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WILD Trending for Broken Wheel Detection

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Summary

Transportation Technology Center, Inc. (TTCI) examined the use of Wheel Impact Load Detector (WILD) trending to identify high impact wheels with an increased risk of breaking. The dynamic difference method is significant for potentially identifying broken wheels from the population of high impact wheels. This investigation was made using multiple WILD passes to trend the wheels for risk of breaking. The study segregated 263,000- and 286,000-pound gross weight freight cars. The analysis used risk assessment, a method of quantifying the risk of an event — a broken rim in this case — compared to representative population of freight cars in revenue service.

TTCI examined two trending methods: 1) WILD prompt jump supported by BNSF; and 2) WILD dynamic differences supported by Union Pacific Railroad (UP). Results of the risk assessments indicate that trending of WILD passes is a more effective means of identifying wheels for removal than the existing criteria of identifying a single maximum peak value. In this case, a screening criteria based on WILD trending could help identify wheels that are at risk of failing. Results of the analysis are summarized here:

- Prompt jump criteria filtering at 90 peak kips and above would identify about nine broken wheels and 6,237 other +90-kip wheels annually.
  - Lowering the filtering criteria to 75 peak kips from 90 peak kips would not be effective. It identifies less than one additional broken wheel per year while doubling the number of wheels removed from the representative population.
  - All of the 6,237 wheels identified exceed 90 kips.
- Dynamic difference criteria would identify about 12 broken wheels from the 4,802 other wheels in the representative population annually.
  - Most of the 4,802 wheels in the representative population exceed 90 peak kips.
- Eight broken wheels (three in 2015 and five in 2016) overlap between the two methodologies, and all eight exceed 90 peak kips.

Most of the wheelsets identified with the dynamic difference and all with prompt jump exceed 90 peak kips. As an additional screening criteria, these techniques can be used to identify which wheels are at higher risk of breaking when it is not practical to remove all 90-kip or greater wheels.

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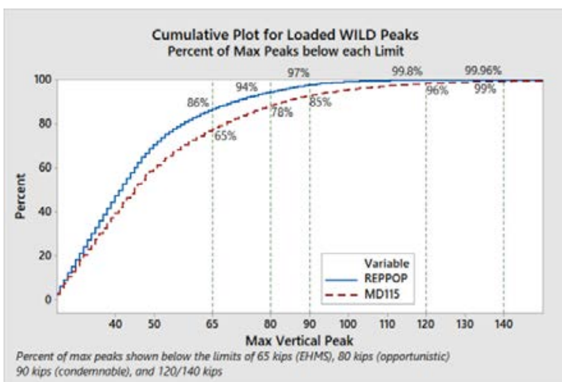
INTRODUCTION

Wheel impact load detectors (WILD) are wayside detectors that use a series of strain gages installed onto the rail web that measure vertical load forces of passing wheels.[1] The strain gages measure the highest, or peak, vertical forces and report the measurement in thousands of pounds of force (abbreviated as kips). For a wheel in good condition, the peak force is near the wheel weight. Peak forces are elevated when wheels are worn, damaged, or out of round. For some wheels, an elevated peak force may be due to a crack or break. Broken wheels can be detected by one of several developing wayside technologies for the detection of cracked wheels.[2,3,4] Unbroken high impact wheels may be screened for risk of breaking by the methods outlined here.

WILD Max Peak Effectiveness

WILD peak forces have been correlated to some broken wheels. In Figure 1, the max peak of each wheel from the MD-115 AAR Failed Wheel Report[5] is compared to the representative population of wheelsets in service. Data is from the period of January 2014 and June 2017.



*REPPOP=Representative Population

Figure 1. Percent of Wheels below a Max Peak from January 2014 to June 2017

The majority of all wheels have a maximum peak below 65 kips. Thirty-five percent of broken wheels (red line) and fourteen percent of the representative population (blue line) have maximum peak of greater than 65 kips. Given the large percentage of condemnable wheels in each sample, it is not useful as a single parameter to predict a future cracked wheel. The change in peak value may be a better indicator of cracked wheels than a single maximum peak reading.

WILD trending is a composite of many WILD passes to identify patterns in the progression of the peak values. The following trending methodologies are analyzed to identify their ability to maximize the number of broken wheels identified while minimizing removals in the representative population.

WILD Trending Methodology

Two WILD trending methods are examined for 263,000- and 286,000-pound gross weight freight car traffic.

- Prompt jump, based on work by BNSF, analyzes the current and prior three detector passes.
- Dynamic difference, based on work by UP, analyzes the most recent 5 of 10 detector passes.

Prompt Jump

Prompt jump is a sudden elevation of the current WILD pass compared to the prior three detector passes. The four most recent detector passes are used to determine the trend in dynamic vertical forces. The dynamic vertical force equals the peak vertical force minus the wheel weight. Figure 2 shows a wheel with low dynamic forces which then progresses to increase in the last two detector passes before breaking.

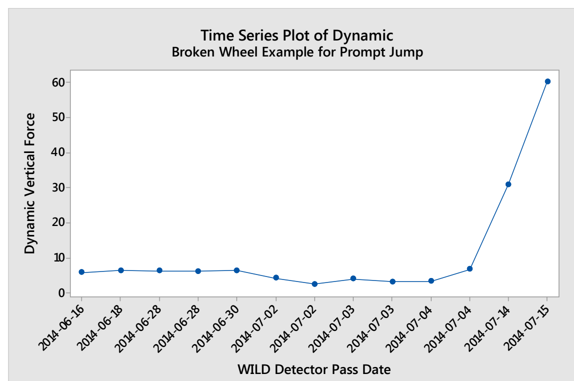


Figure 2. Broken Wheel with Increase of Dynamic Forces

Prompt jump measures the most recent dynamic vertical force minus the highest dynamic of the prior three passes. Alerts are generated based on a sudden increase in dynamic load and the length of time that the wheel has been experiencing elevated impacts. Peak kip-days is a measure of how long a wheel has been in service as a 65-kip or higher wheel. The higher the peak kip-day value of wheel, the longer it has been in service above a 65-kip load. The reasoning is that wheels that have remained in service for an extended time with elevated kip loads are likely to be structurally sound.

As shown in Table 1, a wheel can alert from the criteria of any of the three rows. For example, a wheel that has recently degraded (peak kip days less than 500) needs only a low current dynamic of 25 to generate an alert. Another wheel may have a history of higher WILD readings with kip-days less than 10,000, but now requires a higher dynamic increase of 37 or more kips to generate an alert. For prompt jump, the alert criteria are the same for both axle loads studied.

Table 1. Three Alert Criteria for Prompt Jump

Alert Criteria for Cars with a Maximum Weight of 263,000 or 286,000 Pounds	
Current dynamic minus highest prior dynamic:	**Peak kip-days must be less than:**
>25	≤500
>37	≤10,000
>45	No Limit

Dynamic Difference

The dynamic difference method looks at differences in impact load between two wheels on the same axle. Normally, both wheels on an axle wear about the same. The dynamic difference identifies those instances when one wheel is much worse than its mate. Dynamic difference is the difference in the dynamic vertical forces between both wheels of a wheelset as measured over six consecutive detector passes (from the fifth to the tenth pass). The regression slope is used to generate an alert. If the regression slope exceeds the threshold for that level, an alert is generated. Figure 3 illustrates an example of dynamic difference trending for a broken wheel.

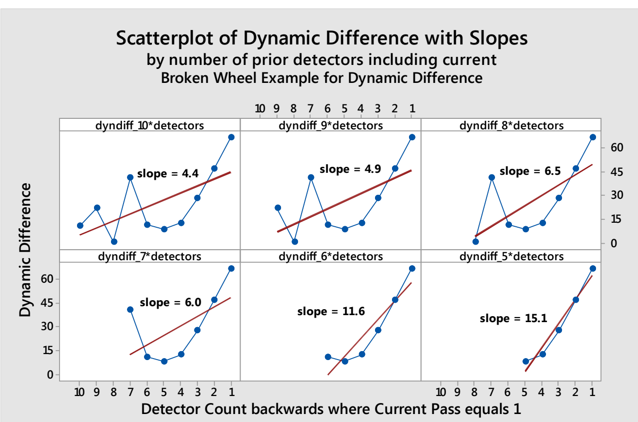


Figure 3. Broken Wheel with Slopes for 5 of 10 Passes

The last 5 (bottom right) to 10 (top left) cumulative detector passes are shown. The dynamic difference values are shown in blue. The calculated regression slopes for each graph are shown in red. The calculated slopes are tested against the alert criteria in Table 2. If any one of the slopes exceeds the limit for that detector count then an alert is generated.

Table 2. Dynamic Difference Alert Criteria

Last N Detectors in Calculated Slope	263,000-lb. Maximum Car Weight	286,000-lb. Maximum Car Weight
5	11 or higher slope	
6	9 or higher slope	
7	7 or higher slope	
8	6 or higher slope	
9	5 or higher slope	
10	5+ slope	4+ slope

WILD Trending Results

The alert criteria for prompt jump is further filtered by the maximum peak of the wheel. Table 3 shows annualized removal rates based on four years of broken wheel and representative population data.

Table 3. Prompt Jump Alert Rates (Annualized)

Max Peak	Broken Rims	Additional 90 kip Wheels Identified
>=65	11	19,312
>=70	11	16,447
>=75	9	12,328
>=80	9	9,557
>=85	9	7,617
>=90	9	6,237
>=100	7	4,093
>=110	6	2,427
>=120	5	1,315
>=130	3	675
>=140	3	350

Prompt jumps with a maximum peak of 90 or more kips would alert nine broken wheels annually on average, and identify another 6,237 wheels with a maximum peak of 90 kips. A lower maximum peak criteria such as 75 kips would alert, on average, no more broken wheels, but also alert an additional 6,091 wheels from the representative population.

Even though the prompt jump alert would identify over 6,000 additional wheels as candidates for removal, all of the wheels are already condemnable under current rules.

Dynamic difference alerting for 263,000- and 286,000-pound gross weight traffic has annualized alert rates based on two years of broken wheel and representative population data. Annualized alerts average 12 broken wheels and 4,802 wheelsets. The alerted wheelsets are categorized by peak kip and car weight as follows in Table 4.

Table 4. Dynamic Difference Alert Rates

	263,000-lb. cars		286,000-lb. cars	
	Broken	**Additional Wheels**	**Broken**	**Additional Wheels**
Max. Peak less than 80 kips	1	22	1	88
Max. Peak 80 to 89 kips	0	102	1	225
Max. Peak 90+ kips	3	1006	8	3346

Most of the wheelsets that meet the criteria are 286,000-pound maximum car weights exceeding 90 peak kips. When the prompt jump and dynamic difference criteria are combined, there are eight broken wheelsets (three in 2015 and five in 2016) that alert with both criteria and all exceed 90 maximum peak kips.

CONCLUSION

Prompt jump and dynamic difference methodologies each generate alerts that distinguish broken wheels from the representative population. These are mostly comprised of wheelsets with a 90-kip or higher WILD peak. Dynamic difference also identifies a few broken wheels with a maximum peak below 90 kips.

There is an overlap of some +90-kip wheels being alerted by both methodologies. The +90-kip wheels are already condemnable at any time per AAR Rule 41.A.1.r, but both methodologies could be used as a screening criteria to remove higher risk wheels when it is not practical to remove all 90-kip or greater wheels.

Acknowledgements

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