TECHOLOGY DIGEST

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EFFECTS OF RAIL GRINDING PRACTICES ON CURVES ON WHEEL/RAIL PERFORMANCE UNDER 39-TON AXLE LOADS

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Summary

Transportation Technology Center, Inc., engineers have been performing tests to help determine the effects of grinding on the life of rail on curves, as limited by wear and fatigue. A Heavy Axle Load (HAL) train, consisting of 70 loaded hopper cars and tank cars, each weighing approximately 315,000 pounds, is being operated at the Facility for Accelerated Service Testing. The cars are equipped with improved-suspension trucks designed to improve curving performance of HAL vehicles. Premium, head-hardened test rails in curved track have now accumulated more than 550 million gross tons (MGT). Five grinding practices are being evaluated.

In addition to studying the effects of grinding on rail life, three wayside load-measuring stations have been installed in 5- and 6-degree curves on track to monitor how contact geometry resulting from various grinding practices affects vehicle curving.

Findings to date include:

- No internal defects have been detected in either ground or non-ground rails after 550 MGT of HAL traffic. This indicates clean, premium rail is resistant to developing internal defects.
- Rails ground to two-point contact profiles on curves had much higher gage-face wear rates than non-ground rails.
- The ground and non-ground rails have comparable surface conditions, with the exception of some minor high-rail gage-corner checking on the non-ground rail.
- Spalling developed along the gage side of the top of the head of the low rail in the wood-tie, ground zone of the 5-degree curve after about 50 MGT. Unloaded track gage in the section was from 0.5 inch to 1.0 inch wide. After regaging, and without corrective grinding, the spalling has mostly worn away.
- Two-point contact conditions on the high rail on curves increase wheel set angle of attack and lateral curving forces, thus accelerating rail wear and increasing rolling resistance.

The tests are being performed through a joint effort between the Association of American Railroads and the U.S. Federal Railroad Administration. The rail-grinding test is part of a larger overall program that examines the effect of HAL cars on various track components to improve railroad safety and productivity.

Suggested Distribution:
- ❑ Maintenance of Way
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by TTCI Transportation Technology Center, Inc.
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INTRODUCTION AND CONCLUSIONS

Rail-profile grinding is widely practiced in North America with the intent of reducing surface and internal fatigue damage, and increasing rail life. Rail is the most significant capital asset of most railroads. The widespread adoption of rail-grinding practices by revenue-service railroads prompted a series of rail-profile grinding tests at the Facility for Accelerated Service Testing (FAST). The tests have helped determine effects of grinding on the life of rail, as limited by wear and fatigue. They have also aided in the study of how contact geometry resulting from various grinding practices affects vehicle curving.

Results of this testing have shown that grinding significantly increases rail-metal loss (and reduces wear life). Surface conditions of the ground and non-ground rails are similar, and there have been no internal fatigue defects in either rail up to 550 MGT. Grinding intended to provide gage-corner relief may also produce two-point contact conditions on the high rail. This increases lateral curving forces that lead to increased rail wear and increased rolling resistance.

FAST RAIL GRINDING TESTS

The two grinding test curves, one 5-degree curve and one 6-degree curve, used to evaluate the effectiveness of various North American grinding practices are located on the 2.7-mile High Tonnage Loop (HTL) at FAST. Premium head-hardened rails (NKK 133 RE HH) installed on wood and concrete ties in various test sections have accumulated a total of 550 million gross tons (MGT) as of March 1999.

Of the 550 MGT, 450 were accumulated using improved-suspension trucks. These trucks were designed with improved warp restraint and primary suspension pads. Both of these features allow the trucks to steer through curves better than the standard three-piece trucks used in the first 100 MGT of testing.

Annual tonnage on the HTL is about 125 MGT. Virtually all of the tonnage is applied by the HAL train, made up of 65 to 75 cars (currently coal gondolas and tank cars), each with a gross vehicle weight of 315,000 pounds. Train speed is 40 mph resulting in a cant deficiency of about 1.7 inches in both curves. Traffic is split nearly equally in each direction.

Five-Degree Test Curve

There are wood and concrete ties in this curve. The 5-degree test curve (Section 3 in Exhibit 1) is made up

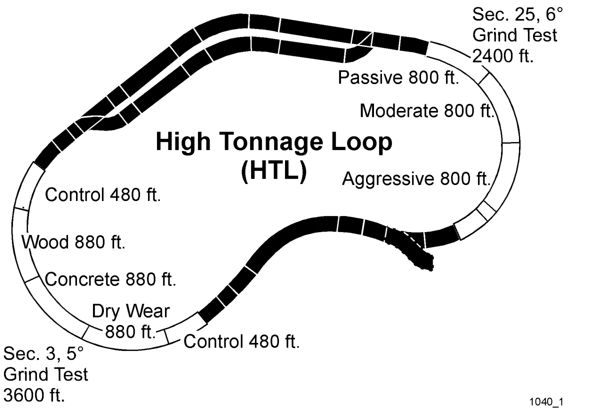


Exhibit 1. High Tonnage Loop at FAST

of five test sections, including two control zones. Each control zone is 480 feet long, one at each end of the curve. The rail in these zones is not ground.

An 880-foot-long “dry-wear” zone is included in this section. The high rail in this section was originally installed for 15 MGT in another 5-degree curve, which was not intentionally lubricated (light lubrication is carried onto the rail of this curve from other lubricated curves in the loop). Thus, the rail was “worn in” when installed in the lubricated high rail of the test curve. The objective of this test is to determine whether work-hardened regions in the dry-worn rail help increase fatigue resistance of the rail.

The two grind zones, each 880 feet long, are located near the center of the curve. One zone is on concrete ties with elastic fasteners and the other is on wood ties with cut spikes. Both zones are ground every 50 MGT with a nominal gage-corner relief on the high rail of 0.025 inch. Actual grinding is close to this amount, but may vary. The rail is generally worn to a conformal shape by the time it is ground. The low rail was initially ground to a 5-inch crown radius. Normal grinding is intended to maintain this crown radius.

Six-Degree Test Curve

The test rail is on wood ties in this 6-degree curve (Section 25 in Exhibit 1). The high-rail gage face is lubricated using wayside lubricators installed at each end of the curve. The high rail is ground to maintain continuous two-point contact on the high rail in all zones. The low rail is ground to an 8-inch crown radius.

The curve consists of three 800-foot long test zones. The first is referred to as the “aggressive-grind” zone that is ground every 12.5 MGT to achieve a nominal gage-corner relief of 0.010 inch. The second test zone is referred to as the "moderate-grind" zone ground every 25 MGT to achieve a nominal gage-corner relief on the high rail of 0.025 inch. The last test zone in this curve is referred to as the "passive-grind" zone. It is ground every 75 MGT to achieve a nominal gage-corner relief of 0.040 inch.

RESULTS OF GRINDING TESTS

The primary objective of the rail-grinding tests at FAST is to quantify the benefits of rail grinding by determining the effects on rail surface and internal fatigue damage.

RAIL PERFORMANCE

Three metal-loss measurements are taken: transverse rail profiles (using a device called Miniprof™; "snap-gage" measurements that measure head height at the center of the rail relative to the base, and gage loss 5/8 inch from the top of the railhead; and head-height loss measurements taken across the railhead at 0.1-inch intervals. Results reported in this section are from snap-gage measurements.

The amount of metal loss that has occurred in 515 MGT is illustrated in Exhibits 2 through 4. Measurements are taken at the predetermined grind cycles, and 515 MGT is the most recent cycle when all zones were measured. The metal loss at the gage point is entirely due to natural wear, since the grinder does not touch the rail where this measurement is taken. The metal loss on the head of both rails is a combination of wear and grinding.

Exhibits 2 and 3 show metal loss at the 5/8-inch point on the high rail, and head loss at the center of the railhead. Metal loss at each location is higher in the zones where the rail is ground. There is more metal loss in the dry-wear zone than in the other two non-ground zones. But aside from metal loss during the first 15 MGT, when the high rail was not lubricated and the low rail was ground (once) to a 5-inch crown radius, wear rates were similar.

Exhibit 4 shows the transverse profiles providing a comparison of rail shapes and a qualitative representation of the differences between the ground and non-ground rail sections.

The wear life of the rail can be projected based on wear rates, and the amount of wear allowed. These projections assume that wear rates will remain fairly consistent. Failures caused by fatigue defects are not accounted for (there have been no failures

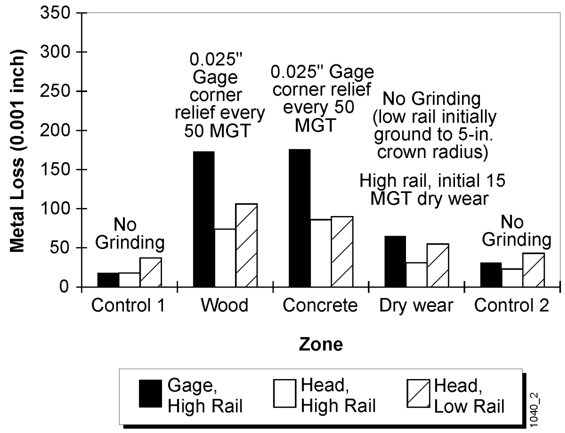


Exhibit 2. Total Metal Loss in 5-Degree Test Curve after 515 MGT HAL Traffic

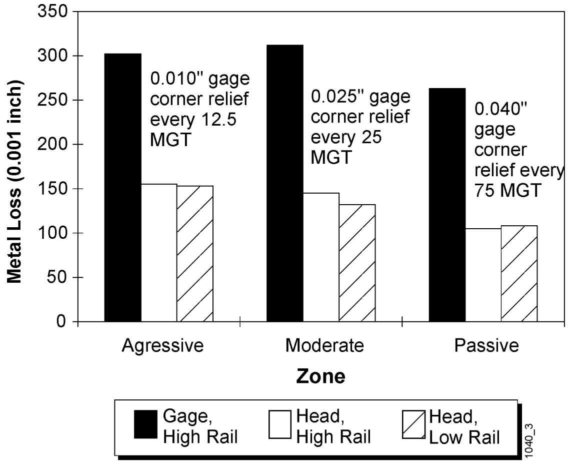
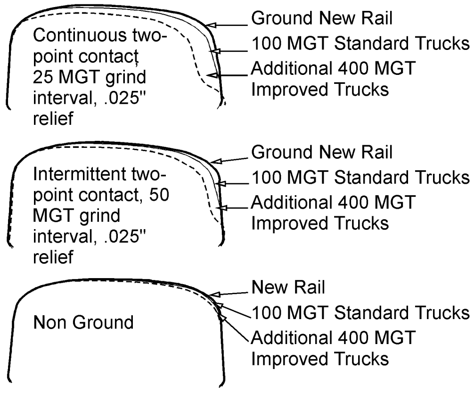


Exhibit 3. Total Metal Loss in 6-Degree Test Curve after 515 MGT HAL Traffic



All HH 133 RE Rail, Lubricated

Exhibit 4. Comparison of Ground and Non-ground Lubricated Rail Profile Shapes

caused by internal fatigue defects to date). The wear limit used for these projections is 7/8-inch combined gage and head wear. The general wear life projections are:

- Ground rail, 6-degree curve, about 1,000 MGT
- Ground rail, 5-degree curve, about 1,700 MGT
- Non-ground rail, 5-degree curve, more than 5,000 MGT

The estimated rail-wear life at FAST is substantially higher than that in revenue service. The fatigue life of the test rail will be monitored as long as it is practical to do so. It is not expected that the fatigue life can approach the projected non-ground wear life. Based on 550 MGT operations at FAST, the premium, head-hardened rail appears to be fatigue-resistant.

Wheel/Rail Contact Geometry and Curving Forces

All three grind zones in Section 25 (aggressive, moderate, and passive) have similar amounts of gage wear even though the grinding intervals vary from 12.5 to 75 MGT. This is likely due to the constant gage-corner relief in all zones. Though the ground profiles vary slightly in the three zones, the rail does not wear enough between grind cycles to allow wheels to contact the high rail gage corner. The dynamic behavior of passing cars, as influenced by wheel/rail contact is similar (in all of the zones).

The rails in Section 3 are ground to similar(2-point contact) profiles as those in Section 25. But the gage-corner relief in these zones is nearly gone when the rails are reprofiled every 50 MGT. Finally, those rails that are not ground (Control Zones and the Dry-Wear Zone) have extremely low gage wear. These observations indicate that profiling a high rail of a curve with gage relief will result in increased gage wear.

There are three wayside load-monitoring systems on the HTL for measuring forces on the rail. Two of the three load stations are located in the 6-degree curve. One is in the moderate-grind zone, where there is continuous two-point contact. The other is in a non-ground test zone, where the rail is worn to a conformal shape. In order to document the effect of wheel/rail contact geometry and lubrication conditions on vehicle dynamic behavior, lateral rail forces were measured as the HAL train passed over each location. Data was collected with the train operating at normal speed of 40 mph.

Exhibit 5 provides a comparison of the wayside lateral rail loads measured in two-point contact and conformal contact zones. This type of a measurement provides information on train loading at a given point in the track. This plot shows one complete train pass at each location.

As seen in Exhibit 5, high-rail lateral forces are considerably higher in the two-point contact zone than they are in the conformal contact zone. This was expected. High-rail gage-corner relief reduces the steering ability of the wheel set by contacting the high-rail wheel at two points rather than one point, thereby reducing curving performance of the vehicle.

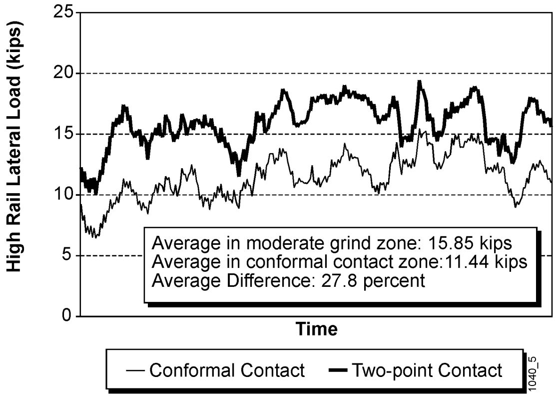


Exhibit 5. Comparison of Lateral Rail Loads in Conformal and Two-Point Contact Zones, Lubricated 6-Degree Curve

FAST AND REVENUE SERVICE DIFFERENCES

Results at FAST are not always duplicated in revenue service tests due to a number of operational characteristics unique to FAST. However, FAST provides a more-uniform, controlled environment in which the effects of many variables (such as lubrication conditions, train speed, and car types) can be isolated to quantify the impact of a major underlying parameter (grinding) and can be quantified as a function of HAL operations.

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A MORE DETAILED REPORT, WHICH MAY CONTAIN REVISED INFORMATION, MAY BE AVAILABLE AT A LATER DATE THROUGH AAR/TTCI, PUBLICATIONS, P.O. Box 79780, BALTIMORE, MD, 21279-0780.