TECHNOLOGY DIGEST

Timely Technology Transfer — 99-020

Advanced Suspensions Meet Ride-Quality Performance Standards for Tri-Level Auto-Rack Cars

by Ken Rownd and Darrell Iler

Summary

Railroad-service tests have demonstrated that auto manufacturers expectations for shipping quality can be met using existing tri-level auto-rack cars equipped with new suspension designs. This digest summarizes a 5,578-mile railroad-service ride-quality test of tri-level auto racks equipped with three suspension types: a baseline three-piece design, an improved premium design, and an advanced design.

The advanced design and the premium design met ride quality requirements identified by the railroad and automobile industry.

The advanced design was a Krupp TI-7L made to fit in a tri-level rack designated D5. The premium design was a modified NACO Swing Motion truck made to fit in a D5 tri-level rack. The baseline was an enhanced three-piece design made to fit in a tri-level rack designated D-4.

Partnerships between the railroad and automotive industries have identified performance objectives for transporting finished automobiles by rail. Auto manufacturers wish to eliminate rail transportation as an automobile design consideration while attaining error-free transportation. Controlled testing of these suspensions was reported in TD98-025.

Tests were performed in cooperation with TTX Company as part of the Association of American Railroads Advanced Freight Car Truck Design program. Additional support has been received from a joint railroad and automotive industry group, the Quality and Maintenance of Equipment.

Suggested Distribution:
- Car Department
- Research & Development
- Equipment/Rolling Stock
- Intermodal

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

Auto-rack ride-quality tests performed by Transportation Technology Center, Inc. (TTCI), and TTX as part of the Advanced Freight Car Truck Design program indicate that ride quality for transportation of finished automobiles can be improved with new freight-car suspensions under existing tri-level railcars. Evaluations were performed in controlled tests at TTC and in more than 5,000 miles of railroad service.

TTCI has designated two autorack types for improved trucks. These are designated D4 and D5. The D5 rack has room for a longer travel suspension than the D4 rack.

Three suspension designs were tested in baseline tri-level auto racks at the Federal Railroad Administration's Transportation Technology Center. One D4 and one D5 met controlled-test criteria. The railroad-service test program demonstrated the following:

- Performance improvements measured in controlled tests were confirmed in railroad service.
- NACO Swing Motion and Krupp TI-7L suspensions met RP limiting criteria for number of vertical acceleration events greater than 0.5 g per 1,000 miles.
- All suspensions met limiting criteria for number of lateral acceleration events greater than 0.35 g per 1,000 miles.
- The Krupp suspension had one vertical event (1.2 g) greater than 1.0 g in 5,500 miles. The NACO suspension did not exceed 1.0 g.
- The baseline suspension did not meet vertical acceleration criteria.

BACKGROUND

Partnerships between the railroad and automotive industries have been established to identify performance objectives for transporting finished automobiles by rail. Acceptable performance is defined by acceleration criteria as measured in tests described in a recommended practice titled: "Ride Quality Performance Requirements for Motor Vehicle Shipments" (RP803-96).

Requirements include controlled tests over specially constructed track anomalies and railroad-service tests using auto-rack trains. The controlled tests are used to identify weaknesses in design and to promote design development. The over-the-road tests document in-service performance for designs which meet controlled test requirements.

TRUCKS TESTED

Baseline Machine Center Truck: This suspension serves as the baseline in the advanced truck tri-level program. It has 28-inch wheels with 70-ton design sideframes and bolsters. This truck has a secondary coil-spring suspension with friction snubbing. The spring group consists of five outer and five inner D4 coils. The baseline suspension had constant damping in the secondary suspension controlled by two each 1670 (outer) and 3222 (inner) coils per side. It is equipped with Stucki 656 CRH constant-contact side bearings and RFE18 friction shoes. This suspension has 61-inch axle spacing. The baseline suspensions are referred to as "machine center" suspensions. This indicates that machining work has been performed on the original castings to improve mating surfaces and dimensional tolerances.

NACO Swing Motion: The premium suspension also has 70-ton design sideframes and bolsters. The sideframes are connected by a transom acting as a shear plate to increase warp resistance. Special bearing adapters with a rocker seat allow the sideframes to swing laterally. This lateral degree of freedom de-couples the wheel set and suspension motion from the lateral motion of the car body. The secondary suspension utilizes variable friction damping provided by wedges controlled by two outer and inner No. 52064 coils per side. Low-friction material is applied to the vertical surface of the wedges. The secondary spring nest consists of five D5 outer coils and two D5 inner coils. The suspension is equipped with Stucki 656 CRH constant-contact side bearings.

Krupp TI-7L: The advanced suspension is a modified 70-ton design with 28-inch wheels. The suspension has a leaf-spring bolster that rests on a nest of five outer and five inner Krupp coil springs per side. The coils ride on a transom, which rests in the bottom of a modified 70-ton sideframe. The connections between the transom and the sideframes allow lateral motion. The side bearings are Miner TCC II-35 long travel, set at 4¼ inches height under load. The side bearings are attached to the leaf-spring bolster. Some damping occurs as the leaf springs deflect. In

addition, constant friction damping is applied (through a low-friction surface) as the coil springs deflect. Damping is constant because the low-friction surface is (horizontally) spring loaded to 3,000 pounds normal force.

CONTROLLED TESTS AT TTC PER RP803-96

These tests are performed to document ride quality and safety performance by exciting the rail-car rigid-body modes of pitch, bounce, twist, and roll. In addition, safety performance in curving and high-speed-stability performance are tested. The Krupp suspension met controlled-test criteria under tri-level auto racks. The Swing Motion suspension did not meet vertical-test criterion in pitch and bounce. The baseline did not meet lateral or vertical criteria.

Pitch and Bounce Controlled-Test Result

Exhibit 1 shows the vertical acceleration performance for all three suspensions at the leading end of the tri-level car. The RP limit is 0.5g at speeds up to 70 mph. The Swing Motion and the TI-7L suspensions meet the criterion. The baseline exceeded criterion at 60 mph. The leading end is measured in the railroad-service test.

Exhibit 2 shows the trailing-end acceleration

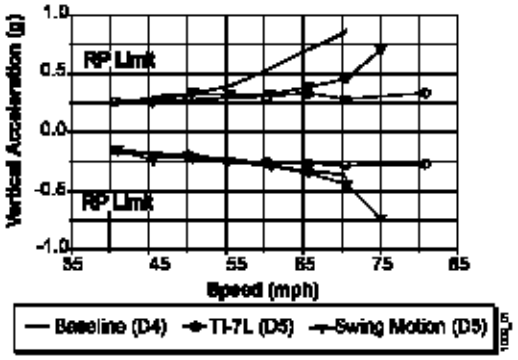

Exhibit 1. Vertical Acceleration in Pitch and Bounce Testing – Leading End

performance. The TI-7L meets criterion while the Swing Motion slightly exceeded criterion at 70 mph. The trailing end is not measured in railroad-service testing.

RAILROAD-SERVICE RIDE-QUALITY

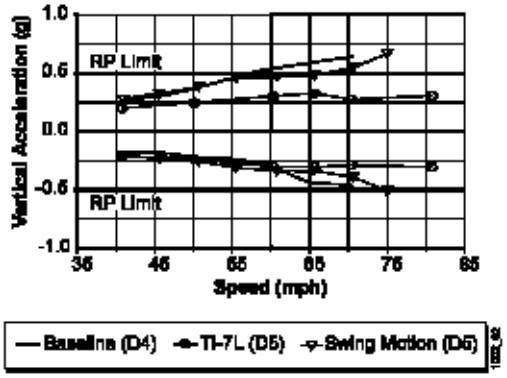

Exhibit 2. Vertical Acceleration in Pitch and Bounce Testing – Trailing End

TESTING PER RP803-96

The recommended practice defines an over-the-road test which measures vertical, lateral, and longitudinal acceleration at top and bottom decks. The test route is: Newark, New Jersey, to Chicago, then from Chicago to Milpitas, California, and finally from Los Angeles to Chicago. Criteria for success are not to exceed set number of occurrences above a predetermined level for each acceleration measurement as follows:

- Vertical: one occurrence at 1.0 g or 100 above 0.50 g per 1,000 miles
- Lateral: one occurrence at 0.75g or 100 above 0.35 g per 1,000 miles

Railroad-service data can be dominated by local factors such as train handling, performance of adjacent cars, weather, special track (switches etc.), and train speed. The TI-7L and the Swing Motion suspensions were tested in identical auto racks that were coupled together. The baseline suspension was tested in 1997.

Lateral Performance in Railroad Service

Lateral performance criterion was met for all three suspensions.

Vertical Performance in Railroad Service

Exhibit 3 compares vertical performance for each of the three trip segments. The vertical performance criteria has been the most difficult to meet at TTC and in railroad service. The Swing Motion tri-level met this criterion. The TI-7L suspension met the criterion with the exception of one event

greater than 1.0 g. This maximum acceleration event amplitude was 1.2 g.

Exhibit 4 compares vertical acceleration performance for the test segment between Chicago and Milpitas, California. This segment has the highest maximum speed. Results are as follows:

- TI-7L performance was better than the baseline at all acceleration levels.
- Swing Motion and baseline performance was equivalent for negative accelerations (upward travel).
- Swing Motion performance was better than the baseline for positive accelerations (downward travel) when amplitude exceeded 0.3g.
- Swing Motion and TI-7L suspensions met the RP vertical criterion of less than 100 events per 1,000 miles. The baseline did not meet criterion.
- Comparing the TI-7L to the Swing Motion and baseline, the number of vertical events per 1,000 miles was lower at each acceleration level. The total number of events greater than 0.3g was 281 for the TI-7, 2,079 for the Swing Motion, and 2,453 for the baseline.

SUMMARY

This completes the test portion of the program to promote new suspensions for multi-level autoracks. In 1999, TTX and AAR propose to monitor a limited number of the successful suspensions in railroad service to document durability. Other Technology Digests from this program are 96-021, 96-022, 97-038, 97-039, 98-014, 98-025, and 98-032.

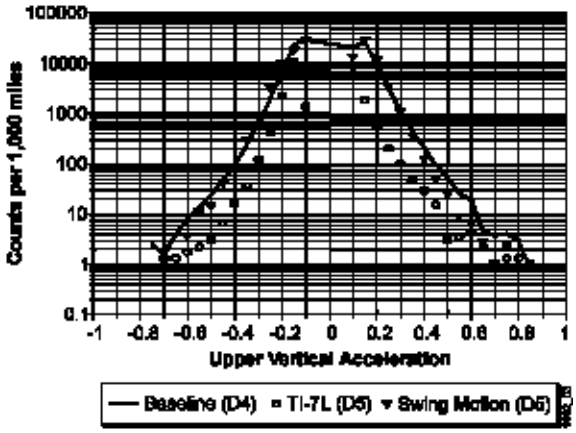

Exhibit 3. Vertical Acceleration Railroad Service Testing – Leading End

Exhibit 4. Vertical Acceleration Histogram in Railroad Service – Leading End Chicago to Milpitas, California

Events/1,000 Miles	Tri-Level Auto Rack			
	Criteria	Krupp TI-7L	NACO Swing Motion	Baseline
Newark – Chicago				
Deck 1 Events > 0.5*	100	33	31	11
Deck 1 Events > 1.0	0	0	0	0
Deck 2 Events > 0.5*	100	37	53	11
Deck 2 Events > 1.0	0	0	0	0
Chicago – Milpitas				
Deck 1 Events > 0.5*	100	22	40	105
Deck 1 Events > 1.0	0	0	0	1
Deck 2 Events > 0.5*	100	24	61	147
Deck 2 Events > 1.0	0	0	0	1
Los Angeles – Chicago				
Deck 1 Events > 0.5*	100	45	26	29
Deck 1 Events > 1.0	0	1	0	0
Deck 2 Events > 0.5*	100	46	61	35
Deck 2 Events > 1.0	0	1	0	1

ACKNOWLEDGMENT

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