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WILD Empty Alerting for Four-axle Cars

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Key Findings:

- The vast majority of WILD peak force readings of 80 kips or greater occur on loaded equipment.
- Nearly 8 percent of cars that pass a WILD system do so only empty within a six-month period.
- Ninety percent of wheels that produce a WILD peak force of 75 kips on empty four-axle equipment produce at least 80 kips of peak force when the car is loaded. Ninety percent of wheels that produce a WILD peak force of 85 kips on empty four-axle equipment produce at least 90 kips of peak force when the car is loaded within 30 days of the empty pass.
- A similar study of intermodal equipment with varying load conditions and wheel sizes is in progress.

Transportation Technology Center, Inc. (TTCI) conducted an analysis to identify potential industry alerting levels for wheel impact loads produced by unloaded railcars. It is desirable to identify wheels in empty cars that have a strong possibility of exceeding AAR criteria once the cars are loaded. This way, the car owner and handling railroad have opportunity to conduct maintenance on the car before it is loaded with freight to be delivered to a customer.

This work was performed under the direction of the Association of American Railroads (AAR) Strategic Research Initiatives (SRI) program and in close coordination with the AAR's Equipment Health Monitoring Committee (EHMC).

For roughly two decades, Wayside Wheel Impact Load Detectors (WILD) have been in service in North America to identify high impact wheels due to tread conditions. AAR criteria specify that a wheel can be removed once a WILD reading of at least 90 kips peak load is reported. Further, a wheel with a WILD reading of at least 80 kips peak load but less than 90 kips peak load can be removed if the car is on a shop or repair track for any reason.[1] In this issue of *Technology Digest*, a wheel exceeding either of these criteria (at least 80 kips peak load) is deemed a high impact wheel (HIW).

Currently, there are 191 active WILD wayside systems in use. In the first half of 2020, there were 334,063 detector wheel passes between 80 and 89.99 peak kips of which 96.5 percent were loaded four-axle cars. For the same period, there were 147,656 detector wheel passes greater than or equal to 90 peak kips of which 97.4 percent were loaded cars.

Most WILD alerts occur with the car in the loaded condition; however, some cars rarely cross a WILD system in a loaded condition. Of the 1,334,515 unique cars that passed a WILD system in the first half of 2020, 7.8 percent were always empty while passing. This study examined potential alert limits for empty car passes from the WILD system in North America.

A peak kip is 1,000 pounds of force on the rail by the wheel and is known to increase as a function of car load, wheel condition, and train speed.[2]

Dynamic vertical forces are measured in kips and represent the additional forces generated by the tread condition of the wheel in excess of the weight of the wheel.

For example, a rotary gondola with a tare weight of 44 kips would have an average static wheel weight of just 5.5 kips when the car was empty. A wheel in this empty car would require an additional 74.5 kips of dynamic load to reach 80 peak kips. If the car was instead a tank car with a tare weight of 74 kips, then it would have an average static wheel weight of 9.25 kips when empty and would require an additional 70.75 kips of dynamic load to reach 80 peak kips.

Dynamic ratio is a multiple of the weight of the wheel to the peak kips; dynamic ratio is always 1.0 or greater since the peak kips are not less than the wheel weight. Equations 1 and 2 define the dynamic vertical force and dynamic ratio, respectively.

$$dynamic\ vertical\ kips = Peak\ Kips - Wheel\ Weight$$

Equation 1. Dynamic vertical equation

$$dynamic\ ratio = \frac{Peak\ Kips}{Wheel\ Weight}$$

Equation 2. Dynamic ratio equation

ANALYSIS

The analysis is performed in three steps to consider any differences by empty car weights and the dynamic force measure.

1. Determine empty car (tare weight) groupings by maximum gross weight.
2. Identify known HIWs and examine empty pass performance.
3. Determine probabilities of HIWs based on empty car WILD values.

Empty Car Performance of Known HIWs

To analyze the impact loads of empty passes, wheels are identified that exceed AAR impact load criteria prior to and after the empty pass with the following conditions:

1. There must be a prior WILD pass of 80 to 89.99 peak kips.
2. Within 14 days of the first pass, there must be an empty car pass with a train speed within 9 mph of the first pass.
3. Within 14 days and 9 mph after the second pass, there must be another 80 to 89.99 peak kips reading from a WILD pass.

The same method above is used for 90- to 99.99-peak-kip wheels. Using over four years of WILD data, 1.3 million unique wheelsets were identified and included in the analysis. The wheels were analyzed by gross car weight and tare weight groupings using dynamic vertical and dynamic ratios.

Car Weight Grouping

Each freight car has an empty weight of the car as well as a maximum gross rail load. Heavier empty cars and heavier loaded cars can reach the 80+ peak kip alert levels with less additional force due to the wheel conditions, therfore it is appropriate to analyze cars based on groupings of tare weight and gross rail load. For example, a fully loaded car rated for 286 kips gross rail load has an average static wheel weight of 35.75 kips and only requires 44.25 kips of additional dynamic force to reach 80 peak kips.

Included in the analysis are the most common cars with gross weights of 286, 268, 263, 220, 195 and 179.2 kips. Each car gross weight group has different tare weight cars, which are further grouped by approximately 7-kip ranges for the analysis. For example, 286-kip cars are further grouped in the following tare weight ranges:

- Less than 45.000 kips
- 45.000 to 51.999 kips
- 52.000 to 58.999 kips
- 59.000 to 65.999 kips
- 66.000 to 72.999 kips
- 73.000 to 79.999 kips
- 80.000 to 86.999 kips
- 87.000 to 93.999 kips
- Over 94.000 kips

Figure 1 shows the number of cars in each grouping. The car weight groupings are next used to analyze the impact loads of empty passes on known HIWs.

Dynamic vertical forces and ratios in Figures 2 and 3, respectively, indicate a large range of values when the cars are in the empty condition. As the graphs do not show a consistently high value while empty, a probability analysis was performed to determine limits that consistently predicted the HIWs.

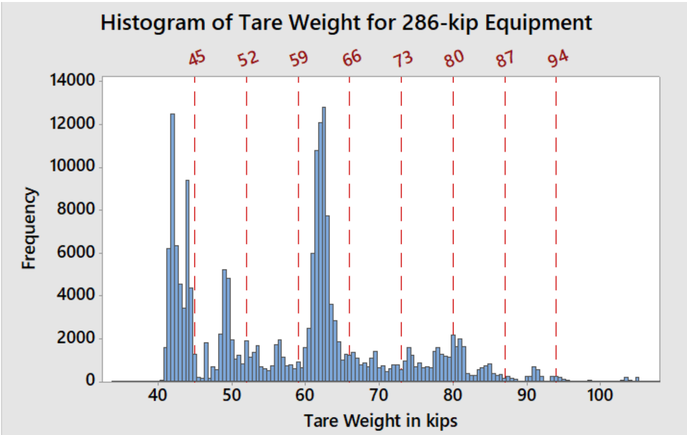

Figure 1. UMLER car volumes by tare weight for 286-kip equipment

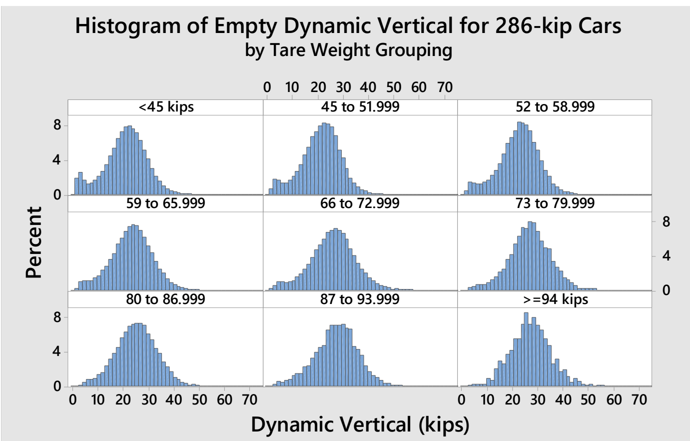

Figure 2. Frequency of empty dynamic verticals on 80-89 peak kips

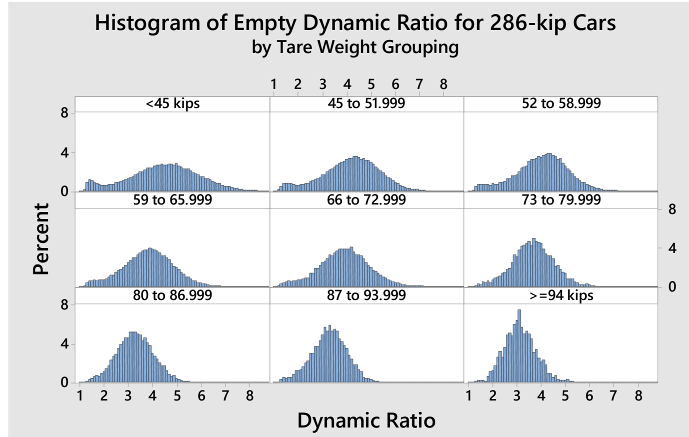

Figure 3. Frequency of empty dynamic ratios on 80-89 peak kips

Probability Analysis

A different, more inclusive set of WILD data was categorized by the same gross weight and tare weight groupings used in the known HIW analysis and analyzed to determine the probability that a particular empty car dynamic vertical force would be recorded on a HIW that typically exceeded AAR criteria when in the loaded condition. Wheels with no loaded car WILD data reported within 30 days of the empty car WILD data were excluded from this data set. Figure 4 shows the likelihood of an empty car pass with a dynamic vertical (x-axis) and the probability the wheel will be at least an 80-peak-kip wheel.

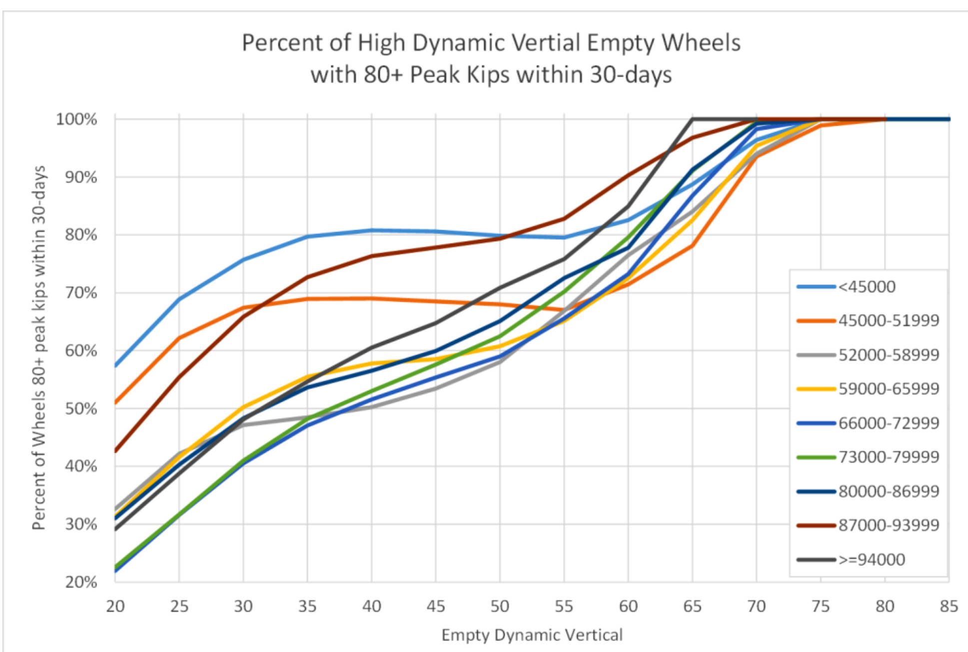

Figure 4. Probabilities of 286-kip cars by tare weight groupings

In the figure, the red oval indicates the dynamic vertical forces for each tare weight that are 90 percent likely to be a HIW within 30 days. Dynamic ratios (not shown) did not exceed 70 percent likelihood on average for a similar analysis using ratios up to 11.5. The probability value of 90 percent is a non-statistical conservative value chosen as an example to provide high confidence of a HIW. Other empty peak kip levels can easily be developed for other levels of probability.

The dynamic verticals range from about 60 to 69 kips for wheels with a 90 percent likelihood of recording an exceedance of AAR impact load criteria within 30 days. When adding each unloaded car's wheel weight to the values above, Table 1 shows the approximate peak kips (wheel weight plus dynamic vertical) that are expected when the car is unloaded.

Table 1. Estimated peak kips for empty traffic

Tare Group (kips)	Wheel Weight (kips)	Dynamic Vertical Kips at 90%	Estimated Peak Kips of Empty Car
45	5.63	About 69	74.63
52	6.50	67	73.50
59	7.38	67	74.38
66	8.25	66	74.25
73	9.13	64	73.13
80	10.00	64	74.00
87	10.88	60	70.88
94	11.75	62	73.75

For cars with gross rail load rating of 286 kips, Table 1 shows that a peak kip reading of approximately 74 kips while empty means that there is a 90 percent probability the wheel will produce an impact load within the next 30 days of sufficient magnitude to be considered a HIW. Results for other gross car weights are typical to the 286-kip equipment.

CONCLUSIONS AND FUTURE WORK

Empty four-axle cars produce smaller peak kip forces than comparable loaded cars. For cars that do not regularly pass WILD systems while loaded, an opportunity exists to be actionable with some of those cars.

With 90 percent probably, an alerting level of 75 peak kips on empty four-axle equipment could be used to identify wheels which would produce peak kip WILD readings of 80 kips or greater, if loaded. Similarly, an alerting level of 85 peak kips on empty four-axle equipment could be used to identify wheels which would produce 90 peak kip or greater WILD readings, if loaded. A lower probability than 90 percent would lower the alert limit for empty four-axle equipment.

A similar study of intermodal equipment with varying load conditions and wheel sizes is in progress.

References

1. *Field Manual of the AAR Interchange Rules.* 2020. Rules 41.A.1.r and 41.A.2.e. Association of American Railroads. Washington, D.C.
2. Kalay, Semih. May 1993. "Wheel Impact Load Detector Tests and Development of Wheel-flat Specification." Report R-829, AAR/TTCI, Pueblo, Colorado.

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