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Survey and Analysis of Winter Rail Breaks on a U.S. Railroad

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Summary

Transportation Technology Center, Inc. (TTCI) conducted a survey on a major U.S. railroad during the winter of 2016–2017 to examine whether there is a correlation between rail fractures from head defects in parent rail material and the incidence of high impact wheels (HIW). Within the HIW load levels observed during the survey, and in particular for HIW loads less than 100 kips, no obvious relationship was found between HIW and the incidence of rail breaks.

The current condemnable HIW removal level is 90 kips. This survey suggests that any downward revision of this level, for example, to 80 kips, is unlikely to reduce the incidence of service failures.

This survey also indicates that on the railroad surveyed:

- Weld breaks remain the highest source of service failures.
- Although the highest incidence of service breaks in parent rail is associated with head defects, relatively few of these failures are from “traditional” transverse defects (TD). Most are associated with detail fractures (DF). It would appear from the DFs examined that the source of the DF was often in the form of subsurface shelling. Surface rolling contact fatigue (RCF) damage was often present that could obscure ultrasonic detection of the subsurface defects.

This survey was conducted under the Strategic Research Initiatives (SRI) Program of the Association of American Railroads (AAR).

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INTRODUCTION

TTCI has concluded, under an associated SRI investigation,[1] that there is no relationship between rail fractures from head defects in parent rail material (as opposed to welds) and the incidence of HIW. In order to substantiate this conclusion, TTCI conducted a survey and analysis of a limited number of rail breaks occurring on a major U.S. railroad during the winter of 2016–2017. This *Technology Digest* (TD) reports on the methodology used and the results of the survey.

This survey was conducted under the Strategic Research Initiatives (SRI) Program of the Association of American Railroads (AAR).

METHODOLOGY

The participating railroad identified 15 routes contiguous with 16 wheel impact load detector (WILD) sites. Rail breaks occurring on these routes were compared against the highest HIW level occurring on the train traversing the break immediately prior to the rail-break occurrence, on the leg of the rail (left or right) on which the break occurred.

The date and time of the break was recorded together with the train identification number and lead locomotive number of the train traversing the break immediately prior to the break. The ambient temperature at the weather station closest to the site at the time of the break was recorded. Photographs were taken of the break to:

- Identify if the break was at a weld or in parent material, as displayed in Figure 1. The focus of the survey was on breaks in parent material and not those in welds.

(a) Weld Break (b) Break in Parent Material

Figure 1. Photographs discriminate between a break in a weld and one in the parent material of the rail

- Identify the location and origin of the break in the parent rail material; example:
  - In the head, web, or base.
  - TD, reverse TD, DF, or breaks from base defects.
  - At a bolt hole or associated with fretting contact with the tie plate.
- Identify contributing factors, for example, the presence of RCF on the running surface.
- Estimate the critical crack size at fracture.

Figures 2 through 6 show photographs of rail breaks illustrating, together with Figure 1, that they are generally sufficiently detailed to support the proposed process.

Figure 2. Example of a TD

Figure 3. Example of a DF

Figure 4. Example of a reverse TD

Figure 5. Example of fracture from a base defect

Figure 6. Example of fracture from a bolt hole

All breaks were classified and associated with relevant HIW and thermal data.

FINDINGS

Data associated with 109 rail breaks occurring during the winter of 2016–2017 was processed by TTCI.

Of all breaks received and processed:

- 61 percent occurred at or immediately adjacent to a weld.
- 38 percent occurred in parent material.
- 1 percent were not able to be determined.

Of the breaks in *parent material*:

- 37 percent developed from TDs or DFs of which:
  - Only 8 percent of fractures developed from what may be termed "traditional" TDs (Figure 2).
  - 29 percent developed from DFs or TDs that branched from shells; these failures appeared possibly to be "masked" from ultrasonic detection by RCF damage (Figure 3).
- 18 percent developed from reverse TDs.
- 32 percent developed from base defects:
  - 11 percent from defects on the underside of the base.
  - 21 percent from defects on the toe of the base.
- 13 percent were defined as "other" with the majority developed from bolt holes.

Estimates were made from the photographs of the critical crack size prior to fracture with the following general conclusions. The critical size of cracks in the railhead averaged approximately 50 percent of head area. The minimum size was approximately 20 percent of the head and maximum size was greater than 100 percent of the head area, where the crack ran into the web of the rail. These sizes are generally larger than those determined using the fracture mechanics program *RailGrow* and described in Reference 1, using the following major input parameters:

- A thermal overload condition of 100°F below the neutral rail laying temperature.
- A 120-kip HIW load.
- A fracture toughness of 35 ksi-in$^{1/2}$.

Service temperatures associated with the service failures were as low as 0°F with HIW loads approximately 90-kip. Single maximums of 120 kips and 127 kips, respectively, were recorded.

Figure 7 shows the relationship between the estimated critical crack size in the railhead, as a percent of the unworn head area, and the highest measured wheel load at the WILD site immediately after fracture. There is no clear indication that HIW loads cause premature failure in the railhead by causing fracture at reduced critical crack sizes, particularly for HIW loads less than 100 kips.

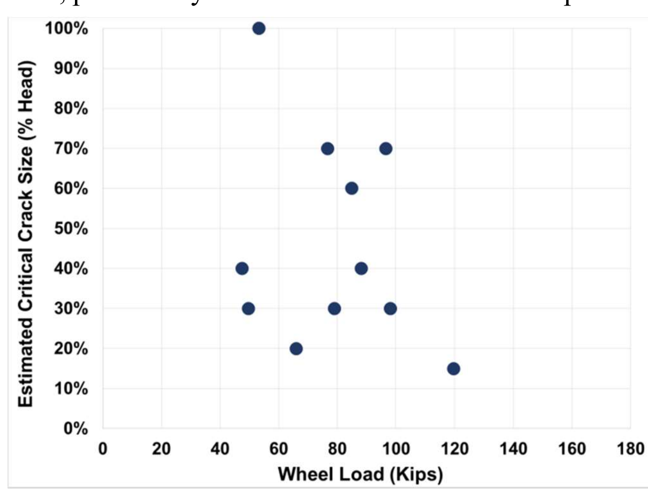

Figure 7. Relationship between the critical crack size in the railhead and the highest measured wheel load at the WILD site immediately after fracture

Base and toe defects recorded in the survey were generally significantly smaller than those recorded for the head, averaging approximately 1/2 inch (the major dimension of the critical crack size) with a minimum major dimension of approximately 1/8 inch and a maximum major dimension of approximately 3/4 inch. These fractures occurred under recorded ambient temperatures as low as 0°F and HIW loads of approximately 90 kips. One base defect, related to corrosion on the underside of the base, was associated with a HIW load of 174 kips. This latter HIW load was by far the highest linked to failure from a base defect. The next highest HIW load was 120 kips.

Figure 8 shows the relationship between the estimated major dimension of the critical crack and the highest measured wheel load at the WILD site immediately after fracture. Again, there is no clear indication that HIW loads cause premature failure in the railhead by causing fracture at reduced critical crack sizes, particularly for HIW loads less than 100 kips.

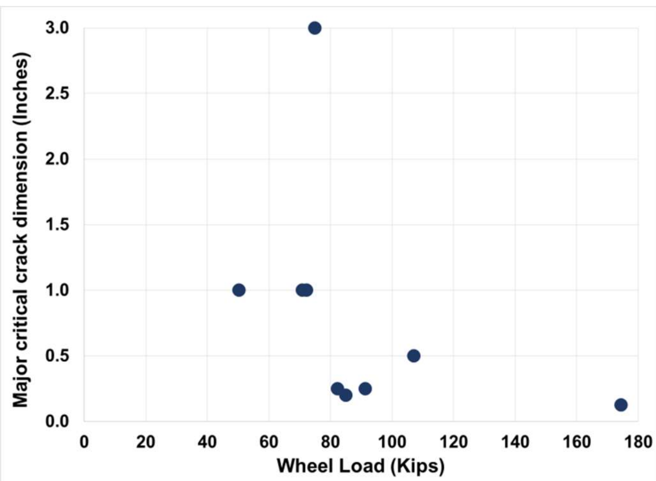

Figure 8. The relationship between the major dimension of the critical crack in the rail base and the highest measured wheel load at the WILD site immediately after fracture

CONCLUSIONS

No obvious relationship has been found between HIW and the incidence of rail breaks on the railroad surveyed and within the HIW load levels observed during the survey conducted, and particularly for HIW loads less than 100 kips.

The current condemnable HIW removal level is 90 kips. This survey suggests that any downward revision of this level to, for example, 80 kips, is unlikely to reduce the incidence of service failures.

This survey also indicates that on the railroad surveyed:

- Weld breaks remain the highest source of service failures.
- Although the highest incidence of service breaks in parent rail is associated with head defects, relatively few of these failures are from "traditional" TDs. Most are associated with DFs. It would appear from the DFs examined that the source of the DF was often at sub-surface shelling, and that surface RCF damage was present that would likely obscure ultrasonic detection.

References

1. Tournay, H. et al. December 2016. "The Effect of High Impact Wheels on Rail Failure: Supporting Theory: Role of Head Defects under Indirect Loading." *Research Report* LA-045, Transportation Technology Center, Inc., Pueblo, CO.