TECHNOLOGY DIGEST

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Side Bearing Performance Under Adverse Conditions

by Russell Walker

Summary

In support of railroad industry efforts to "reduce the stress state of the railroads," Transportation Technology Center, Inc. has evaluated the benefits of applying constant contact side bearings to the freight car fleet. A concern, which led to this evaluation, is that the increased turning resistance between the car body and truck bolster resulting from constant contact side bearings might be detrimental to curving performance. The Association of American Railroads' Mechanical Research Committee sponsored this program to evaluate different types of side bearings in curving, dynamic curving, and high-speed stability.

Because the tests and modeling program only examined performance under baseline conditions (e.g., new wheels, dry rail, new trucks), a concern was that an increased turning moment might cause problems that would not be apparent under the test conditions. For this reason, NUCARS™ modeling was used to examine the performance of an aluminum gondola car under a variety of adverse conditions. Variations of load condition, side bearing clearance/setup height, truck condition, wheel/rail profile, and lubrication condition were made for four types of side bearings to determine any apparent performance differences.

Findings from these tests include:

- All side bearing configurations met M-1001 Chapter XI performance measures in limiting spiral entry, limiting spiral exit, constant curving, and twist-and-roll for nominal truck conditions, dry rail, and new wheel profiles.
- Although all loaded model results met Chapter XI performance measures for constant curving, truck warp occured in several cases leading to increased gage-spreading forces. Roller side bearings showed only slightly better performance under conditions that cause truck warp.
- A constant contact side bearing set at the solid height, either through improper setup or wear, resulted in extremely poor curving and spiral negotiation performance, regardless of the other conditions present.
- Long-travel constant contact side bearings generally showed better performance in twist-and-roll and spiral exit, and were less susceptible to changes in side bearing set-up height.
- Long travel, constant contact side bearings showed slightly worse performance than other types of side bearings for cases involving offset loads.

Suggested Distribution:

- ☐ Operations
- ☐ Mechanical Dept.
- ☐ Planning & Analysis
- ☐ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

INTRODUCTION AND CONCLUSIONS

In 2001, a proposal was made by some members of AAR's Technical Services Working Committee to apply constant contact side bearings (CCSB) to all railroad freight cars. Many railroad industry experts have expressed concern that CCSBs may not be appropriate for all cars or for all types of service due to the increased truck turning resistance between the car body and truck bolster. Under the auspices of the AAR's Mechanical Research and Equipment Engineering committees, TTCI has conducted experimental and analytical studies to help the industry make informed decisions about the proper application of constant contact side bearings.

Because the cost of testing various types of side bearings on many different types of cars is prohibitive, a compromise solution was adopted to test four distinctive car types and to use computer modeling to estimate the performance of six additional types. The testing and modeling simulations evaluate each car's performance under the regimes of spiral negotiation, constant curving, dynamic curving, and high-speed stability. Test conditions included dry rail, moderately worn wheels and rails (a very good condition for steering), new trucks, and properly adjusted side bearings. It is conceivable that the possible detrimental effect to curving performance from increased turning moment of the CCSB might not be apparent under the ideal curving conditions listed above. To determine the effects that different types of side bearings have on curving, spiral, and twist-and-roll performance under a variety of adverse conditions, a matrix of simulations was prepared for one of the car types to be tested and simulated.

A series of computer simulations of an aluminum gondola car show that constant contact side bearings produce similar or better performance than roller side bearings under most simulation conditions. Four types of side bearings (roller, standard travel CCSB, standard travel CCSB with roller assist, and long travel CCSB) were modeled under a variety of conditions, with the following results:

- All side bearing configurations met Chapter XI performance measures in limiting spiral entry, limiting spiral exit, constant curving, and twist-and-roll for nominal truck conditions, dry rail, and new wheel profiles.
- Although all loaded model results met Chapter XI performance measures for constant curving, truck warp occurs in several cases leading to increased gage-spreading forces. Roller side bearings show only slightly better performance under conditions that cause truck warp.
- A constant contact side bearing set at the solid height, either through improper setup or wear, resulted in extremely poor curving and spiral negotiation performance, regardless of other conditions present.
- Long travel CCSBs generally showed better performance in twist-and-roll and spiral exit, and were less susceptible to changes in side-bearing setup height.
- Long travel CCSBs showed slightly worse performance than other types of side bearings for cases involving offset loads.

METHODOLOGY

Constant contact side bearings are known to improve high-speed stability performance by increasing the turning resistance between the car body and truck bolster. The increased resistance could cause adverse effects on curving performance. To determine if CCSBs would tend to make a bad situation worse, several parameters were varied from nominal to worst-case conditions, and the effect on curving and spiral negotiation performance for several types of side bearings was observed.

The simulations used the aluminum gondola car tested as a part of the side-bearing research project as a baseline. This car weighs 43,900 pounds empty and 286,000 pounds loaded. In the empty condition, it is relatively flexible; but in the loaded condition, it is modeled as a rigid body. The car is equipped with Barber S-2HD trucks with a dual-rate spring package. The three types of CCSBs modeled have identical preloads and stiffness characteristics. Plain roller side bearings were simulated with 1/4-inch clearance. The standard travel CCSB has 5/16-inch travel before going solid, the roller-assist CCSB also has 5/16-inch travel but goes solid on a roller, and the long-travel CCSB has 5/8-inch travel.

When leaving a superelevated curve, the lead, outside wheel of a freight car tends to unload. The ability of the vehicle to distribute, or equalize, the load between the inside and outside wheels during spiral negotiation is an important part of car performance. Side bearings limit the amount of twist that can occur between the truck bolster and car body, and therefore have a large effect on the spiral exit performance for many cars.

The parameter variations were designed to adversely affect steering, load equalization, and roll performance.

In many cases, poor performance of cars equipped with CCSBs results from improper side bearing setup height. In some cases, cars have one or more side bearings in the solid condition due to improper installation. Depending on the design, an inspector could easily overlook a CCSB in this condition. Typically, the setup height for side bearings is specified at 5 1/16 inches (±1/16″). Cases were modeled with the side bearings at 1/8-, 1/4-, and 3/8-inch tight. The condition of 1/2-inch tight leaves the roller side bearings just touching the wear plates. The standard-travel and roller-assist CCSBs have only 1/16-inch clearance before going solid in this condition. In the 3/8-inch tight condition, all of the car weight is held on the side bearings for all types except the long-travel CCSB.

Offset load conditions were modeled since they can lead to poor curving performance. The car was modeled with a centered load, with the car body center of gravity shifted 6 inches to the high rail of the curve, and with the center of gravity shifted 6 inches to the low rail of the curve. A 6-inch offset causes a load difference of 15,000 pounds between the left and right wheel of an axle — 60,000 pounds for the entire car.

The warp restraint of a truck degrades with wear, compromising curving performance. New and fully worn truck conditions were modeled.

Wheel profiles are critical to curving performance. The wheel/rail interaction produces longitudinal forces that tend to steer the truck around the curve. New wheel on new rail is used as the baseline condition. The moderately worn wheel on moderately worn rail produces higher beneficial steering forces. The hollow-worn wheel on moderately worn rail shows slightly lower longitudinal forces, and the hollow-worn wheel on ground rail (a grinding pattern that produces severe two-point contact) shows the least longitudinal force.

Lubrication can hurt curving performance; depending on how it is applied. The lubrication conditions simulated were dry rail and differential lubrication. Differential lubrication, lubed high rail and dry low rail, has an adverse affect on curving performance because the lubricated high rail reduces the ability of the wheelset to steer, but the dry low rail allows for generation of high lateral forces.

Curving simulations were run for each of the parameter variations listed. Twist-and-roll simulations were run only for the three types of side bearings (roller, standard travel CCSB, and long travel CCSB), empty and loaded, with the four setup heights.

RESULTS

Each side bearing configuration met Chapter XI performance measures for spiral entry, spiral exit, constant curving, and twist-and-roll, when simulations used standard setup height, centered loads, new truck conditions, new wheel/rail profiles, and dry rail.

Twist-and-roll was the regime most affected by the type of side bearing. Exhibit 1 shows a plot of minimum vertical wheel load for the three types simulated in loaded twist and roll. Long-travel side bearings show the best performance and roller side bearings show the worst.

Different types of side bearings have a large effect on spiral exit performance for many cars. Because the empty aluminum gondola car is relatively flexible in torsion, the car-body twist behavior, rather than the type of side bearings, dominates the load-equalization performance in the spiral. The loaded car, however, is modeled as a rigid body, so some variation in performance is seen, with the long-travel CCSB having better load equalization than the other types of side bearings.

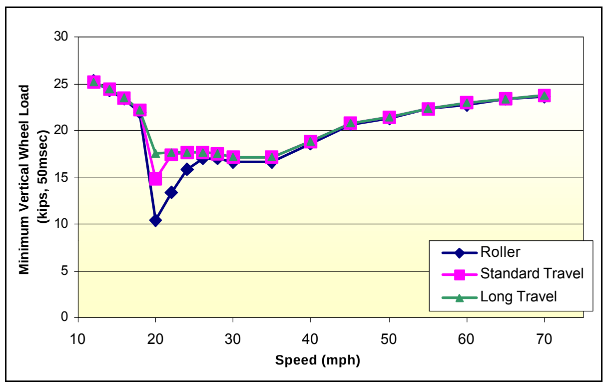

Exhibit 1. Twist-and-Roll Performance for Several Types of Side Bearings

Parameter Variations

Of the several parameters varied, side bearing setup height and offset load conditions stood out by showing different performance with different types of side bearings. Exhibit 2 is a plot of the curving performance by side-bearing type for offset load conditions. In the constant curving zone, the car body tips onto the side bearing at underbalance speed, when the center of gravity is shifted to the inside of the curve. Since the long-travel CCSB allows the body to tip further, it produces somewhat worse performance in this zone than the other types of side bearings. The difference in performance between the types of side bearings is small compared to the change due the offset load itself.

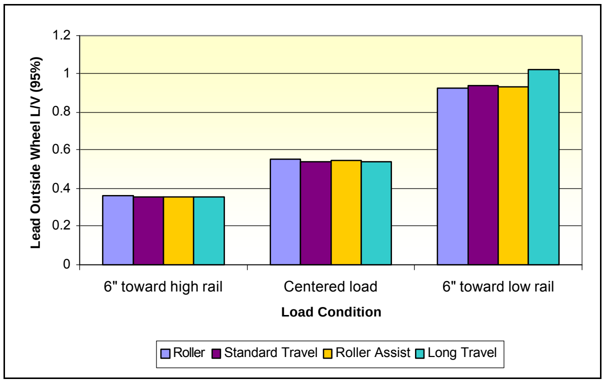

Exhibit 2. Variation in Curving Performance for Offset Loads

Figure 3 is a plot of worst-case twist-and-roll performance, by side bearing setup height, for three different side bearings. It is apparent that because the long-travel side bearing has more reserve travel than the other two side bearings, it is much less sensitive to changes in setup height. Spiral negotiation showed similar, although somewhat less dramatic results.

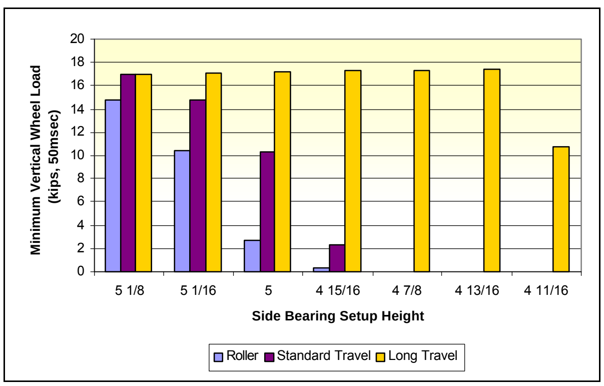

Exhibit 3. Variation in Twist-and-Roll Performance with Side-Bearing Setup Height

Constant curving performance was not affected by setup height except for the cases in which the entire weight of the loaded car body rested on the side bearings. This condition caused the trucks to warp regardless of the truck condition, wheel profile, rail lube, or offset load condition. This is a very important condition to consider because in many cases observed by TTCI, poor performance attributed to CCSBs occurs because of improper setup height.

The additional turning moment from CCSBs with appropriate setup height did not significantly affect the curving or spiral negotiation performance of the vehicle, even when conditions were such that the steering performance of the car was hindered by poor wheel-rail profiles and differential track lubrication. Exhibit 4 is a plot of the low rail lead truck side lateral/vertical (L/V) ratio for different side bearing types under conditions that reduce the steering performance of the vehicle.

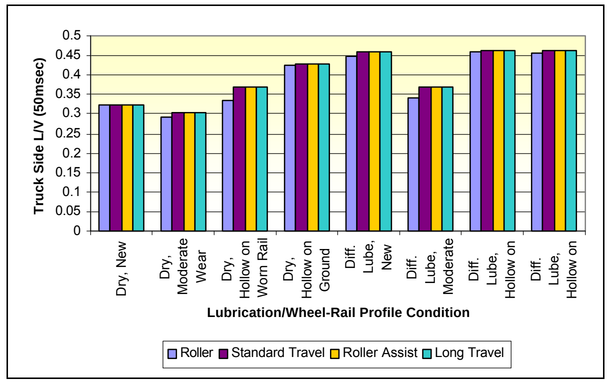

Exhibit 4. Variation in Spiral Entry Performance for Various Conditions that Affect Steering

Low rail L/V ratios approaching 0.45 indicate truck warp. Examination of the cases in which truck warp is occurring shows that roller side bearings perform slightly better than other side-bearing types — although not to the extent that one might expect. In this regime, the effects of the variation in wheel/rail interaction conditions far outweigh the effect different side bearings have on performance.

FUTURE WORK

TTCI has tested four cars with various side bearing configurations. The performance of each car will be outlined in future issues of *Technology Digest*. Further, six more cars were modeled using NUCARS™. These results will also be published.

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