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# Simulations of Rail Grinding in Turnouts

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**Key Findings:**

- Applying a tangent grinding template to both the main and diverging routes of a service-worn turnout shows benefits in regard to predicted rail wear on the closed switch rail/stock rail.
- Compared to a tangent grinding template, the use of high- and low-rail grinding templates on the diverging route shows a predicted increase in rail wear on the closed switch rail/stock rail. This is due to the abrupt changes in the rail profile and the increased flatness of the profile associated with the low-rail grind template.
- Grinding the main route of a turnout to a tangent rail template decreases predicted single-wheel lateral-to-vertical (L/V) values by reducing vehicle hunting.

As specialty rail grinders begin to incorporate new technology to better control the resulting rail profile, questions arise regarding target grinding templates in turnouts. In response to these questions, TTCI conducted parametric NUCARS®* simulations to investigate the effects of different rail profiles on vehicle performance and rail wear in a Number 20 AREMA turnout. Profiles representing new rails, service-worn rails, and rails ground according to open track templates were considered. This work is part of the Association of American Railroads (AAR) Strategic Research Initiatives Program.

## BACKGROUND

The process for controlling the cross-sectional rail profile when grinding open track with a large production grinder takes advantage of technological advances such as laser-based measurement systems to capture the existing worn rail profile. This process allows software algorithms to arrange the angles of the grinding stones in a “pattern” that will concentrate metal removal from different portions of the rail head. Grinding done using this method can minimize the differences between the post-grind and the target-template profiles.

To avoid causing damage to any portion of a turnout, a production grinder will lift its grinding stones about 50 feet ahead of the point of switch (POS) and set them back down to resume grinding again about 50 feet past the frog. A smaller specialty grinder is used to grind a turnout because it can grind to within several feet of the POS and frog without causing damage. A specialty grinder can independently lift or lower various carts containing the grinding stones at different locations on the track allowing grinding nearer to the POS for carts with stones arranged at angles to grind the gage corner. Additionally, in areas of the turnout where insufficient lateral clearance from the switch point to the stock rail exists, carts with stones arranged at angles to grind the field side of the rail stay lifted longer to avoid gouging the stock rail.

Unlike open track grinding done with a large production grinder, typical grinding in turnouts is still a relatively manual process for the purpose of rail profile control. The majority of turnouts are still ground the traditional way

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*NUCARS® is a registered trademark of Transportation Technology Center, Inc.

with a worker estimating the crown radius of the worn rail using a special gauge and selecting a grind pattern based on the judgment of what the rail needs. This worker calls grind patterns to the operator of the specialty grinder who makes grinding passes until the rail crown has reached the target radius. Some specialty grinding equipment, however, has the capability to at least partially automate the process in a way similar to open track grinding.

Most turnouts are located on the tangent track, and the production grinder typically uses the railroad's default tangent template profile to shape the rails on either side of the turnout. Therefore, it also makes sense that the specialty grinder shapes the turnout rails to the tangent template, particularly on the straight or main route. When the specialty grinder also has time to grind the diverging route, typically it will use the tangent template on both rails here as well. Because the diverging route is effectively a curve, this may not be the optimal use of templates.

## SIMULATIONS

NUCARS® multi-body dynamic simulations were conducted to simulate a freight car negotiating a Number 20 AREMA turnout with 1/4-inch switch point risers. All simulations were conducted with nominal turnout geometry (i.e., with track curvature and switch entry angle, but without alignment or surface deviations). Rail profile changes throughout the frog were not simulated. An older hopper car equipped with standard three-piece trucks was used for all simulations to represent vehicle performance at or slightly below the expected performance of the North American fleet. The simulated empty and loaded cars weighed 63,000 pounds and 263,000 pounds, respectively.

The simulation matrix consisted of 1,260 cases, including both routes (main and diverging); both directions (facing point and trailing point moves); multiple speeds (40, 50, and 60 mph for main route; 35, 40, and 45 mph for diverging route); and three wheel-rail friction conditions (dry, gage face lubrication, and gage face lubrication plus top-of-rail friction modifier).

Five different wheel profile combinations were used to cover a range of conditions. The AAR-2A profile was simulated on all positions in the car to represent a new condition. Profiles from two service-worn wheelsets were selected to represent moderate and heavy wear. The moderately worn wheelset had a 0.5-mm hollow worn wheel on one side of the axle and its naturally worn mate with minimal hollowing on the other side. The heavily worn wheelset had a 4-mm hollow worn wheel and its naturally worn mate with a 0.5-mm hollow on the other side. Two moderate wear conditions (using the moderately worn wheelset) and two heavy wear conditions (using the heavily worn wheelset) were simulated by positioning the hollowest wheels in diagonally opposite corners of each truck (positions L1, R2, L3, and R4 and again in positions R1, L2, R3, and L4).

Three rail profile conditions were simulated for the main route. A new rail profile condition was represented with a series of rail profiles measured on a newly installed turnout. A service-worn turnout was represented with a series of rail profiles measured on a mainline turnout with more than a decade of service. A freshly ground turnout was simulated by applying a tangent rail grinding template to the service-worn turnout profiles. In addition to these three rail profile conditions, the diverging route was also simulated by applying a low-rail template to the inside rail of the diverging curve and stock rail on the open side and a high-rail template to the curved closure rail and closed switch rail/stock rail. For all ground rail cases, both rails were ground to a tangent track template on the open track up to the POS.

The rail grinding process was simulated using a previously developed MATLAB® script.[1] The script aligned the grinding templates with the measured rail profiles at various locations throughout the turnout, then produced ground rail profiles by removing material wherever the worn profile existed above the template. Near the POS, it was impossible to use the regular grinding templates because they would have cut deeply into the stock rail. Instead, truncated templates were used to simulate rail grinding between 10- and 45-degree contact angles on the gage side only. This allowed the simulation of a specialty grinder raising and lowering different carts with the grinding stones at different locations on the track.

Table 1 and Figure 1 contain details of the five different zones considered in the analysis. Zone 1 covers the open track before the POS. Zones 2, 3, and 4 include the switch rails and stock rails. All three zones are used to demonstrate the different grinding template applications in this important transition area. Zone 5 encompasses the closure rails and associated curved and straight main rails. The frog and all rails beyond the frog are not considered.

**Table 1.** Turnout analysis zones for the main route and diverging route

| Zone | Distance from POS | | Rail grinding template | |
|---|---|---|---|---|
| | Start | End | Open Side | Closed Side |
| 1 | -50 ft. | 0 ft. | Full | Full |
| 2 | 0 ft. | 8.5 ft. | Full | None |
| 3 | 8.5 ft. | 20.5 ft. Main<br>15.5 ft. Diverg. | Full | Truncated |
| 4 | 20.5 ft.Main<br>15.5 ft. Diverg. | 39 ft. | Full | Full |
| 5 | 39 ft. | 140 ft. | Full | Full |

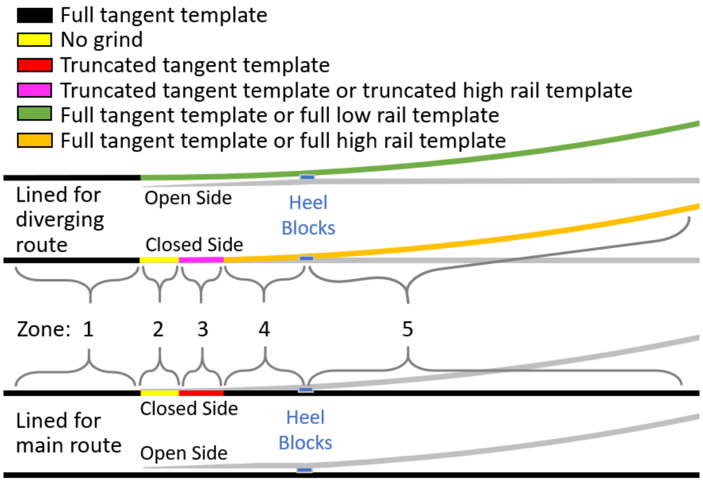

**Figure 1.** Graphical representation of turnout analysis zones

## RESULTS

Two vehicle dynamic criteria were considered when evaluating the results: maximum L/V wheel force ratio and minimum vertical wheel load. Both metrics were analyzed according to 3-foot/50-millisecond limits as defined by the AAR.[2] Minimum vertical wheel loads did not drop below 50 percent of the static value under any condition and are therefore of little interest for additional investigation. Maximum L/V values are shown in Figure 2. When lined for the main route, rail grinding was observed to reduce the highest L/V values from approximately 0.8 to less than 0.5. The simulations predicted moderate hunting at higher speeds for the unground rail profiles due to a higher effective conicity of the wheelsets on the new and worn rail profiles. Grinding had less of an effect on the L/V values in the diverging route due to the slower speeds (no hunting) and curved nature of the track geometry producing wheel flange contact with the rail.

**Figure 2.** Highest single-wheel L/V values

In addition to the dynamic criteria, the effect of grinding on the predicted rail wear was analyzed. NUCARS® provided a wear metric that was useful for relative comparisons by multiplying the creep force at the contact patch times the creepage.[3] The averages of this metric are shown in Figures 3 and 4 for the mainline and diverging routes, respectively. By using the average of the rail wear metric within each zone, any discrepancies due to zone length are nullified.

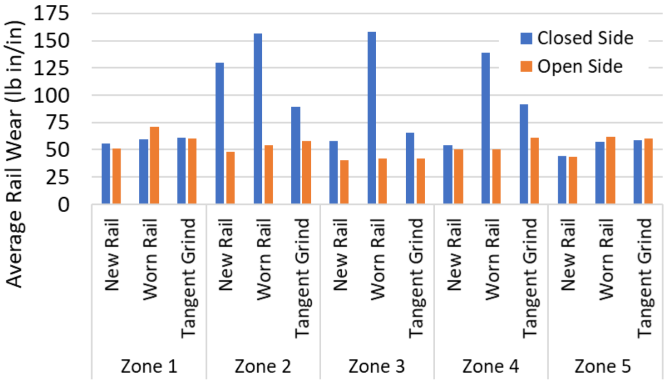

**Figure 3.** Main route rail wear

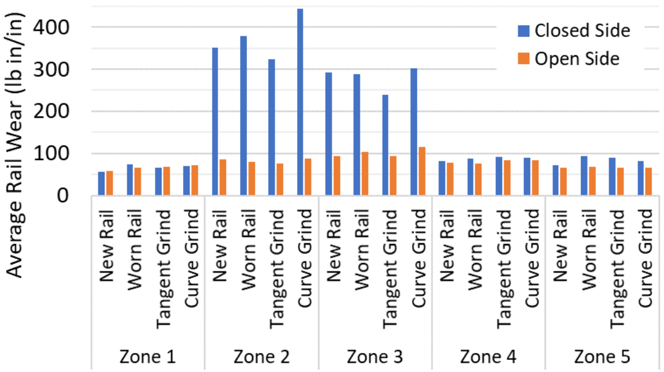

**Figure 4. Diverging route rail wear**

On the main route, the worn rail profiles resulted in the most predicted wear on both the stock rail and closed switch rail. Rail grinding brought the rail wear rate closer to the condition of new rail and actually improved the wear rate over both the new and naturally worn rail in Zone 2 nearest the POS. Because no grinding was simulated on the closed side of the turnout in Zone 2, these benefits occured due to the wheel/rail contact conditions generated by grinding on the open side stock rail in Zone 2.

Though it was not surprising to see more wear on the diverging route compared to the main route due to the track curvature, it was somewhat counterintuitive that the tangent grinding template would outperform the high- and low-rail curve grinding templates in Zones 2 and 3. A detailed investigation of this phenomenon in the simulation results showed several contributing factors. During facing point moves, the lateral contact position of the wheel on the open side stock rail shifted dramatically at the transition between Zones 1 and 2 when the rail profile changed from a tangent template grind to a low-rail template grind. This caused an abrupt wheelset steering reaction toward the closed side of the turnout and resulted in heavy flange contact with the switch rail gage face. In an actual grinding operation, this transition in rail profiles would occur less abruptly and would be expected to have less of an effect on the results. In Zones 2 and 3, severe two-point contact occured between heavily hollow worn wheels and the switch rail/stock rail on the closed side of the turnout. The flatter low rail template on the open side of the turnout contacted the wheels closer to the flange compared to the tangent rail template. This restricted the beneficial rolling radius differential between mated wheels and resulted in a larger flanging force and more predicted wear on the gage face of the switch rail. As the wheels on the closed side of the turnout transitioned from shared contact with the switch rail and stock rail in Zone 3 to full contact with the switch rail in Zone 4, larger rolling radius differences developed and the resulting predicted wear rates were substantially lower.

## CONCLUSIONS

Simulations of rail grinding in turnouts show beneficial results in terms of reducing vehicle hunting on the main route and reducing rail wear rates in the critical switch rail/stock rail areas of the main and diverging routes. Although using high-rail and low-rail templates appropriately on the diverging route may provide some benefit to rail wear rates on the closure rails, tangent grinding templates appear to produce more desireable results in the switch rail/stock rail area of the turnout.

### References

1. Keylin, A. and S. Cummings. 2016. "Comparison of Rail Grinding Template Alignment Methods." *Technology Digest* TD16-053. TTCI/AAR. Pueblo, CO.
2. "Service-Worthiness Tests and Analyses for New Freight Cars," AAR *Manual of Standards and Recommended Practices*, M-1001. Washington, DC. Implemented 2015.
3. *NUCARS® Manual.* 2020. Transportation Technology Center, Inc., Pueblo, CO.

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