TECHNOLOGY DIGEST

Timely Technology Transfer — 01-019

Wheel and Rail Profile Maintenance

by Kevin Sawley

Summary

Transportation Technology Center, Inc. is designing software to extract more information from measured rail profiles in an effort to reduce the stress state between wheel and rail, extending life and reducing costs. The software automatically matches measured rail profiles against a database of wheels typical of those in North American service, calculates the wheel/rail interaction and assesses results against preferred interactions. The software has the flexibility, however, to access any customized wheel database. The software is being developed under the Association of American Railroads' Strategic Research Program.

At this time, the interaction parameters incorporated into the software are:

- Contact stress, which influences wheel/rail wear and rolling contact fatigue (cracks, flakes, spalls, and shells).
- Contact angle, which is a measure of the risk of flange-climb derailment.
- Conicity, which is a measure of combined wheelset and rail geometry and influences vehicle steering in curved and tangent track.
- Two-point contact on the high rail, which leads to increased rolling resistance, affecting fuel use and wheel/rail wear.

Initial preferred values have been identified for contact stress and contact angle, but work continues to set values for conicity and two-point contact. Early results suggest that contact stress calculations from the software can be used to explain historic patterns of surface damage at rail grinding test sites.

At present, the software is being tested as a research tool for use in wheel/rail projects at TTCI. Eventually, however, the goal is to make the software available for the real-time analysis of rails measured using automatic profiling methods. Currently the software can match 150 wheelsets against a pair of rails, make all calculations, and produce the required outputs in about 25 seconds on a fast (1 GHz) desk-top personal computer.

Suggested Distribution:

- ❑ Mechanical Operations
- ❑ Planning & Analysis
- ❑ Track Maintenance
- ❑ Safety

Work performed by TTCI Transportation Technology Center, Inc.
a subsidiary of the Association of American Railroads

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Introduction

North American railroads have about 48 million tons of rail in some 200,000 miles of track. The typical life of rail varies from about 1,400 million gross tons (MGT) in tangent track to about 350 MGT in highly curved track. There are also some 12 million wheels in service, with about 1 million removed each year, generally for defects such as spalls, shells, flats, out-of-rounds, and built-up treads. Few wheels approach their maximum amount of allowable wear. The numbers demonstrate that wheels and rails are major railroad assets.[1]

Wheel/rail wear and surface fatigue depend greatly on the contact stress, which in turn is controlled by the wheel/rail profiles and the way they interact. This interaction also affects fuel use, derailment risk, and vehicle stability. A key part of reducing railroad costs and improving safety is better management of wheel and rail profiles to extend life, reduce vehicle and track maintenance, and improve vehicle stability.

Manual wheel and rail profile measurement systems have been available for some years, as have automatic rail profiling systems. Automatic wheel profiling systems have emerged recently, and are now being used or tested in North America. Profiles traditionally have been used to indicate the extent of wear. This is useful, but profiles hold much more information. As part of the Association of American Railroads' Strategic Research Program, TTCI is developing software designed to extract more information from measured rail profiles to reduce the stress state between wheel and rail, extending life and reducing costs.

Methodology

TTCI's approach is to match measured rail pairs against wheels typical of the vehicles passing over, calculate the wheel/rail interaction, and assess against the preferred interaction.

The following steps have been followed:

1. From a large wheel survey, a range of wheel profiles typical for North America were defined. Forty-nine profiles described about 90 percent of the survey wheels less than 3 mm hollow.
2. Four wheel/rail interaction parameters have been defined: contact stress, contact angle, conicity, and degree of two-point wheel/rail contact.
3. The 49-wheel database profiles are idealized by a series of circular arcs. Software has also been designed to automatically describe measured rail profiles by a series of circular arcs. This circular arc method was adopted to speed the calculation of contact stress.
4. Software matches the wheels against the pair of rails for all positions of lateral wheelset shift and calculates the wheel/rail interaction. For contact stress, contact angle, and degree of two-point contact, the software uses the 49 typical wheels with identical wheels at each end of the axle. To find conicity the software uses 49 typical wheelsets.
5. At the end of processing, the software com pares the calculated interaction with the preferred interaction.

The software has been designed for general use. It can accept any database of wheels and wheelsets, and variable track gage. A goal has been to make the software fast enough that eventually rail profiles can be analyzed in real time. At present, after inputting a pair of rail profiles, the software calculates the interactions for 150 wheels and gives all outputs in about 25 seconds on a fast (1 GHz) desk-top PC.

Interaction Parameters

Four parameters have been chosen, although the software has the flexibility for more. User-defined preferred values can be assigned to these parameters. Initial work has focused on contact stress and contact angle. Interim preferred values for these parameters have been set. Work continues to set values on the degree of two-point contact and conicity.

Contact Stress

Contact stress is the maximum stress in wheel/rail contact. Wear and rolling contact fatigue increase as contact stress rises. Examples of output are shown in Exhibits 1 and 2. Exhibit 1 shows all the possible contact points between one of the wheels

TTCI = Transportation Technology Center, Inc.; AAR = Association of American Railroads and a measured rail. Some of these contacts are less likely to occur in reality. In curved track for example, contact of the wheel flange on the low rail is unlikely, and some contacts can only occur when the wheel climbs the rail gage face. The software can filter these contacts out since high contact stresses in these situations are not relevant. Also, limits on the allowable range of lateral wheelset shift can be set.

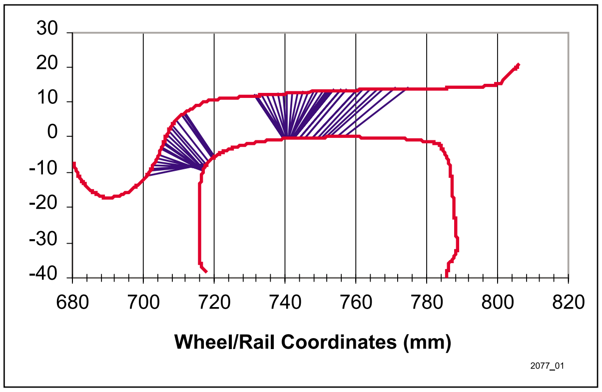

Exhibit 1. Possible Wheel and Rail Contact Points

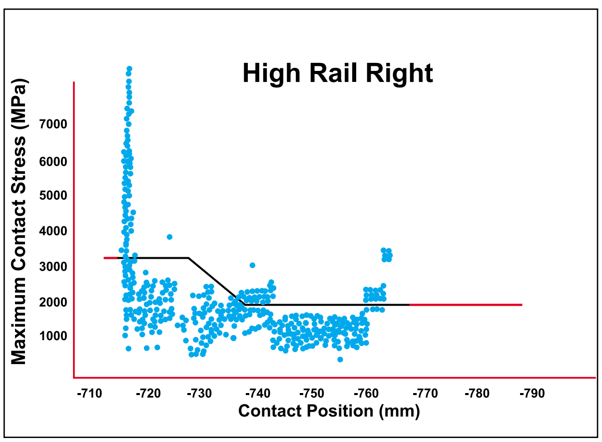

Exhibit 2: Contact Stresses caused by 49 Wheels on the High Rail

Exhibit 2 shows all the possible contact stresses when 49 wheels are matched against a measured high rail in curved track. It also shows the critical maximum contact stresses that ideally should not be exceeded. Stresses above these critical values are likely to cause rolling contact fatigue damage, while lower stresses are likely to be relatively harmless. The position of contact is given in millimeters (mm) with respect to the track centerline. In this example, the high-rail gage face is at about -720 mm. To calculate these critical stress values, the model assumes that the critical stresses are equal to the shear yield stress of the rail steel, multiplied by three factors: (1) a work hardening factor, (2) a strain rate factor, and (3) a shakedown factor.

Exhibit 2 illustrates a number of points about wheel/rail stresses and the analysis method:

- Stresses at the gage face are high and practically uncontrollable. High wear rates will occur unless lubrication is applied.
- For the particular high rail used, high stresses are predicted on the gage corner (at about -740 mm). These stresses are likely sufficient to cause spalls and shells.
- High stresses, caused by a few wheels, are predicted at the field side of the high rail. These stresses require a wheelset shift to the low rail and may be unlikely in practice.

Contact Angle

The contact angle is the angle that the plane at the wheel/rail contact point makes with the horizontal to the track. Flange-climb derailment risk rises as this angle is decreased. Based on previous work at TTCI, to reduce derailment risk the maximum contact angle at flange contact should be greater than 68 degrees.

Degree of Two-Point Contact

To prevent shells on the high rail, grinding is at times used to give two-point contact, where the wheel contacts the rail on the gage face and rail top. Properly applied, such grinding can be good at reducing defects (especially in softer rails), but it worsens steering, leading to higher wear and rolling resistance. Early work at TTCI has indicated that resistance rises with the vertical distance between the two contact points. This distance may be a way of defining the degree of two-point contact. No value for the maximum allowable of two-point contact has yet been set.

Conicity

Conicity describes the combined geometry of a rail pair and a wheelset. A low value impairs vehicle steering in curves. High values can give hunting in tangent track. Conicity is an output of the method used to calculate contact stress, and work is in progress to see whether preferred ranges can be set for given vehicle/truck combinations. The goal is to set limits on conicity, and thus on wheel and rail profiles, so that the speed of hunting can be expected to be above the operating speed. Work suggests this may be possible, but much needs to be done.

Software Testing

Rail grinding site trials in North America have documented rail profiles, surface conditions, and lubrication. The software has been tested by relating predicted wheel/rail stress condition at these sites with changes in surface damage. Exhibit 3 shows results from a 6.5-degree curve. The x-axis gives accumulated tonnage, and the y-axis gives the percentage of wheels judged to give damaging stresses. The site had little lubrication until 154 MGT, and was ground for the first time at 164 MGT and at intervals after. Before grinding and lubrication, the high rail showed rolling contact fatigue damage, while fatigue damage has been minimal after. This damage history correlates with the results Exhibit 3 shows. Before 154-164 MGT, most of the wheels passing over were predicted to give damaging stresses. Lubrication and grinding have caused the percentage of damaging wheels to drop, eliminating surface damage.

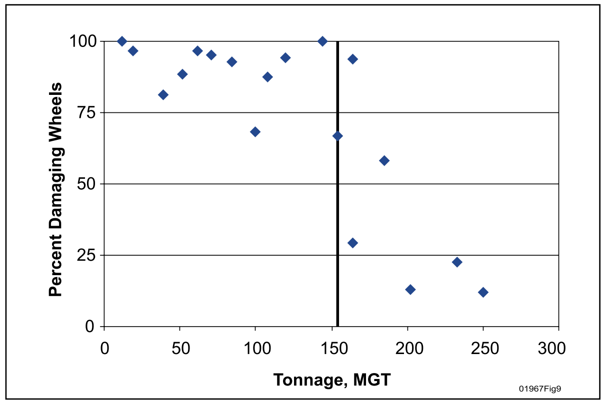

Exhibit 3. Wheels applying Damaging Stress

Conclusion

Software has been produced that automatically calculates the way wheel and rail profiles interact. Four interaction parameters have been defined, and work is progressing to assign critical values to the parameters. Early results indicate that the software can be used to reduce wheel/rail stress and predict vehicle stability. The goal is to give railroads improved decision methods for rail, and eventually wheel, maintenance.

Reference

1. Judge, Tom. “The search for longer rail life,” *Railway Age*, pp. 45-47, March, 2001

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