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TIMELY TECHNOLOGY TRANSFER

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Investigation of Track Curve Breathing and its Effects on Rail Neutral Temperature

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Summary

Transportation Technology Center, Inc. has conducted a survey of curve breathing movement due to seasonal weather changes. The locations of the track and its components have been monitored with time and tonnage for two 5-degree curves in the Facility for Accelerated Service Testing High Tonnage Loop. Rail neutral temperature (RNT) measurements are also being made at the same locations. Preliminary findings from the work are the following:

- RNT shows a small decline over a year (150 MGT) of heavy axle load operations.
  - The average decline in RNT was about 4°F.
- RNT varies with season and long term average temperature.
  - RNT mostly recovers year over year, but individual rail movement (longitudinal) does not. Curve breathing movement (radial) recovers to a lesser extent than RNT.
  - Longitudinal rail movement is inversely correlated with lateral curve movement.
- In one test curve, the individual rails are moving longitudinally in opposite directions.
- The amount of curve breathing movement is related to fastener type.
  - Cut spike anchored track – This type of track exhibits more radial movement (averaging 0.8 inch) than elastic fastener track (averaging 0.2 inch).
  - Elastic fastener track – For both timber and concrete ties, this type of track exhibits more individual rail longitudinal movement (0.25 inch versus 0.13 inch for cut spike track).
- Plate to tie movement in timber tie track is small.
  - Lateral (radial) direction – nil. From observing painted witness marks, there is no visual indication of lateral plate movement on ties. Track gage also stayed well within maintenance limits.
  - Longitudinal direction – insignificant. From observing painted witness marks, the average longitudinal plate movement on ties is 0.02 inch.

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INTRODUCTION

Thermal forces in rail develop as temperature changes and the rail is constrained by fasteners, ties, and ballast. These thermal forces are determined from a zero stress point known as rail neutral temperature (RNT). As the climate changes throughout the seasons, these thermal forces can cause curved portions of track to shift, and thus cause a change in RNT.

The intent of this experiment was to determine what factors have an effect on curve breathing and how it relates to changes in RNT.

TEST DESCRIPTION

Track movement and rail neutral temperature were measured monthly in Sections 3 and 38 at the Facility for Accelerated Service Testing (FAST) on the High Tonnage Loop (HTL).

Section 3 is a 5-degree curve with 4.3 inches of superelevation, a balance speed of 33 mph, and an operational speed of 40 mph. This section contains a mixture of wood and composite ties and various fasteners. Section 38 is a 5-degree curve with 4.1 inches of superelevation, a balance speed of 33 mph, and an operational speed of 40 mph. This section contains all concrete ties with elastic fasteners. Figure 1 shows the test section locations on the FAST HTL.

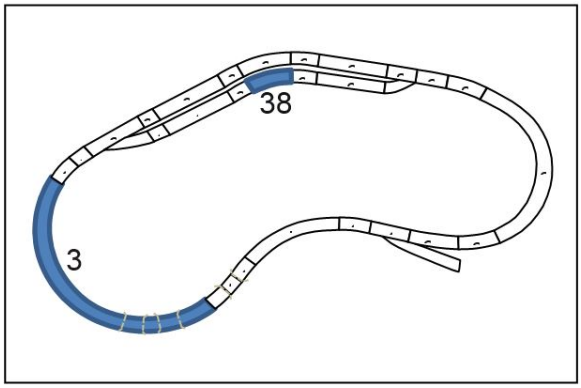

Figure 1. Map of Test Sections on HTL

Thermal stress and RNT were measured using Safetraks sensors from Datatraks, spaced 100 feet apart on 500 feet of each curve. These sensors combine a standard strain gage and thermocouple to calculate an output of RNT. Figure 2 shows a sensor installed on the web of the rail.

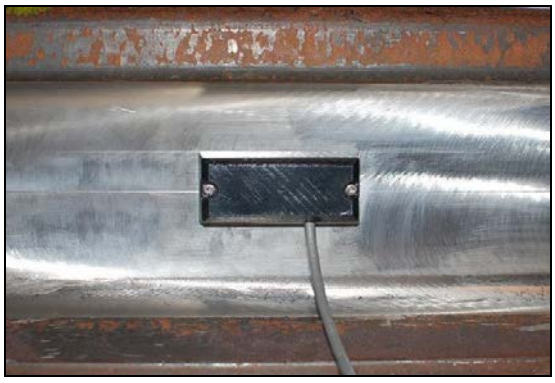

Figure 2. RNT Sensor Mounted to Rail Web

Breathing of the curve was measured using survey stakes placed every 100 feet for 1,000 feet of the curve in Section 3, and every 100 feet for the 500-foot curve that is Section 38.

Relative longitudinal component movement was measured using match marks painted on the rail web, rail plates, and ties at the beginning of the test. Shifting was measured using a tape measure. Figure 3 shows the match marks.

Figure 3. Match Marks for Monitoring Rail to Plate and Plate to Tie Movement

WINTER RESULTS

As summer transitioned to autumn and then winter, the curve in Section 3 began to creep inward as expected. Figures 4–6 show measured performance (i.e., changes in RNT, radial curve movement, and individual rail longitudinal movement) of the track during this period. The track also began to shift longitudinally, as the inside rail crept one way and the outside rail crept the other way. The neutral temperature of the outside rail decreased in conjunction with the radial shifting, yet the inside RNT changed minimally.

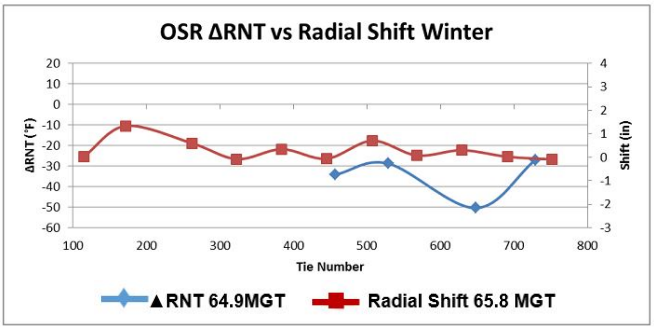

Figure 4. Radial Shift and RNT of Outside Rail in Section 3

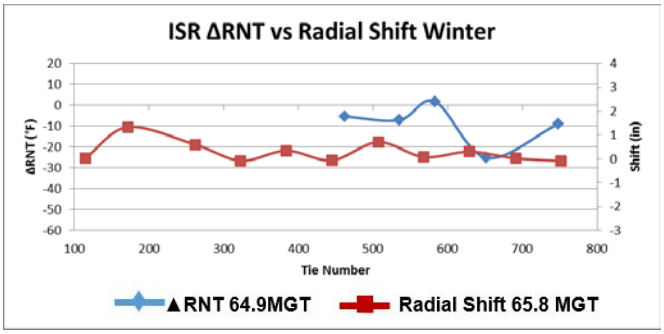

Figure 5. Radial Shift and RNT of Inside Rail in Section 3

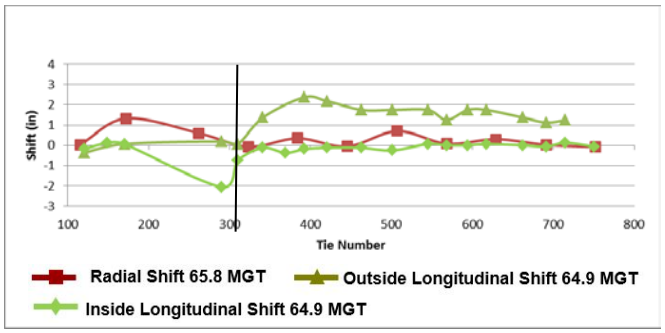

Figure 6. Radial Shift and Longitudinal Shift in Section 3

SPRING RESULTS

As winter transitioned to spring, the curve began to expand outward; however, only the inside rail returned to similar RNT before the shift from the cold weather. Figures 7–9 show measured performance of the track during this period.

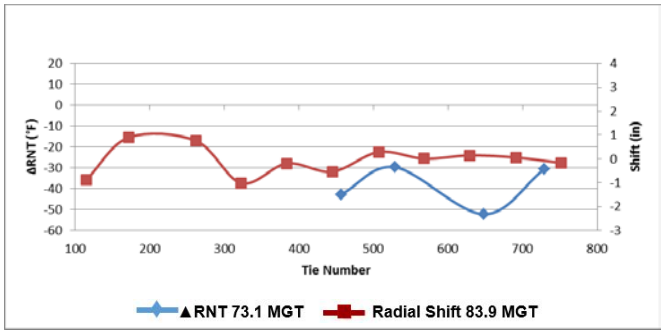

Figure 7. Radial Shift and RNT of Outside Rail in Section 3

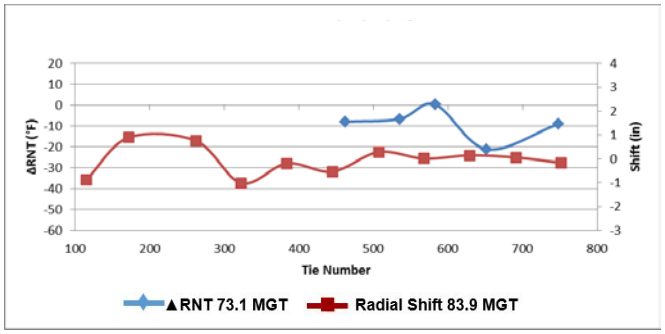

Figure 8. Radial Shift and RNT of Inside Rail in Section 3

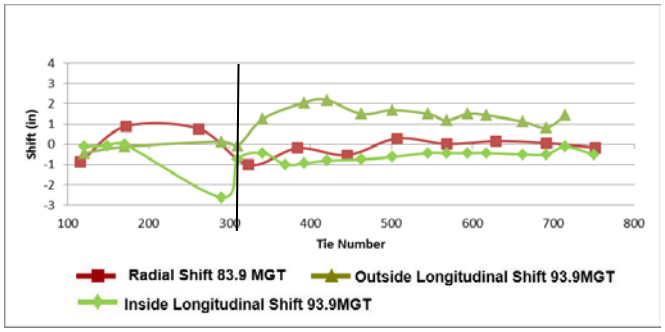

Figure 9. Radial Shift and Longitudinal Shift in Section 3

SUMMER RESULTS

As spring transitioned to summer, the RNT returned to temperatures similar to the beginning of the test. Figures 10–12 show measured performance of the track during this period. The radial shift of the track also shifted back towards the baseline position, but still was significantly different from the initial measurements. The longitudinal shift of the rail did not revert to its initial state, and it continued to creep along the ties.

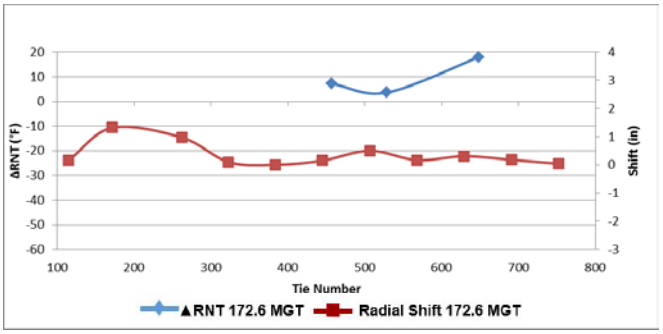

Figure 10. Radial Shift and RNT of Outside Rail in Section 3

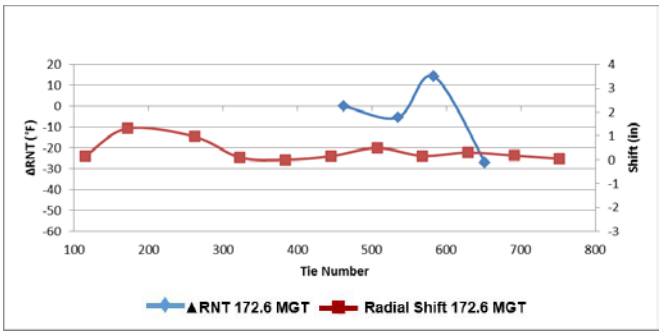

Figure 11. Radial Shift and RNT of Inside Rail in Section 3

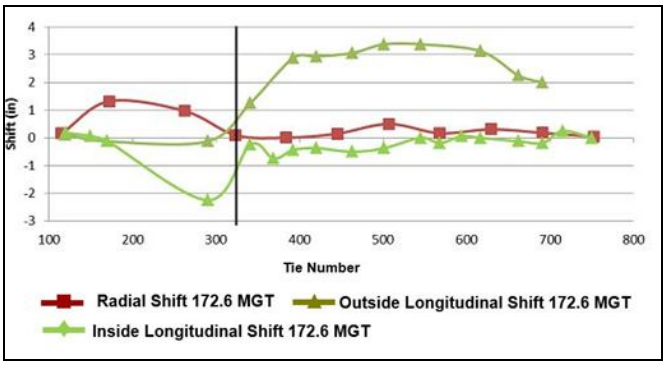

Figure 12. Radial Shift and Longitudinal Shift in Section 3

LONG-TERM TRENDS

A look at the long-term changes in section 3 at specific tie locations shows the seasonal changes more clearly. Figure 13 shows RNT curve radial and rail longitudinal movement for track at tie 500. It is important to note that even though the RNT returns to near initial conditions, the radial shift does not completely return to initial conditions, and longitudinal shift of the rails does not rebound whatsoever.

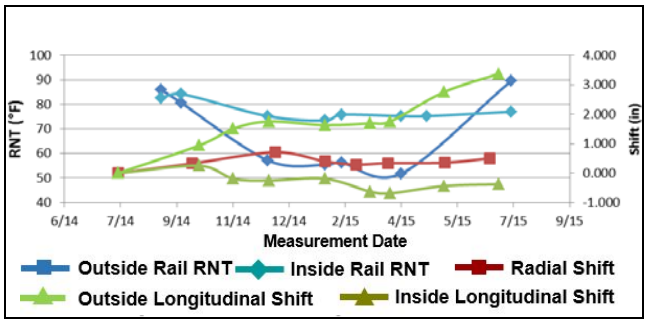

Figure 13. RNT, Radial, and Longitudinal Shift in Section 3

Measurements taken in section 38 do not show as drastic of a change as section 3, but it should be taken into consideration that Figure 14 only contains radial shift data starting in January 2015. It should also be noted that section 38 is located in the two track portion of the loop and is essentially newly rebuilt track. It is more uniform in track strength and has a lower traffic rate than section 3. Thus, it is likely to have smaller changes in performance for the same time periods as the more heavily used section 3.

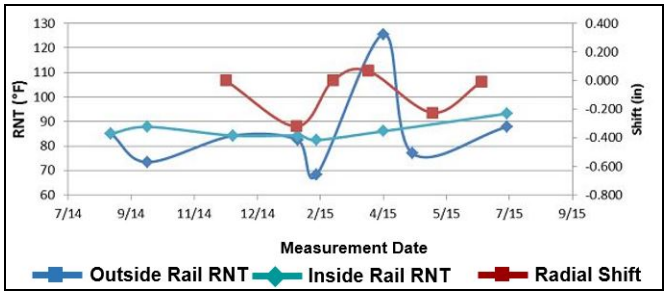

Figure 14. RNT, Radial, and Longitudinal Shift in Section 38

It can also be noted that the degree of the radial and longitudinal shifts were dependent on fastener type. Cut spiked sections of rail had minimal longitudinal movement but more radial shift, while elastic fastener sections had considerable longitudinal movement and minimal radial shift. Figure 15 shows this activity, where the left side consists of cut spikes and anchor fasteners, and the right side contains elastic fasteners. It suggests rail anchors were more effective than elastic fasteners at limiting rail longitudinal movement. At FAST this results in more curve radial movement. But in revenue service, with a larger portion of tangent track, this may also reduce curve radial movement.

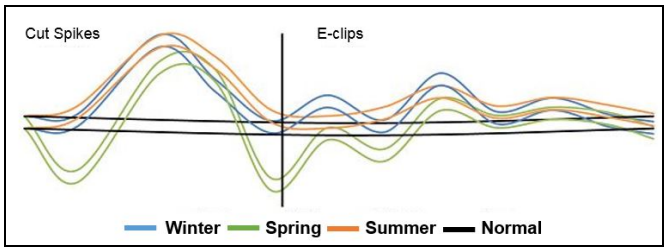

Figure 15. Radial Shift of Rail over the Seasons

It is difficult to display the interactions of various test variables in this experiment. Figure 16 shows the relationships between changes in RNT, curve radial position, and rail longitudinal movement for the section 3 inside rail. The plot shows a surface that is shaped like a saddle (i.e., a hyperbolic paraboloid) in that changes in RNT are associated with rail longitudinal movement. Whereas, changes in RNT are associated with no or minimal changes in curve radial position.

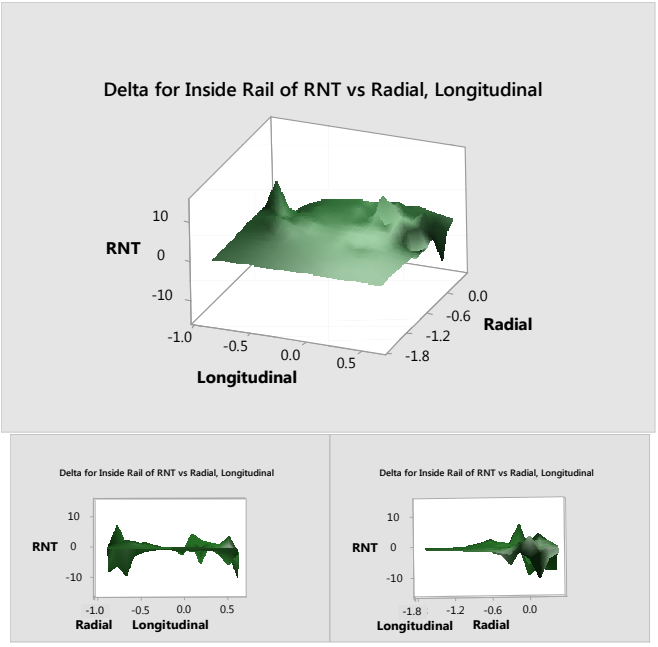

Figure 16. Delta RNT, Delta Curve Radial Position and Delta Rail Longitudinal Position: FAST Section 3, Inside Rail

SUMMARY AND CONCLUSIONS

The mechanics of rail curve breathing are perhaps more complex than expected. It appears that movement of the track and individual rails in a curve are not completely elastic. The hysteresis in these relative movements likely accounts for the change in RNT that has long been observed by railroaders. Additional measurements and more test cases are required to better understand the effects of track design and maintenance factors.

Changes in RNT are most strongly associated with rail longitudinal movement. Whereas, changes in RNT are associated with no or minimal changes in curve radial position. It is interesting to note that the longitudinal shifting did have an effect on radial shifting, where high radial shifts had little longitudinal shifts and vice versa. With more data, the interrelationship between these two parameters will become better defined.

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