURE ACTION

There are additional plans to investigate methods to mitigate spike stresses and thus reduce spike failures in the lab and field. Additional results will be provided when the work is completed.

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ACKNOWLEDGEMENTS
The authors would like to thank Norfolk Southern, Vossloh Fastening Systems, Lewis Bolt & Nut, Transportation Technology Center, Inc., Burlington North Santa Fe Railway, CSX, Union Pacific, Progress Rail, and Pandrol for their partnership.

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KEYWORDS
Broken spikes, elastic fastening system, spiral washer, timber crossties, track

CONTRACT NUMBER
DTFR