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Update on AAR-2A Wheel Profile Service Tests

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Summary

In September 2016, the Association of American Railroads (AAR) instituted the AAR-2A wheel profile as an alternate standard for use by wheel shops when reprofiling wheels. Transportation Technology Center, Inc. (TTCI) designed, modeled, and tested the AAR-2A wheel profile as part of AAR's Strategic Research Initiatives (SRI) program. Compared to wheels with the current standard AAR-1B wheel profile, modelling and revenue service testing of wheels with the AAR-2A profile shows benefits in terms of wear rates and wear patterns, gage-spreading forces, and in one case early-life wheel survival rates.

Wayside data continues to show similar high speed stability values far below the AAR criteria for the AAR-2A and AAR-1B wheels in both eastern and western U.S. revenue service tests. In the larger eastern U.S. service test, about 140,000 miles have accumulated on 150 covered hoppers, 75 of which were initially equipped with the AAR-2A wheel profile. In this test, wear rates show positive results for the AAR-2A wheels, including a 39 percent reduction in wheel tread wear based on the flange height readings. Survival data shows a statistical benefit for AAR-2A wheels between 100,000 and 140,000 miles. About 350,000 miles have accumulated in the smaller western U.S. service test involving 50 covered hopper cars, 25 of which were initially equipped with the AAR-2A wheel profile. Survival analysis confidence intervals overlap until 345,000 miles in this test, indicating no statistical difference between the different profiles to that point. Advantages from the initial wheel profile are expected to be most evident in the early life of the wheels, and the effects later in life are likely to be more dominated by differences such as route and environmental characteristics.

AAR has declared an intention to eliminate the AAR-1B profile on January 1, 2019. Acceptance of the AAR-2A wheel profile for use on new wheels is still under consideration by AAR.



INTRODUCTION

This *Technology Digest* provides an update regarding revenue service test results of the AAR-2A wheel profile. Transportation Technology Center, Inc. (TTCI) designed and tested this profile with the intention of improving vehicle curving performance and reducing the wheel wear-in period compared to the current standard AAR-1B wheel profile.

BACKGROUND

A wheel with an AAR-1B profile produces severe two-point contact when matched with a typical worn high rail profile. This limits the beneficial rolling radius difference that allows tapered wheels to steer through curved track. A wheel with the AAR-1B profile wears to a high rail conformal profile while in service; while the AAR-2A profile is designed with a high rail conformal profile and maintains this shape while in service.

Throughout the course of its testing, the AAR-2A profile has also been known as the “TTCI-1A” profile and the “SRI-1A” profile. Initial simulation results for the AAR-2A profile machined on wheels in a loaded car on a 7.5-degree curve showed lateral wheel/rail force reductions of 10 percent or better and rolling resistance improvements in excess of 20 percent compared to the AAR-1B wheel profile.¹ Small sample size revenue service tests involving a five-unit articulated well car^{1,2} and 10 coal hoppers³ were conducted to define the revenue service performance of the AAR-2A as compared to the AAR-1B. These tests showed reduced wear rates (35 percent reduction in cross-sectional area loss after 30,000 service miles), reduced track gage spreading forces on curved track, and more symmetric wheel wear patterns attributable to the AAR-2A wheel profile.

Wheel profiles with good curving performance can experience lateral instability (i.e., hunting) at lower speed thresholds compared to wheel profiles with poor curving performance. Thus, the high speed stability of the AAR-2A profile is an issue that must be addressed. Although a new AAR-1B outperforms a new AAR-2A in terms of high speed stability, the AAR-1B profile changes shape dramatically while in service and railroads are already operating at high speeds with worn AAR-1B profiles.

Two separate revenue service tests of the AAR-2A wheel profile were initiated in 2010: 150 covered hopper cars in service in the eastern U.S., and 50 covered hopper cars in service in the western U.S. Half of the cars in each test were equipped with AAR-2A wheel profiles while the other half were equipped with AAR-1B wheel profiles. Results from these tests have been reported previously.⁴

EASTERN SERVICE TEST RESULTS

Table 1 contains wheel wear values for the AAR-1B and AAR-2A wheels after approximately 140,000 service miles in the eastern service test. The data shown in Table 1 was sourced from a wayside wheel profile monitoring system using only original test wheels after filtering out any data from wheelsets that had been installed after test initialization.

Table 1. Average Wheel Wear Comparison, Eastern Test

	Nominal New	Condemnable	AAR-1B	AAR-2A
Count of wheels analyzed	N/A	N/A	514	554
Average flange thickness	1.38 in. AAR-1B 1.25 in. AAR-2A	0.94 in.	1.48 in.	1.45 in.
Average asymmetric flange wear per wheelset	0.00 in.	N/A	0.07 in.	0.04 in.
Average flange height	1.09 in.	1.50 in.	1.27	1.20 in.
Average tread hollow	0.000 in.	0.157 in. (4 mm)	0.034 in. (0.9 mm)	0.027 in. (0.7 mm)

Flange height is a good metric of tread wear. The tread wear rate of the AAR-2A wheels is 39 percent less than the AAR-1B wheels $((1.27-1.20)/(1.27/1.09) = 39\%)$, using flange height as the parameter. The flange thickness values are measured at a wheel radius value based off of a reference from the tread surface rather than a reference from the flange tip. As the tread wears, the flange thickness measurement often moves radially into a thicker area of the flange root. This is done to more closely represent the method used to condemn wheels for flange thickness, but often produces a flange thickness reading that is greater than the nominal new value. On average, the AAR-1B wheels continue to show flange thickness values greater than the AAR-2A wheels, but the difference in flange thickness has decreased from 0.13 inch at the nominal new condition to 0.03 inch at 140,000 miles. Thus, the flange thickness wear rate is higher for the AAR-1B wheels than the AAR-2A wheels. Asymmetric flange wear (calculated here as the absolute value of the difference of flange thicknesses for mated wheels), flange height, and tread hollow all show benefits for the AAR-2A wheels. Every wear comparison shown in Table 1 is statistically significant at the 95 percent confidence level.

Figure 1 shows results of a survival analysis conducted on wheel removals in the eastern test. Of the 600 AAR-1B profiled wheels that began the test, 104 have been removed for cause other than Why Made Code (WMC) 11: “Removed in good condition account of associated repairs.” Of the 600 AAR-2A profiled wheels

that began the test, just 63 have been removed for cause other than WMC 11. Wheels removed for WMC 11 were censored at their removal mileage. Wheel removal data from both profiles does not adequately fit a defined distribution, so a non-parametric analysis was used instead. The central line in each series indicates the estimate of survival probability and the matching lines on either side indicate the 95 percent confidence intervals. As illustrated by separation of the confidence bands, this analysis shows a statistically significant difference in wheel life in favor of the AAR-2A wheels between 100,000 and 140,000 miles. The survival probability lines diverge by as much as 9 percent at 125,000 miles. The non-parametric analysis cannot be used to predict wheel removal rates into the future.

Figure 2 shows the general categories for removals. The relative percentage of removal causes is similar for both wheel types. The thinner initial flange of the AAR-2A profile is not causing problems in terms of removals due to wear.

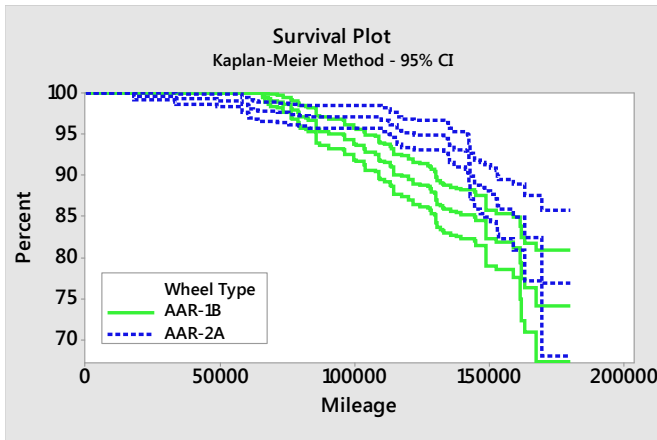


Figure 1. Non-Parametric Survival Analysis, Eastern Test

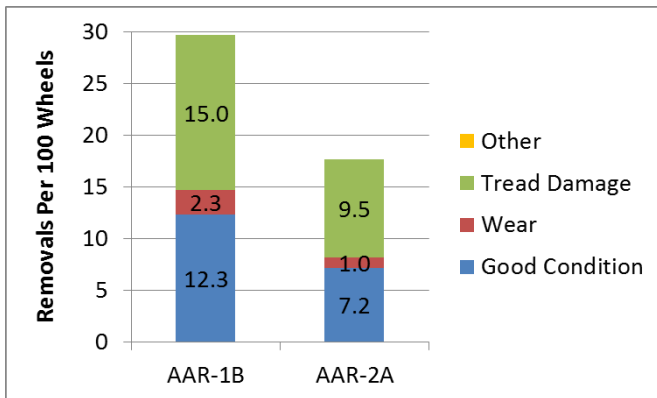


Figure 2. Cause for Removals, Eastern Test

Figure 3 shows revenue service data from wayside Wheel Impact Load Detectors/Hunting Detectors (WILD/HD) over a recent 1-year period for the eastern

test cars. The y-axes are shown in logarithmic scale to highlight the few occurrences at the upper tails of the distributions. Based on these plots, both wheel profiles exhibit similar and acceptable high speed stability performance.

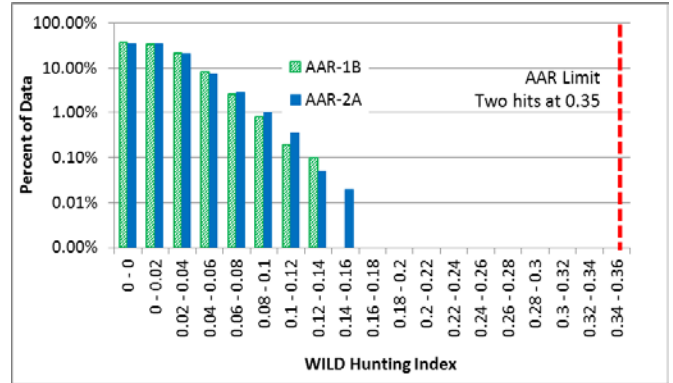


Figure 3. WILD/HD Results, Eastern Test

WESTERN SERVICE TEST RESULTS

In the western service test, large quantities of detailed wheel profile data are harder to acquire and process. Additionally, the majority of test wheels have already been removed from service, limiting the usefulness of a comparison of current worn wheel profiles. Removal causes, mileage, and WILD/HD data are analyzed here. Figure 4 shows that the causes for wheel removal are similar between the two wheel profiles, and the thinner initial flange of the AAR-2A profile is not causing problems in terms of removals due to wear.

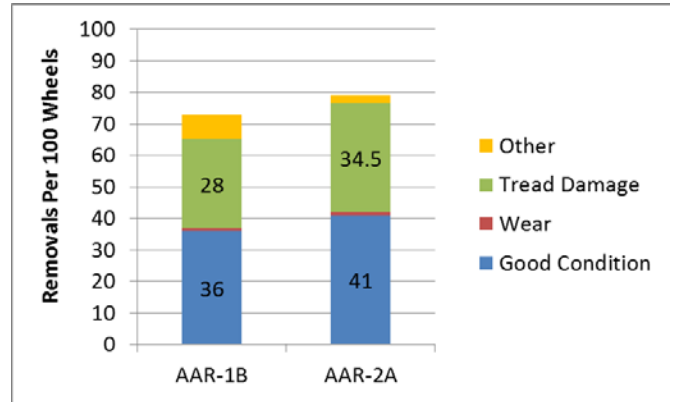


Figure 4. Cause for Removals, Western Test

Figure 5 shows results of a survival analysis conducted on wheelset removals in the western test. Here the data is categorized per wheelset rather than per wheel. Of the 100 AAR-1B profiled wheelsets that began the test, 55 have been removed for cause other than WMC 11. Of the 100 AAR-2A profiled wheelsets that began the test, 71 have been removed for cause other than WMC 11.

Wheelsets where both wheels were removed for WMC11 were censored at their removal mileage. Similar to the presentation style in Figure 1, the central line in each series is the estimate of survival probability and the matching lines on either side indicate the 95 percent confidence intervals. The confidence intervals for the different wheel profiles overlap until 345,000 miles, indicating no statistical difference in the survival data up to that point. Advantages from the initial wheel profile are expected to be most evident in the early life of the wheels, as reported previously,^{1,2,3} and the effects later in life are likely to be dominated by differences such as route and environmental characteristics.

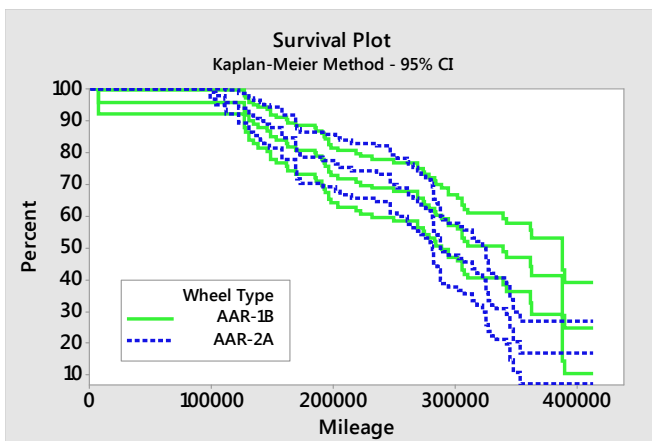


Figure 5. Non-Parametric Survival Analysis, Western Test

Figure 6 shows revenue service data from wayside WILD/HD over a recent 1-year period for the western test cars. Data from any truck with at least one wheelset replaced during the test was excluded. Both wheel profiles exhibit similar and acceptable high speed stability performance.

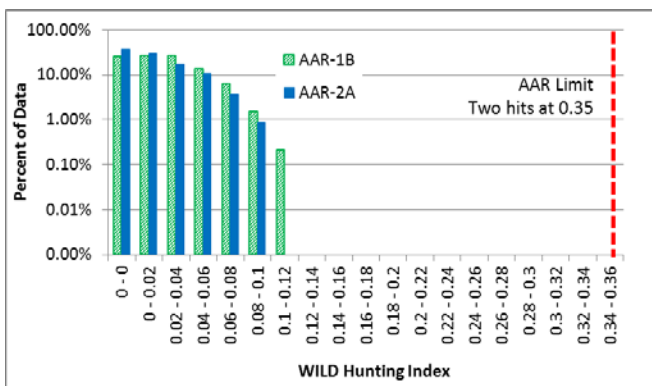


Figure 6. WILD/HD Results, Western Test

CONCLUSION

Revenue service tests comparing the AAR-2A wheel profile to the current standard AAR-1B wheel profile involving covered hopper cars in the eastern and western U.S. show the following:

- In the eastern test, AAR-2A wheels have lower wear rates than AAR-1B wheels. As determined by average flange height, the tread wear rate of the AAR-2A wheels is 39 percent less than the AAR-1B wheels after 140,000 miles.
- The eastern test shows a higher wheel survival percentage (as much as 9 percent) for AAR-2A wheels than AAR-1B wheels early in the test when the effects of the initial profile are expected to be most evident. The western test shows no statistical difference in wheel survival until 345,000 miles. Initial profile is unlikely to have any effect after this much service.
- Worn AAR-2A wheels and worn AAR-1B wheels have similar lateral stability at high speeds.

THE PATH FORWARD

The AAR has adopted the AAR-2A profile as an alternate standard available for use when reprofiling wheelsets with the stated intent of eliminating the AAR-1B profile on January 1, 2019.⁵ Approval of the AAR-2A profile for new wheels remains under consideration. TTCI will continue to monitor revenue service results of the AAR-2A profile.

References

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