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Possible Root Cause for High Conicity Wheel Profiles on Grain Cars Associated with Loaded Car Hunting

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Summary

Data from dynamometer tests suggests that some brake shoes may wear the wheel tread to a degree that the contact conicity is increased to levels adversely affecting the hunting stability of vehicles in general and that of loaded grain cars in particular. Worn wheel profiles and dynamometer wheel tread and shoe wear data were examined to substantiate this conclusion.

Worn wheel profiles suggest that there are two regions of wear: traditionally, that in the flange due to high rail contact and then a region of hollow wear on the tread, resulting mainly from brake shoe contact. These regions are separated by a region of relatively unworn tread in the flange fillet, and this unworn region is the cause for the high contact conicities associated with these wheels.

Consequently, aggressive brake shoe wear is seen to be the root cause of high conicity wheel profiles associated with loaded car hunting.

The conicity associated with the worn wheel tread plays a critical role in the hunting stability of the vehicle and its tangent tracking ability, which impacts wheel flange wear life. Control of the worn tread shape is essential to vehicle performance and to the parameters used to specify the performance of the vehicle.

Transportation Technology Center, Inc. has been tasked to identify the root causes for loaded car hunting and unusual wheel wear patterns on M-976 trucks including asymmetric wheel flange wear. The work is being conducted through the Association of American Railroads' Strategic Research Initiatives Program.

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INTRODUCTION

The investigation by Transportation Technology Center, Inc. (TTCI) into the root causes for loaded car hunting identified unusually high contact conicities as one contributing factor.[1,2] Conicities as high as 0.65 were calculated when the wheelsets contacted track having a relatively tight gage and with rails having "flat" head profiles and material flow to the gage corner.

Examination of a number of these profiles in comparison with the new AAR-1B profile (Figure 1) suggested:[1,2]

- Accelerated flange wear associated with initial two-point contact with the high rail profile in curves
- Apparent high tread wear, which was not explained in the references
- A region of low profile wear in the flange fillet between the two regions of high wear. Again, this was unexplained, but was associated with the generation of observed high conicities when contact was made in this region.

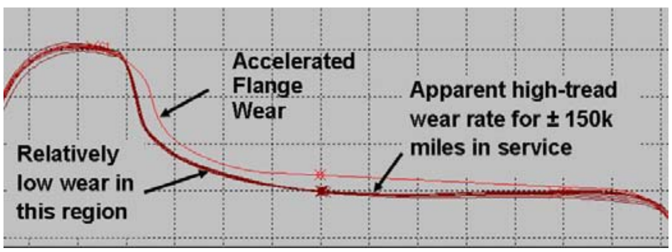

Figure 1. Worn Grain Car Profile in Comparison with the New AAR-1B Profile

Further comparison based on mileage suggested that there was a certain uniqueness associated with the profiles from these cars (termed Gen 2 and fitted with M-976 trucks) when compared with other car types (Figure 2):

- Up to 250,00 miles, most profiles showed a conicity in the range 0.4 to 0.65, which is high and very unusual.
- Similar grain cars (termed Gen 1 and fitted with non-M-976 trucks) generally showed conicities in the range 0.05 to 0.4.
- Coal cars fitted with M-976 trucks and in the range of 300,000 miles showed a range of conicities between 0.05 and 0.5.

During an investigation into asymmetric wheel flange wear, it was hypothesized that tread wear, originating from the brake shoes, together with laterally asymmetric forces on the brake beam, may be the root cause for asymmetric wheel flange wear.[3,4,5] An examination of limited data from Association of American Railroads (AAR) shoe certification tests (i.e., dynamometer wheel profile measurements in combination with shoe wear measurements) suggested that shoe wear could have a significant influence on wheel profiles after some 300,000 miles.[5]

This observation led to the re-examination of the profiles associated with loaded car hunting.

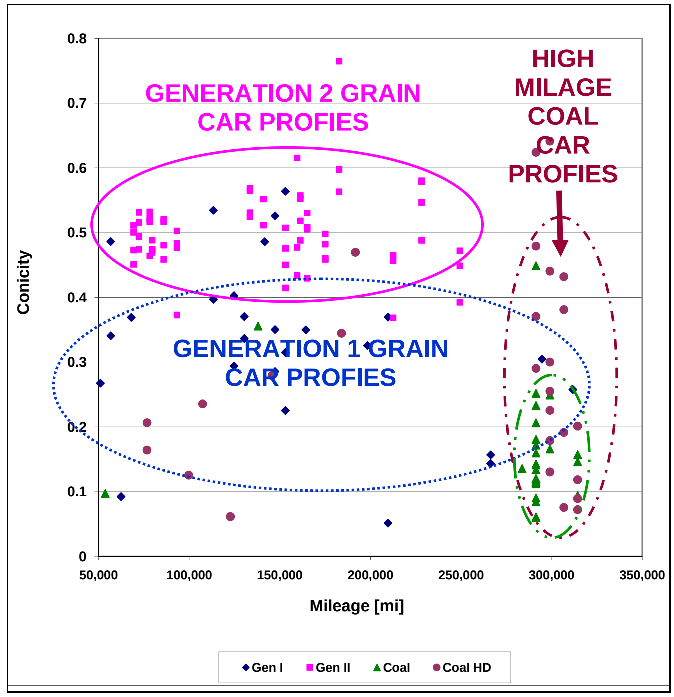

Figure 2. Measured Contact Conicities of Different Car Types with Respect to Mileage

There is a need to establish and control the magnitude of contact conicities in service. High conicities in excess of the so-called KR profile used in certification tests[6,7] can lead to in-service hunting instability in empty, loaded, and partially loaded conditions. The design of a truck, current trucks and in particular, the so-called integrated freight car truck being developed conceptually under the current Strategic Research Initiatives Program, could be severely impacted by the demand for acceptable dynamic performance under high conicity conditions.

Consequently, the establishment of the root cause for high conicity wheel profiles and the establishment of possible means to control contact conicities are critical to the development of car and truck standards and designs in North America.

This *Technology Digest* (TD) suggests that a possible root cause for high contact conicities is the action of the brake shoe on the wheel tread and suggests means to verify the hypotheses made. A future TD will address means to control contact conicities based on the assumption that shoe/tread interaction is a root cause.

TREAD WEAR ATTRIBUTABLE TO BRAKE SHOES

AAR certification reports on tests conducted on the brake dynamometer at TTCI quote, amongst others, the wear resulting from the specified grade and stop tests.

A dynamometer wheel is machined to a cylindrical shape (Figure 3) for each shoe type tested. The shoes used during the test are each machined to fit the wheel. Both drag and stop tests are conducted, each with three shoes chosen from a batch.

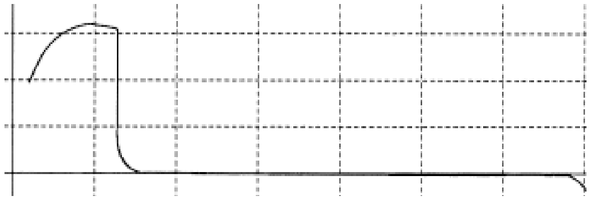

Figure 3. Dynamometer Wheel Profile before the Test

Shoe wear results are quoted in terms of shoe volume lost in inches for each shoe; the change in shoe thickness can be derived from knowledge of the bearing area between tread and shoe, and from some test results examined is generally between 0.003 and 0.02 inch per shoe, depending on the type of shoe used.[3]

Some test reports provide Miniprof™ profiles of the wheel profile before and after the test using three shoes. The difference in profile is then shown (Figure 4). Zero indicates zero wear.

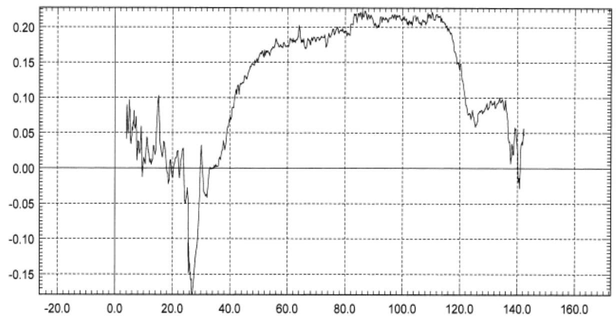

Figure 4. Difference in Dynamometer Wheel Profile (wear)

Consequently, this profile gives an indication of profile wear after three shoe applications; this may be said to be the equivalent of 3 times the wear of one of the three shoes.

Figure 3 shows the tread wear:

- Of 0.2 millimeter (7.9/1,000 inch) maximum
- Resulting from the equivalent shoe wear of 3x0.003 inch (a particularly wear-resistant shoe)

The shoe thickness was 1.875 inches. With a condemning thickness of 3/8 inch (0.375 inches), the projected shoe life might then be estimated as the equivalent of:

$$(1.875-0.375)/\ 0.009 = 166 \text{ brake shoe tests}$$

Consequently, in the life of a shoe, the equivalent tread wear for one shoe life might be projected to be:

$$166 \text{ x } (7.9/1{,}000 \text{ inch}) = 1.3 \text{ inches}$$

This projection appears to be overly pessimistic in predicting tread wear. One reason that this order of wear is not seen in service may be that the dynamometer wheel did not experience work hardening due to rail/wheel contact. Nevertheless, the results suggest:

- The shoe that was tested wore the wheel tread aggressively.
- Developed a wear shape on the tread of the dynamometer wheel which is similar to that seen on the service-worn wheel tread depicted in Figure 1 (see also the next section).

TREAD WEAR SHAPE AS A POSSIBLE CONSEQUENCE OF SHOE WEAR AND RAIL CONTACT

Given the typical pitch between brake shoe across a brake beam and the typical width of shoe and assuming centralized contact of the beam with respect to the wheel set,[5] Figure 5 shows the approximate contact between a shoe and the worn tread of a measured grain car profile.

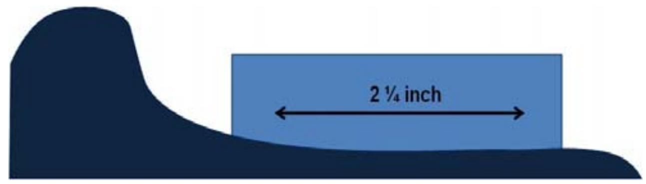

Figure 5. Approximate Contact between Shoe and Tread

Figure 3 indicates that tread wear is not evenly distributed across the width of the shoe; it may reach approximately 80 percent of the maximum rate between 10 and 20 millimeters (i.e., ½ inch) from the flange side and field side edges of the shoe. The shoe is approximately 2 ¾ inches wide. Consequently, if tread wear is dominated by shoe/tread contact, the deepest portion of tread wear in Figure 5 should be approximately 2 ¼ inches wide as indicated. This suggests a strong relationship of the tread wear observed with shoe contact.

Figure 6 shows the new wheel contacting the high rail.[1] It has been inverted to show the wheel in the same sense as Figures 1 and 5.

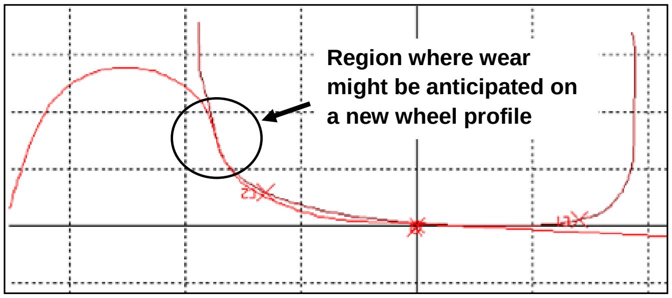

Figure 6. Wear Region on the Flange of the New Wheel Resulting from High Rail Contact

This region accords with that of accelerated flange wear indicated in Figure 1.

The only region with reduced wear is that where neither the shoe/tread or flange/high rail contact occurs, although contact commences with wheel wear as described in Reference 1 (Figure 7), and it may be argued that delayed contact and the fact that this is single-point contact is the reason that wear has not been as aggressive as on other parts of the profile.

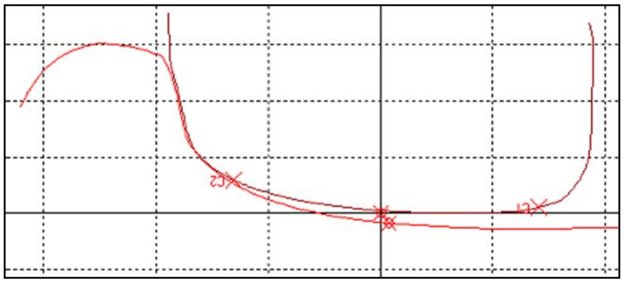

Figure 7. Contact of the Worn Wheel on the High Rail

Figure 8 shows the difference in profile between two asymmetrically wheel profiles on the same wheel set and the original AAR-1B profile. It also indicates the possible position of the shoes on each tread from the shape of the hollow wear toward the field side of the tread. Flange contact has resulted in high wear rates on the tread of the flanging wheel, which is to be expected with two-point contact. This is further evidence of the action of the shoe on the tread.

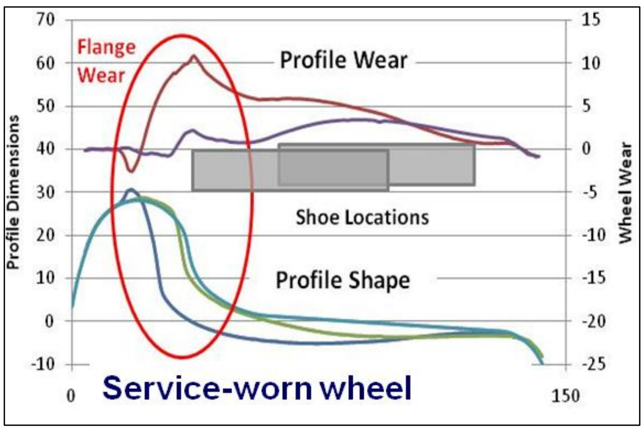

Figure 8. Contact of the Worn Wheel on the High Rail

CONCLUSIONS

- Observations and measurements from brake dynamometer tests suggest that there can be aggressive contact resulting in tread hollow wear larger than traditionally anticipated with wheel/rail contact.
- This wear could account for the apparent high tread hollowing rate observed on wheels from grain cars subject to loaded car hunting.
- Flange wear on these profiles is still attributed to two-point contact with the worn high rail.
- These two wear regions are linked by a region of apparent low wear in the fillet of the flange; this region accounts for the high (up to 0.65) conicities measured in service.
- Consequently, aggressive brake shoe wear may be the root cause of high conicity wheel profiles associated with loaded car hunting.
- Observations are inconclusive because the portion of the worn tread under consideration is shared by both shoe and rail contact. Recommendations are made to further verify the role of shoe contact on the shape of the worn wheel tread.
- These conclusions need further verification through:
  - Extended dynamometer tests of the effects of different brake shoes
  - Comparative in-service monitoring of wheels subject to shoes with differing aggressiveness

RECOMMENDATIONS AND FUTURE WORK

- Conduct the dynamometer tests and controlled in-service comparative tests mentioned in the conclusions.
- Place a limit on the aggressiveness of brake shoes.
- Evaluate the effectiveness of tread-conditioning shoes with respect to the degree of aggressive tread wear produced.
- Investigate a means to control tread hollowing given a certain degree of shoe aggressiveness. This will be the subject of a further TD in reaction to this TD and the one on asymmetric wheel flange wear.[3]
- Seek a better understanding of the role of brake shoes on wheel tread hollowing before altering specifications quoting contact conicities.

It should be noted that loaded car hunting is a system problem associated with vehicle dynamic properties as well as contact conicities. Consequently, the control of contact conicity is seen as only a partial solution to the problem, and vehicle dynamic properties require attention.

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