U.S. Department of Transportation
Federal Railroad Administration

RESEARCH RESULTS
FRA OFFICE OF RESEARCH, DEVELOPMENT & TECHNOLOGY

RR 19-14 | **May** 2019

TIMBER CROSSTIE SPIKE FASTENER FAILURE INVESTIGATION

SUMMARY

University of Illinois' (UIUC) researchers completed an investigation of timber crosstie spike fastener failures on North American railroads between April and October 2018. This investigation, funded by the Federal Railroad Administration (FRA), included a review of derailment reports and literature, an industry survey, and an extensive program of field visits to determine the extent of spike failures in track and to characterize the track conditions where these failures occur. In addition, UIUC developed a preliminary finite element model (FEM) to help describe the spike failure modes. The investigation discovered that spike failures are prevalent under specific track conditions and they pose a significant risk to railroad operations.

Eight out of the nine railroads polled in the industry survey experienced broken spikes and many respondents were concerned about the rapid gage deterioration that can occur in broken spike clusters, as well as the inspection challenges associated with broken spikes.

During the field visits, researchers found many broken cut spikes and lag screws in track. These failures were almost exclusively in premium elastic fastening systems (Figure 1). Failures were most often found in new crossties installed in curves. UIUC found 121 broken spikes in the high rail in one curve (about 23 percent of the spikes in that section). One railroad reported finding up to 150 broken spikes in one curve.

The current practice for locating and fixing broken spikes is to walk curves tapping every single spike to check if it is broken. In some cases, Gage Restraint Measurement System (GRMS) testing points to locations of concern, but walking and tapping is still required to find and remediate failures.

Figure 1. Premium elastic fastener with five broken spikes

BACKGROUND

At least 10 mainline derailments were caused by wide gauge due to broken cut spikes or screw spikes since 2000. Several recent derailments have brought attention to the problem of broken spikes. Notable derailments include major oil train derailments in 2014 and 2016 and an Amtrak derailment in 2009.

Spikes typically break 1.5 inches beneath the top of the tie but continue to sit within the spike hole once broken, often making visual inspection impossible. Derailment reports showed that broken spikes can be present in track that meets relevant geometry standards.

Many spike failures occur in premium elastic fastening systems. Premium fastening systems use a clip to clamp the rail to the tie plate, and spikes or screws are used to hold the tie plate to the timber crosstie. These premium systems are popular because they offer increased resistance to rail rollover, improved gauge widening resistance, and typically do not require rail anchors to control longitudinal rail forces

METHODS

UIUC designed an industry survey to learn more about the magnitude of spike failure problems. The survey contained questions about the magnitude of the failures, where and when spike breakage occurs, and how railroads are currently locating and mitigating spike failures. Twenty-four responses were received from employees at 9 railroads: Amtrak, BNSF Railway (BNSF), Canadian National Railway (CN), CSX, Kansas City Southern Railway, Norfolk Southern Corporation (NS), Southern California Regional Rail Authority (SCRRA), Transportation Technology Center, Inc. (TTCI), and Union Pacific Railway (UP). Respondents were primarily track standards engineers or maintenance-of-way field managers.

Field visits were used to complement and further investigate the survey results. Researchers visited 10 different locations on 4 Class I railroads (BNSF, CSX, NS, and UP) as shown in Figure 2. These field visits involved inspecting track with a history of spike failures and interviewing field maintenance personnel and track standards engineers about their experience with spike failures. UIUC collected information about the grade, curvature, traffic characteristics, track conditions, fastening system characteristics, climate, maintenance practices, etc. to help identify trends and conditions that lead to failures.

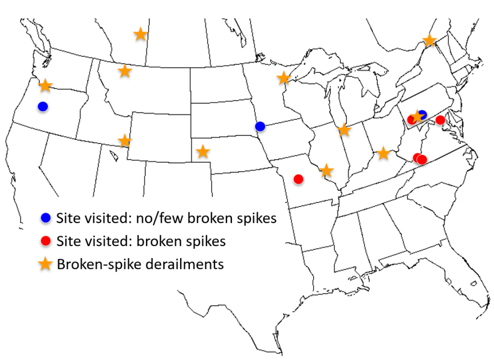

Figure 2. Field visit and derailment locations

RESULTS

A literature review found evidence of broken spikes as early as 1915, though the problem has become more pronounced with the recent adoption of premium fastening systems. Testing conducted at the Transportation Technology Center (TTC) between 1978–1979 found broken spikes to be a problem in premium fastening systems. Subsequent tests at the TTC have found similar problems with broken lag screws and spikes. Dick et al. (2007) studied spike stresses in screw spikes and found that stresses may be unevenly distributed among spikes in a plate. Gao et al. (2018) used a NUCARS® model and finite element analysis to investigate the effects of rail uplift and spike contact position on spike stress.

The literature review and derailment reports reveal that spike failures occur in multiple types of cut spikes and screw spikes (Figure 3), with various geometries, steel properties, and manufacturers. Spikes have broken in multiple different fastening systems on different railroads. This suggests that spike failure is a mechanism problem due to a certain stress condition, and not a material problem or a matter of manufacturing defects.

Figure 3. Broken lag screws in McKay fastening system

Eight of the nine railroads responding to the survey had experienced broken spike problems in some form. When asked if the problem was a relatively small, moderate, or large problem compared to other track-related challenges, opinions were divided equally among the severity levels.

Respondents expressed concern over the challenges of inspecting for broken spikes (walking curves, tapping every spike) and the rapid gage deterioration that can occur in broken spike clusters. One respondent said, “On several heavy tonnage, steep grade territories, broken spikes are the problem that represents the greatest risk to the safety of train operations.”

Field interviews shed light on the amount of time maintenance-of-way crews spend on locating and fixing broken spikes (Figure 4). Railroads rely on manual methods performed by experienced personnel to locate broken spikes before they lead to defective conditions. At present, there is no reliable, automated inspection method for identifying broken spikes.

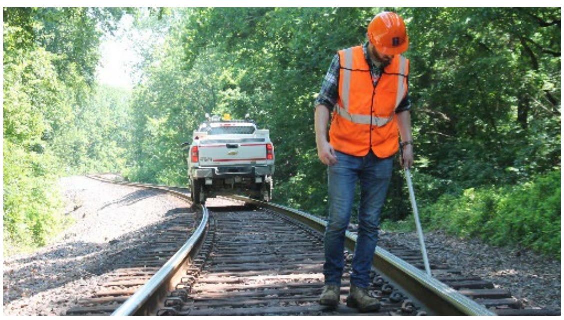

Figure 4. Spike inspection methods involve walking curves and tapping each spike

Researchers found locations with singular broken and other locations with clusters of broken spikes, including multiple ties with broken spikes. The most severe site had 121 broken spikes in length of 150 ties along the high rail.

Researchers developed a set of mechanistic hypotheses about the causes of spike breakage based on the results of the literature review, survey, and field visit data. As shown in Figure 5, in a traditional fastening system with cut spikes and anchors, spike stresses tend to increase with greater curvature (lateral forces), and in extreme cases this may cause spike breakage. It is theorized that premium fastening systems further increase spike stress because they do not use rail anchors to transfer longitudinal load into the ties. The longitudinal force is carried by the fasteners. Finally, premium fasteners are thought to be stiffer in both the lateral and longitudinal directions, further increasing spike stress by reducing the number of ties over which loads are distributed.

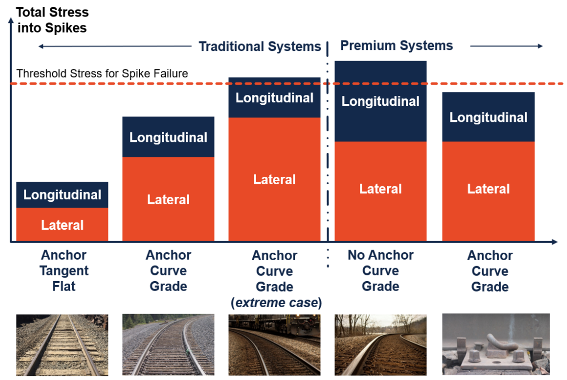

Figure 5. Hypothetical graph showing relation of spike stress to curvature, grade, and fastener type

A preliminary FEM was developed and used to investigate the effect of load direction and magnitude on spike stress. It was found that a longitudinal load was more detrimental to the spike health than an equivalent lateral load and the magnitude of load affected the location/depth of maximum stress.

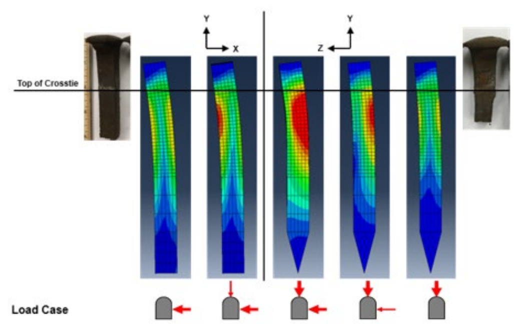

Figure 6. Preliminary qualitative FEM stress results with varying load cases.

CONCLUSIONS

The results of this investigation provide evidence that broken spike conditions are present in North American railroad track and may pose a risk to rail safety. Additional research is needed to determine the root cause(s) of spike failures and to develop solutions that will prevent future failures.

FUTURE ACTION

In a planned Phase 2 effort, UIUC researchers will test the hypotheses developed in this project through laboratory and field experimentation, and FEM methods to determine the mechanisms of force transfer in premium fasteners and the effects of fastener stiffness and spike stress. This next effort is expected to lead to improved fastener designs and/or installation and maintenance practices that prevent spike failures.

REFERENCES

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ACKNOWLEDGEMENTS

The authors would like to thank FRA for sponsoring this research, as well as NS, UP, BNSF, CSX, Pandrol, and CN for their industry partnership.

CONTACT

Cameron D. Stuart
Program Manager
Federal Railroad Administration
Office of Research, Development and Technology
1200 New Jersey Avenue, SE
Washington, DC 20590
(202) 493-6384
cameron.stuart@dot.gov

Tom Roadcap
Graduate Research Assistant
RailTEC at University of Illinois
Civil and Environmental Engineering
205 N. Mathews Ave., Rm B118
Urbana, IL 61801
roadcap2@illinois.edu

Marcus Dersch
Senior Research Engineer
RailTEC at University of Illinois
Civil and Environmental Engineering
205 N. Mathews Ave., Rm 1240
Urbana, IL 61801
mdersch2@illinois.edu

KEYWORDS

Broken spikes, lag screws, elastic fastening systems, wide gauge derailment