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A Review of the Performance of Brake Rigging in Three-Piece Trucks

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Summary

A literature review on the performance of brake rigging in three-piece trucks carried out by Transportation Technology Center, Inc. suggests poor truck rigging design results in:

- Tapered brake shoe wear
- Brake beam wear
- Lateral forces on the brake beam
- Uneven shoe forces

According to information found, it is estimated that these effects result in increased maintenance costs for shoe replacement, brake beam wear, and wheel damage amounting to over $150 million per year.

Forces in the truck brake rigging acting on the brake beam have been well defined and account for the many variations in observed and measured shoe force.

Forces and reactions on the shoes and brake heads do not seem to have been adequately analyzed. Some authors allude to the inefficiencies inherent in the brake beam extension/brake pocket system. One rigging supplier has developed a "link support" system to counter the effects presumed to occur in the slide as well as lateral forces developed by some rigging arrangements on the brake beam. This supplier has produced test results and analyses in support of his approach. While encouraging, the analysis does not address fundamentally, the relationship between uneven shoe wear, the forces at the shoe/wheel interface, brake beam reactions as well as the influence of the sense of wheel rotation.

Consequently, this review recommends that a further fundamental and integrated approach to both truck and brake rigging design be used to identify opportunities for performance improvement prior to soliciting and evaluating improvements from the industry.

This research has been conducted as part of the Association of American Railroads' Strategic Research Initiatives Program.

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INTRODUCTION

Railroads experience poor brake rigging component and wheel performance, both of which have been attributed to poor brake rigging design:

- Brake beams are frequently replaced because of wear. The cost of beam replacement is estimated to be $7 million/year. Brake beam wear is associated with uneven brake shoe wear. Tapered brake shoe wear (difference in wear between top and bottom of the shoe) results in premature shoe replacement, estimated to cost $35 million per year. This figure has been inflated from the original estimate of $22 million per year.[1]

- Wheels are being replaced for shelling at an estimated cost of $175 million per year.[1] Shelling is associated with a combination of rolling contact fatigue (RCF) and elevated temperatures:

  - RCF is associated with poor truck curving characteristics and is being addressed by the industry through improved truck design.

  - Elevated wheel temperatures are a consequence of uneven thermal loads, resulting, under extreme braking conditions, in tread damage on those wheels with the highest temperature and stress.[2]

  The cost associated with overheated wheels is thus less than $175 million per year but still considered to be appreciable and more accurate costs are being sought. Total costs may be greater than $150 million per year.

Transportation Technology Center, Inc. (TTCI) has been tasked, under the Association of American Railroads' Strategic Research Initiatives Program, to solicit improved body and truck brake rigging to improve brake and wheel performance. Consequently, TTCI has reviewed literature on the design and performance of truck brake rigging.

This *Technology Digest* provides a review of the available literature on truck brake rigging design.

Literature Review

In a paper to the Air Brake Association, Carlson[1] provides a comprehensive overview of the causes for uneven shoe forces in cars. He quotes measured wheel temperature variations within trucks in a double-stack train from a maximum of 625°F to a minimum of 275°F. He suggests that causes for shoe force variations are as follows:

- The use of rod-through (the bolster) rigging under larger capacity cars requires the use of bent truck levers due to clearance constraints (Figure 1).

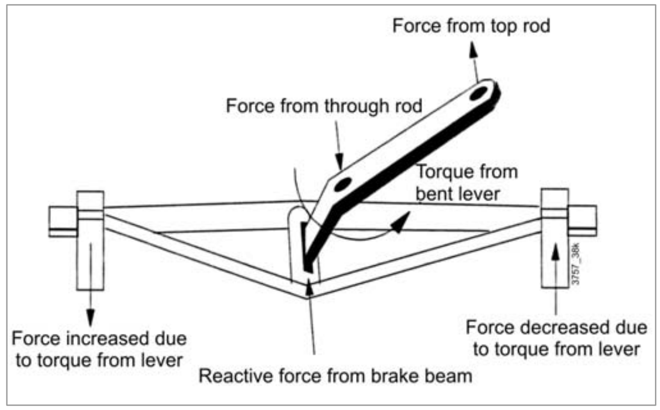

Figure 1. Rod-through Rigging

This configuration produces a torque along the axis of the lever and a difference in brake shoe forces on the attached beam of up to 45 pounds. Rod-through rigging is used because it obviates derailments that can arise from the pushrods in rod-under (the bolster) arrangements falling on the track and causing derailments (if securing straps are not attached).

- Truck rigging with the "dead lever" attached to the bolster can result in a torque being applied to the truck when the brakes are applied and can cause the truck to warp (Figure 2).

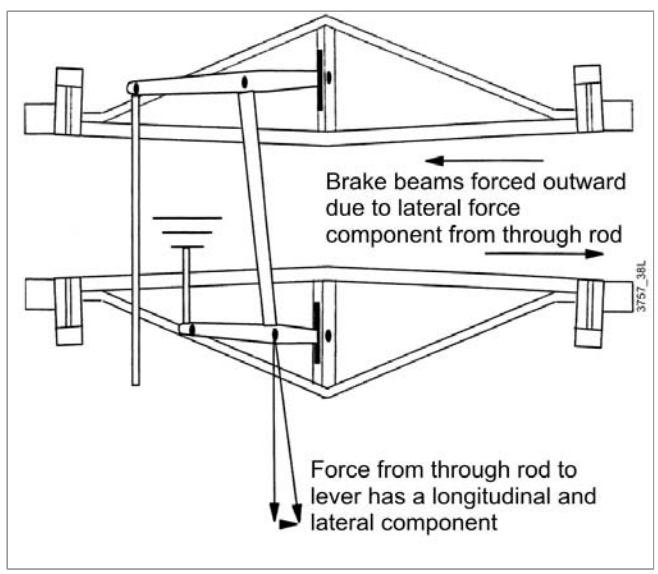

Figure 2. Truck Rigging

The torque is as a result of the angle the truck levers make to the vertical, off-setting the line of action of the brake force to the longitudinal truck center line. This can result in poor truck performance. Carlson does not mention that truck warp could cause the brake beam to jam in the brake slide.

- WABCOPAC® truck mounted brakes with slack adjusters can result in a shoe force difference of 535 pounds between wheels in a truck with a full-service application.
- "Binding" of beams in the brake beam/side frame interface is probably the biggest source of variation in any rigging system, according to Carlson.[1] He shows measured differences in shoe force, due largely to this effect, of 900 pounds for an average shoe force in a truck of approximately 3,000 pounds.

Carlson further addresses tapered shoe wear. He suggests that tapered wear increases with wear of the beam end extensions and unit guide pocket wear liner and can vary with the tolerances of the unit guide pocket and beam twist. He estimates that tapered shoe wear might be costing the industry about $22 million annually.[1]

Carlson concludes with calculations of the loss in rigging efficiency with car age. It is not clear how much this changes shoe forces relative to one another within a car, but certainly changes shoe forces between cars.

In another report, Carlson describes the results of a survey of tapered shoe wear.[3] Over 1,000 shoes were inspected in trucks in service. Each observation was associated with car and truck type and manufacture, car and truck rigging type, and manufacture as well as age. Carlson found:

- Tapered wear generally prevailed (85 percent of the sample) as against 15 percent of shoes having worn evenly.
- 83.8 percent of shoes had significantly more wear on the top of the shoe.
- Only 1 percent of shoes wore more on the bottom than the top.
- It appears from the graphs presented, that on average, for the entire population recorded, shoes are worn approximately 20 to 25 percent more on the top than on the bottom.
- Shoes on rod-through rigging performed better than those on "rod-under" or "hook-and-eye."
- Shoes on rigging with dead levers to the truck performed marginally better than those with a dead lever to the carbody.
- There were further (possibly marginal) differences in tapered wear patterns between:
  - Truck capacity
  - Truck brand
  - Brake beam type
  - Equipment and component age

Carlson estimated that tapered wear cost the industry about $11.2 million in wasted shoe material.[3]

Another report by Carlson provides additional data from a similar survey.[4] In this instance, data from a total sample size of 3,909 brake shoes is discussed, which suggests:

- Twisted brake beams, resulting in differences in top taper between shoes on either end of the beam may account for about 25 percent more shoe material being wasted on one of two shoes. In addition, a twisted beam may result in binding of the beam in the side frame pockets
- Again, shoes on rod-through rigging performed better than those on rod-under

Of particular interest is that neither report mentions differential worn shapes between two shoes on the same side of the truck (in other words, on either side of the bolster). When a truck is running, the rubbing direction on one shoe is from top-to-bottom, whereas on the shoe (on the other side of the bolster), the rubbing direction is from bottom-to-top. Similar wear at the top of the shoe implies either:

- The cars are regularly turned and have even braking duties in either direction.
- Or the rubbing direction and, by implication, the direction of the frictional force and its reaction have little influence on tapered shoe wear. (Later reports will address this matter in more detail.)

In TD-02-003, Carlson and Malachowski reported on tests conducted on a "link support system."[5] Initial tests showed "a significant reduction in tapered shoe wear, an increase in brake rigging efficiency, and a reduction in brake force variations." They conducted an economic analysis on the assumption of a $150 new-car cost, a $500 cost to retrofit, and a 15-year system life. Based on this analysis, a retrofitted car running 90,000 miles per year and a new car running 30,000 miles per year would achieve payback over the assumed 15-year life of the system.

In TD-02-022, Carlson and Malachowski reported on body-mounted brake rigging efficiency losses in service. Effective loaded brake ratios changed from 9 to 8.2 percent after 75,000 miles in service.[6]

Differences in car brake efficiency will alter wheel temperatures between cars; this reduction is probably less than those differences within a truck. No mention is made on the effect of the efficiency changes on shoe forces within the truck or on tapered shoe wear and beam wear.

In a paper published in 2008, Malachowski and Cline developed force relationships for shoes and heads for the case of link brake stabilizers.[7] They used a "lumped" or "simplified" force approach at the shoe/wheel interface. Malachowski and Cline also only analyzed the forces as a consequence of clockwise rotation, which may prove significant. They do, however, include rigging weight and analyze forces in the brakes "on and off" conditions.[7] And in TD-02-003, Carlson and Malachowski provide reasons for the improved performance of the link support system.[5]

CONCLUSIONS

Variations in shoe force, beam, and tapered shoe wear are caused by a combination of:

- Rigging designs that apply unequal and lateral forces to the brake beams and shoes
- A brake beam slide system that, even as it requires tight tolerances and clearances to eliminate tapered shoe wear, can:
  - Bind within side frame and brake beam twist tolerances and warp deflections of the truck
  - Rapidly wear, resulting in tapered shoe wear
- Forces in the brake rigging have been adequately defined, whereas the required forces and reactions on the shoe for even shoe wear are currently ill-defined.

Consequently, TTCI recommends that:

- A fundamental analysis of the forces on the brake shoe is conducted. This should include defining the contact pressures and frictional reactions at the wheel / brake shoe interface as well as the relationship between these forces and the application and reaction forces on the brake shoe.
- A further fundamental and integrated approach to both truck and brake rigging design is used to identify opportunities for performance improvement prior to soliciting and evaluating improvements from the industry.

These analyses will be reported in future TDs.

An improvement in the application of brake forces may also assist in developing more predictable train stopping distances — a feature that will become more desirable with the advent of electronically controlled pneumatic brakes and positive train control.

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