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Effects of Rail Profile Grinding on High-Hardness Premium Rail at FAST

Joseph LoPresti

Summary

The effects of rail grinding on the performance of high-hardness premium rail have been evaluated at the Facility for Accelerated Service Testing (FAST) since 2003. A 6-degree test curve is divided into three test sections, representing two different grinding practices as well as unground rail. There are three types of rail, two of approximately 395 Brinell hardness number (Bhn) and one approximately 370 Bhn, in each section. By the spring of 2007, 515 million gross tons (MGT) of traffic had accumulated on the rails.

The following results, which are typical at FAST (revenue service conditions may differ), provide insights into the effects of wheel/rail contact conditions and rail mechanical properties on rail performance.

- Grinding tests at FAST indicated that state-of-the-art high-hardness rail required little or no grinding. Unground rail in 515 MGT of traffic developed only minor, isolated rolling contact fatigue (RCF), and had no internal railhead defects under 315,000-pound car operations. Because wheels on the test train at FAST tend to wear to a shape conformal with the rail in the High Tonnage Loop, and gage face of high rail and the top of the low rail are lubricated, contact stresses remained acceptable throughout the test.
- Compared to the unground rail, total metal loss in the preventive grinding zone was about 77 percent higher on the high rail and about 240 percent higher on the low rail. The metal removed by preventive grinding was the primary reason for the increase; wear rates were similar.
- The 370 Bhn rail wore and deformed more than the 395 Bhn rails. The difference in wear was about 15 percent.
- A profile intended to produce higher contact stresses resulted in more RCF, but it was not severe.
- There is much less RCF on the low rail of the lubricated 6-degree curve, than there is on the low rail of the unlubricated 5-degree curve at FAST.
- Unrelated to rail grinding tests, there were six rail breaks originating at base defects in the 395 Bhn test rails. No breaks were in the 370 Bhn rail.

The test train at FAST typically consists of 75-80 heavy axle load cars loaded to 315,000 pounds gross rail load. Train speed during operation is 40 mph. The program is funded by the Association of American Railroads and the Federal Railroad Administration. The Heavy Axle Load Engineering Research Committee directs the research.



INTRODUCTION

Rail is a valuable asset and costly maintenance item for railroads, with over one-half million tons being laid annually in North America. Extending the life of rail can improve the economics of railroad operations. This is more difficult, and important, when car weights are increased. Higher axle loads can increase the occurrence of surface and internal defects in rail. Rail profile grinding is one way of reducing the occurrence of defects, extending rail life, and improving safety. Railroads have effectively used rail grinding to achieve these goals.

Rail grinding tests at FAST have evaluated various grinding strategies, with metal removal amounts and grinding intervals recommended by railroad technical advisory groups. Variables that can affect defect occurrence in rail can be controlled easier at FAST than in revenue service. These variables include rail lubrication, wheel profiles, and train handling. The objectives of the rail profile grinding test at FAST include evaluating the effect of various grinding practices on rail surface condition, defect occurrence, wear life, and vehicle curving.

TEST DESCRIPTION

The grinding test on high-hardness premium rail started in the spring of 2003. It was conducted in a 6-degree curve with 5-inches of superelevation. The typical train speed of 40 mph results in a cant deficiency of about 1.7 inches. The gage face of the high rail was lubricated with lithium based molybdenum disulfide (MoS₂) grease, and the top of the low rail was lubricated with 90w oil. Traffic was split nearly equally in each direction.

The test evaluated the effects of various grinding practices on premium rail. The test curve was divided into three zones, (Figure 1). Each zone represented one grinding practice, and within each zone were three types of 141-pound rail:

- Nippon Steel Corporation
 - High-carbon Hypereutectoid (HE) 400, approximately 400 Bhn
- Rocky Mountain Steel Mills
 - 1-percent Carbon Pearlite, approximately 395 Bhn

- Rocky Mountain Steel Mills
 - Deep Head Hardened (DHH) 370, approximately 370 Bhn

TTCI evaluated the following grinding practices:

- Preventive Grind: The rail was ground at approximately 30-MGT intervals. An average of 0.011 square inches of metal was removed from the high rail and 0.016 square inches from the low rail with the goal of producing a two-point conformal profile on the high rail and an 8-inch crown radius on the low rail. Grinding also removed surface damage such as RCF cracks and spalls.
- High-Contact Stress Zone: Intentionally grinding of the rails to create a mismatch between the rail profile and the average worn wheel profile at FAST created a high-contact stress zone. TTCI's proprietary WRTOL™ software was used to develop the ground rail profiles that led to poor wheel/rail interaction. WRTOL is a software package that assesses wheel/rail contact conditions to predict RCF, wheel/rail wear, and vehicle performance. Principal outputs are contact stress, wheel rolling radius difference, and contact angle. A database of typical wheel profiles at FAST was generated and compared to rail profiles at FAST.
- No Grind (control) Zone: This zone was not to be ground unless it would compromise safety, or necessitate the removal of the rail. The rail was unground in 515 MGT of traffic.

RESULTS

The results of this test were consistent with the results of previous grinding tests on premium rail at FAST.^{1,2} Clean high-hardness premium rail is resistant to RCF and to development of transverse defects. When adverse wheel profiles are avoided, and conditions that produce high vehicle dynamic forces are addressed, the need for grinding can be greatly reduced. Under the conditions at FAST, namely:

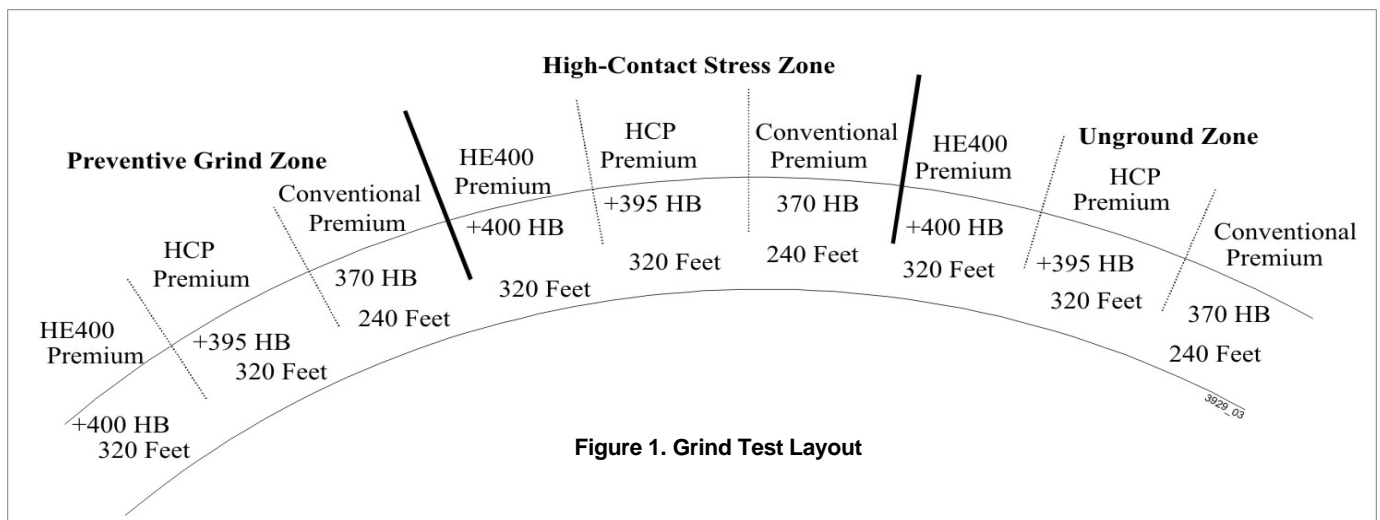


Figure 1. Grind Test Layout

- Conformal, uniform wheel/rail contact conditions – no severely hollow wheels
- Consistent, overbalance speed with limited braking and acceleration
- Lubrication on the gage face of the high rail and on the top of the low rail
- Dry climate

The premium rails in the unground zone developed only light, isolated RCF in 515 MGT of traffic, and there were no rail breaks initiating in the head of the rail. Figure 2 shows the condition of the unground rails.

Because it is difficult, if not impossible, to achieve these conditions in revenue service, rail grinding there can extend the life of premium and standard rail.



Figure 2. Condition of Unground Rails after 515 MGT. Low Rail Left, High Rail Right

Metal Loss

Total metal loss in the preventive grind zone was approximately 77 percent higher than for the unground zone on the high rail, and approximately 240 percent higher on the low rail (the high-contact stress zone is excluded because it is an atypical practice, and heavy metal removal was required to achieve the desired profiles). The metal removed by grinding was the primary reason for the increase; natural wear rates were similar in the unground and preventive grind zones (Figure 3).

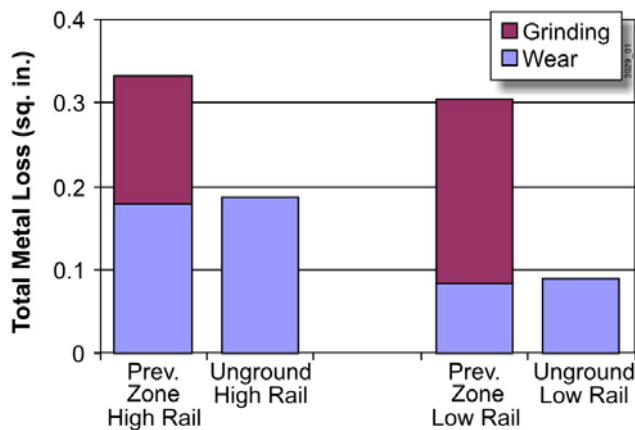
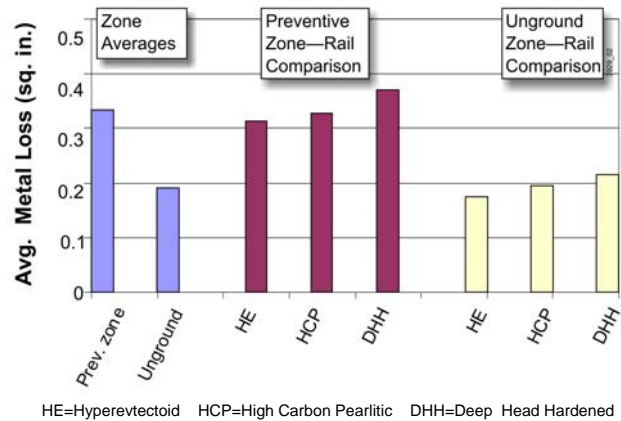


Figure 3. Total Metal Loss and Natural Wear in Ground and Unground Rail

The DHH 370 rail showed slightly more metal loss and more wear than the higher hardness rails. Figure 4 shows results for the high rail. There was less of a difference on the low rail where the amount of metal removed by grinding far exceeded metal loss from natural wear.



HE=Hypereutectoid HCP=High Carbon Pearlitic DHH=Deep Head Hardened

Figure 4. Metal Loss by Rail Type

Effects of High-Contact Stress Profiles

High-contact stress profiles were ground on both the high and low rails of one zone after 150 MGT. The upper gage corner of the high rail and the field side of the top of the rail were heavily ground. This produced an exposed gage corner and a narrow contact band on the top of the rail. The field side of the top of low rail was heavily ground to narrow the contact band, and to move it toward the gage side of the rail (inhibiting vehicle curving). Figure 5 shows profiles illustrating these grind patterns.

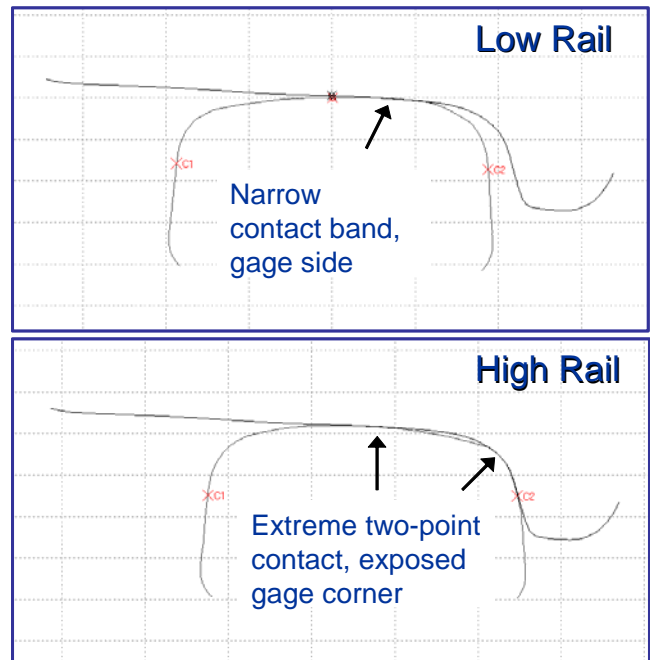


Figure 5. High-Contact Stress Profiles

These profiles were maintained when the rail was ground at approximately 30 MGT intervals. WRTOL analysis of the modified profiles predicted an increase in contact stress and a concentration of the stresses. The high rail of the high-contact stress zone showed more RCF than the high rails of either of the other two zones, but it did not become problematic. The RCF was not on the gage corner, but on the head of the rail. The low rail of the high-contact stress zone showed RCF similar to that in the preventive zone. The presence of lubrication, as was on the gage corner of the high rail and the top of the low rail at FAST, can have a mitigating effect on RCF.

A further illustration of this is a comparison of the condition of the unground low rail in this curve, with that of the unground low rail in a unlubricated (but contaminated) 5-degree reverse curve at FAST. The premium rail in the unlubricated curve developed significant RCF after 265 MGT. The unground rail in the lubricated curve was in good condition after 515 MGT. Other studies have shown that top of rail lubrication can reduce RCF.³

Rail Conditions in the Preventive Grind Zone

The grinding in the preventive grind zone is similar to what many railroads practice; i.e., light metal removal at regular intervals and was recommended by the rail grinding TAG. This grinding practice was effective in removing shallow cracks and checks from the surface of the high rail. The surface condition of that rail was better than the high rails in the other two zones. On the low rail, the 8-inch crown radius concentrated contact in the center of the rail and resulted in slightly more RCF than was observed on the unground low rail.

Rail Breaks

There were no rail breaks initiating in the head of the rail, but six breaks did initiate in the base of the rail. These breaks are not related to grinding practices, but noted here as they may be affected by the mechanical properties of the rails. All six breaks were in the higher hardness rails, and all were initiated by mechanical damage at the base of the rail. The mechanical damage was caused in all cases by interaction between rails and tie plates and fasteners. Such damage is nearly unavoidable during high tonnage, heavy axle load operations. Previous tests have suggested that high hardness in the base of the rail may reduce the toughness of the base and increase the likelihood of rail fractures initiating at mechanical damage.^{4,5}

CONCLUSIONS

Clean high-hardness premium rail is resistant to fatigue damage. With good wheel/rail contact conditions and rail lubrication, premium rail can provide hundreds of MGT of HAL service without rail grinding. It is difficult, if not impossible, to achieve this in revenue service, where rail grinding is successfully used to improve rail surface conditions and increase rail life.

FUTURE TESTING

TTCI is developing a plan to modify the grind test to continue to provide valuable information to the railroad industry.

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