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Key Findings:

- Asymmetric hollow wear is not caused by initial diameter difference of mate wheels within the allowable variation of the same tape size.
- The tape size matching required by AAR Standard S-659 does not result in unacceptable asymmetric hollow wear performance.
- Asymmetric hollow wear develops more frequently on intermodal and vehicular flat railcar types (AAR types Q, S, and V).
- Asymmetric hollow wear does not cause a greater angle of attack, but results in a lateral offset of the wheelset relative to the center of tangent track.
- The difference in hollow wear of mate wheels is related to a difference in hollow wear location and a difference in flange wear.
- Hollow wear of an individual wheel is not strongly related or dependent on any other wear parameter of that wheel.

This research was performed by MxV Rail, a wholly owned subsidiary of the Association of American Railroads.

Analysis of Asymmetric Hollow Worn Wheels

Ulrich Spangenberg, Kenny Morrison, and Scott Cummings

As part of the Association of American Railroads' (AAR) Wheel/Rail Profile Design and Maintenance Strategic Research Initiatives project, MxV Rail (formerly TTCI) investigated the formation of hollow worn wheels in an effort to reduce asymmetric hollow wear (i.e., the development of a substantial difference in hollowing between the two wheels of a single wheelset). Wheels with excessive hollow wear are a cause for removal according to the AAR *Field Manual of Interchange Rules,* Rule 41.A.1.ab and Rule 41.A.2.b.[1]

MxV Rail researchers conducted a study of worn wheel profiles and wheel wear data from wayside wheel profile detector (WPD) systems to understand the development of hollow worn wheels. In addition, the team studied wheelset assembly practices, hollow wear prevalence on given railcar types, and the wheelset on-track performance.

INTRODUCTION

Hollow wear is a typical and anticipated form of wheel wear, which is measured and monitored through the service-life of the wheels. In this study hollow wear was defined consistently with *AAR Field Manual* Rule 41.C.1.j, as shown in Figure 1.[1] The hollow wear position was defined as the distance from the point of hollow wear measurement to the flangeback.

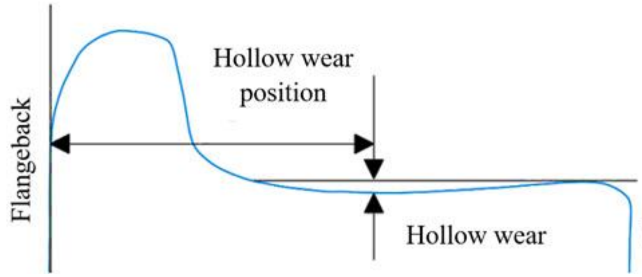

Figure 1. Definition of hollow wear and hollow wear position

Many studies have been performed on rail damage that results from hollow worn wheels.[2,3] Hollow worn wheels are known to cause rail damage in the transition zones of special trackwork and contribute to rolling contact fatigue initiation and growth.[2,3,4] The damage typically requires rail grinding; or welding in turnouts. Moderate to severe hollow worn wheels can increase the lateral wheel-rail forces and increase railcar rolling resistance.[4] The goal of this research was to seek a means of managing or eliminating the rate and severity of hollow wear

wear formation and mitigating the effects of adverse, hollow-worn wheel profiles to reduce rail damage.

The root causes of high hollow wear rates and asymmetric hollow wear are indistinct. This *Technology Digest* reports on the findings related to the study of wheel wear patterns to determine relationships or correlations between wheel wear values, factors internal to the manufacturing of the wheels (e.g., diameter differences), the influence of the railcar type, and wheel performance on track.

METHOD

The analysis of wheel wear parameters was based on measurements from WPDs. The cartesian coordinates of approximately 320,000 wheel profiles were obtained from a WPD for detailed analysis and will be referred to as Dataset 1. These profiles were used to calculate not only hollow wear and other wear parameters such as flange width and height, but also wear parameters that are not regularly calculated by WPDs such as the hollow wear position. A second dataset including WPDs from across North America contained more than 4 million records of measured wheel profile metrics (e.g., flange height) and will be referred to as Dataset 2.

The maximum hollow wear and associated measurement data was determined from the two datasets for a given axle of a vehicle for the wheelset's service life. The other wear parameters and studied variables were linked to this measurement data. The wear parameters from mate wheels were processed to obtain the difference in hollow wear position from Dataset 1 and the difference in hollow wear amount from Datasets 1 and 2. The difference of any two values that were considered or reported should be interpreted as the railcar side's left value being subtracted from the right value (i.e., R3 minus L3). Dataset 2 and Railinc's UMLER® System were used to determine the railcar type associated with each measurement.

A dataset of ~41,700 manufacturing records listing the as-manufactured wheel diameters was obtained. There were 7,000, 24,150 and 10,550 data records for nominal 28-, 33-, and 36-inch wheels, respectively. Dataset 2 was used to determine the hollow wear of these wheels over their respective service lives.

The tracking position of a wheelset is the lateral displacement of the wheelset relative to the center of the track. The angle of attack of a wheelset is the angle of the axle centerline relative to a line perpendicular to the track centerline. The team extracted measurement data from a database with wayside truck geometry detector (TGD) measurements reporting the tracking position and angle of attack of wheelsets across North America. Measured TGD data that occurred within two weeks of the date that the hollow wear was measured was incorporated into Dataset 2.

RESULTS

On an individual wheel basis, many of the wear parameters appeared to be unrelated to one another and described the wear state of the wheel independently. As a somewhat counterintuitive example of this independence, flange height and hollow wear did not show a strong relationship. However, the hollow wear, difference in hollow wear, difference in hollow wear position, and difference in flange width of two mate wheels were found to be related on many wheelsets. Using Dataset 1, the hollow wear measured on the right wheel was compared to the hollow wear measured on the left wheel with the results shown in Figure 2. Initial hollow wear of wheelsets up to ~0.5 mm is often more symmetric with similar amounts of hollow wear on the left and right wheel. Newly applied wheelsets are not expected to be perfectly symmetric due to manufacturing and assembly tolerances. However, starting at ~0.5 mm hollow (and certainly at 2 mm hollow) most wheelsets appear to wear asymmetrically with relatively little hollow wear on one side of the wheelset compared to the other side.

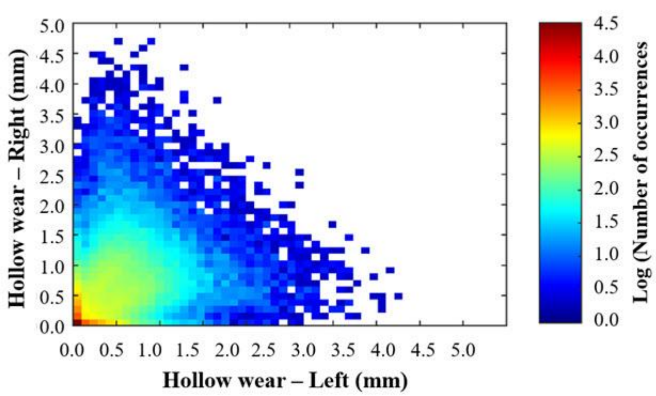

Figure 2. Comparison of the hollow wear on the left and right wheels of the same axle – Dataset 1

The difference in hollow wear was found to be related to the difference in hollow wear position. With more asymmetry in hollow wear, there is a greater potential to have asymmetry in the hollow wear position. Figure 3 shows an example of such asymmetric wheel wear. The difference in hollow wear positions show the right wheel has more hollow wear and the wear is located closer to that wheel's flange while the left wheel has a very small amount of hollow near the rim face and a nearly full flange width.

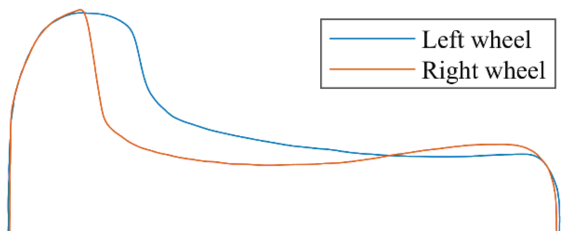

Figure 3. Comparison of mate wheels with severe hollow wear difference

The same result was found for the comparison of the difference in hollow wear and the difference in flange wear. Mate wheels with a large difference in flange wear often had large differences in hollow wear—thus, asymmetry in wheel wear. The results indicate that the difference in hollow wear values is a good indicator of asymmetric wheel wear.

Studying the tracking position and the angle of attack of the wheels in Dataset 2, the differences in hollow wear were grouped with 1 mm bounds for this evaluation. The angle of attack on tangent track did not change significantly with asymmetric hollow wear. However, the tracking positions of the wheels were dependent on the difference in hollow wear as shown in Figure 4. The figure also shows how the flange clearance (plotted for a new AAR-2A wheel profile and 136RE rail profile assuming nominal wheel back-to-back spacing and track gage) limits tracking position. Populations where tracking position exceeds flange clearance evidence flange and gage face wear. Asymmetric hollow wear causes the wheelset to run off-center relative to the track in tangent sections and influences the steering behavior of the wheelset in curves. This increases gage spreading forces and the risk of rolling contact fatigue development.[4] By running offset from the center of track, assymetric hollow worn wheels may further exacerbate the asymmetric wear and increase the rate of hollow wear on the wheel with more existing hollow wear.

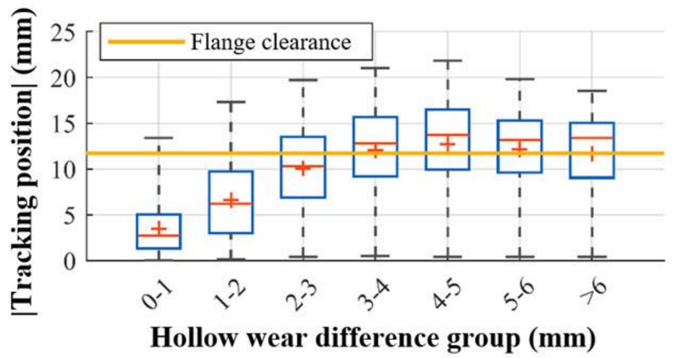

Figure 4. Box plots of absolute value of tracking position for various hollow wear groups

The difference in hollow wear associated with each railcar type was studied to determine if asymmetric hollow wear is more prevalent on a given railcar type as shown in Figure 5. The number of data entries associated with the box plot for each railcar type is shown next to the railcar type letter. The box plots show the median as an orange line and the mean value as an orange cross. The "Q," "S," and "V" railcar types (intermodal railcars and vehicular flat railcars) exhibited more asymmetry in hollow wear compared to other railcar types.

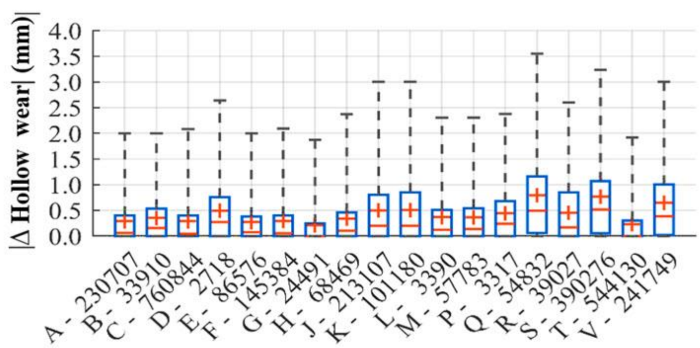

Figure 5. Box plots used to study the distribution of the difference in hollow wear per railcar type

The hollow wear difference on the individual axles of the vehicular flat railcars and intermodal railcars were examined. Wheelsets located in vehicular flat railcars and in the leading and trailing trucks at either end of articulated railcars appeared to have more severe asymmetric hollow wear than the other wheels. These wheels usually have a smaller diameter (28- or 33-inch) compared with the wheels used by other railcar fleets.

The initial diameter difference between two mate wheels at mounting has been thought to be a cause of asymmetric hollow and/or flange wear.[4] AAR's Standard S-659 requires new mate wheels to be of the same tape size.[5] Because tape numbers represent 0.125 inch of circumference, that level of resolution can mean up to 0.040 inch (~1 mm) diameter difference.

The measured as-manufactured diameters of mate wheels were calculated from the manufacturing dataset. The hollow wear differences on these wheels measured in service were calculated. The hollow wear differences were compared to the initial diameter differences of mate wheels (Figure 6) for wheels with a nominal diameter of 28, 33, and 36 inches. The results show that mate wheels with severe hollow wear difference can occur on wheels with small initial diameter differences. Conversely, wheelsets with the maximum initial diameter difference do not show significant differential hollow wear. The diameter difference initially present on mate wheels is not driving the severe difference in hollow wear.

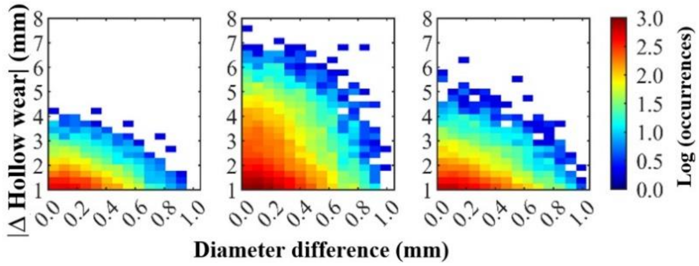

Figure 6. Hollow wear difference as a function of initial diameter difference for (a) 28-inch, (b) 33-inch or (c) 36-inch wheels.

CONCLUSIONS

Hollow wear is a typical form of wheel wear. A wheel with significant hollow wear near the flange root and a thinner flange usually mates to a wheel with less hollow wear near the rim edge resulting in a wheelset that is asymmetric in nature. While the root cause(s) of asymmetric hollow wear remain elusive, some aspects of its development were discovered.

- Hollow wheel wear is not caused by initial diameter difference of mate wheels within the allowable variation of the same tape size.
- The tape size matching required by AAR Standard S-659 results in acceptable asymmetric hollow wear performance.
- Hollow wheel wear develops more frequently on intermodal and vehicular flat railcar types (AAR types Q, S, and V).
- Hollow wear does not cause a greater angle of attack, but rather results in a lateral offset of the wheelset relative to the center of tangent track.
- Consistent with the tracking position finding, the difference in hollow wheel wear between the mate wheels is related to a difference in hollow wear location on the profile and a difference in flange wear.

References

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5. *AAR Manual of Standards and Recommended Practices*, Section G-Part II, Wheel and Axle Manual, Standard S-659, Association of American Railroads, Washington, D.C., 2014.

For comments or questions about this publication, contact Ulrich_Spangenberg@aar.com