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Wheel/Rail Tolerance Software

by Kevin Sawley

Summary

Software to help railroads reduce the stress state between wheels and rails has been developed by Transportation Technology Center, Inc. Identified as WRTOL™ (Wheel/Rail Tolerance),* it is software that calculates the geometric interactions between a measured pair of rails and any number of wheel profiles held in a user-defined database. The database will typically hold measured wheel profiles representative of most of the wheels passing over the rails. The interactions calculated include:

- Wheel/rail contact stress, which influences wear and rolling contact fatigue.
- Wheel/rail contact angles that affect flange climb derailment risk.
- Rolling radius difference (right-wheel radius minus left-wheel radius), which influences vehicle steering and stability.

WRTOL, which in principle can accept any profile in digital form, is currently being tested, validated, and demonstrated by TTCI in a number of projects, before it is released to the railroads. It has been successfully used to explain the occurrence and non-occurrence of rail surface fatigue in grinding test sites, to identify inappropriate ground rail profiles, to decide on the optimum design rail profile for use with current worn wheelsets, and to explain the adverse effect of rail re-inclination on rail rollover risk.

Although WRTOL is currently being tested in research and development projects, the ultimate goal of development is to achieve an automated system that can accept wheel and rail profiles measured by automatic methods, judge the fitness-for-purpose of the profiles, and identify remedial treatments if necessary.

In the past, railroads have countered increasing vehicle speeds and axle loads by making vehicles and track more durable. This has worked, but it has become clear that making components bigger and stronger may not be the most efficient strategy. This has led to the current railroad focus on reducing the stress state. The highest stresses occur at the wheel/rail interface and usually exceed the tensile strength of the wheel and rail steels. Profiles have the greatest effect on stress — they can double or triple stress — and hence controlling profiles is key to improving rail life by reducing wear and surface fatigue.

*WRTOL™ is a trademark of Transportation Technology Center, Inc.



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INTRODUCTION

The traditional approach to increasing speed and axle load has been to make vehicles and track more durable. This has generally worked, but it has become clear that making components bigger and stronger may not be the most efficient strategy. This has led to the current railroad focus on reducing the stress state. Hence, the current drive in the railroad industry is to seek ways, by applying research, of reducing the stress state in the vehicle/track system.

The highest stresses occur at the wheel/rail interface. Stresses routinely exceed the tensile strength of the wheel and rail steels, leading to wear and rolling contact fatigue (RCF) that leads to cracks, spalls, and shells. Control of these stresses is essential to reducing wear and fatigue, thereby increasing the life of rails and wheels. Stress increases with axle load, but the effect is weak. Of more importance are the wheel and rail profiles. Inappropriate profiles can lead to a doubling or tripling of stress.

Reducing wheel/rail stress depends on improved control of profiles, which in turn requires methods of analyzing how wheel and rail geometries interact. Methods are available and have been used often in the past to see how individual wheels and rails interact. But this is not enough. The important thing is to quantify how the rail is affected by the population of wheels that pass over. This digest describes software developed by TTCI to do just that.

What is WRTOL™?

WRTOL is PC-based software that calculates the interactions between a pair of rails and a database of wheelsets. It was first designed to calculate contact stress (the maximum stress between the wheel and rail), but it was found that the calculation process gave other valuable information, such as the wheel/rail contact angle and wheel rolling radius. WRTOL now outputs this other information to the user. Information itself is of little value without interpretation, so WRTOL includes user-defined tolerances on the calculated parameters. For example, if the user sets an upper limit on allowable contact stress, WRTOL will identify those wheels that give stresses above the limit. This allows rapid identification of inappropriate profiles. WRTOL is in current use as a research tool, for testing and validation. But we must stress that our ultimate goal is to provide software that will automatically process wheel and rail profiles (however measured) and rapidly decide whether the profiles are fit-for-service, and what should be done if they are not.

What Does WRTOL Do?

The principle of WRTOL is very simple. It allows the user to specify a pair of rail profiles and a database of measured wheelset profiles. It then takes each wheelset in turn and

matches it against the rails, using proprietary algorithms used in NUCARS™. During this process, the wheelset is moved laterally in small steps, from flange contact against one rail to flange contact against the other. Wheel/rail interaction parameters are calculated at each step. Figure 1 shows the main input page where profiles are specified and where rail site information can be given.

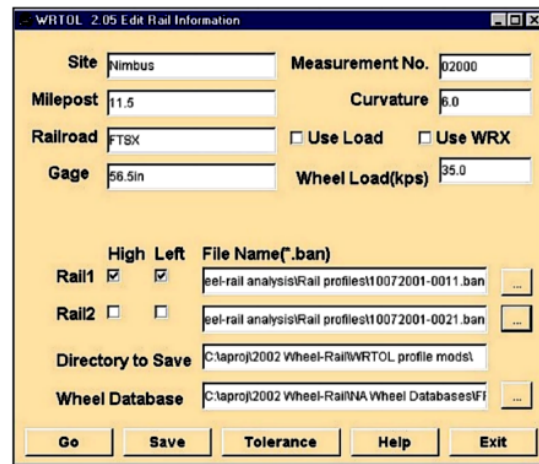


Figure 1: Main WRTOL™ Input Page

The principal parameters calculated are:

- Wheel/rail contact stress (Figure 2).
- Wheel/rail contact angles that affect flange climb derailment risk (Figure 3).
- Rolling radius difference (RRD, right-wheel radius minus left-wheel radius) that affects vehicle steering and stability (Figure 4).
- All the points of contact between individual wheels and rails (Figure 5).

These various outputs can be customized, so that users can look at specific wheelset lateral shifts (e.g., to distinguish between lead and trail wheelset interaction), or at interactions with multiple or single wheelsets.

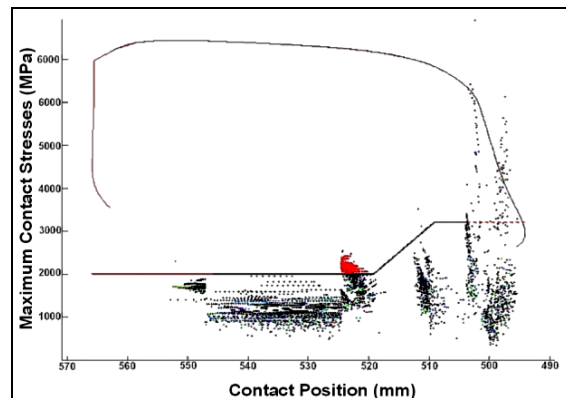


Figure 2: Contact Stresses on the Surface of a High Rail
(Straight Lines Show Allowable Contact Stress Limits)

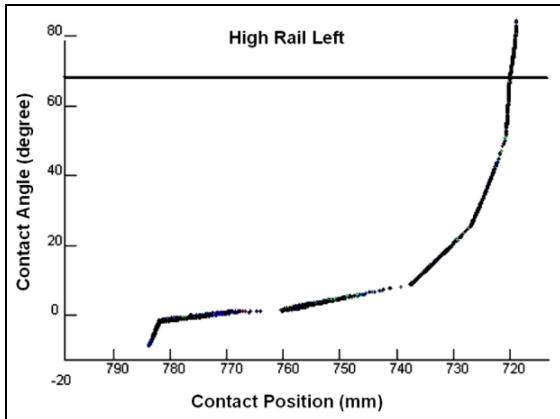


Figure 3: Contact Angles on the High Rail
(Horizontal Line shows the critical contact angle)

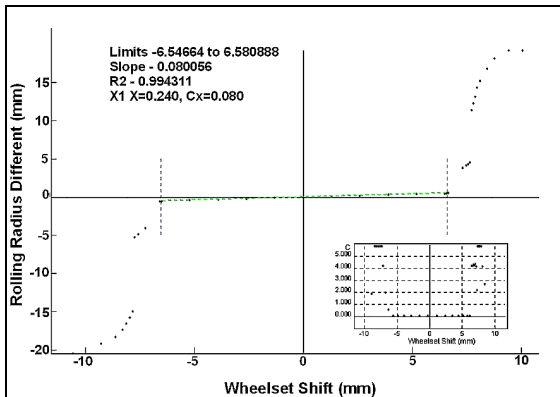


Figure 4: RRD versus Wheelset Lateral Shift for a Single Wheelset
(Insets show average and instantaneous slope)

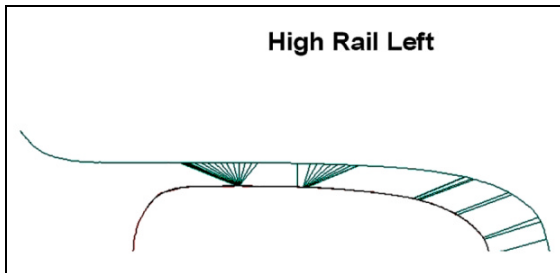


Figure 5: Examples of Wheel/Rail Contact

STATUS OF WRTOL™

WRTOL is being used now by TTCI on research, development, and consultancy projects. This will help validate the software and to demonstrate its capabilities and usefulness. Beginning in 2003, a major demonstration of the software will be undertaken on a Class I railroad. As it stands, WRTOL will accept digital wheel and rail profiles measured using Miniprof™. However, in principle, WRTOL can accept any profiles in a suitable digital format.

Once validation is complete and the software is accepted, work to develop a fully automated system will start. Programming for this ought to be straightforward, but criteria for judging wheel and rail profiles will also be needed. Simply put, “badness” indices will need to be defined for wheel and rail profiles – based on economic and possibly risk calculations. Work is also planned in 2003 to “invert” the software. That is, to change the software to let individual wheelsets be matched against a database of rail pairs. This will be needed for an AAR project to re-assess the suitability of the AAR-1B wheel profile.

Examples of Use

Below are just two examples of how the software is being used and validated.

Example 1: Understanding rail grinding

For several years, TTCI and Canadian National have conducted rail grinding site trials at Kamloops, BC. Records of profiles, lubrication, and rail surface conditions have been kept. WRTOL has successfully explained surface damage observations at two curve-track sites, using a database of common North American wheel profiles.

At a 7.1-degree, well-lubricated curve, subject to regular grinding at 12-MGT intervals, RCF damage was not observed over a period of 250 MGT. WRTOL calculations explained this by demonstrating that very few of the database wheelsets gave contact stresses above the predicted critical level.

A nearby 6.5-degree curve showed very different behavior. Rails in this curve were left unground for the first 164 MGT of traffic, after which routine grinding was applied. The rails were also dry until about 154 MGT, when good lubrication was applied. Not unexpectedly, significant surface cracks and spalls were observed up to about 150 MGT, but not after. (No internal defects were seen on this curve, or at any of the other trial sites.) Figure 6 shows results of the WRTOL calculation.

The x-axis shows the applied tonnage, the y-axis shows the estimated percent of wheels that give “damaging” stresses; i.e., stresses above the critical level. The solid squares are for the actual test conditions. Figure 6 shows that up to the introduction of grinding and lubrication about 30 percent of wheels give damaging stresses, which led to fatigue damage. After 154 MGT, virtually no wheels give damage. Hence, the calculations explain the appearance and disappearance of cracks and spalls.

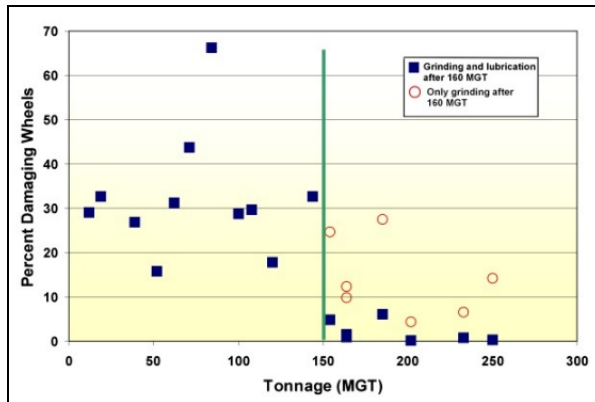


Figure 6: Effect of Grinding and Lubrication Rail Fatigue

Of interest are the relative effects of grinding and lubrication. The open circles in Figure 6 show calculations assuming that lubrication had not been applied at 154 MGT. In this case, about 10 percent of wheels are predicted to give damaging stresses. This shows that grinding *and* lubrication together give the best defense against surface fatigue. This is because grinding lowers the applied stresses by improving the profile, and lubrication increases the critical stress level by reducing shear stresses. The two together give maximum benefit.

Example 2: Rail rotation and rail rollover

After re-establishing the correct cant on rail that had rolled outwards through tie-cutting in curved track, a railroad suffered a rail rollover derailment. Using measured wheelsets from the derailed train, a WRTOL calculation confirmed a lengthier dynamic analysis, by showing that re-canting had caused most wheelsets to contact on the field side of the rail. This reduces the gravitational moment holding the rail down, and thus increases the risk of rail rollover. Figure 7 shows the results and should be compared with the more usual contact conditions illustrated in Figure 2. Further study indicated that re-inclination had probably also led to higher gage-spreading forces that also contributed to rail rollover.

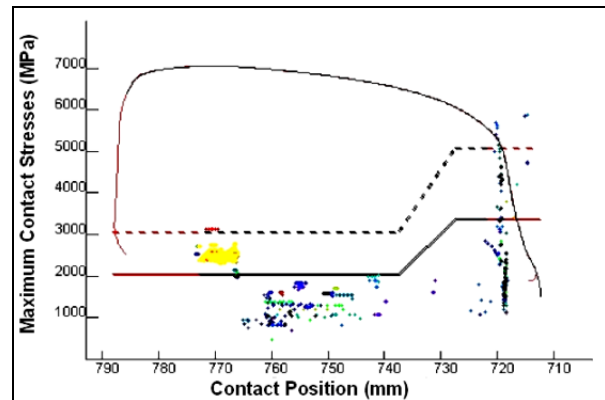


Figure 7: Contact Conditions on a Re-inclined Rail

CONCLUSIONS

WRTOL is being used now for testing and validation, and a major demonstration is planned for 2003. Performance is good, and TTCI believes that the software will offer great scope for improving the wheel/rail interface and reducing the stress state of the railroad. In manual mode the software is being used to:

- Understand the causes of rail surface fatigue
- Identify deficiencies in grinding practice and produce optimized grinding profiles
- Define the best design rail profile for a given population of wheelsets

Further studies will be undertaken within the next year to demonstrate and improve the software capabilities. But the final goal is to get an automatic system that can accept wheel and rail profiles measured by automatic methods, judge the fitness-for-purpose of the profiles, and identify remedial treatments if necessary.

**Note: Contact Kevin Sawley at (719) 585-0636 with questions or comments about this document.
E-mail: kevin_sawley@ttci.aar.com
Web Site: www.ttci.aar.com**