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

Effect of Eccentric Loading and Primary Suspension Pads on Vehicle Curving Performance

by Huimin Wu, Joe LoPresti, Ken Rownd, and Curtis Urban

Summary

Investigation results indicate that compared to standard three-piece trucks, improved suspension (IMSP) trucks can significantly reduce wheel lateral forces when the operating conditions are properly controlled. Significant eccentric loading, unrestrained primary suspension pads, incompatible wheel/rail profiles, and improper rail lubrication can have negative effects on the curving performance of IMSP trucks.

This investigation was initiated when higher than expected lateral forces were measured at the Facility for Accelerated Service Testing (FAST), High Tonnage Loop, on a group of aluminum gondola cars received from a member railroad in early 2002. The cars were equipped with IMSP trucks including frame braces and primary suspension pads.

Two IMSP trucks of similar design were tested at the Transportation Technology Center in 1999. Results from those tests indicated that compared to the base trucks (standard three-piece truck), the IMSP trucks reduced the average lateral forces by as much as 50 percent in the curves up to 10 degrees of curvature. Testing at FAST from 1995 to 1999 also showed that IMSP trucks produced significant performance benefits of lower lateral forces and reduced rail wear.

The major differences in vehicle and test conditions between the car tested in 1999 and the cars from revenue service in 2002 were identified as eccentric loading, unrestrained primary suspension pads, and incompatible wheel/rail profiles when operating on the Wheel Rail Mechanism Loop, which contains high degrees of curves.

This investigation demonstrated that:

- A significant offset in the vertical load toward the low rail resulted in higher lateral wheel forces during curving.
- Unrestricted primary suspension pads allow the bearing adapters to shift longitudinally against the side frames and limit the axle yaw motion required for curving.
- Incompatible wheel and rail profiles produced severe two-point contact resulting in high lateral forces due to reduced steering

Recommendations to revenue service railroads for operating IMSP trucks:

- Carefully control the car loading procedures to avoid a significant load offset.
- Specify installation guidelines for primary suspension pads to ensure the pads function as designed.
- Optimize wheel and rail profiles to reduce wheel lateral forces.
- Regularly monitor the curving performance of cars in order to identify and repair truck problems.
- Develop laboratory procedures to determine the performance of primary suspension pads.

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Suggested Distribution:
- ❑ Maintenance-of-Way
- ❑ Engineering
- ❑ Mechanical
- ❑ Safety

INTRODUCTION

An investigation has been conducted by Transportation Technology Center, Inc. to identify the causes of elevated wheel lateral forces produced by a group of aluminum gondola cars equipped with improved suspension (IMSP) trucks operating at FAST.

Nine 125-ton aluminum gondola cars, with approximately 300,000 of revenue service miles, arrived at TTC in early 2002 from a member railroad. These cars were equipped with Barber S-2-HD trucks with frame braces and primary suspension pads (SM-1006-5), defined as IMSP compared to the standard three-piece truck. When operating at FAST, the average wheel lateral forces produced by these cars were similar to or even higher than the standard three-piece trucks (base cars) in the same train. Figure 1 shows the average wheel lateral forces obtained from 10 base and 9 IMSP cars on a 5-degree for 15 consecutive passes. TTCI's Truck Performance Detector (TPD), installed on the High Tonnage Loop (HTL), measured the forces.

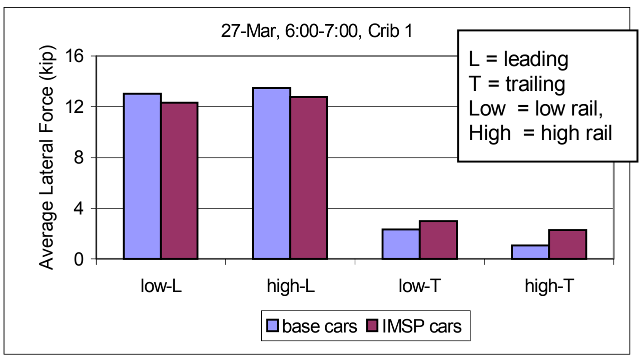

Figure 1. Average Wheel Lateral Forces of the Base Cars (10 cars) and the IMSP Cars (9 cars)

The primary suspension pads were expected to provide the IMSP trucks with better steering ability because the pads can shear to provide passive axle alignment. The frame braces should prevent truck warp.

Two IMSP trucks of similar design were tested at TTC in 1999. Results from those tests, as Figure 2 shows, indicated that compared to the base trucks, the trucks with IMSP reduced the average lateral forces by as much as 50 percent in the curves up to 10 degrees of curvature. Testing at FAST from 1995 to 1999 also showed that IMSP trucks produced significant performance benefits of low lateral forces and reduced rail wear.

The differences in vehicle and test conditions between the cars tested in 1999 and the cars received in 2002 were identified through an inspection (see Table 1). These differences were carefully examined during the investigation.

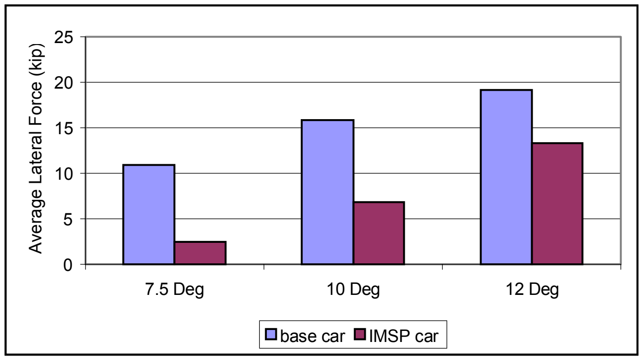

Figure 2. Test Results of 1999

Table 1. Differences in Vehicle and Test Conditions

Conditions	Previous Test	Current Condition
Vertical Load	Evenly loaded	Side-side offset
Track Lubrication	Dry	Varied by time
Wheel Profile	AAR1B	FAST worn profile
Primary Pads	J-15688-8	SM-1006-5
Pad Installation	Centered by welded shims	Without restriction

EFFECT OF ECCENTRIC LOADING

The inspection showed that the loads contained in the IMSP cars were clearly offset. The uneven loading was quite severe for some of the cars. The differences in vertical wheel loads on the two wheels of the same axle were in the range of 15-20 kips.

Both test and modeling results indicated the wheel lateral forces would be much higher when the center of gravity (CG) shifted to the low rail than when it was shifted to the high rail. This is because the lateral force is the resultant force of contact normal force and lateral creep force. The resultant force was high when CG was offset to the low rail.

Figure 3 shows the average wheel lateral forces after the loads in the cars were redistributed for balance. The average lateral forces of IMPS trucks were approximately 45 percent lower compared to the regular trucks in the same train.

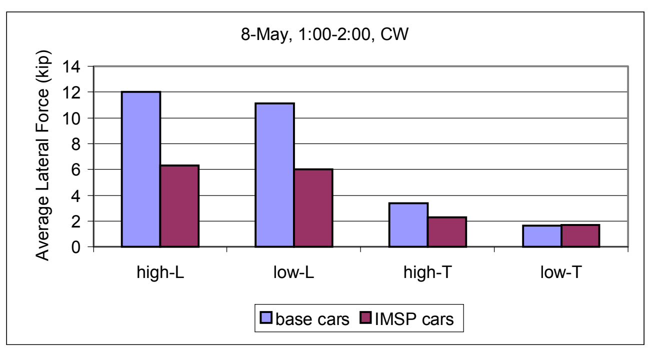

Figure 3. Average Wheel Lateral Forces after Load Redistribution

EFFECT OF PRIMARY SUSPENSION PADS AND THEIR INSTALLATION

Two types of primary suspension pads — J-15688-8 (used in the test of 1999, thick pad) and SM-1006-5 (currently equipped, thin pad) — were tested after the eccentric loading was corrected. The thickness and stiffness of the pads are listed in Table 2. To study the effects of pad wear on wheel lateral forces, the new pads (new) and old pads that had about 120,000 of service miles (thick-old) and about 300,000 miles of service (thin-old) were evaluated. Six cars were tested, and each car (except the base car) was equipped with four types of pad arrangements; i.e., thin-new, thick-new, thin-old, and thick-old, in four test days. The average wheel lateral force was computed from five consecutive laps.

Table 2. Thickness and Stiffness of the Primary Pads

	J-15688-8	SM-1006-5
Thickness (inch)	1 5/16	1 1/16
Shear Stiffness (pound/inch)	38,000	31,000
Vertical Stiffness (pound/inch)	750,000	1,400,000

Figure 4 shows the results from the first day of testing at FAST for each of the six test cars. The axle numbers are the sequence of axles in the running direction. Compared to the base car, the IMSP cars generally produced lower average lateral forces at the leading axles (axle 1 and 3).

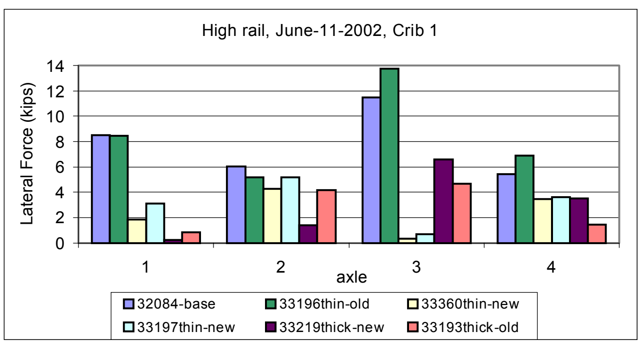

Figure 4. Average Wheel Lateral Forces on High Rail

However, as Figure 4 shows, the lateral wheel forces at the leading axles of car 33196 were much higher than the other IMSP cars. During the inspection, after the first day test, it was found that all pads and bearing adapters on this car had shifted longitudinally against the side frames, as Figure 5 shows. Consequently, the yaw motion of axles could be limited during curving, resulting in higher wheelset angle of attack and higher lateral forces. The pads on other IMSP cars in the test train were also shifted, but most of them were not touching the side frames. The pads were designed to be shimmed as illustrated at the lower-right corner of Figure 5. The restrained pads provide better axle steering from pad shearing.

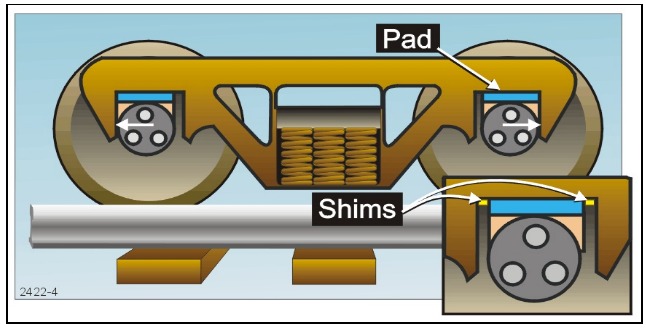

Figure 5. Restrained and Unrestrained Primary Suspension Pads

After this problem was discovered, the pads and axles were carefully centered before each later test (but without using shims to restrict pad motion). The inspection after test showed that most pads and axles were either centered or had slightly shifted, without contacting the side frames, after a few laps of test runs. Figure 6 shows the test results after centering the pads and axles. The lateral wheel forces for all IMSP cars (including car 33196) were lower than that those seen on the base car. However, without the longitudinal restriction of the pads, it would be very likely that the pads and the axles would eventually shift against the side frames, especially under the effect of braking.

Figure 7 summarizes the average lateral forces computed for the leading wheels involved in the four days test. The average lateral forced produced by the IMSP cars was more than 40 percent lower compared to the base car. The average lateral forces computed from eight wheels of each car, which was taken as an indication of total lateral force produced from different arrangements of pads, followed the same trend.

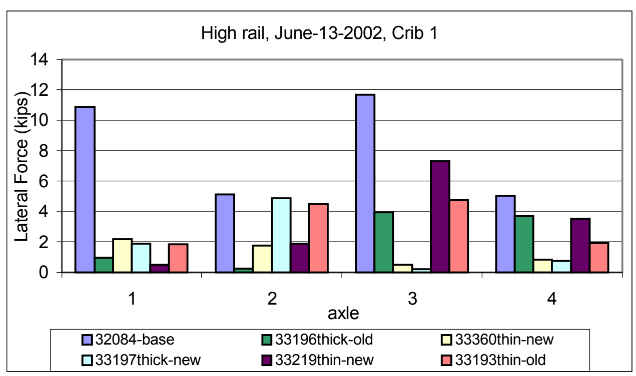

Figure 6. Average Wheel Lateral Force on High Rail after Centering the Pads

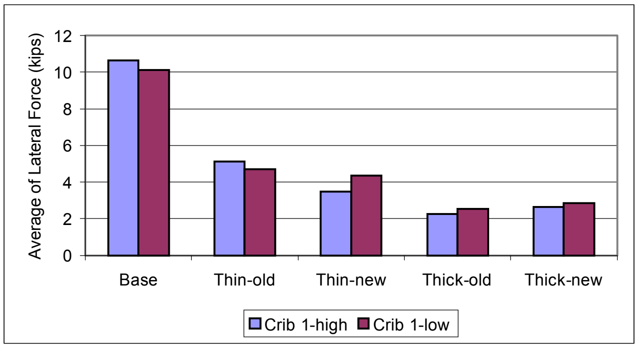

Figure 7. Average Wheel Lateral Forces of Leading Wheels for four days test

These test results suggest that the two types of pads tested and their existing service mileages did not produce a considerable difference in lateral wheel forces. The thick pads (J-15688-8) produced slightly lower lateral forces than the thin pads (SM-1006-5). However, according to the service observation, the thick pads showed signs of rubber degradation and bond separation earlier compared to the thin pads because of the different contour at the edge of the pad and bond design.

EFFECT OF WHEEL/RAIL PROFILES

Tests were also conducted on the WRM loop to further investigate the pad performance on sharper curves.

Figure 8 shows the lateral wheel forces measured on the high rail of the 10-degree curve. The average wheel lateral forces of IMSP cars were lower than those of the base car. The 40 percent reduction in lateral force seen in the test of 1999, however, was not achieved.

An analysis of the wheel/rail profile contact showed that the high rails measured on 7.5- and 10-degree curves contacting the AAR1B wheel (used in the test of 1999, Figure 2) would produce continuous single-point contact, and the same rails contacting the FAST worn profile wheels (installed on the current test cars) would produce severe two-point contact. Previous research and tests have indicated that severe two-point contact would reduce the wheel steering moment resulting in higher wheelset angle of attack and higher wheel lateral forces.

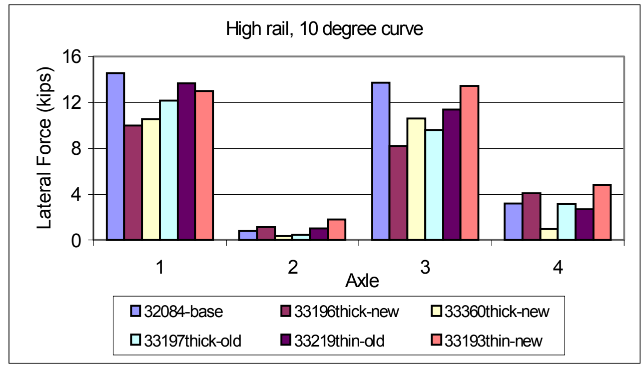

Figure 8. Wheel Lateral Force Measured on 10 Degree of Curve

CONCLUSION

1. Compared to the standard three-piece trucks, the IMSP trucks can significantly reduce wheel lateral forces when the operating conditions are properly controlled.
2. A significant offset in the vertical load toward the low rail could result in higher lateral wheel forces.
3. Unrestricted primary suspension pads allow the bearing adapters to shift longitudinally against the side frames and limit the axle yaw motion required for proper curving.
4. Incompatible wheel and rail profiles can cause high lateral forces due to reduced steering forces and higher wheelset angle-of-attack.

RECOMMENDATIONS

Recommendations for operating IMSP trucks in revenue service:

- Carefully control the car loading procedures to avoid a significant load offset.
- Specify installation guidelines for primary suspension pads to ensure the pads function as designed.
- Optimize wheel and rail profiles to reduce wheel lateral forces, where possible.
- Regularly monitor the curving performance of cars in order to identify and repair truck problems.
- Develop laboratory procedures to determine the performance of primary suspension pads.