

"EFFECTS OF PROFILE GRINDING AND LUBRICATION ON GAGE SPREADING,"

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TD 95-006

Summary

The Association of American Railroads (AAR) conducted a brief course and full-scale demonstration concerning the effects of wheel and rail profiles and track lubrication on gage widening forces at the Transportation Technology Center (TTC), Pueblo, Colorado. The demonstration confirmed the following ideas:

- The beneficial wheel set steering moments, which steer the truck through the curve, decrease with increased gage corner relief from grinding.
- Truck warp angles and gage spreading forces increase with increased gage corner relief.
- Rail lubrication decreases the wheel set steering moments and increases truck warp angles.
- Lubricating the running surface of the inner rail decreases gage spreading forces.

For the demonstration, three test zones in a 7.5-degree curve were prepared by progressively grinding more material from the outer rail gage corner. Strain gage circuits were installed in each zone to measure the vertical and lateral forces produced by the test car.

The test car was a 100-ton hopper car equipped with instrumented wheel sets having hollow worn wheel profiles. Wheel set steering moments and truck warp angles were measured on board.

Three track lubrication conditions were tested (1) both rails dry, (2) outer rail gage face lubricated, and (3) outer rail gage face/inner rail running surface lubricated.



Association of American Railroads
Research and Test Department

Suggested Distribution :

- R&D/Test Dept.
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INTRODUCTION AND CONCLUSIONS

Recent investigations of rail rollover derailments by the Association of American Railroads (AAR) implicated the following as contributing factors:

- Worn wheel profiles
- Heavy rail profile grinding
- Inadequate truck warp restraint
- Differential track lubrication
- Inadequate track strength

Rail profile grinding is currently employed by many railroads to reduce rail fatigue. As a result, its implication as a factor in derailments became a point of controversy in the industry. In response, the AAR conducted a brief curving dynamics course and full-scale track test at the Transportation Technology Center (TTC) to demonstrate the effects of heavy rail profile grinding and track lubrication on gage spreading forces. Track and mechanical engineers, track maintenance personnel/contractors, and members of academia were invited to attend.

For the demonstration, three rail zones were prepared with progressively more material removed, by grinding, from the gage corner of the high rail. These zones represent the spectrum of current rail profile grinding practices from no grinding to light and heavy gage corner grinding.

The demonstration confirmed the following ideas:

1. The beneficial wheel set steering moments, which steer the truck through the curve, were reduced as material was progressively removed from the gage corner of the rail.
2. Truck warp angles and gage spreading forces increased with progressive removal of material from the gage corner of the rail.
3. Track lubrication reduced the steering moments.
4. Lubricating both rails reduced the steering moments, increased the truck warp angles, yet nearly eliminated the gage spreading forces.

CURVING DYNAMICS DISCUSSION

Truck Warp

The systems of forces and moments that act on a three-piece truck during curve negotiation are complicated. In the study of gage spreading behavior, however, it is possible to focus on the forces and moments which cause the truck to warp.

Truck warp, sometimes referred to as parallelogramming, is defined as skew of the truck bolster relative to the side frames about a vertical axis. This condition causes the angles-of-attack of both wheel sets to increase relative to the rails. As a consequence, the wheel sets can generate large lateral gage spreading forces.

The moments which cause truck warp are generated in two ways: (1) by excessive turning resistance between the truck and car body, such as that produced by a dry center bowl or tight side bearings, and (2) by reversal of the normally beneficial wheel set steering moments which turn the truck in the curve. Truck warp caused by steering moment reversal was the focus of the recent AAR derailment investigations and the demonstration at TTC.

Wheel Set Steering Moment Reversal

During curve negotiation, longitudinal forces are generated by the slip between the wheel and rail surfaces in contact. Slip occurs because the wheels are joined by a solid axle, yet they must negotiate rails of different lengths; i.e. the outer rail is longer than the inner rail.

Ideally, slip is minimized by the conical design of the wheels which allows the outer wheel to have a larger radius than the inner wheel. However, as wheels wear, they often develop hollow treads, as shown in Exhibit 1. As a consequence, the beneficial conicity is lost across the tread, and the wheel must move into flange contact with the outer rail to establish the necessary rolling radius.

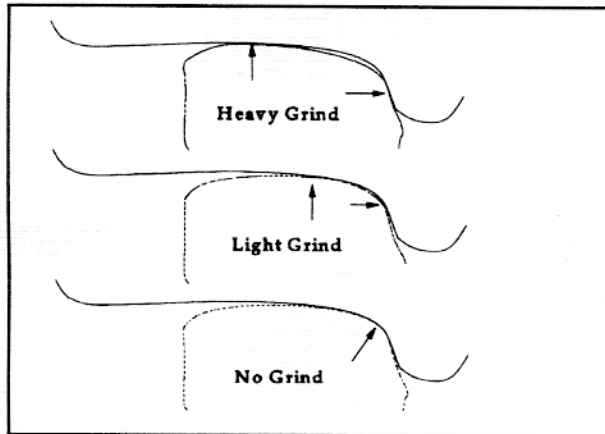


Exhibit 1. Wheel/Rail Profiles For Test

In the top profile in Exhibit 1, two contact areas occur between the flanging wheel and the rail because of the gage corner relief provided by heavy grinding. Slip occurs at both areas, such that each generates longitudinal forces. The *flange* contact area, having a large rolling radius, produces a longitudinal force that pulls the outer wheel ahead. This generates a positive steering moment acting to turn the wheel set to follow the curve. By contrast, the *tread* contact area has a small rolling radius which produces a longitudinal force that pulls the outer wheel back. This generates a negative steering moment. The net wheel set steering moment is the sum of its flange and tread steering moments.

If lubrication is applied to only the gage face of the outer rail, then the size of the positive flange steering moment is reduced. In the extreme case, the tread steering moment can be large enough to produce a net negative wheel set steering moment, which can warp the truck.

The middle profile in Exhibit 1 shows a rail with light gage corner grinding. The tread contact point occurs on a larger radius than in the heavy grind case. This would result in a smaller negative steering moment.

The bottom profile in Exhibit 1 shows an unground rail. In this case, only one area of contact occurs between the wheel and rail at a relatively large rolling radius. This condition would be expected to produce only positive steering moments, in moderate curves.

DEMONSTRATION OF RAIL PROFILE AND TRACK LUBRICATION FACTORS

The ideas discussed above formed the context for the AAR demonstration. Three track zones, with the outer rail profiles shown in Exhibit 1, were prepared for the demonstration in the 7.5-degree curve of the TTC Balloon Loop. Strain gages were installed in each zone to measure the lateral and vertical forces produced by the test car.

The trailing truck of the 100-ton test car was equipped with AAR instrumented wheel sets to measure the steering moments. These wheel sets had the worn profile shown in Exhibit 1. The test truck warp angles were also measured.

Three lubrication conditions were tested (1) both rails dry, (2) lubrication on the outer rail gage face, and (3) both rails lubricated.

Wheel Set Steering Moments

Exhibit 2 shows the truck steering moments, which are the sums of the two wheel set steering moments, in the three test zones for the three lubrication conditions. The largest *negative* steering moments were measured in the heavy grind zone for each test. The steering moments improved as the test car moved from the heavy grind zone to the light grind and unground zones. These results support the idea that heavy grinding of the outer rail gage corner reduces steering moments by moving the wheel tread contact area away from the flange to a smaller rolling radius (Exhibit 1).

In addition, the truck steering moments were reduced by lubrication, especially when it was applied to the inner rail running surface (Both Rails Lubed). This confirms the idea that steering moments are generated by friction between the wheel and rail.

In general, the truck warp angles, shown in Exhibit 3, followed the truck steering moments. For example, the truck warp angles improved as the test car moved from the heavy grind zone to the light grind and unground zones, except when the inner rail running surface was lubricated. In



this case, the negative steering moment (Exhibit 2) continued to warp the truck.

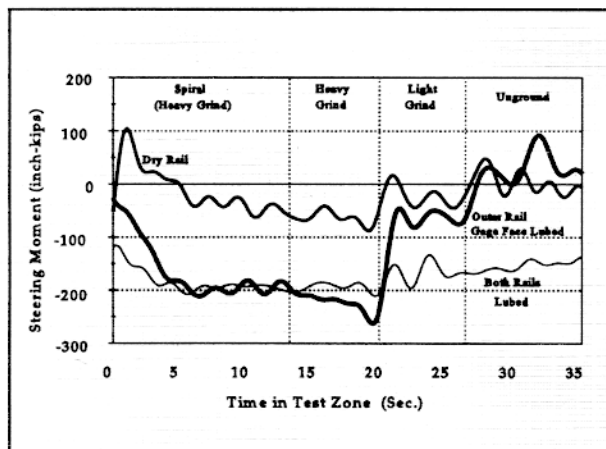


Exhibit 2. Truck Steering Moments

These results confirm the idea that negative steering moments can cause a truck to warp.

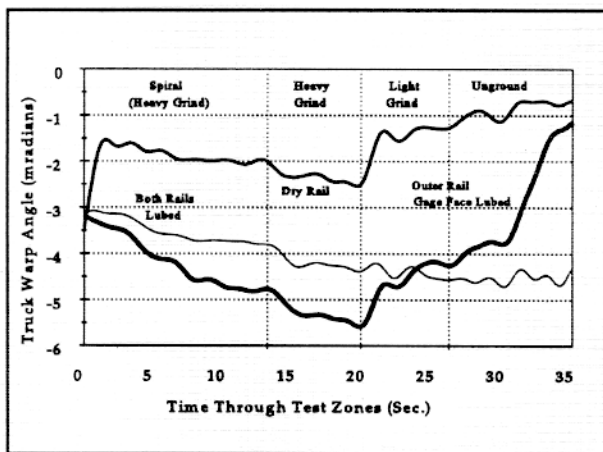


Exhibit 3. Truck Warp Angles

Exhibit 4 shows the sum of the low rail wheel lateral forces measured for all 10 test runs. By design, runs 1-2 were conducted on dry rails, runs 3-8 were conducted with only the gage face of the outer rail lubricated, and runs 9-10 were conducted

with both rails lubricated. However, after run 2, the lubricant was inadvertently applied to the outer rail running surface in addition to the gage face. This delayed the increase in negative steering moments and consequent lateral force increase, until the running surface had dried just before run 6.

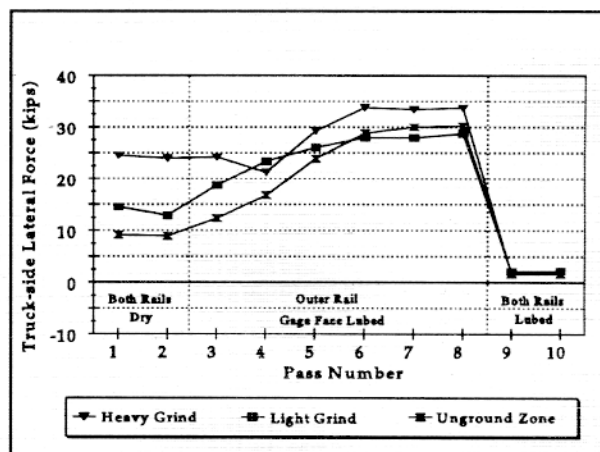


Exhibit 4. Truck-side Lateral Forces

Another problem was found when the lateral forces measured in the unground zone were larger than expected. This occurred, unfortunately, because the measurement site was not located deep enough in the unground zone for the test truck to recover from warp. In fact, Exhibit 3 shows that the truck warp angle was nearly -4 mrad at this point.

With no lubrication on the running surface of the inner rail (runs 1-8), the lateral forces were relatively large, especially in the heavy grind zone. After the inner rail running surface was lubricated for run 9, however, the lateral forces decreased dramatically, even though the truck warp angles were large (Exhibit 3). This confirms the idea that the lateral forces are generated by friction from lateral slip between the low rail and wheel.

Note: Contact Jon Hannafous at (719) 584-0682 with questions or comments about this document.

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