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Wheel Life and Maintenance Practices of Heavy Haul Railways

Scott Cummings

Summary

A survey by Transportation Technology Center, Inc.(TTCI), of five heavy haul railways in Australia, Brazil, South Africa, and Sweden found that the typical heavy haul freight car wheel life (from manufacture to scrap) of the railways surveyed is 985,000 miles — approximately double the expected wheel life in the North American freight railroad environment. This is due to a combination of wheels with thicker rims and a maintenance strategy to reprofile wheels after they have reached a certain service time or mileage requiring less material removal on the reprofiling lathe. The survey was conducted as part of the Association of American Railroads' (AAR) Strategic Research Initiatives Program.

Ultrasonic and microcleanliness test criteria for new wheels purchased by the survey respondents range from more stringent to less stringent than the applicable standard in North America: AAR M-107/M-208.[1] The wheel failure rates (broken rim, broken flange, and broken hub) as reported in this survey are typically described as "none," "very rare," or "rare." In North America, approximately one cracked or broken wheel was reported in 2014 for every 55,000,000 freight car miles operated. Although a similar rate on a system with a smaller scale would result in fewer failures, it would not likely be categorized as "rare" or "very rare."

This survey was the first in a series of steps to evaluate methodologies to optimize wheel life in the North American freight railroading environment. Additional steps include evaluating the effects of thicker rims on new wheels and evaluating the potential effects of shifting from a system with wheelset maintenance based solely on condemnable criteria to a system with a maintenance strategy to reprofile wheels after a certain service time or mileage.

Please contact **Scott Cummings (719) 584-0739** with questions or concerns regarding this *Technology Digest.* E-mail: scott_cummings@ttci.aar.com.

TTCI Transportation Technology Center, Inc.

INTRODUCTION

TTCI distributed a survey regarding wheel life of heavy haul railroads worldwide. The survey responses were collected from heavy haul railways in countries with diverse climates including Australia, Brazil, South Africa, and Sweden. Wheels are the single most expensive rolling stock maintenance item in North American freight operations, consistently accounting for more than half of all rolling stock maintenance spending.

The main purpose of the survey was to quantify the amount of revenue service mileage obtained per wheel by railroads outside North America. This is a function of several variables including initial rim thickness, maintenance practices, and operating environment. The survey also provided an opportunity to compare and contrast wheel practices of other heavy haul railways. This includes controlling wheel quality from the manufacturer, monitoring wheel condition, and learning about the condemnable conditions and failure modes of wheels.

SURVEY

The survey questions were as follows:

1) Newly manufactured freight car wheels:
   a) Wheel design: Nominal radial rim thickness of a new wheel?
   b) Wheel profile: Nominal flange thickness of a new wheel?
   c) Wheel properties:
      i) If applicable, what AAR wheel class is used (e.g., Class C)?
      ii) Otherwise, what is the hardness range of a new wheel?
   d) Wheel testing:
      i) Is AAR M107/M208 standard used for ultrasonic and microcleanliness testing?
      ii) If not, please provide details regarding ultrasonic and microcleanliness testing of new wheels.
2) Removal and Reprofiling of freight car wheels
   a) Typical number of reprofiling operations during the course of a complete wheel life?
   b) Typical time and/or operating distance between wheelset removal or reprofiling operations?
   c) What triggers a removal or reprofiling?
      i) Time and/or operating distance?
      ii) *AAR Field Manual* rules?
      iii) Other visual inspection and/or physical gauge criteria? (Please describe.)
   d) Percentage breakdown in causes for removal/reprofiling (e.g., flange wear, tread hollow, thin rim, shelling, slid flats)?
   e) Wheel testing
      i) Please provide details regarding any ultrasonic and/or other non-destructive testing of wheels that occurs in conjunction with reprofiling.
3) Service environment of freight car wheels: Typical axle load?
4) Failure modes of freight car wheels
   a) Number of wheels found per year with:
      i) Broken plate?
      ii) Deep shelling/shattered rim?
      iii) Vertical split rim?
      iv) Broken flange?

RESPONSES

TTCI received a total of five surveys. The responses from each individual railway are not listed because it would be possible for a knowledgeable reader to discern the identity of the railway based on some of the responses. Table 1 contains a summary of the responses related to newly manufactured wheels.

Other railways apply new wheels with more rim thickness compared to the single-wear wheels that are common in North America. Interestingly, other railways also apply new wheels with thinner flanges compared to North America even though they expect to reprofile the wheels multiple times. Wheels can be softer or slightly harder than in North America depending on the particular railway. Ultrasonic test criteria spans a wide range of values outside North America. The use of the Distance Amplitude Correction allows the AAR criteria to reject defects of a specific size regardless of their depth in the rim. Specifications that do not require Distance Amplitude Correction will reject the specified defect size at the depth of the calibration defect, but may allow larger defects at different depths in the rim.

Table 1. Newly Manufactured Wheels

Topic	North America	Survey Responses
New wheel rim thickness	Generally 1.5" In some cases 2.0"	2.0 to 2.75" (50 to 70 mm)
New wheel flange thickness	1.375"	1.02 to 1.26" (26 to 32 mm)
Wheel class	Generally C. In some cases D.	B+, C, or modified C
Wheel hardness	321 to 363 Brinell Hardness Number (BHN) for C, 341 to 415 BHN for D	277 to 331 BHN for B+, 321 to 363 BHN for C, 341 to 388 BHN for modified C
New wheel ultrasonic testing	Reject for an indication ≥ 25% of a 1/8" diameter flat bottom hole. Approximately equivalent to 1.6 mm diameter reflector	0.7 mm to 2 mm approximate equivalent diameter of rejectable indicators
New wheel microcleanliness testing	0.1% oxide plus voids average, 0.75% oxide plus voids worst field, 0.75% sulfide worst field	Two railways use AAR specification. One uses their own specification. Two use European specifications

Table 2 contains a summary of the responses related to removal and reprofiling of wheels. The combination of applying new wheels with thicker rims and (in many cases) reprofiling the wheels according to a maintenance planned date or mileage before they reach a condemnable condition allows the responding railways to achieve many more reprofiling operations on each wheel than is typical in North America. The total service life of a wheel in North America can be highly variable depending on a number of factors including type of car, type of service, and type of truck. Unfortunately, in North

America it is difficult to determine the total service miles of a particular wheel if it has been reprofiled because, until recently, no industry-wide records were kept relating the service miles before and after reprofiling. Using a rough estimate of the total average life of a wheel in North American service shows that the responding railways are typically able to achieve approximately twice as many total service miles per wheel (487,500 miles versus 985,000 miles).

Many of the railways use a maintenance plan that calls for reprofiling the wheels at specified time or distance intervals (or in one case, a proxy for service mileage: hollow wear). This allows for a small amount of material to be removed by the lathe; and accordingly, more reprofilings in the life of the wheel. This is somewhat comparable to the grinding of rail at targeted gross tonnage intervals to control shallow crack growth due to rolling contact fatigue and restore the desired rail profile.

Wayside detection combined with visual inspection of wheels is common both in North America and elsewhere. When a wheel does reach a condemnable condition, some survey respondents reported the distribution of tread damage and wear conditions similar to the North American experience. However, two railways reported very small percentages of condemned wheels with tread damage: 5 percent in one case and 18 percent in another case. AAR specifications call for ultrasonically testing each reprofiled wheel before it re-enters service. This is not necessarily the case in other railway systems. Three of the 5 respondents use only visual inspection following a reprofiling operation.

The service environments of the railways that participated in this survey vary greatly in terms of axle load and climate. Axle loads ranged from 27.5 tons (25 tonnes) to 42.5 tons (38.5 tonnes). Typical North American axle load is 36 tons (32.5 tonnes). The climates of these railways offer a significant variety of conditions: from artic, to sub-tropical, to hot and arid. In North America, many cars travel to different climatic regions during their service life.

Reported train speeds in the survey responses ranged between 37 and 50 mph (60 and 80 km/hr). North American freight train speeds cover this range and can reach faster speeds as well in some services.

Wheel failures occur rarely, if ever, among the railways surveyed according to their responses. Broken plates, broken flanges, and shattered rims were mentioned by some railways either as rare but recurring issues or as problems that arose at a specific time. Vertical split rim (VSR) reportedly do not occur on three of the responding railways (although one of these did specifically mention VSR as something they look for during visual inspection). One railway reported one VSR in the past 5 years. Another railway reported that VSR occurrences are "very rare," implying that they do occur. When considering North American wheel failures, it is important to keep in mind the scale of the system. In 2014, there were 37,193,000,000 freight car miles operated by Class I railroads in the United States alone.[6] That same year, there were a total of 453 broken or cracked wheel rims, wheel flanges, or wheel plates reported through the AAR Car Repair Billing system.[7] A multiplier of 1.5 is typically used projecting industry-wide values from this database, 453*1.5=680. This gives an estimated rate of 55,000,000 freight car miles operated per cracked or broken wheel. Although a similar rate on a system with a smaller scale would result in fewer failures, it would not likely be categorized as "rare" or "very rare."

Table 2. Removal and Reprofiling of Wheels

Topic	North America	Survey Responses
Number of reprofiling operations in the life of a wheel	Generally 0 or 1. In some cases 2.	3 to 8
Typical time between reprofilings	Highly variable	2 to 3.5 years
Typical operating distance between reprofilings	Generally 200,000[2] to 450,000 miles[3,4]	115,000 to 315,000 miles (185,000 to 505,000 km)
Approximate calculated total operating distance for wheel (Number of lives × Service miles per life)	1.5 lives × 325,000 miles/life = 487,500 miles (785,000 km)	775,000 to 1,160,000 miles (1,250,000 to 1,870,000 km) Average: 985,000 miles (1,585,000 km)
Trigger for reprofiling	Generally a condemnable condition as found by wayside detector or visual inspection	0% to 82% reprofiled as part of the regular maintenance strategy (no condemnable condition). Condemnable conditions are found by wayside detectors and visual inspections
Condemnable Conditions	67% tread damage, 27% wear, 6% other[5]	5% to 83% tread damage, 17% to 95% for wear
Ultrasonic testing at reprofiling shop	Reject for an indication ≥ 25% or ≥ 50% of a 1/8" diameter flat bottom hole depending on radial depth.	Three railways rely on visual inspection only. One railway performs ultrasonic and residual stress testing if more than 0.5" rim material has been worn or cut from the radius. Another railway uses ultrasonic testing to check for tread surface cracks.

DISCUSSION

The wheel survey revealed several notable differences between North American freight operations and railways elsewhere. Four of the five survey respondents reported using a maintenance strategy whereby the wheelsets are reprofiled after they have reached a certain time or mileage in service rather than waiting until one or both wheels on the wheelset reached a condemnable condition.

This strategy allows for less material removal during reprofiling, which in turn allows for more reprofilings in the life of the wheel. This maintenance strategy in combination with thicker rim wheels, allows the surveyed railways to achieve close to 1,000,000 service miles per typical wheel — about twice as much service life as a typical wheel used in North American freight operations. In exchange for a longer wheel life, these railways spend more time and effort removing, reprofiling, and re-installing wheelsets.

Of the subgroup of wheels that reach a condemnable condition before reaching the program maintenance time or mileage level, three of the five respondents reported a similar distribution of condemnable causes compared to the North American experience: 67 percent tread damage, 27 percent wear, 6 percent other.[5] The two other respondents noted a dramatically lower percentage of condemnable wheels due to tread damage and a correspondingly higher percentage of condemnably worn wheels. One of these respondents follows the AAR M-107/M-208 criteria for ultrasonic and microcleanliness testing of new wheels and uses axle loads higher than in North America. The other respondent uses different criteria that are generally stricter than the AAR M-107/M-208 criteria, but uses axle loads that are lower than in North America. One of these railways reports using steering trucks with relatively straight track, which may help explain the extremely low percentage of wheels that develop tread damage.

The rejection levels for ultrasonic testing of new wheels spanned a wide range between reflectors with approximate equivalent diameters of 0.7 to 2 mm. This is in comparison to AAR rejection criteria with an approximate equivalent diameter of 1.6 mm and the use of a Distance Amplitude Correction designed to reject the specified defect size at different depths in the rim.

CONCLUSION

A survey of heavy haul railways in Australia, Brazil, South Africa, and Sweden shows the following in comparison to the North American freight railroading experience:

- Typical wheel life is approximately doubled due to a combination of application of wheels with thicker rims and a maintenance strategy to reprofile wheels after they have reached a certain service time or mileage requiring less material removal on the reprofiling lathe.
- Ultrasonic and microcleanliness test criteria for new wheels range from more stringent to less stringent than AAR M-107/M-208.
- Wheel failure rates (broken rim, broken flange, and broken hub) are typically described as “none,” “very rare,” or “rare.”

FUTURE WORK

This survey was the first in a series of steps to evaluate methodologies to optimize wheel life in the North American freight railroading environment. Additional steps include evaluating the effects of thicker rims on new wheels and evaluating the potential effects of shifting from a system with wheelset maintenance based solely on condemnable criteria to a system with a maintenance strategy to reprofile wheels at a certain service time or mileage.

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