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Large-Scale SRI-1A Wheel Profile Service Tests

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Summary

In July 2015, the Association of American Railroads' (AAR) Wheels, Axles, Bearings, and Lubrication (WABL) Committee began the process to include a new wheel profile known as "SRI-1A" as an officially accepted profile, based on positive results of large-scale testing by Transportation Technology Center, Inc. (TTCI).

TTCI designed, modeled, and tested the SRI-1A wheel profile as part of AAR Strategic Research Initiatives (SRI) program. Modeling and revenue service testing of wheels with the SRI-1A profile shows benefits in terms of wear, longevity, gage-spreading forces, and wheel wear patterns compared to wheels with the current standard AAR-1B wheel profile.

After positive results were found in small-scale revenue service tests, two larger-scale tests were initiated involving 150 covered hopper cars in eastern U.S. service and 50 covered hopper cars in western U.S. service. One half of the cars in each test were equipped with SRI-1A wheel profiles, and the other half had AAR-1B profiles. After more than 100,000 service miles, the tests show a lower rate of wheelset removals for SRI-1A profiled wheels compared to AAR-1B profiled wheels. In one test, just 24 SRI-1A wheels have been removed for cause other than Why Made Code (WMC) 11 compared to 51 AAR-1B wheels. Wheel wear rates are lower for the SRI-1A profiled wheels for every parameter analyzed including flange thickness, asymmetric flange wear, flange height, and hollowing. For example, using the average flange height measurements, the tread wear rate of SRI-1A wheels is 40 percent less than AAR-1B wheels. The flange root shape has stayed largely the same for the SRI-1A wheels throughout the testing while it has changed dramatically for the AAR-1B wheels. This is an expected result because the flange root shape of the SRI-1A profile is designed to produce a better match with a typical worn high rail profile compared to the AAR-1B profile.



INTRODUCTION

The Association of American Railroads’ (AAR) Wheels, Axles, Bearings, and Lubrication (WABL) Committee has begun the process to include a new wheel profile known as “SRI-1A” as an officially accepted profile based on positive results of large-scaled testing by Transportation Technology Center, Inc. (TTCI). The SRI-1A profile, designed and tested under the direction and support of the AAR’s Strategic Research Initiatives (SRI) program, was intended to improve vehicle curving performance and reduce 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 SRI-1A profile is designed with a high rail conformal profile and maintains this shape while in service. Figure 1 shows each wheel profile overlaid on the same typical high rail profile.

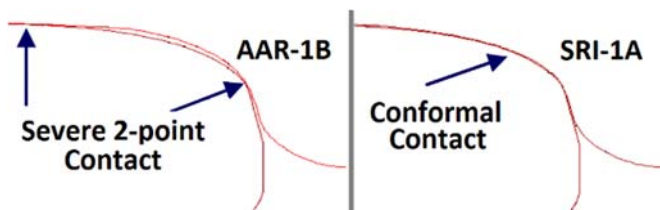


Figure 1. SRI-1A and AAR-1B Wheel Profiles Overlaid on Typical Worn High Rail

Initial simulation results for the SRI-1A 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 SRI-1A in comparison 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 SRI-1A wheel profile.

During the course of these initial revenue service tests, the design of the SRI-1A wheel profile was slightly modified to incorporate a flange thickness of 1.25 inches rather than the 1.38-inch flange thickness used for the AAR-1B and the original SRI-1A wheels. The shape of the flange root is the essential feature of the SRI-1A profile and was not altered. The flange was thinned slightly to allow more lateral wheelset shift for two purposes:

1. To increase the high speed stability by allowing larger track alignment deviations without making flange contact.
2. To increase the potential rolling radius difference between the mate wheels (and associated steering) when negotiating curved track.

The additional revenue service tests described here were initiated to increase the sample size of the results and test the slightly thinner flange version of the SRI-1A wheel profile.

LARGE-SCALE SERVICE TEST RESULTS

Two separate revenue service tests of the SRI-1A 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 SRI-1A wheel profiles while the other half were equipped with AAR-1B wheel profiles. Except where noted, the following results pertain to the larger test involving 150 cars due to the larger sample size and better availability of data.

Table 1 contains wheel wear values for the AAR-1B and SRI-1A wheels after approximately 115,000 service miles. A large sample of wheel profile information was not available at an earlier service interval. 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

	Nominal New	Condemnable	AAR-1B	SRI-1A
Count of wheels analyzed	N/A	N/A	432	460
Average flange thickness	1.38 AAR-1B 1.25 SRI-1A	0.94	1.47	1.42
Average asymmetric flange wear per wheelset	0.00	N/A	0.06	0.03
Average flange height	1.09	1.50	1.24	1.18
Average tread hollow	0.00	0.16	0.02	0.01

Flange height is a good metric of tread wear. The tread wear rate of the SRI-1A wheels is 40 percent less than the AAR-1B wheels ($(1.24-1.18)/(1.24/1.09) = 40\%$), 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 SRI-1A wheels, but the difference in flange thickness has decreased from 0.13 inch at the nominal new condition to 0.05 inch at 115,000 miles. Thus, the flange thickness wear rate is higher for the AAR-1B wheels than the SRI-1A 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 SRI-1A wheels. Every wear comparison shown in Table 1 is statistically significant at the 95 percent confidence level.

Figure 2 shows results of a survival analysis conducted on wheel removals. Of the 600 AAR-1B profiled wheels that began the test, 51 have been removed for cause other than Why Made Code (WMC) 11 “Removed in good condition account of

associated repairs.” Of the 600 SRI-1A profiled wheels that began the test, just 24 have been removed for cause other than WMC 11. Wheels removed for WMC 11 were censored at their removal mileage. The SRI-1A wheel removal data does not adequately fit a defined distribution, so a non-parametric analysis was used instead. This analysis shows a statistically significant difference in wheel life in favor of the SRI-1A wheels based on the removal and mileage data so far. The non-parametric analysis cannot be used to predict wheel removal rates into the future.

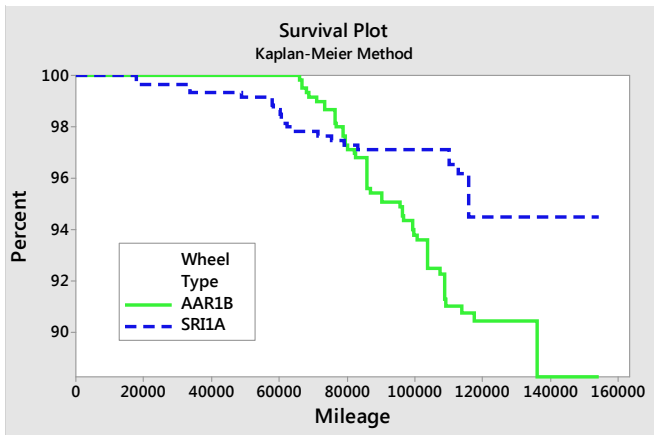


Figure 2. Non-Parametric Survival Analysis

Figure 3 shows the general categories for removals. The percentage of removals due to tread damage is similar for both wheel types. The percentage of removals due to wheel wear is twice as high for AAR-1B wheels compared to SRI-1A wheels. This follows the trend of higher wear rate for the AAR-1B profile.

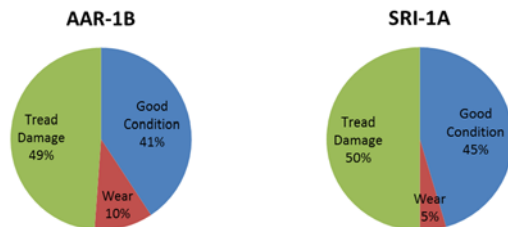


Figure 3. Cause for Removals

Figure 4 contains overlays from many worn AAR-1B and SRI-1A wheels (shown in teal color) superimposed on a typical worn high rail profile (shown in black). The respective nominal new wheel profile in also included (shown in black) to emphasize the areas of wheel wear. It can be seen that the AAR-1B wheels no longer have the same flange root shape as a new wheel, while the SRI-1A wheels still have the same flange root shape as a new wheel. The worn wheels are generally conformal with the typical high rail profile. This is a visual indication that the SRI-1A profile is working as intended and maintaining its flange root shape throughout the course of its life. Comparatively, the AAR-1B profile must undergo significant shape changes in the flange root throughout its life.

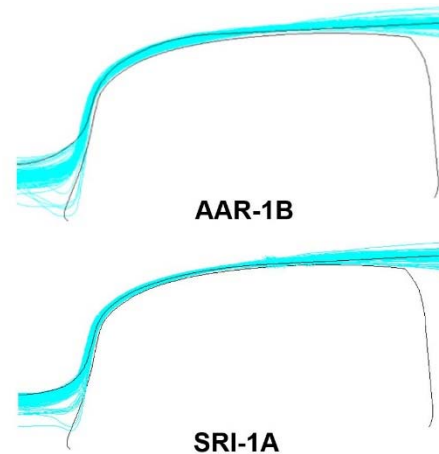


Figure 4. New and Worn Wheel Profiles Shown with Typical Worn High Rail

In the 50-car revenue service test, nearly all of the removals, thus far, have been due to tread damage. Interestingly, the AAR-1B and SRI-1A wheels show similar counts of wheels removed for each WMC with the exception of WMC 75 “Tread Shelled,” in which the SRI-1A wheels hold a substantial advantage over the AAR-1B wheels. Wheel profile overlays from this test are similar to Figure 4, indicating that the flange root shape has stayed largely the same for the SRI-1A wheels while it is changed dramatically for the AAR-1B.

HIGH SPEED STABILITY

Wheel profiles with good curving performance can experience lateral instability (also known as hunting) at lower speed thresholds compared to wheel profiles with poor curving performance. Thus, the high speed stability of the SRI-1A profile is a question that must be addressed. Although a new AAR-1B wheel profile outperforms a new SRI-1A wheel profile 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. A comparison of the high speed stability of worn AAR-1B and worn SRI-1A wheel profiles is addressed in two ways. First, Figure 5 shows revenue service data from wayside Wheel Impact Load Detectors/Hunting Detectors (WILD/HD) over a recent 1-year period. 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.

High speed stability of the worn profiles was also evaluated with NUCARS® modeling. Three wheelsets from each profile group were selected based on conicity (the rolling radius difference between mate wheels as a wheelset shifts laterally across the track) when placed on typical worn rail profiles. SRI-1A wheelsets with relatively high, typical, and low conicities compared to the other SRI-1A wheelsets were selected for modeling.

The same process was used to select three AAR-1B wheelsets for modeling. Measured rail profiles from revenue

service tangent tracks and shallow curves were applied to the model, which included measured track geometry deviations in sections with tangent track and a 0.8-degree curve. Modeling was conducted at a variety of speeds using loaded and empty cars with trucks configured to produce a range of performance levels. The ranges of high speed stability performance of the worn AAR-1B and worn SRI-1A wheelsets overlapped for every condition modeled, although the SRI-1A wheelsets tended to perform as well or slightly better as a group than the AAR-1B wheelsets. Figure 6 shows a typical result set for one combination of load condition and truck configuration.

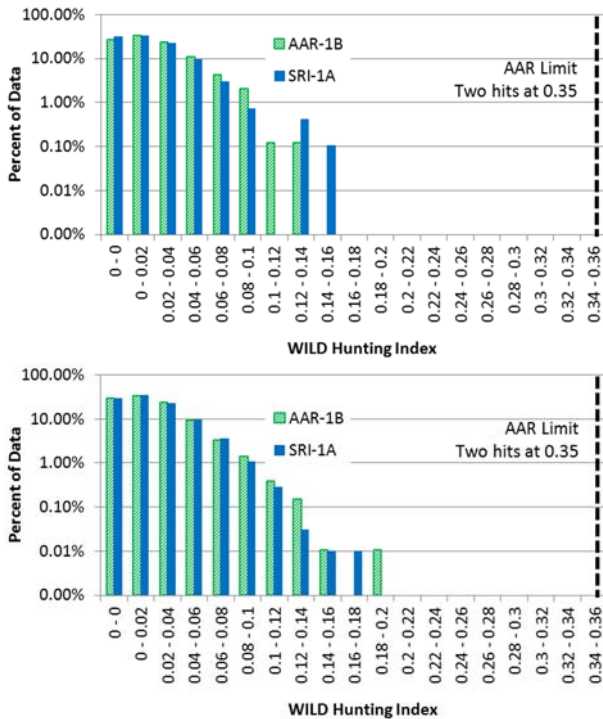


Figure 5. WILD/HD Results from the Western U.S. (top) and Eastern U.S. (bottom) Revenue Service Tests

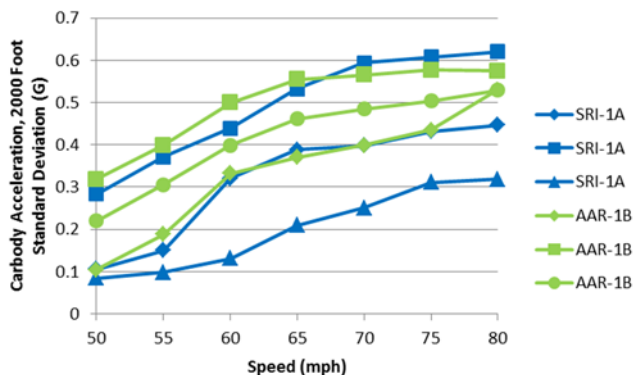


Figure 6. Typical Modeling Result with Overlapping Performance between Worn AAR-1B and Worn SRI-1A Wheelsets

Previous revenue service tests showed a similar lack of problems with high speed stability of the SRI-1A wheel profile.^{1,2,3} However, it should be noted that after a comprehensive review of the data from the initial multi-unit car test was conducted following report¹ publication, one brief instance of high speed instability on one truck equipped with SRI-1A wheel profiles was discovered while the car was traveling at 69 mph. The SRI-1A profiles used in this test had a thicker flange; and thus, would have less ability to shift laterally without encountering high conicity conditions and an increased tendency for instability at high speed. No indications of high speed instability have been noted in any of the other revenue service tests since the flange thickness was reduced to 1.25 inches. It should be noted that the recent test involved only covered hoppers. The different car types make statistical comparisons between tests for hunting propensity invalid.

CONCLUSION

Revenue service tests comparing the SRI-1A wheel profile to the current standard AAR-1B wheel profile involving a total of 200 covered hopper cars in the eastern and western U.S. show the following after approximately 115,000 service miles:

- SRI-1A wheels have lower wear rates than AAR-1B wheels. As determined by average flange height, the tread wear rate of the SRI-1A wheels is 40 percent less than the AAR-1B wheels.
- SRI-1A wheels have fewer removals than AAR-1B wheels. In one test, more than twice as many AAR-1B wheels (51 compared to 24) have been removed for causes other than WMC 11.
- Worn SRI-1A wheels and worn AAR-1B wheels have similar lateral stability at high speeds
- Based on visual inspection of transverse profiles, worn SRI-1A wheels have largely maintained the same flange root shape while AAR-1B wheels have experienced substantial flange root shape change during the test

THE PATH FORWARD

Pending the standard AAR process involving economic assessment and a comment period, the SRI-1A could become an officially accepted wheel profile for use in North America.

REFERENCES

1. Wu, H., B. Madrill, and S. Kalay. 2006. "New Wheel Profile Design and Preliminary Service Test Results." TD06-023. TTCI/AAR.
2. Wu, H., B. Madrill, and S. Kalay. 2008. "Service Test Results of a New Designed Wheel Profile." TD08-025. TTCI/AAR.
3. Wu, H. and B. Madrill. 2009. "SRI-1A Wheel Profile Service Test on Coal Cars." TD09-002. TTCI/AAR.

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