TECHNOLOGY DIGEST
Timely Technology Transfer

RAIL GRINDING: THE EFFECTS OF PROFILE ON RAIL WEAR AND INTERNAL FATIGUE

by
R. K. Steele
TD95-008

Summary

In-track tests at the Transportation Technology Center (TTC) and revenue service tests have shown that rail profiles that separate the gage side of the high rail running surface from the throat of the wheel (two-contact type rail profiles) cause increased gage face wear even in well lubricated conditions. This result could be expected, but what do we know about improvements in rail fatigue life which is the primary reason for rail profile grinding?

Over the course of three grinding profile experiments, the development of internally initiated shell/DF (Defect Fracture) defects has exhibited some variability. In the first two experiments, the two-contact type profile was most prone to shell/DF occurrence. The shells were located at very shallow depths beneath the high rail gage corner. In the second test, the rail condition most resistant to shell/DF occurrence was a dry worn rail. However, in a much larger third test, wherein two-contact, ground conformal, and lubricated worn-to-conformal rail profiles were evaluated, the ground conformal profile condition yielded the greatest number of shell type defects with the lubricated worn-to-conformal profile next. Work hardening in the process of forming conformal profiles appeared to improve resistance to internal fatigue defect introduction for an appreciable period of time, but could not prevent defect initiation ultimately without grinding. The two-contact profile ground at 25 Million Gross Ton (MGT) intervals yielded only a few shell/DF defects and that ground at 12.5 MGT intervals yielded none.

Hardness maps were made on transverse sections of rails from the TTC tests and from revenue service tests which had contained shell/DF defects. These revealed where wheel loads had been carried on the gage corners. Two-contact profiles from both TTC and revenue service, which had shelled, exhibited regions of concentrated work-hardening on the gage corners even though the corners originally had been relieved by grinding.

The hardness maps also showed that the dry worn rail profile condition resisted shell/DF formation much better than the two-contact profile condition, because at the depth at which the shell/DF would have formed, the hardness was notably greater. This increased hardness resulted in metal with greater fatigue resistance.

Suggested Distribution:
Operating/Engineering Department —
- ☐ Maintenance of Way/Planning
- ☐ Track Maintenance

Association of American Railroads
Research and Test Department

March 1995

INTRODUCTION AND CONCLUSIONS

Work at the Transportation Technology Center and by CP Rail has shown how severe two-contact profiles can adversely affect lateral wheel/rail forces. This is especially true where the high rail gage face is well lubricated. This Digest addresses the wear and internal fatigue performance of the high rails as a consequence of using different types of profiles.

Three terms often used to describe rail profiles are (1) single point, (2) conformal, and (3) two-contact. Each is illustrated in Exhibit 1. For a single point contact, the wheel profile radius can be much greater than the rail profile radius (at the contact) leading to a very narrow contact band and very high contact stresses. In the conformal contact, the wheel and rail profile match over substantial distances from the gage face over onto the ball of the rail. Where localized wheel-on-rail contacts do occur, the profile radii of each half are essentially the same. For both single point and conformal contacts, the effective rolling radius of the leading axle high rail wheel is in the wheel throat. The two-contact profile can substantially separate the flange and tread contacts, each of which can have a very different rolling radius tending to diminish steering of the wheelset.

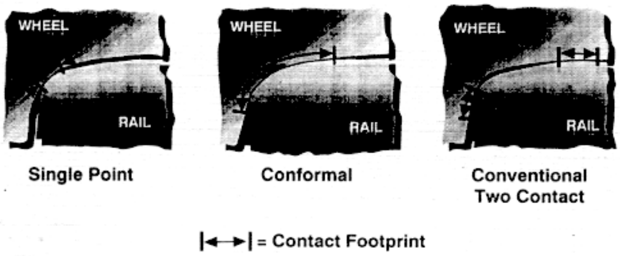

Exhibit 1. **Conceptual Types of W/R Contact.**

The effect of rail profile type on rail performance (gage face wear and internal fatigue defect occurrence) has been difficult to establish clearly in revenue service. In part, this is because few carefully controlled wear tests have been run. Also, in the relatively long periods of service exposure needed for internal fatigue behavior assessment, other factors besides profile alone will have changed as well.

The controlled test conditions at AAR's Facility for Accelerated Service Testing (FAST) High Tonnage Loop (HTL) have offered an excellent opportunity to evaluate both wear and internal fatigue performance for different profiles under 100- and 125-ton cars albeit for softer rails (≤ 300 BHN) in the limited service exposure periods possible (≤ 200MGT). Three tests have been conducted and a fourth is just beginning. The tests were conducted mostly in a 6° curve. Exhibit 2 illustrates the gage face wear rates from the first experiment while Table I summarizes the gage face wear rates for the second experiment. Exhibit 3 portrays the typical profile shapes in the middle of the third experiment. In all three experiments, the two-contact profile exhibited gage face wear rates many times higher than those of the conformal profiles. Recently, wear results have become available from revenue service tests on the Norfolk Southern (Exhibit 4). These tests confirm that conformal profiles (achieved thru wear/metal flow) tend to have the lowest gage face wear rates.

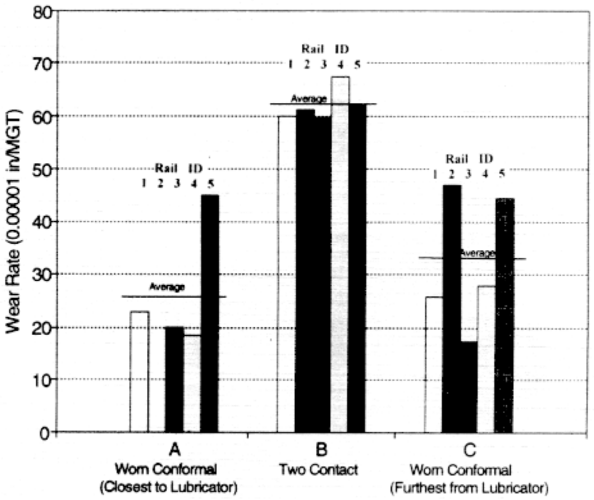

Exhibit 2. Gage Face Wear Rates from the First Experiment.

Tables II and III summarize the shell/DF occurrence data from the first two experiments respectively. Exhibit 5 presents the defect rates for different profiles as a function of MGT from the third experiment. All rails for which defect data is presented were 300 BHN or less.

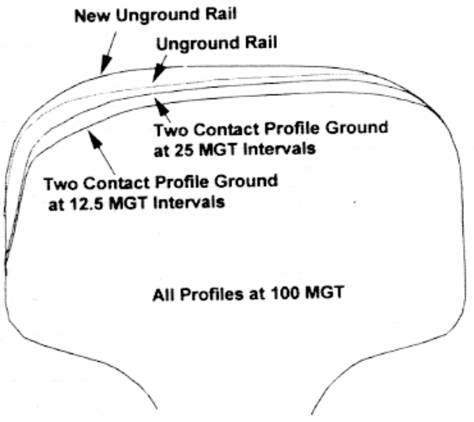

Exhibit 3. High Rail Profiles Midway Through The Third Experiment.

At 25 MGT, Ingot Cast HH

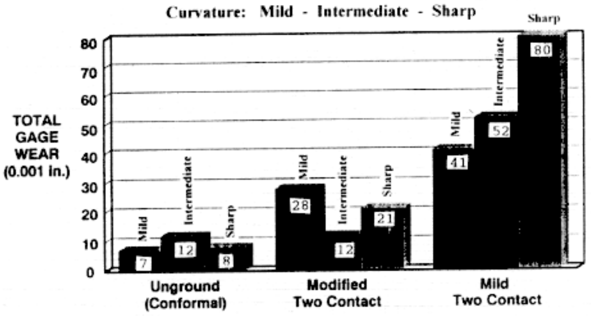

Exhibit 4. Gage Face Wear vs. Profile Type & Curvature Severity at 25 MGT.

The first two tests showed, surprisingly, that the shell/DF occurrence rate was highest in the two-contact ground regions and lowest in regions of conformal contact achieved either thru dry or lubricated wear (but not by initial grinding to shape). The superior performance after dry wear exposure (second experiment) is in line with past FAST experience where alternating dry and lubricated running was very effective at suppressing shell/DF occurrence. Exhibit 5 shows that in the third experiment the profile <u>ground</u> to conformality at the very beginning generated shell/DF at the highest rate. The rail which became conformal by wear and plastic deformation (and was not ground) produced fewer defects initially, but eventually its defect rate rose quickly. The delay before the rise in the defect rate suggests that work hardening may have been helpful. In contrast to the previous two experiments, the two-contact profile ground at the 25 MGT interval, produced only a modest defect rate. Indeed, when ground at a 12.5 MGT interval, no defects were formed in 180 MGT.

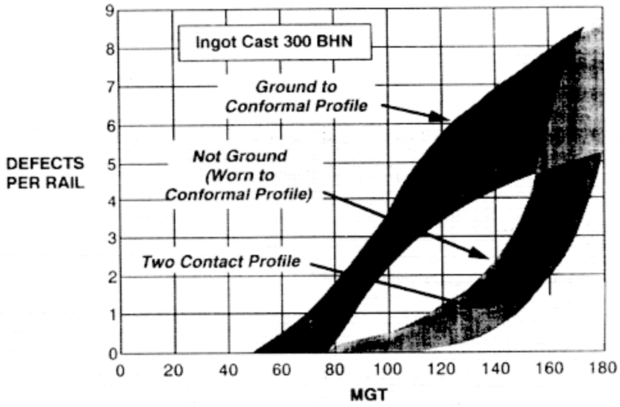

Exhibit 5. FAST HTL Rail Profile Test Results.

In tests where shells have occurred in rails that have been ground to two-contact profiles, they usually appear tucked up under the gage corner, sometimes at two planes, at an angle to each other(Exhibit 6). Hardness maps made on transverse sections from such rails have been used to determine where the wheels have been borne by the rails. In each case, a localization of work hardening in the gage corner has been found (Exhibit 7). This suggests that the gage side corners of high rails (originally ground away to prevent contact with the wheel throat) may have returned quickly because of the higher gage face wear rate characteristic with two-contact profiles. If the corner carried wheel loads long enough before regrinding, shell/DF occurrence could be expected.

Hardness maps can also help understand why the dry worn profile used in the second experiment (and in previous FAST rail experiments) performed so well. Exhibit 8 illustrates that at the depth at which the shell initiated under the two-contact profile, dry wear had increased the hardness by about 5 points Rockwell C (R_c34->R 39). This would be expected to improve fatigue resistance at that depth.

Exhibit 6. Biplanar Shell Under Gage Corner of Two-Contact Ground Rail.

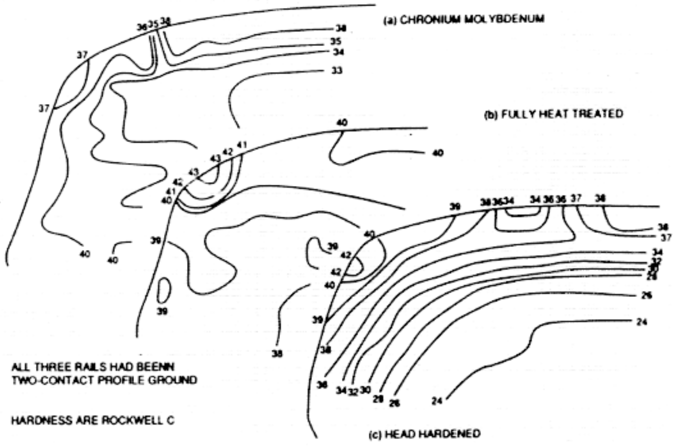

Exhibit 7. Deformation Patterns of Three Revenue Service Rails Exhibiting Unexpected Shell/DF Occurrence.

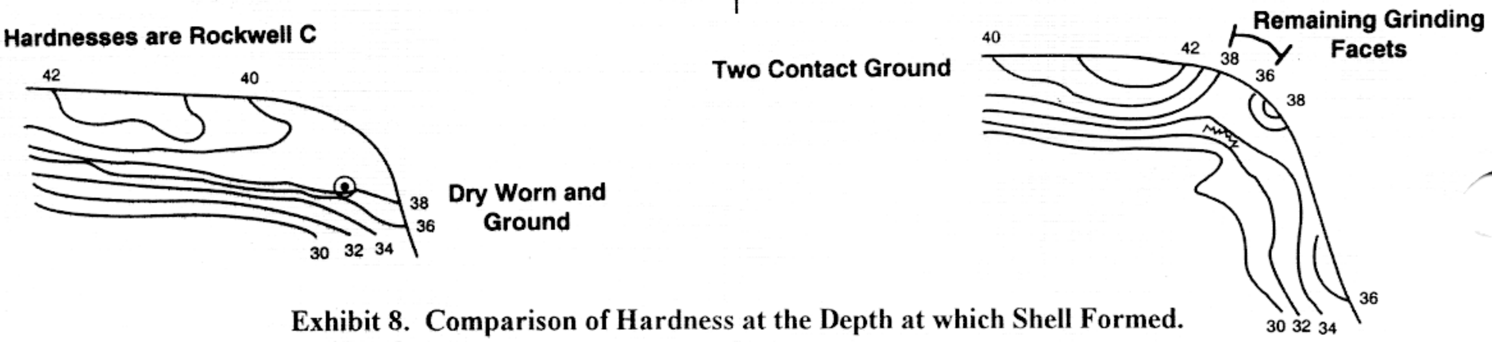

Exhibit 8. Comparison of Hardness at the Depth at which Shell Formed.

Table I. Gage Face Wear Rates from the Second Experiment

Segment ->	A (Dry Worn)		B (Ground)		C (Ground)	D (Not Ground/Worn Conformal
Profile ->	2-Contact	Conformal	2-Contact	Conformal	2-Contact	Conformal
Wear rate -> inches/1000 MGT	1.3	0.143	1.4	0.14	1	-0.1

Table II. Shells in 90 MGT in Standard Carbon Rail (≤300BHN)

Seg A	Seg B	Seg 3
44	158	20

Seg's A, C were unground }
Seg B was ground to a 2-contact profile } 6°

Table III. Shells by Profile Type (6° Curve)

Type Profile			
Dry Worn (Conformal)	Ground Conformal	2-Contact	As-rolled unground
0	9	13	2

Note: Contact K. L. Hawthorne at (719) 584-0541 with questions or comments about this document.