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A Review of the Root Causes for Loaded Car Hunting

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Summary

Loaded hunting has been found to be a system problem associated with:

- A low truck warp restraint, which is a consequence of friction saturation at the suspension wedges arising from resonance of the loaded grain carbody on the secondary suspension of the car
- The resonance of the loaded grain carbody, which is a consequence of the inertial characteristics of the body, the vertical and lateral suspension characteristics of the car, and the high conicities encountered on certain track with particular rail profile shapes and tight gage

Currently, cars with degraded adapter pads are being fitted with standard adapters. This action is endorsed as an interim measure, but will result in less than optimal tracking performance on both tangent and curved track.

Also, a stiffer, more durable adapter pad is being tested in revenue service. An Association of American Railroads' (AAR) specification for adapter pad stiffness and durability is recommended.

In addition, a project is in process to evaluate the effectiveness of a systems approach to the problem, which considers the costs and benefits associated with a combination of improved rail and track maintenance, together with a truck design that has improved warp restraint and improved tracking performance on both tangent and curved track.

This work was conducted by Transportation Technology Center, Inc. under the direction of the AAR as part of its Strategic Research Initiatives Program.

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INTRODUCTION

Loaded car hunting has been experienced on 286,000-pound grain cars equipped with AAR M-976 trucks resulting in accelerated adapter pad degradation. Vehicle hunting can cause damage to other vehicle components, to the track and track components, and increases the risk of derailment.

Transportation Technology Center, Inc. (TTCI) was tasked under the AAR's Strategic Research Initiatives Program to establish the root causes for loaded hunting and to provide remedies for this phenomenon. TTCI has conducted tests and analyses to establish these causes. This *Technology Digest* reviews findings and recommendations; detailed results are reported separately.[1,2]

LOADED HUNTING TESTS

Tests at Transportation Technology Center established the stability threshold speeds for the grain cars under various conditions. Table 1 shows the significant results of these tests: loaded and empty, with different wheel profiles and different adapter pad stiffness.

Table 1. Threshold Speeds for Grain Cars

Wheel Profile	Empty	Loaded		
	Standard Pads		Stiff Pads	Standard Adapters
Worn	65 mph	47.5 mph	65 mph	70 mph
KR	80 mph	65 mph	75 mph	80 mph
AAR 1-B	>80 mph	75 mph	80 mph	80 mph

Conclusions are that the loaded hunting speed threshold:

- Is lower than that for the empty car
- Increases with decreasing conicity; the conicity on TTC tangent track is between 0.6 and 0.7 for the worn wheel, 0.2 for the KR profile, and 0.05 for the new AAR 1-B profile
- Increases with pad stiffness and is a maximum for a truck fitted with standard adapters. It reduces with increasing ambient, and thus pad, temperature

WHEEL PROFILE ANALYSIS

Wheel profiles were measured on a number of grain cars in revenue service. The average flange thickness of these wheels is plotted against service miles in Figure 1.

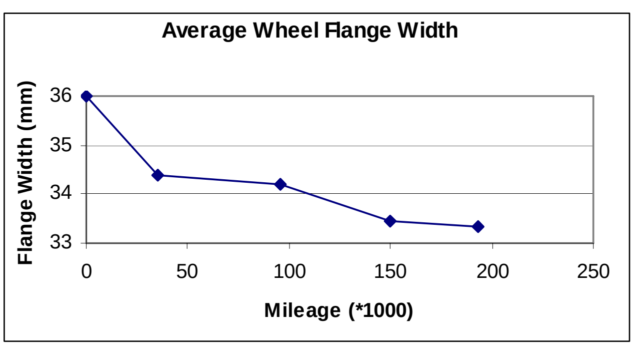

Figure 1. Average Flange Thickness vs. Service Mileage

The accelerated flange wear during the first 120,000 miles was attributed to two-point contact between the new AAR-1B wheel profile and the worn high rail (Figure 2); the worn high rail is representative of a large number of worn high rails measured in curves of varying radius on track in revenue service.

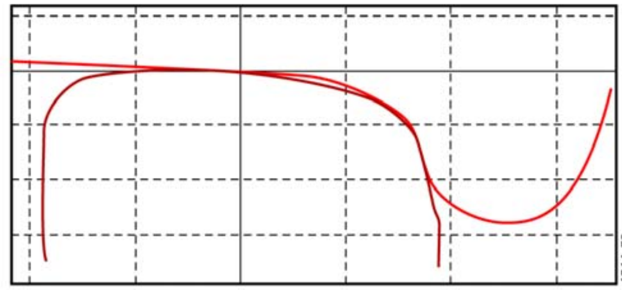

Figure 2. Flange Contact: New AAR 1B Wheel Profile and Worn High Rail

After approximately 120,000 miles, this rate reduced to almost zero, which was attributed to the elimination of two-point contact on the high rail.

Reduced two-point contact, while improving vehicle curving, resulted in increased conicities on tangent track up to 0.7 at TTC. Loaded hunting, as described in the Rail Profile and Vehicle Dynamic Analyses sections, is found to be attributed to high conicity conditions.

A question that remains is whether the worn wheel tread shape resulting in high conicities is unique to cars with AAR M-976 trucks or not. A limited survey was made of wheel profiles on 286,000-pound coal cars with identical trucks.[1] The survey suggests that wheel profile shapes may be a function of car type and/or service. The cause for this relationship is unclear; it is recommended that this be a subject for future research.

RAIL PROFILE ANALYSIS

TTCI wheel/rail geometry measurement equipment and analysis (WRCI™) software was used to measure track geometry and rail profiles on routes where the cars are known to operate. Results were as follows:

- The worn high rail shape in Figure 2 was confirmed.
- All *tangent* rail profiles resulted in low conicities when contacting the *new* wheel and were not attributed to loaded hunting.
- *Worn* tangent track and rail (Figure 3) indicated:
  - Low conicities on worn and previously ground tangent rail
  - High conicities of up to 0.7 on new rail, rail with a "flattened" crown, or rail with material flow to the gage corner of the track; this was exacerbated when in combination with tight gage

High conicity conditions were only encountered on approximately 10 percent of the track measured suggesting that these conditions may be treated by:

- Introducing a profile for new rail closer in shape to that of the high rail; this is currently in process for a number of rail sections to improve contact stress conditions and should be extended to all remaining rail sections

- Grinding of rail with flattened crowns and material flow to the gage corner. It may be argued that the high conicities encountered on new rail result in high stresses and creep and contribute to crown flattening and material flow to the gage corner, and that a modified rail profile will reduce the need for subsequent rail profile maintenance interventions.

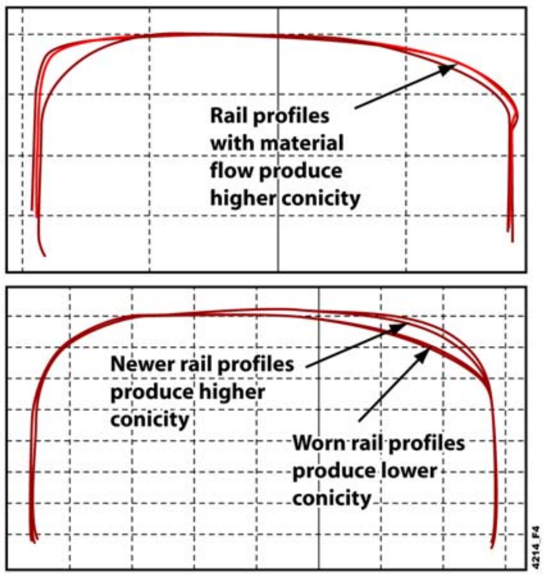

Figure 3. Measured Rail Profiles

The question remains, however, as to why the loaded car is unstable and whether the suspension is adequate for all revenue service conditions. A dynamic analysis was conducted in answer to this question.

VEHICLE DYNAMIC ANALYSIS

Modes of motions of the car and suspension were analyzed:

Modal Results from On-Track Tests at TTC

The results of the on-track tests at TTCI showed the following motions:

- The carbody oscillated in a yaw-dominated mode coupled to upper body roll.
- This motion was almost exactly in phase with the yaw motion of the wheelsets in the lead truck, with a frequency approximating the kinematic frequency to be expected from a wheelset with a conicity of 0.7 (Figure 4).

The yaw motion of the lead wheelset could be attributed to two components:

- Truck warp (60% of the wheelset yaw motion)
- Truck rotation (40% of the wheelset yaw motion)

One percent of the motion of the lead wheelset could be attributed to longitudinal motion of the adapter within the pedestals.

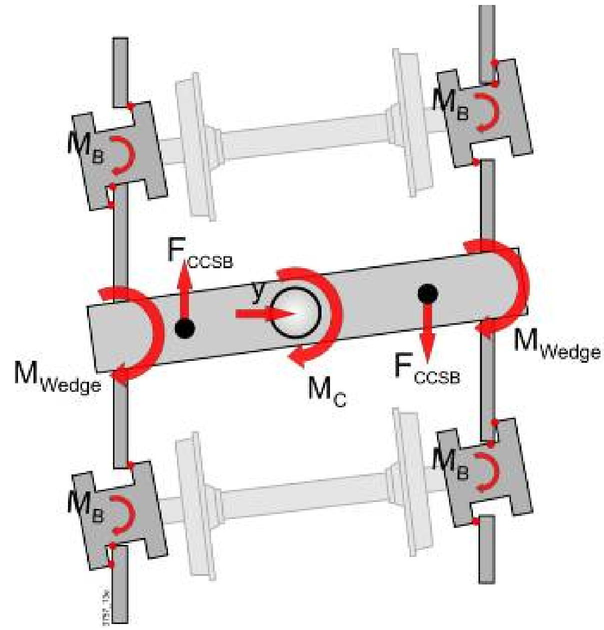

Figure 4. Motion of the Lead Truck in Loaded Hunting

It appeared as if truck warp was:

- Due to the moments created by both wheelsets in the truck when these wheelsets were displaced laterally on the track
- With little longitudinal motion taking place at the adapters
- With longitudinal motion of the side frames in opposite (warp) senses; the side frames being held with insufficient warp restraint to the bolster through the secondary suspension of coil springs and wedges and to the rotational constraints provided by the adapter pads
- With some of the longitudinal side frame motion translated into bolster yaw, the bolster rotational constraint to the body through side bearings and center plate not being designed for, or sufficient to restrain bolster rotation

Removing the adapter pads increased the hunting threshold, presumably because of the increased moment provided by the frictional restraint between the adapter and pedestal roof (M_B in Figure 4).

Laboratory Tests of the Truck Warp Restraint

The truck warp constraint was measured in the laboratory. It did not differ much from previous tests on trucks of similar type.[3] The average warp restraint was found to be 140,000 lb/inch/mrad per spring nest.

During this test, the carbody is bounced vertically at a frequency of 2 Hz. This frequency was appreciably higher than that for the warp input. TTCI observed that under the maximum vertical suspension velocity in this bounce mode, the warp constraint seemed to reduce significantly.

Consequently, this test was repeated and the truck was manually warped in phase with the vertical bounce frequency. The warp restraint reduced appreciably to approximately 12,500 lb/inch/mrad per spring nest, a reduction in warp restraint by a factor of approximately 11.

This led to the hypothesis that the friction at the suspension wedges, which was responsible for both vertical and lateral damping as well as providing warp restraint, was saturating under test when the vertical and warp motions coincided.

This hypothesis could not be fully verified as the current warp test configuration does not lend itself to an automated in-phase warp and vertical or lateral suspension motion. Nevertheless, it would explain the observed breakdown in warp stiffness and progression of dynamic modes:

- The wheelsets are deflected from the center of the track at some form of track discontinuity.
- Restoring yaw forces are generated at the wheelset
- The restoring motion of the wheelsets causes the carbody to move laterally and vertically relative to the side frame in a yaw and roll mode.
- Friction saturates at the wedges, reducing the warp restraint allowing the truck to warp and the wheelsets to yaw with a larger amplitude, closer to the kinematic frequency of the wheelsets; stiffer pads and steel adapters increase the warp restraint to provide the observed improved stability.
- The kinematic frequency of the wheelsets with worn wheels and 0.7 conicity equals the frequency of the loaded grain carbody in a yaw dominated mode at approximately 47 mph.
- The yaw motion of the grain carbody is under damped because of friction saturation and hence resonance takes place between the body and the wheelsets in yaw.

This explanation accounts for the:

- Breakdown of the warp restraint
- Resonance of the carbody wheelset and truck warp
- Sensitivity of loaded hunting to conicity
- Low hunting thresholds encountered in the loaded car

NUCARS® Analysis of the Car and Truck System

NUCARS analyses[1] confirmed many of the above conclusions. These analyses showed:

- The dependence of loaded hunting on low truck warp constraint. If the truck warp was increased, loaded hunting did not occur; indeed, the stiffness of the adapter pads could be somewhat reduced without loaded hunting if the truck warp constraint was sufficiently high.
- The dependence of loaded hunting on a combination of high conicity and a low carbody natural yaw frequency. Lower conicities resulted in stable running. For a given conicity, shorter carbodies showed higher hunting speed thresholds, as the excitation frequency provided by the wheelsets was required to be higher, which can only be provided by wheelsets with a higher conicity, or by running at a higher speed.
- For a given warp constraint, stiffer adapter pads resulted in an increased loaded hunting speed threshold.

CONCLUSIONS

Loaded hunting is a system problem associated with:

- A low truck warp restraint, which is a consequence of friction saturation at the suspension wedges arising from resonance of the loaded grain carbody on the secondary suspension of the car
- The resonance of the loaded grain carbody is a consequence of the inertial characteristics of the body, the vertical and lateral suspension characteristics of the car, and the high conicities encountered on certain track with particular rail profile shapes and tight gage

RECOMMENDATIONS

Currently, cars with degraded adapter pads are being fitted with standard adapters. This action is endorsed as an interim measure, but will result in less than optimal tracking performance on both tangent and curved track. Also:

- A stiffer, more durable adapter pad is being tested in revenue service. This pad has hunting characteristics similar to that depicted under “stiffer pads” in Table 1. A specification for adapter pad stiffness and durability is recommended.
- Loaded car hunting can be reduced by selective grinding of sections of tangent track showing high conicities.
- The AAR M-976 specification should be updated to include a provision for testing for loaded car hunting and a specification developed describing durability requirements for adapter pads.

In addition, a project is in process to evaluate the effectiveness of a systems approach to the problem, which considers the costs and benefits associated with a combination of improved rail and track maintenance, together with a truck design that has improved warp restraint and improved tracking performance on both tangent and curved track.

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