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Simulation Results of Different Side Bearing Types for Six Different Freight Cars

by Russell Walker and Darrell Iler

Summary

Simulation results for six freight cars indicate that long-travel* constant-contact side bearings (CCSB) provide the best overall performance in spiral negotiation, curving, and dynamic curving. The results of these studies will help the industry make informed decisions about the proper application of CCSB for different types of freight cars. Car performance is most sensitive to side bearing type in the regimes of empty spiral exit and empty dynamic curving, with the long-travel CCSB performing better than roller or standard travel CCSB. The six car types were:

- Center-beam car
- 60-foot box car
- Grain covered hopper
- Plastic pellet covered hopper
- Short tank car
- Mill gondola

The Transportation Technology Center, Inc. (TTCI), on behalf of the Association of American Railroads' (AAR) Equipment Engineering and Mechanical Research committees (EEC and MRC), conducted computer simulations (no on-track testing was done) of six types of railroad freight cars as part of a program to examine the effectiveness of using constant-contact side bearings to reduce the stress state of the railroads. The program also included full-scale testing and computer simulations of four other car types, which are reported separately.

Based on results obtained from these studies and on-track tests, the EEC has recommended to the Technical Services Working Committee (TSWC) that after January 1, 2003, all new and rebuilt cars, cars given extended service, or increased in gross rail load, in accordance with *AAR Office Manual* Rule 88, be equipped with long-travel CCSBs. The balance of the fleet will be considered after that date.

*Reference to "long-travel" is equivalent to extended travel or any device with 5/8 inch of travel.

Suggested Distribution:

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

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INTRODUCTION

In an effort to improve performance of the vehicle-track system, some members of the AAR's Technical Services Working Committee (TSWC) made a proposal to require the use of constant contact side bearings (CCSB) on heavy axle load railroad freight cars. Under the auspices of the AAR's Mechanical Research and Equipment Engineering committees (MRC and EEC), TTCI has conducted experimental and analytical studies to help the industry make informed decisions about the proper application of constant-contact side bearings for different types of freight cars.

To efficiently analyze several types of side bearings on many types of cars, a combination of modeling and testing was adopted. Four very distinct car types were modeled and tested. The results from each are presented in the following *Technology Digests*:

- TD02-021 – "Assessing Constant-Contact Side Bearing Performance for an Aluminum Coal Gondola."
- TD02-027 – "Assessing Constant-Contact Side Bearing Performance for a Long Tank Car."
- TD02-023 – "Assessing Constant-Contact Side Bearing Performance for a Short Covered Hopper Car."
- TD03-006 – "Assessing Constant-Contact Side Bearing Performance for a Bulkhead Flat Car."

The results for these cars are used to establish the appropriate confidence level in the models.

For this simulation, the following car types, chosen to represent a wide range of car lengths, torsional stiffness, and center of gravity height, were exclusively modeled:

- Center-beam car
- 60-foot box car
- Grain covered hopper
- Plastic pellet covered hopper
- Short tank car
- Mill gondola

Background

The regimes modeled were spiral negotiation, steady-state curving, dynamic curving, and high-speed stability. These regimes and the relative performance criteria are described in Specification M-1001, Chapter XI of the AAR's *Manual of Standards and Recommended Practices*. All regimes were modeled in both the empty and loaded condition except for high-speed stability, which was only modeled empty.

The following list summarizes the modeling conditions.

- New wheel and rail profiles for curving simulations
- Worn wheel profiles for high-speed stability simulations
- Dry rail, friction=0.5
- New truck condition
  - No wedge rise
  - Reasonably high warp stiffness
- Trucks were variable damped designs with D5 spring nests

Side bearing manufacturers provided lists of three appropriate side bearings for each car type. TTCI requested that they choose side bearing models corresponding to the minimum acceptable, conventional, and a state of the art technology. TTCI engineers chose side bearings from the lists provided by the manufacturers for use in the simulations. In most cases, the side bearings modeled were roller type, standard travel CCSB, and long-travel CCSB.

The results from cars that were modeled and tested showed that the modeling results matched test data well, showing the correct trends and similar performance levels with each side bearing type. Two exceptions were the regimes of loaded dynamic curving and high-speed stability.

The model results from loaded dynamic curving show a lower center roll resonance at the right speed, but the resonance is not as severe as seen in the tests. Model results do show the correct trends with side bearing type in this regime.

The model results from high-speed stability simulations do not show as large an increase in critical speed when constant-contact side bearings are used as was seen in the test. Test data shows that the critical speed increases 10-15 mph, whereas the model results show increases of only 0-5 mph. Because the model does not properly distinguish between side bearing types in the high-speed stability regime, and because the effect of CCSB on hunting performance is already well established, the high-speed stability data is not presented here.

RESULTS

Center-Beam Car

The center-beam car modeled for this program has a light weight of 66,200 pounds and a loaded weight of 286,000 pounds. The truck center spacing is 56 feet. The empty car torsional stiffness was matched to the data from a static jacking test presented in AAR research report R-925. The center-beam car was modeled with a standard travel-roller assist CCSB and two types of long-travel CCSB.

Table 1 shows the modeling results for the center-beam car. (In all tables, "Met' indicates that the modeling results met Chapter XI criteria for the test regime; Conversely 'Did Not Meet' indicates that they did not. Further, E=empty and L=loaded.)

Table 1. Model Results for the Center-Beam Car

Regime	Roller Assist	1st Long Travel CCSB	2nd Long Travel CCSB
Spiral Entry (E)	Met	Met	Met
Spiral Exit (E)	Met	Met	Met
Curving (E)	Met	Met	Met
Dyn. Curve (E)	Met	Met	Met
Spiral Entry (L)	Met	Met	Met
Spiral Exit (L)	Met	Met	Met
Curving (L)	Met	Met	Met
Dyn. Curve (L)	Met	Met	Met

The center-beam results show that the car performs adequately with either standard travel roller assist CCSB or long-travel CCSB. Even though the car has long truck center spacing, empty spiral negotiation performance was adequate due to the car's torsional flexibility.

60-foot Boxcar

The 60-foot boxcar has a light weight of 80,300 pounds and a loaded weight of 286,000 pounds. The truck center spacing is 46 feet 3 inches. The car body was modeled as a rigid body. The boxcar was modeled with roller side bearings, standard travel CCSB, and long-travel CCSB. Table 2 lists the modeling results. L/V ratios were higher than the Chapter XI criteria in empty spiral exit with the roller and standard travel CCSB, but the car met the criteria with long-travel CCSB.

Table 2. Model Results for the 60-ft Boxcar

Regime	Rollers	Stand. Travel	Long Travel
Spiral Entry (E)	Met	Met	Met
Spiral Exit (E)	Did Not Meet	Did Not Meet	Met
Curving (E)	Met	Met	Met
Dyn. Curve (E)	Met	Met	Met
Spiral Entry (L)	Met	Met	Met
Spiral Exit (L)	Met	Met	Met
Curving (L)	Met	Met	Met
Dyn. Curve (L)	Met	Met	Met

Grain Covered Hopper

The grain covered hopper car model was based on the standard cars used for the M-965 truck test. The car has a light weight of 59,800 pounds and a loaded weight of

Plastic Pellet Covered Hopper

263,000 pounds. The truck center spacing is 40-feet 8-inches. The empty and loaded car bodies were modeled as rigid bodies. The mass moments of inertia were taken from a characterization done as part of a previous project. The grain covered hopper car was modeled with roller side bearings, standard travel CCSB, and long-travel CCSB.

The empty car results with roller and standard travel CCSB shows L/V ratios above the criteria for the spiral exit regime, and vertical wheel loads below the criteria for the dynamic curving regime. The empty car met these criteria with long-travel CCSB (Table 3).

Table 3. Model Results for the Grain Covered Hopper

Regime	Rollers	Stand. Travel	Long Travel
Spiral Entry (E)	Met	Met	Met
Spiral Exit (E)	Did Not Meet	Did Not Meet	Met
Curving (E)	Met	Met	Met
Dyn. Curve (E)	Did Not Meet	Did Not Meet	Met
Spiral Entry (L)	Met	Met	Met
Spiral Exit (L)	Met	Met	Met
Curving (L)	Met	Met	Met
Dyn. Curve (L)	Met	Met	Met

Figure 1 shows minimum vertical wheel loads for loaded dynamic curving with the grain car. There is a resonance at 18 mph. Although the model results meet Chapter XI criteria, experience indicates that the resonance in an actual test is much more severe than is seen with the model. The relative performance shows that the long-travel CCSB perform the best and the roller type performs the worst.

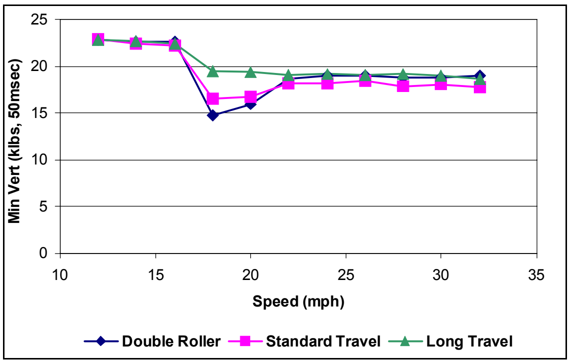

Figure 1. Model Results for the Loaded Grain Car In Dynamic Curving

The plastic pellet covered hopper has a light weight of 66,500 pounds and a loaded weight of 286,000 pounds. The truck center spacing is 54 feet 1 inch. The empty and loaded car bodies were modeled as rigid bodies. The car was modeled with roller side bearings, standard travel roller assist CCSB, and long-travel CCSB. Table 4 lists the modeling results.

The empty plastic pellet car results had L/V ratios above the criteria in spiral exit with the roller side bearings and standard travel roller assist CCSB. The empty car met criteria with the long-travel CCSB.

Table 4. Model Results for the Plastic Pellet Covered Hopper

Regime	Rollers	Roller Assist	Long Travel
Spiral Entry (E)	Met	Met	Met
Spiral Exit (E)	Did Not Meet	Did Not Meet	Met
Curving (E)	Met	Met	Met
Dyn. Curve (E)	Met	Met	Met
Spiral Entry (L)	Met	Met	Met
Spiral Exit (L)	Met	Met	Met
Curving (L)	Met	Met	Met
Dyn. Curve (L)	Met	Met	Met

Short Tank Car

The short tank car has a light weight of 58,000 pounds and a loaded weight of 263,000 pounds. The truck center spacing is 29 feet 6 inches. The empty and loaded car bodies were modeled as rigid bodies. The car was modeled with roller side bearings, standard travel CCSB, and long-travel CCSB. Table 5 shows the results.

Table 5. Model Results for the Short Tank Car

Regime	Rollers	Stand. Travel	Long Travel
Spiral Entry (E)	Met	Met	Met
Spiral Exit (E)	Did Not Meet	Did Not Meet	Met
Curving (E)	Met	Met	Met
Dyn. Curve (E)	Did Not Meet	Did Not Meet	Met
Spiral Entry (L)	Met	Met	Met
Spiral Exit (L)	Met	Met	Met
Curving (L)	Met	Met	Met
Dyn. Curve (L)	Met	Met	Met

The empty short tank car results had L/V ratios above the criteria in spiral exit and vertical loads below the criteria in dynamic curving with the roller side bearings and standard travel CCSB. The empty car met criteria with the long-travel CCSB.

52-foot Mill Gondola

The 52-foot mill gondola had a light weight of 68,000 pounds and a loaded weight of 263,000 pounds. It has a 46 foot 3 inch truck center spacing. Both the empty and loaded car bodies were modeled as rigid bodies. It is apparent from its shape and makeup that the empty mill gondola should have some torsional flexibility, but since no data was available to make a reasonable estimate of the stiffness, it was modeled as rigid, which is probably the worst case. Table 6 lists the results of this simulation. The mill gondola met the criteria for every regime

Table 6. Model Results for the Mill Gondola Car

Regime	Rollers	Stand. Travel	Long Travel
Spiral Entry (E)	Met	Met	Met
Spiral Exit (E)	Met	Met	Met
Curving (E)	Met	Met	Met
Dyn. Curve (E)	Met	Met	Met
Spiral Entry (L)	Met	Met	Met
Spiral Exit (L)	Met	Met	Met
Curving (L)	Met	Met	Met
Dyn. Curve (L)	Met	Met	Met

CONCLUSION

All of the simulated cars met Chapter XI criteria for the regimes modeled with the long-travel CCSB. The EEC has recommended to the TSWC that after January 1, 2003, all new and rebuilt cars, cars granted extended service status, or increased in gross rail load, in accordance with *AAR Office Manual* Rule 88, be equipped with long-travel CCSBs. The TSWC adopted the recommendations effective January 1, 2003.