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Research Results

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Generic Wheel/Rail Profiles for Commuter Railroads

SUMMARY

In support of efforts to address wheel climb and other wheel/rail interaction problems on commuter railroads, the Office of Research and Development of the Federal Railroad Administration (FRA) sponsored a program to develop improved wheel and rail profiles specifically for commuter systems.

The National Research Council Canadas (NRCC) designed wheel profiles improve on the existing profiles of many railroads by:

- Implementing a 75-degree wheel flange angle to minimize the potential for wheel-climb derailment.
- Adopting a shape similar to that generated by averaging the thousands of worn wheels analyzed in this program.

Both 1:40 and 1:20 thread taper variants are provided.A set of five generic rail templates have also been designed for good compatibility with the NRCC-COM40 wheel. A key goal of these rail profiles is to spread out wear on the wheel to help it retain its favorable shape, at the same time controlling contact stress and wear. The FRA-H1 and FRA-H2 rail templates apply to the outside rail of curves. The FRA-H1 provides a single point, conformal contact and promotes steering. The FRA-H2 is relieved in the mid-gauge and provides a two-point conformal contact for softer steels and/or long grinding intervals. The FRA-CPG (tangent-gauge), FRA-CPC (tangent central), and FRA-CPF (tangent field) templates provide three distinct tangent track running bands that spread wear across the wheel tread, with the goal of reducing wheel hollowing and maintaining the rail shape. Either the FRA-CPC or FRA-CPF can be applied to the low rail.

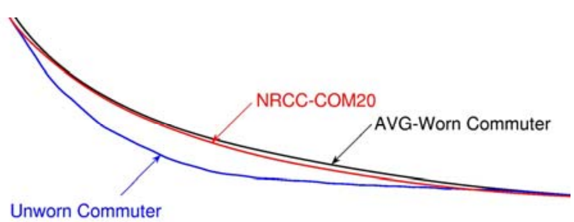

Figure 1. A typical example from one commuter railroad shows that even though the flange-root of the unworn wheel may differ significantly from the COM40 (or COM20) wheel, the worn shape is very similar for several of the fleets considered.

BACKGROUND

Northeast commuter railroads suffered a number of low-speed wheel-climb derailments in the late 1990s [1], which prompted them to pay much closer attention to the shapes of wheels involved in the incidents. The realization that a shallow flange angle was a significant contributing factor came quickly. Subsequent review of existing wheel profile designs identified those with steeper flange angles. The steeper flange angle of these profiles did address the wheel climb issue, but have in practice brought problems of their own, including poor steering, high rates of wheel-flange wear (and rail side wear), and increased lateral rail forces. Recognizing that the safety (and commercial needs) of the commuter industry were poorly served by this approach, the Office of Research and Development of FRA sponsored a program to develop improved wheel and rail profiles specifically for commuter systems.

METHODS

Several commuter systems in the northeastern United States were surveyed including Amtrak (conventional fleet, not Acela), Metro North, Maryland Area Regional Commuter, Massachusetts Bay Transit Authority, Southeastern Pennsylvania Transit Authority, and New Jersey Transit. The transverse profile of worn wheels was measured at random from vehicles of each system using the Miniprof digital profile measuring system.

The flange-root geometry of the worn wheel is a strong indicator of a compatible shape. Well-worn wheel profiles for each fleet type were extracted from the profile database. The best 10 to 30 well-worn wheel profiles for each fleet were aligned against the RE115 (at 1:40 cant) in a curving superposition and then an average shape calculated.

The flange root geometry of the new wheel was derived using a weighted (normal) distribution (effectively the median) of the well (or “nicely”) worn wheels from each agency. The passenger and locomotive profiles were calculated separately (Figure 2). The largest difference between the two wheel shapes is 0.15 mm (0.006 in), and their difference with the AAR1B is about 0.74 mm (0.030 in) and 0.66 mm (0.026 in) for the passenger and locomotive, respectively. The small geometrical difference between the passenger and locomotive wheels did not justify the use of separate profiles—the average of the two was used for the final wheel profile.

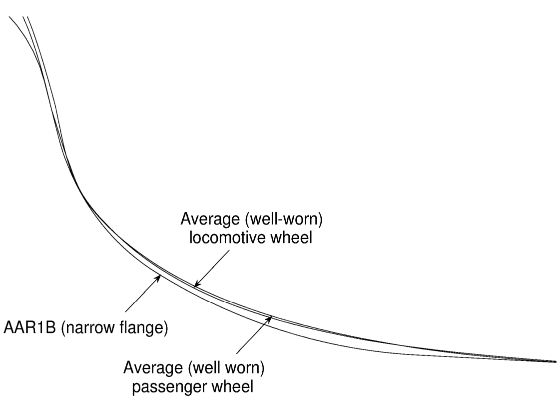

Figure 2. Average geometry of the worn flange-root area for wheels measured from several commuter systems, superimposed on the AAR1B narrow flange wheel.

The flange geometry applied is very similar to the narrow flange AAR1B.

The angle of the flange-face has a strong impact on resistance to wheel-climb derailment. The Northeast commuter systems that suffered from recurring slow-speed derailments in the mid-1990s were machined with a 67-degree flange angle. Using the simple analysis of Nadal from 1896 [2], a flange angle of 75 degrees theoretically improves wheel-climb resistance by more than 30 percent for a friction coefficient of 0.4 (Figure 3).

The resulting wheel has been called the NRCC-COM40 (and NRCC-COM20) and appears in American Public Transportation Association (APTA**)** SS-M-015-06 Standard for Wheel Flange Angle for Passenger Railroad Rolling Stock, as the APTA 320 wheel profile.

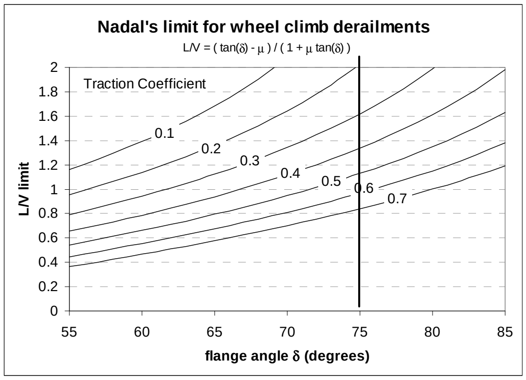

Figure 3. The dependency of the L/V required for wheel climb on the flange angle and friction coefficient is illustrated in this figure.

The design goals for rail profiles to optimally match to this wheel are:

- Provide sufficiently low effective conicity in tangent track,
- Minimize the overall levels of contact stress,
- Promote steering in curved track, and
- Spread out wear across the wheel tread to prolong the optimal wheel shape and thereby maximize wheel life. This point is illustrated in Figure 4.

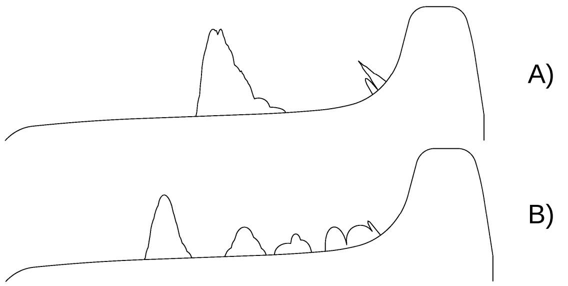

Figure 4. A) An example of the distribution of wear for a system where the same rail profile is applied to all high, low, and tangent rails. B) Pummeling with four different rail profiles promotes a broader distribution of wear across the wheel tread.

RESULTS

A set of 5 rail profiles have been designed to match with the NRCC wheel. As shown in Figure 5, the contact position varies across the wheel tread depending on whether the wheel runs against tangent track (CPG, CPC, CPF), the outside (high) rail of a sharp or mild curve (H1, H2), or against a low rail (CPC, CPF).

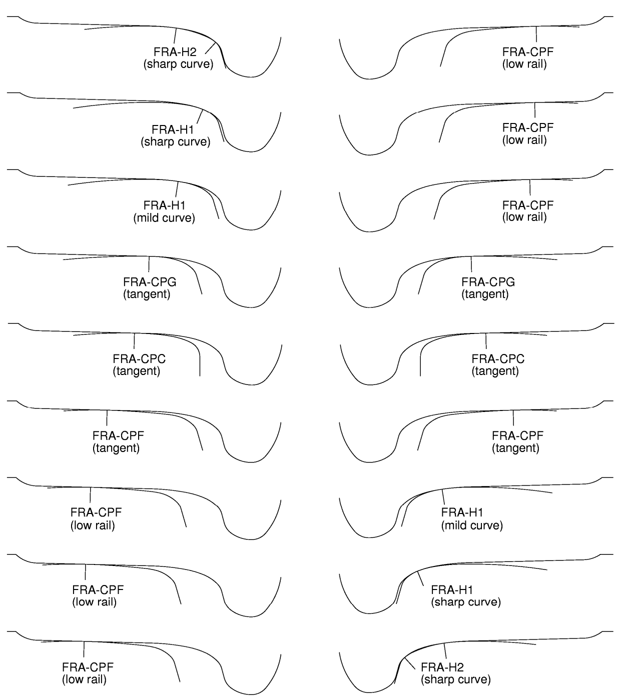

Figure 5. The use of multiple rail profiles not only allows the rail shape to optimize the contact conditions for high rail, low rail, and tangent operation, but also permits a deliberate spread of contact and wear on the wheel to be engineered.

PROFILE VALIDATION

Validation of the wheel profile consists of calculations of conformality [3] to assess wear and contact stress, effective conicity to examine stability and quasi-static curving to examine lateral/vertical (L/V) forces. The new wheel was found to consistently improve performance compared with the nonconformal two-point contact wheels typical of most commuter systems.

Analysis of the wheel shapes makes it clear that the unworn wheel is a poor indicator of what is actually operating on track and that the final worn wheel profile for these systems does not converge on a single shape. However, conformality analysis of the worn wheel shapes confirmed for all fleets that the profiles generally become less “two-point” and more “one-point” with wear. An example of this process is shown in . Wear of the wheel causes the flange-root to “fill-in” and tends toward a more conformal contact.

Quasi-static curving analysis shows that the new wheel, when run against the RE136 8-in rail profile (which more closely represents a typical worn rail shape than shapes like the unworn RE115) provides meaningful reductions in lateral forces for all curvature ranges but especially for broader curves (1) (Figure 6).

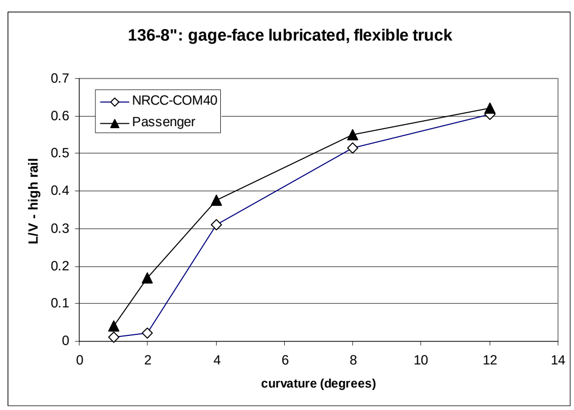

Figure 6. Calculated values of quasi-static L/V on the high rail for a flexible truck on lubricated curves. The NRCC wheel consistently reduces lateral force.

Compatibility analysis of the NRCC designed wheel/rail profiles shows very good control of contact stress and effective conicity (see Ref.4 for further details). But care must be taken if only the new wheel or only the new rails are to be implemented. For example, the measured worn wheels from several U.S. transit fleets exhibit high effective conicities compared to the NRCC wheel designs, especially the worst 5 percent of the worn wheels. Implementation of the rail shapes, without concurrent use of the NRCC-COM40 wheel, must be considered cautiously, on a case-by-case basis. Furthermore, it must be cautioned that the design of system-specific rail templates should consider the current worn state of the rail so that the otherwise optimized shapes do not require excessive rail grinding to apply. Although these generic templates attempt in principal to minimize metal removal, only by overlaying these templates on measurements of the existing worn rails can a commuter system determine if the generic rail templates are practical targets for their railroad.

CONCLUSIONS

A new generic wheel profile has been designed based partly on measured worn shapes from a large number of North American commuter agencies. The new wheel consistently exhibits improved performance compared with the nonconformal two-point contact wheels typical of most commuter systems. Its 75-degree flange angle also provides a significant increase in wheel-climb resistance compared with the wheel profile currently used by some agencies. As a design that is based on the average shape of several different systems, the new wheel shape is a compromise. This new shape may not be perfect for any one system and may not be compatible at all with a few. However, the new wheel should work for most commuter systems and does provide an appropriately engineered alternative to other standard wheel profiles that currently suffer from wheel climb, rapid rates of flange wear, hollowing, and correspondingly poor stability.

A family of five rail templates has been designed to match well with the NRCC wheel shape. These rail shapes minimize contact stress, promote wheelset steering, and work together to spread wear across the wheel tread to minimize wheel hollowing. Before implementation, a railroad should overlay these templates on measurements of the existing worn rails to ensure that excessive rail grinding is not required to achieve the shapes.

FUTURE DIRECTIONS AND ACTIVITIES

Although validated numerically, these wheel and rail profiles have not yet been tested in field service. A candidate railroad is sought for this purpose.

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