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TRACK CIRCUIT SHUNTING PERFORMANCE STUDY

SUMMARY

Transportation Technology Center, Inc. (TTCI) conducted a series of experiments between April 2012 and January 2014 to determine train characteristics and track conditions that affect shunting performance at two revenue service test locations.

Track circuit performance degradation is a rare problem with potentially significant safety consequences for track circuit-based train detection devices. It can occur when a train or any rail vehicle cannot shunt an open electrical circuit in the track. It affects grade crossing warning devices, the detection of the trains by the signaling systems, and in some cases the detection of discontinuities in rail. Reasons for track circuit performance degradation include [1]:

- Rail corrosion and contaminants
- Wheel-rail contact
- Track circuit design and maintenance issues

Optimization of track circuits for train detection is an ongoing effort by the railways and signal equipment suppliers. Most track circuits can be made more effective by having clean ballast and good track drainage. Whetting currents increase the sensitivity of track circuits to shunting and are used effectively at many locations. Use of signal averaging on island circuits has also improved shunt reliability.

BACKGROUND

Track circuit performance degradation is a temporary loss of electrical continuity between the rails and the wheels of a train that affects grade crossing warning devices, signaling and train detection, and in some cases rail discontinuity detection. It has been investigated over many years and is very rare [2]; therefore, documentation on track shunt performance is sparse. Previous studies have found that track circuit performance degradation occurs because of issues at the wheel and rail contact patch. There seems to be a film on the wheel, rail, or possibly both. Because railroad signal systems and grade crossing systems use shunt track circuits to detect trains, track circuit performance degradation is a safety and reliability issue for train operations.

OBJECTIVES

- Document track circuit performance degradation mechanisms.
- Determine the factors that affect shunting performance.
- Identify methods to prevent or mitigate shunt failures.

METHODS

The project employed both top-down and bottom-up analysis of track circuit performance degradation. The top-down analysis reviewed signal activation failure reports to determine any patterns in the shunt failure records. A survey of signal engineers gathered insights on shunt problems. Researchers also gathered best practices in this survey and report.

The bottom-up analysis used revenue service field testing to measure shunt performance at sites of potential concern. TTCI collected the shunt performance of over 10,000 trains in summary form at two sites during this project. The company used the data to evaluate the effects of train characteristics, weather, and track maintenance on shunt performance.

RESULTS

For the 2000–2012 analysis period, track circuit performance degradation events were analyzed to determine the frequency of multiple events at each crossing. This determined if these events were occurring at a few crossings or were more widespread. The 538 documented failures over this 12 year period occurred at 507 different crossings. Figure 1 shows that there were only 21 crossings with 2 failures and 5 with 3 failures. Several of the multifailure crossings had failures occur on the same day (suggesting multiple reports of a single event) or within a few days (suggesting that more than one adjustment was needed to the crossing). No crossing had more than three reported failures during this 12-year period. These results are encouraging in that they suggest railways can permanently fix track circuit performance degradation once it occurs.

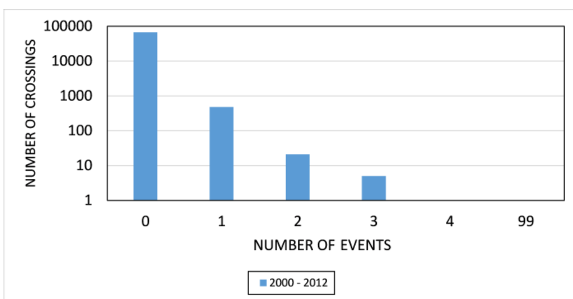

Figure 1. Number of Crossings with Track Circuit Performance Degradation Events

A frequent cause of track circuit performance degradation is the development over time of an electrically resistive film on the rail and wheel surfaces. Some of the contaminants in this film may be intentionally placed on the rail, while others are unintentional. These include, but are not limited to:

- Lubricants and friction modifiers on the wheel and rail
- Brake shoe materials
- Lading, such as grain
- Track materials
- Windblown materials, such as leaves and plants

The effective prevention/removal of the surface film is one of the keys to preventing track circuit performance degradation. Lubricants and friction modifiers, two sources of that film, are used to modify the friction properties of the wheel and rail. These materials do not affect electrical resistance when first applied, but they do remain wet for some time, which allows other materials to attach to the wheel or rail. Figure 2 shows the composition of these films from revenue service components. Wheels tend to have more silicon and rails more iron oxide, carbon, and trace materials.

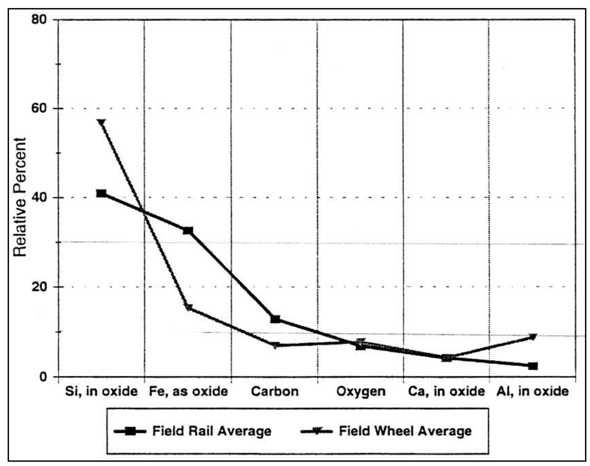

Figure 2. Average Wheel and Rail Film Composition

Additional analysis of shunt failures by timetable speed for the location where the events occurred showed that track circuit performance degradation was not merely a low-speed, branch line problem. Due to the mix of passenger and freight train operations, the data was reported in decades of maximum track speed rather than FRA track class. Figure 3 shows the number of failures in 10-mph increments. The plot also shows cumulative shunt failures versus track speed limit. Note that the largest number of failures occurred on 71 mph to 80 mph track. Also note that more than half of the total failures occurred on track with maximum speed above 40 mph.

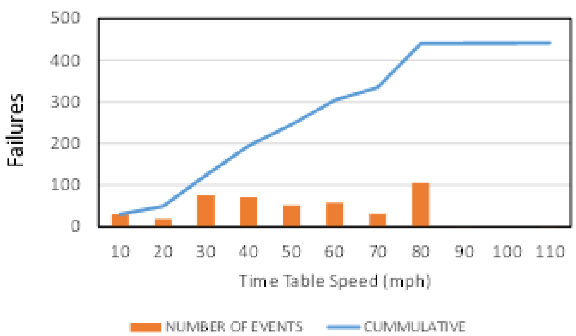

Figure 3. Failures vs. Maximum Track Speed

The data suggested that track circuit performance degradation events were not confined to the low-volume, low-speed branch lines. It was also likely that different failure modes may have been dominant at different speeds so that such events on low-speed track may have been different than those on higher-speed track. Also missing from the analysis was the exposure rate (from track mileage at each speed category). Thus, researchers could not determine if certain track speeds or traffic types were more likely than others to experience track circuit performance degradation.

CONCLUSIONS

Signal engineers from Association of American Railroads member railroads were surveyed to find the extent of and field remedies for shunt issues. Results of the survey confirmed previous findings that shunt is an intermittent problem on some line segments. Factors which contribute to track circuit performance degradation include:

- Low wheel loads
- Rail corrosion on lightly used lines
- Rail contamination (e.g., leaves, car lading, emissions from industry)
- Weather
- Ballast—fouled ballast causing mud deposition on rail.
- Light car braking at high speeds—one railway reported track circuit performance degradation under these conditions.

Best practices include the use of conventional track circuits and some nonconventional equipment for specific situations. Conventional equipment can be optimized with simple changes to the equipment and signal processing. For example, a whetting current can be applied to the circuit so that voltage is increased when a train enters the circuit. The increased electrical potential makes the circuit more sensitive to shunting. In a similar vein, signal averaging can be used to improve the reliability of shunting. Once a shunt is detected, a longer time average of the relay voltage can be used to detect train presence. The longer average will keep intermittent drop-outs from causing the relay to reactivate. This will provide increased reliability at the expense of a small increase in release time once the train exits the circuit.

Unconventional equipment includes many alternatives and supplements to conventional track circuits. Wheel counters, magnetic train presence detection, radar, and machine vision have been tried with some success in very limited applications.

An unexpected conclusion from this study was that spilled product on the top surface of the rail was the leading cause of track circuit performance degradation, exceeding those caused in whole or part by rusty rail. This finding was supported by the relatively high number of shunt failures on high-usage track (i.e., track with more than 20 trains per day and speeds greater than 60 mph).

Besides separating the rail and wheel with a resistive film, spilled lading can contaminate the ballast. Conductive lading can alter the impedance of the ballast, causing frequent adjustments of the track circuits to maintain sensitivity to trains.

FUTURE ACTION

Additional efforts to address the root causes of track circuit performance degradation are needed as well as development and test of devices to improve shunting. The specific need is to keep the resistive films off wheel and rail contact surfaces. This can be done by preventing the formation of the film and by removing it at a sufficiently high rate to allow shunting. Further, the development of devices that provide an alternative path for shunting and processing updates to signal and grade crossing systems will mitigate the risks in instances where it is not possible to fully address the wheel/rail contaminants.

REFERENCES

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