TECHNOLOGY DIGEST

TD-08-021
©JUNE 2008

TIMELY TECHNOLOGY TRANSFER

The work described in this document was performed by Transportation Technology Center, Inc., a wholly owned subsidiary of the Association of American Railroads.

Effect and Formation of Asymmetrically Worn Wheels

Huimin Wu and Benjamin Madrill

Summary

Freight car wheelsets with asymmetric wheel wear between wheels on the same axle have been observed in revenue service. Once asymmetric wear reaches certain levels, vehicle performance can be adversely affected. Additionally, asymmetric wheel wear can lead to a significant decrease in wheelset service life (30 percent reduction or more) compared to the service life of a wheelset with symmetric worn wheels.

As part of the Association of American Railroads' Strategic Research Initiatives Program for improving wheel life, Transportation Technology Center, Inc. has conducted a study on the effects and formation of asymmetric worn wheels.

Two predominant asymmetric wheel wear patterns were noticed. Pattern 1 showed that both wheels on one side of the truck had more flange wear than the wheels on the opposite side. For Pattern 2, diagonally opposite wheels showed more flange wear than their counter part diagonal wheels.

On tangent track, trucks with Pattern 1 wheels continually shifted to one side of the track with wheels in constant flange contact. This shift further aggravated the asymmetric wear pattern of the wheelsets.

Trucks with Pattern 1 wheels curve poorly in one direction because of negative rolling radius difference (RRD) between the wheels mounted on the same axle, but tend to curve well in the reverse direction because of positive RRD. The trucks with diagonal wear Pattern 2 wheels have higher rolling resistance on both curve directions compared to trucks with symmetric worn wheels. Trucks with either asymmetric wear patterns produce higher wear on tangent sections of track than trucks with symmetric worn wheels.

Contributing factors that cause asymmetric wheel wear include warped truck, imbalance load, inconsistent rail lubrication, uneven brakes, and other causes for wheelsets operate at off-center or abnormal positions.

To prevent asymmetric wheel wear, the root-causes need to be identified and corrected, which may involve changes in both operational practices and car maintenance. Simply turning asymmetrically worn wheelsets will not solve the problem, and the new wheelsets may again wear to similar asymmetric patterns.

As wayside wheel profile measurement systems begin to be deployed on revenue service lines, the early stages of asymmetric wheel wear may be detected by defining an asymmetric wear criterion. A preliminary asymmetric wear criterion for the inspection system is suggested herein.

Please contact **Huimin Wu (719) 584-0533** with questions or concerns regarding this *Technology Digest.* E-mail: Huimin_Wu@ttci.aar.com.

INTRODUCTION

Freight car wheelsets with asymmetric wheel wear have been observed in revenue service. Figure 1 shows an asymmetrically worn wheelset removed from a truck. The flange on the left wheel is much thinner than the flange on the right wheel. Figure 2 shows the asymmetric wheel profiles measured on the truck. Two predominant types of asymmetric patterns were noticed. Pattern 1 shows that wheels on one side of the truck wore more than the wheels on the opposite side. For Pattern 2, one set of diagonal wheels wore more than the opposite set of diagonal wheels.

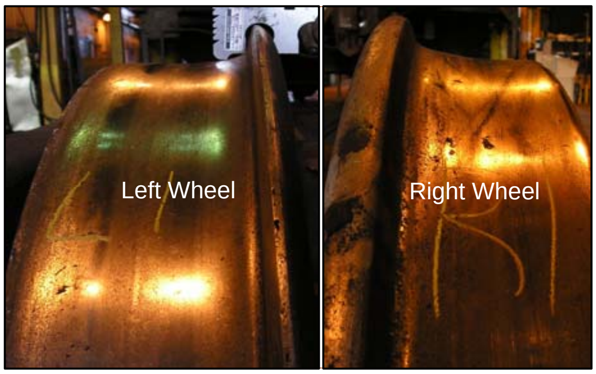

Figure 1. Asymmetrically Worn Wheelset

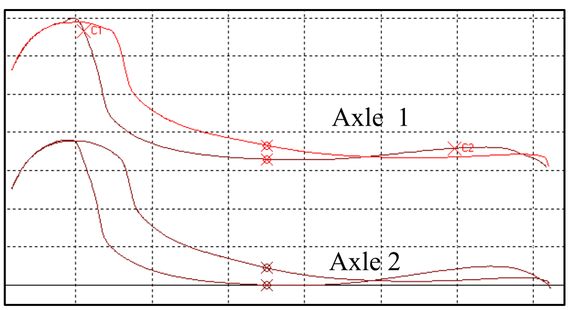

Figure 2. Measured Asymmetric Wheel Profiles

The work presented here discusses the performance of those wheelsets that have reached a certain asymmetric wear level. The asymmetric wheels used for curving simulations, using NUCARS®,* have a 0.12-inch (3-mm) radius difference at the tape line and a 0.12-inch (3-mm) flange width difference measured at 0.6-inch (12.2-mm) down from wheel flange tip. The wheels are still not condemnable.

EFFECTS OF ASYMMETRICALLY WORN WHEELS

Severe asymmetrically worn wheels can affect the vehicle performance significantly both on tangent and curved tracks.

On Tangent Track

The trucks running on tangent track with Pattern 1 wheels can shift to one side of the track with wheels in constant flange contact, as Figure 3 shows. To reach a rolling radius equilibrium position, the wheels with more flange wear tend to go into flange contact on one side of the rail. This tendency further aggravates the asymmetric wear pattern of the wheels.

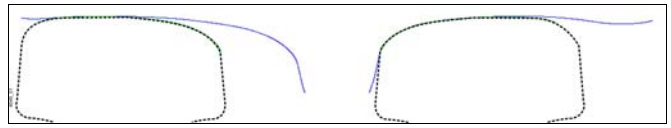

Figure 3. Asymmetrically Worn Wheel on Tangent Track

The asymmetric wheel wear may also induce higher conicity in certain wheelset lateral shift ranges affecting vehicle lateral stability, as exemplified in Figure 4. This asymmetric wheelset reaches a zero RRD at a lateral shift position about -0.1 inch. Under any track perturbations or vehicle dynamic influence, the wheelset can experience higher conicity (0.83) in the negative shift and lower conicity in the positive shift (0.25).

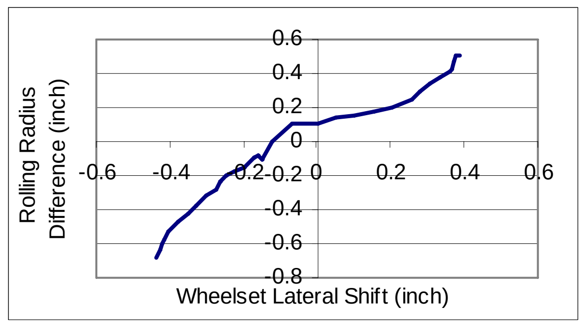

Figure 4. Asymmetric Conicity

In Curving

RRD is required between left and right wheels for properly negotiating curves because the wheel on the outer rail (high rail) needs to travel a longer distance than the wheel on the inner rail (low rail). This requirement is generally met with newly tapered wheels and regularly worn wheels.

However, this requirement may not be met with asymmetrically worn wheels. The trucks with asymmetric Pattern 1 wheels curve poorly in one direction of curves because of negative RRD, but curve well in the reverse direction of curves because of positive RRD (Figure 5).

To quantify the RRD, wheel-rolling radii at high rail top, high rail gage, and low rail are referred to as RR1, RR2, and RR3, respectively.

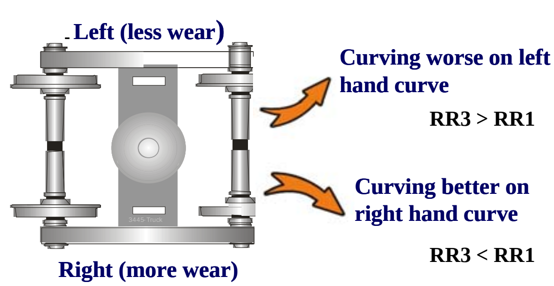

Figure 5. Truck Performance with Asymmetric (Pattern 1) Wheels

* NUCARS® is a registered trademark of Transportation Technology Center, Inc.

Figure 6 compares the rolling resistance produced by symmetric and asymmetric (Pattern 1) wheelsets. The NUCARS simulation was conducted using a 110-ton hopper car negotiating two reversed 6-degree curves.

In the first curve, the asymmetrically worn wheelset has a rolling radius on the low rail (RR3) 0.08 inch (2 mm) larger than the rolling radius on the high rail (RR1). This leads to a poor curving performance, indicated by very high rolling resistance that is more than double of the symmetrically worn wheelsets. In the second reverse curve, the wheel rolling radius of asymmetrically worn wheelsets on the low rail (RR3) is 0.3 inch (7.6 mm) smaller than the rolling radius on the high rail (RR1), which leads to a considerably lower rolling resistance. The RRD for the symmetrically worn wheelset in Figures 6 and 7 is 0.29 inch (7.3 mm) (RR3 < RR1) for both curving directions.

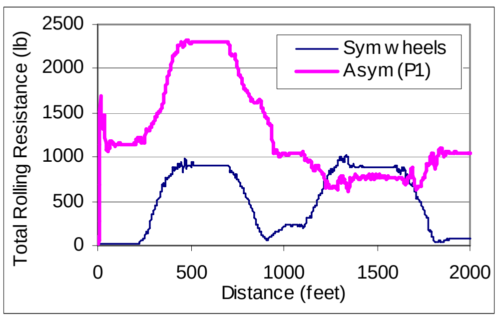

Figure 6. Comparison of Rolling Resistance between Symmetrically and Asymmetrically (Pattern 1) Worn Wheels

Figure 7 displays the simulation results for symmetric wheels versus asymmetric Pattern 2. Pattern 2 wheels had higher rolling resistance on both curves compared to the symmetrically worn wheels. Note that both asymmetric patterns produce higher rolling resistance on tangent sections (Figures 6 and 7).

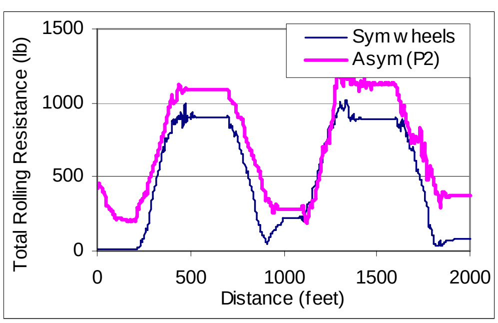

Figure 7. Comparison of Rolling Resistance between Symmetrically and Asymmetrically (Pattern 2) Worn Wheels

Wheel/Rail Life

Compared to symmetrically worn wheels, the life of the asymmetrically worn wheelsets can be reduced 30 percent or more based on wheel measurements taken from wheelsets with known operating mileages. Since wheel replacement has to be done by replacing the entire wheelset, there is a significant waste of material on the less-worn wheel and an overall decrease in the useful life of the wheelset.

The asymmetrically worn wheels also cause excessive rail wear on both tangent track and curves. Reduction in rail life depends on the population size and asymmetric wear level of passing wheelsets.

FORMATION OF ASYMMETRICALLY WORN WHEELS

Warped Truck

Warped trucks, as Figure 8 illustrates, appear to be a main cause of asymmetrically worn wheels. Both the leading and trailing axles of a warped truck tend to have large angles-of-attack relative to the rail. As a result, one wheel may experience flange contact with the rail even on tangent track. Normally the truck will curve well in one direction and poorly in the other direction.

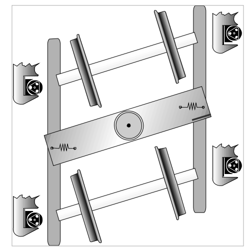

Figure 8. Warped Truck

The main causes of warped trucks include:

- Excessive friction wedge wear (indicated by high wedge rise) that reduces the truck warp restraint.
- Carbody twist that may cause center plate edge contact inducing a high turning moment.
- High friction at truck center plate interface due to very dry interface, surface damage, or external object insertion.
- High friction at side bearings resulting in high-turning moment.

Imbalance Load

Imbalance load (side-to-side) may happen due to improper loading or edge contact on the truck center bowl/carbody center plate due to center plate damage or carbody twist. The resulting unequal truck loading can induce asymmetric wheel wear. Figure 9 shows the simulation predictions for wear index differences on two reversed 5-degree curves for a flanging wheel on the lead-axle and a non-flanging wheel on the trailing axle as the load is shifted from centered to a lateral offset of 2 and 4 inches. The simulation was run at a speed of 3-inch underbalance with symmetric wheelsets. Figure 9 indicates that due to imbalance load, the wheel can experience more wear on one direction of curve. Results indicate the greater the load imbalance, the higher the wheel wear differences.

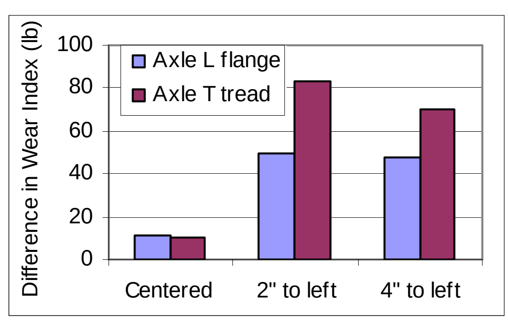

Figure 9. Asymmetric Wear Caused by Imbalance Load

Inconsistent Rail Lubrication

Wheel/rail wear levels and wear patterns are directly related to the wear index (an indication of energy consumption at the wheel/rail interface) at each wheel/rail contact point. Figure 10 shows simulation predictions for the wear index on the wheels of a leading axle for different wheel/rail lubrication conditions. The simulation was conducted using a 110-ton loaded hopper negotiating a 6-degree curve at balance speed. To illustrate the concept, the two-point contact feature on the high rail was selected with a RRD (RR2-RR1) of 0.47 inch (12mm) between the two points.

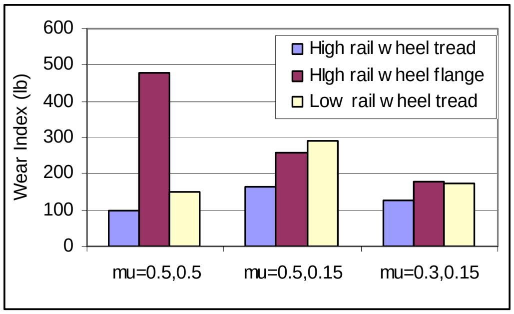

Figure 10. Wear Index at Each Contact Point of Leading Axle

Figure 10 indicates that the different lubrication levels and patterns not only affect the wear levels but also the wear patterns. Under a dry wheel/rail interface condition (μ=0.5/0.5), the wheel flange can have much higher wear compared to the wheel tread. When the high rail gage face is lubricated while both high and low rail tops are dry (μ=0.5/0.15), the wheel flange wear was reduced. However, the wheel tread wear was considerably increased, especially the wheel on low rail. Under a desirable lubrication condition (μ=0.3/0.15), the wear indices were considerably reduced with a relatively even wear pattern on wheel flange and wheel treads.

Therefore, proper wheel/rail lubrication levels and patterns can reduce wheel/rail wear and consistent lubrication can reduce asymmetric wheel wear.

Initial Rolling Radius Difference by Wheel Truing

If an initial RRD offset is induced during wheel truing severe asymmetric wear can result in the future. With an initial RRD offset, the wheelset tends to shift away from the track center on tangent track which further aggravates the condition as the wheels wear.

Other Influencing Factors

The factors that influence the formation of asymmetrically worn wheels may also include uneven braking, uneven distribution of left and right hand curves in a given route, and other asymmetric elements that make wheelsets operate at off-center or abnormal positions.

PREVENTION OF ASYMMETRIC WHEEL WEAR

As discussed, asymmetric wheel wear can considerably reduce wheelset life and cause a high rate of rail wear under certain conditions. Therefore, actions should be taken to prevent this type of wheel wear to reduce operating and maintenance costs.

Asymmetrically worn wheels are generally the result of undesirable operating or vehicle conditions. From an operating perspective, reducing imbalanced loads and maintaining adequate wheel/rail lubrication can help to reduce asymmetric wheel wear. From a car maintenance perspective, when asymmetrically worn wheels are discovered, the associated car should be thoroughly inspected to determine the contributing factors, such as wedge rise, carbody center plate/truck center bowl interface condition, side bearing interface condition, carbody twist and brake shoe force distribution. Once these contributing factors are corrected, severe asymmetric wear can be avoided. If asymmetrically worn wheelsets are only replaced with no other corrective actions, the new wheelsets will soon wear into the asymmetric patterns. The idea that applying bearing adapter pads may reduce asymmetric wheel wear needs to be investigated further.

As wheel profile monitoring systems are deployed on revenue service lines, the early stage of asymmetric wheel wear may be detected by defining an asymmetric wear criterion. A preliminary suggestion for the criterion is 0.08-inch (2-mm) radius difference measured at the tape line and a 0.08-inch (2-mm) flange width difference measured at 0.6-inch down from the wheel flange tip. Those cars being alarmed may be inspected to correct the contributing factors and hence stop or reduce asymmetric wear.

A carefully controlled wheel truing process can ensure a good starting situation for wheels. The current AAR Wheel and Axle Manual limits the radius difference measured at the wheel tape line to 0.02 inch (0.5mm) for the wheels mounted on the same axle after wheel truing. This rule must be complied.

CONCLUSION

Asymmetrically worn wheels, Pattern 1 and Pattern 2, can adversely affect vehicle performance on tangent and curved track. These wear patterns can reduce wheel life by 30 percent or more since one wheel reaches the flange wear limit much sooner than would normally happened under symmetric wear conditions.

To prevent asymmetric wheel wear, the main contributing causes need to be identified and corrected, which may involve both operating and car maintenance practices.

REFERENCE

1. Association of American Railroad Wheel and Axle Manual, Section G.