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Wheel/Rail Forces Associated with the Formation of High Impact Wheels

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Summary

An analysis of instrumented wheelset data suggests that crack formation on the wheel tread leading to the formation of high impact wheels results from high lateral forces on:

- The lead wheel contacting the low rail in a curve, attributable to high angles of attack of the lead wheelset of a nonsteering truck in a curve
- The lead wheels of a truck when exiting a curve, probably attributable to high angles of attack of the lead wheelset when the truck does not centralize on the track immediately after curve exit
- The lead wheels of a truck when negotiating discontinuities on tangent track, attributable to lateral wheelset dynamics

This information will be used to develop alternative truck suspension designs to reduce these forces and, consequently, the incidence of HIW. This development will be reported in future *Technology Digests* in support of an Integrated Freight Car Truck design to address current problems with the performance of current truck designs identified through the Association of American Railroads' Strategic Research Initiatives program.

Approximately 50 percent of high impact wheels (HIW) have been attributed to thermal mechanical shelling,[1] which is considered a consequence of both overheated wheels and rolling contact fatigue. Instrumented wheelset data has suggested a strong correlation between the location of measured tractions on the tread of the lead wheel contacting the low rail in tight curves and observed cracks on the wheel tread of HIW[2] arising from rolling contact fatigue.

A major problem identified is that of HIWs. HIWs are a major cost factor in car operation as well as a contributor to increased track costs and derailments. Car repair billing data suggests that approximately 420,000 wheels were removed in 2008 for HIWs in the North American industry resulting in an estimated cost to car owners of more than $500 million in 2008.

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INTRODUCTION

Transportation Technology Center, Inc. was tasked to develop a conceptual freight car truck design to address truck performance problems identified through Association of American Railroads' Strategic Research Initiatives Program.

Instrumented wheelset data suggests a strong correlation between the location of measured tractions on the tread of the lead wheel contacting the low rail in tight curves and observed cracks on the wheel tread of HIWs.[2]

The object of this report is to further evaluate these tractions and relate them to suspension design attributes. This information will then be used to develop alternative truck suspensions, which will be reported in future *Technology Digests (*TD).

MEASURED TRACTION FORCES AND COMPONENTS

Figure 1 shows the measured net traction forces on the lead wheel contacting the low rail of a curve, associated with tread damage and reported in a previous TD.[2]

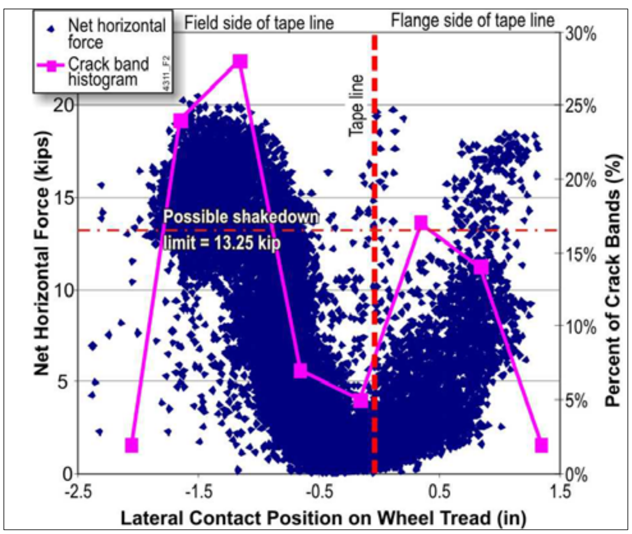

Figure 1. Relationship between Measured Surface Tractions and observed Crack Bands on the Wheel

These traction forces can be separated into longitudinal and lateral components.

The longitudinal traction forces (Figure 2) are generally:

- Proportional to the lateral position of the contact patch on the wheel
- Approach zero when contact is made at the tapeline
- Change direction (sign) as contact moves from the flange side of the tapeline to the field side of the tapeline

This force relationship is to be expected from a quasi-static model of a wheelset deflected laterally on the track.[3] Wheelset dynamics can account for the scatter in the data, and deviations from a pure linear relationship can be attributed to the nonlinear shape of wheel and rail profiles. As the wheel is designed to move laterally until flange contact occurs, these forces must be anticipated and the wheel must be designed to accommodate them without damage.

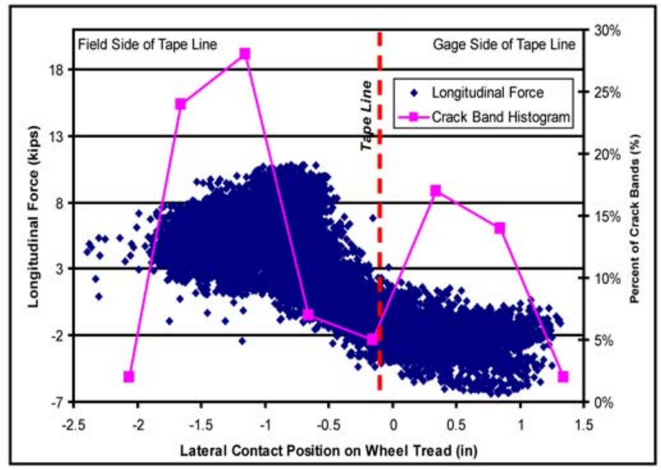

Figure 2. Longitudinal Traction Forces on the Tread of the Lead Wheel Contacting the Low Rail of a Curve

Figure 3 shows the distribution of lateral traction forces which is similar in shape to the net forces on the wheel tread (Figure 1), suggesting that they provide a major contribution to the formation of the crack bands discussed previously.[2]

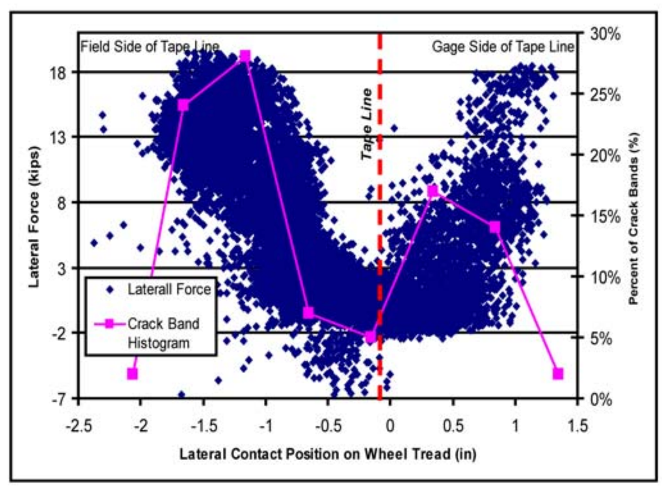

Figure 3. Lateral Traction Forces on the Tread of the Lead Wheel Contacting the Low Rail in the Curve

Lateral traction forces are proportional to:

- The angle of attack of the wheelset on the track[3]
- The lateral velocity of the wheelset relative to the track

To fully understand the circumstances in which high lateral forces are being generated and consequently to develop truck suspension designs to reduce or eliminate these forces, the lateral force data was further segregated according to the track topology over which the test was conducted as Figure 4 shows.

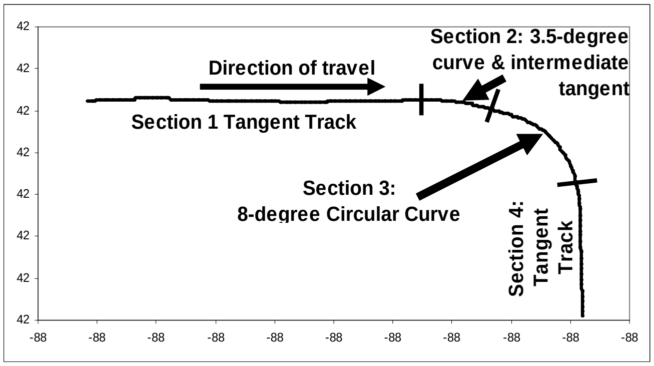

Figure 4. Topology of Test Track

The lateral force data for the lead wheel contacting the low rail in the 8-degree curve and associated with sections 1, 3, and 4 are shown in Figures 5, 6, and 7 respectively.

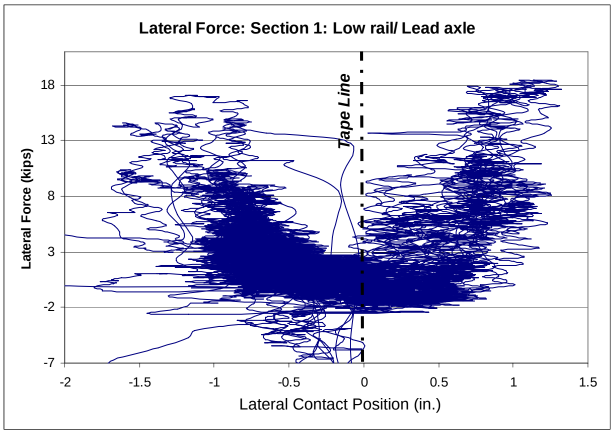

Figure 5. Lateral Forces in Section 1

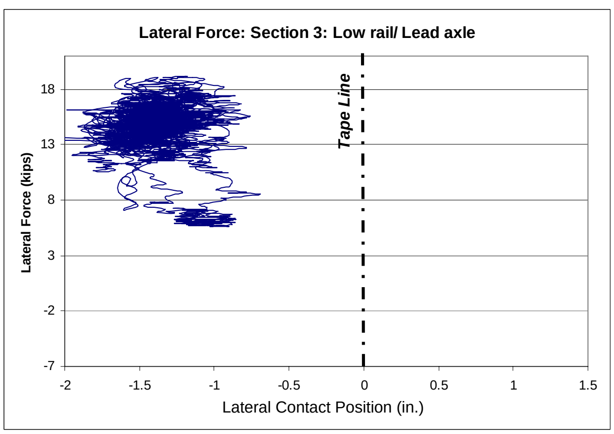

Figure 6. Lateral Forces in Section 3

Figure 6 indicates that in the 8-degree curve, contact on the low rail wheel is concentrated on the field side of the tapeline and that high lateral traction forces are present. This is commensurate with a wheelset curving with an angle of attack and with constant flange contact on the high rail as Figure 8 shows. Steering wheelset suspension designs may substantially reduce these forces and the associated crack band to the field side of the tapeline.

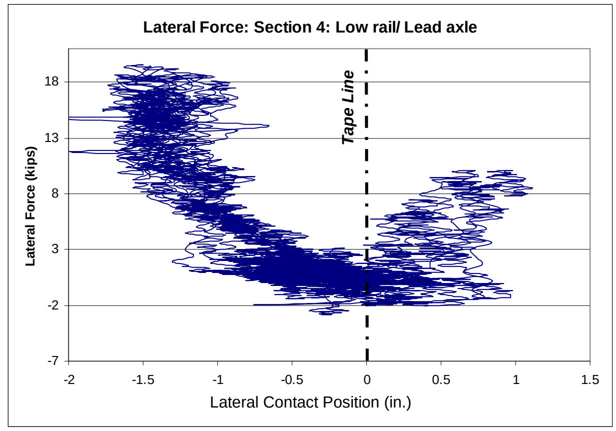

Figure 7. Lateral Forces in Section 4

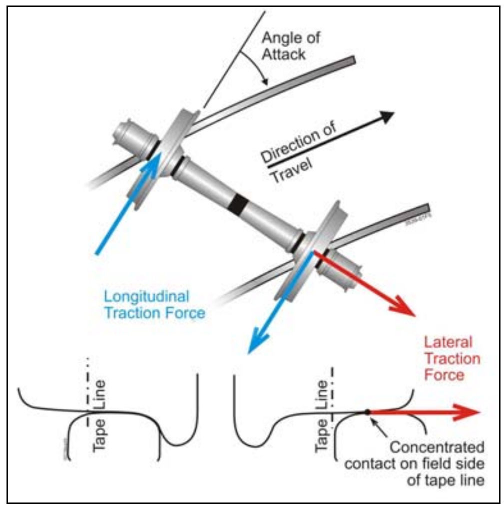

Figure 8. Lateral Forces on the Field Side of the Tapeline of the Lead Wheel of a Truck Contacting the Low Rail in a Curve with an Angle of Attack

Figures 5 and 7 show the lateral forces generated on tangent track both before and after the curve, respectively. They indicate that although the crack band to the field side of the tapeline may be substantially reduced through the use of a steering truck, high tractions still occur on tangent track and on curve exit.

Figure 9 indicates the force and lateral contact history of the lead wheel contacting the low rail through Section 1. This history indicates that the high lateral forces are transient in nature, associated with the vehicle dynamics.

Examination of the wheel profile of the instrumented wheelset (AAR-1B) suggests that any excursion of the contact point beyond 1 inch to the flange side of the tapeline could result in flange contact, as the circled portions of the traces in Figure 9 indicate. Associated forces, indicated in Figure 9, are likely to be as a result of flange contact and not lateral tractions. Nevertheless high lateral tractions are indicated in Figures 1, 3, 5, and 7 for contacts less than 1 inch from the tapeline as well as all indicated high forces to the field side of the tapeline.

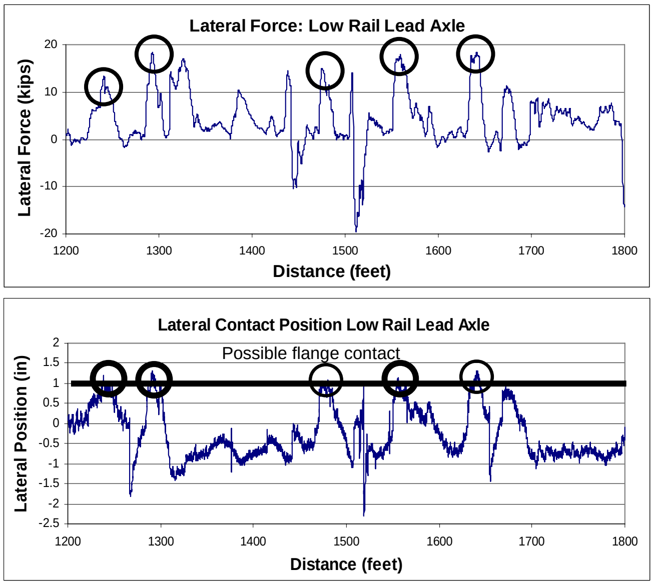

Figure 9. Lateral Force History for Section 1

It is concluded that high lateral traction forces can be developed on tangent track and are possibly associated with track lateral and cross-level discontinuities. Further investigations will be made to verify this conclusion and, if shown to be true, the relationship between the magnitude of the track discontinuity, vehicle speed and suspension characteristics will be thoroughly investigated.

The lateral force history for Section 4 (Figure 4) is similar to that for Section 1, but with a strong bias to contact on the field side of the tapeline. This suggests that in Section 4 the truck retains some of the truck rotation history from the 8-degree curve and has not yet centralized itself on tangent track. It suggests, in turn, that care must be taken in designing the truck / car body interface to provide the least possible rotational constraint to avoid the generation of high tractions and consequently HIWs. Further investigation is necessary to establish the exact nature of this phenomenon and how to counter it through improved design; this will be reported in future TDs.

BALANCING FORCES IN THE CURVE

A discussion on the measurement or analysis of wheel / rail forces in curves requires confirmation as to whether the truck negotiated the curve at balancing speed or not and whether the truck, if of the conventional three-piece type, was in a warped state or not. Consequently, the forces on all four wheels in the truck under consideration were reviewed. With reference to Table 1:

- The trail wheel contacting the low rail experiences an average lateral force of 3,450 pounds; this is 25 percent of the lateral force on the lead wheel contacting the low rail and suggests a small degree of truck warp.
- The net lateral force on the truck is 4,980 pounds acting in a direction to the center of the curve. This indicates curving with 2 inches of excess cant and is in accordance with a speed of 12 mph recorded in the 8-degree curve and will account for a net lateral force of approximately 2,500 pounds on each wheelset. This information does not suggest a truck operating in a degraded / warped condition under unusual excess cant conditions.

CONCLUSIONS

An analysis of instrumented wheelset data suggests that crack formation on the wheel tread leading to the formation of high impact wheels, results from high lateral forces on:

- The lead wheel contacting the low rail in a curve, attributable to high angles of attack of the lead wheelset of a nonsteering truck in a curve; a steering truck design will likely reduce the incidence of HIW
- The lead wheels of a truck when exiting a curve, attributable to high angles of attack of the lead wheelset when the truck does not centralize on the track immediately after curve exit; reduced rotational constraint between the truck and the car body will likely reduce the incidence of HIW; the exact nature of this misalignment requires further definition and possible design improvements require further analysis
- The lead wheels of a truck when negotiating discontinuities on tangent track, attributable to lateral wheelset dynamics; further investigation into the relationship between track discontinuities, vehicle speed and suspension characteristics must be thoroughly investigated

This information will be used to suggest an improved suspension design for the Integrated Freight Car Truck being developed under the AAR SRI program.

It is recommended that the lateral traction forces be modeled using NUCARS®* to confirm this evaluation and resulting conclusions and to evaluate this relationship.

REFERENCES

1. Cummings, S. and D. Lauro. Sept. 24, 2008. “Inspections of Tread Damaged Wheelsets.” Proceedings Rail Transport Division, *Fall Conference ASME*, Chicago, Ill.
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