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SCREW SPIKE AND SPRING WASHER HOLD-DOWN FORCE AND RESILIENCEY INVESTIGATION

SUMMARY

The Rail Transportation Engineering Center (RailTEC) at the University of Illinois (Illinois) is investigating spike failures in timber tie track to determine the root cause(s) and develop failure prevention strategies. This research is part of an ongoing investigation into spike failures sponsored by the Federal Railroad Administration (FRA) that began in 2018.

Through modeling, laboratory, and field work, RailTEC has discovered that maintaining friction between tie plates and ties reduces the stress on spikes up to 80 percent (Dersch, 2022). Screw spikes installed with spring washers is one way to ensure that friction is maintained in the fastening system.

This report documents the laboratory testing of one, commercially available spring washer fastening system to quantify the spring washer's resiliency, hold-down force, and torque-to-displacement relationship. The results show that the washer has a limited working range (low resiliency), and the installation torque varies widely. Additional research into washer styles and materials is recommended to develop a more effective spring washer mitigation method for spike failures.

BACKGROUND

Broken spikes have led to at least 12 derailments on 4 railroads. Broken spike inspection is challenging because spikes fail approximately 1.5 inches below the top of crosstie (Roadcap et al., 2019) and require manual walking inspections to allow for tapping of each spike.

Figure 1. Broken spikes in elastic fastening system

Broken spikes are found on both sides of the tie plate, in all spiking locations, and are often found on the high rail of high degree curves with grade. The problem is most pronounced in elastic fastening systems (Figure 1), particularly when not supplemented with rail anchors (Khachaturian, Dersch, Edwards, & Trizotto, 2022).

The spikes are failing in fatigue, from increased longitudinal load transfer (Roadcap, Kerchof, Dersch, Trizotto, & Edwards, 2019). The wave action of the rail, ahead of a loaded axle, causes plate uplift which reduces tie plate-to-tie friction and increases the load on the spikes (Dersch et al., 2021).

Railroads have pursued various mitigation methods including installing anchors in elastic fastening systems, increasing spike steel strength, and installing plate cleats. These efforts have at best, only delayed spike failures.

Through modeling and laboratory research, RailTEC have discovered that maintaining a 1,000 lb. hold-down force (i.e., to ensure friction between the tie plate and tie) results in a 70 percent reduction in spike stress. This force can be obtained by installing screw spikes with spring washers. A field test of this system at the U.S. Department of Transportation's Transportation Technology Center (TTC) revealed improved performance compared to a system without spring washers. There were no failures in the test zone with spring washers compared to six broken spikes in the control zone during the 170 MGT test.

European and Brazilian railroads have successfully installed the double-helix fe-6 spring washer that RailTEC deployed for the TTC field test. In the 1990s, one North American heavy axle load (HAL) railroad encountered broken spikes after installing these spring washers. An inspection of the curve revealed that the springs were loose and rattled when trains passed.

OBJECTIVES

This research had three primary objectives:

1. Evaluate the working range and resiliency of the washer after fully installed to simulate plate cutting or spike loosening
2. Quantify the spring washer hold-down force when installed as recommended by the manufacturer
3. Investigate the relationship between torque and hold-down force throughout the installation process to assess a torque-based installation procedure

METHODS

RailTEC completed laboratory experiments quantifying the spring washer's applied hold-down force and permanent deformation when subjected to torque loads. RailTEC also quantified the relationship between installation torque and the resulting hold-down force.

RailTEC installed a single screw spike in a crosstie block using a torque wrench (Figure 2). At specified torque intervals the hold-down force and spring washer gap were recorded using an instrumented washer and digital calipers.

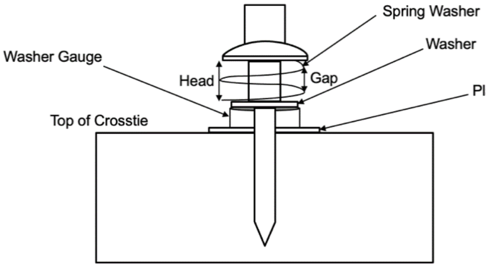

Figure 2. Screw spike and spring washer test arrangement with instrumented washer gauge

Crosstie timber properties are non-homogeneous and vary with timber species and crosstie age (Hailing & Liu, 2020). RailTEC used five timber crosstie blocks taken from new and old crossties. The samples were assumed to be various species of hardwoods, but the exact type was not recorded. RailTEC prepared each tie block by drilling four, 5/8-inch diameter pilot holes, thus providing four testing replicates for each block, 20 total tests.

RailTEC recorded the hold-down force and spring washer gap at 50 ft-lb torque intervals during the following test procedure:

1. Record spring washer gap with no load applied
2. Tighten screw spike until the hold-down force measured 5 kips
3. Loosen screw spike until hold-down force measures 1 kip
4. Tighten screw spike until spring washer gap measures 0.08 inches (manufacturer-recommended installation gap)
5. Loosen screw spike until hold-down force measures 1 kip

RESULTS

For this research, resiliency is defined as the working range where the spring maintains at least 1 kip of hold-down force.

The spring washer plastically deformed when compressed to its recommended gap (i.e., Step 4, above). This deformation is visually evident (Figure 3) and captured in the force-deflection curve (Figure 4).

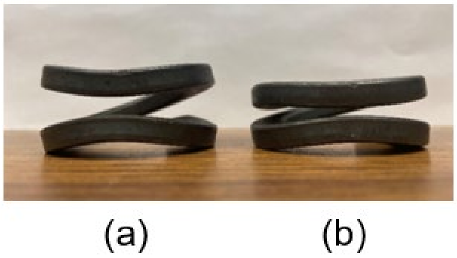

Figure 3. (a) Spring washer after 5-kip load and (b) Spring washer after loading to 0.08-inch gap

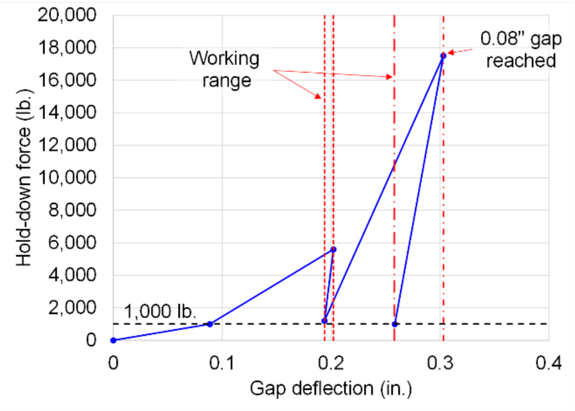

Figure 4. Representative example of hold-down force vs. spring washer gap deflection data

The resiliency of the spring washer was low. At the 5-kip hold down force the working range was approximately 0.05 inches. At full installation (0.08-inch spring gap) the working range is approximately 0.05 inches (Figure 4). A small amount of plate cutting, or a slight loosening of the screw could result in a complete loss of hold down force.

Torque and hold-down force results from the 20 tests show considerable variation in maximum hold-down force and torque at the manufacturer-recommended spring washer gap (0.08 inches) (Figure 5). At the 0.08-inch gap installation, the hold-down forces and torques varied from 8–19 kips and the corresponding torque values 375–475 ft-lb. The lowest hold-down force value of 8 kips was from a tie that split during the test.

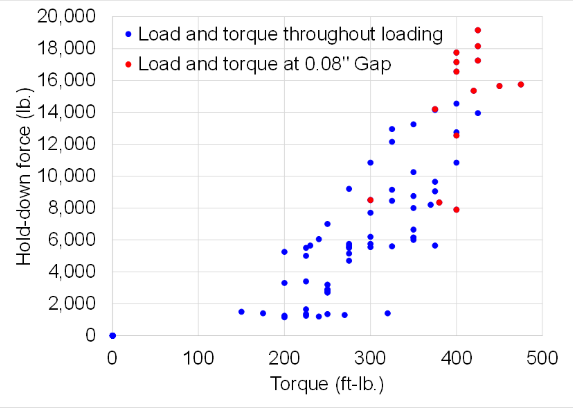

Figure 5. Hold-down force vs. applied torque (20 tests total)

CONCLUSIONS

This research investigated the performance of a screw spike with a spring washer system to provide a positive hold down force for maintaining friction between tie plates and ties. The results of the research are mixed. The data shows that the system provides sufficient force (in excess of 8 kips) to secure the plate to the tie and maintain tie to tie-plate friction but has insufficient resiliency resulting in a very small working range of approximately 0.05 inches. Installing the spring washer to a lower level provided an even smaller working range of 0.03 inches. Finally, the system exhibited considerable variation in maximum hold-down force and torque, thus reducing the feasibility of providing a torque-based installation procedure.

FUTURE ACTION

Future research is needed to identify, or develop, a method to maintain sufficient tie plate to tie friction to reduce spike loads. Such a system must have sufficient resiliency to accommodate normal wear of components, e.g., plate cutting and tie thread wear.

A spring solution should provide a hold-down force of at least 1,000 lb. and working range that would be suitable for the environment. Installation procedures must accommodate automated installation and prevent excessive hold-down force, ensuring that pressures at the spike threads do not exceed the timber compressive strength.

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CONTACT

Cameron 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

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

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