



A Higher Speed Turnout

SUMMARY

Travel through the diverging route of a turnout can produce high lateral forces and accelerations, particularly in the areas of the switch point and frog, as shown on the left and right sides of the graph in Figure 1. These higher lateral forces and accelerations require slower operating speeds and have adverse effects on ride quality and component life.

This study was aimed at finding a low-cost means to reduce lateral forces and accelerations so that safe speeds through turnouts could be increased. Meeting this objective required that the key turnout dimensions of lead length and frog angle be kept fixed so that no track reconfiguration would be needed and the new design could fit within the existing turnout space.

The objective was achieved by reducing the switch angle in the conventional American Railway Engineering and Maintenance of Way Association (AREMA) turnout, along with lengthening the switch points and reshaping and shortening the curved closure. When applied to a No. 20 turnout (Figure 2), dynamic simulations and field measurements showed that this design would allow diverging speeds to be increased from the current limit of 45 mph to 55 mph without producing peak wheel/rail forces and lateral accelerations, which exceed those produced with traditional turnout geometry.

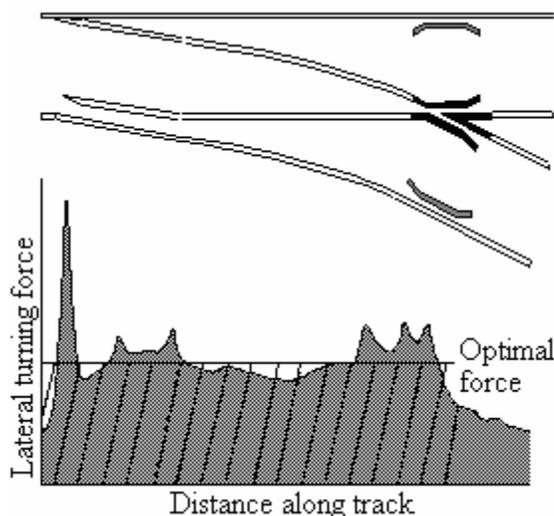


Figure 1. Lateral Forces in a Turnout



Figure 2. Retrofitted Higher Speed Turnout on New Jersey Transit



BACKGROUND

The original objective of this project was to redesign a conventional turnout to allow higher diverging route speeds without exceeding accepted limits for lateral forces and accelerations. The given design constraints required keeping the resulting turnout within existing lead length and maintaining the same frog angle. Retaining these dimensions would allow retrofitting existing turnouts and would keep the cost of any design changes at an affordable level.

As an alternative application, a modified turnout design might also allow operating at current diverging route speeds but with substantially reduced lateral forces and accelerations, thus improving ride quality and potentially decreasing component wear.

Analysis by Zeta-Tech Associates produced a candidate design, and Cleveland Track Materials manufactured the new components for installation on New Jersey Transit (NJT). Zeta-Tech monitored the installation and collected various data before and after the turnouts were rebuilt. They also produced the comparison of data shown here.

Referring to Figure 1, it was determined that to best achieve either application (higher speed or force and acceleration reduction at current speeds), the focus would be on modifying turnout design to reduce the high force spike produced when entering the switch and generally to even out lateral forces throughout the diverging route, keeping them relatively close to the optimal force line shown in the figure.

Considering the design constraints, analysis suggested that a meaningful speed increase might be achieved in a turnout of No. 20 in size, which typically allows a maximum speed of 45 mph through the diverging route.

New Diverging Route Design

Due to its prevalence in the industry, the AREMA No. 20 turnout with straight switch points was selected as the example for geometry optimization. Dynamic simulations of a vehicle negotiating various turnout alignments were performed using NUCARS software. Analysis of the data yielded the diverging route alignment shown in Figure 3. As shown, the

optimized solution has a very low (nearly tangent) entry angle, somewhat increased curvature through the main part of the curved closure section, and an increase in the tangent length leading to the toe of the frog. The total length from point of switch to the frog is the same in both cases, as is the frog angle.

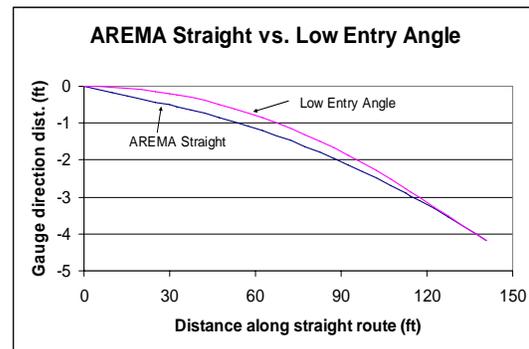


Figure 3. Comparison of Turnout Geometry

The resulting design requires an increase in switch point length from 39 to 60 feet, compensated by a shorter closure length.

Modeling with the selected design showed improvement over both the standard AREMA straight and curved switch point designs. Further, the new design produced lateral forces and accelerations that were nearly as low as those of a true tangential geometry turnout, without the additional 20 feet of lead length the tangential design would require.

Retrofitting The Turnout

The new turnout configuration was installed on NJT in two turnouts, which formed a crossover. The primary new parts required were the modified switch points and undercut stock rails. (Existing stock rails can be used if the undercut is extended to accommodate the longer switch point.) The longer point length also required purchasing other parts, including specialized pocket plates and elastic fasteners, new slide plates, two additional switch rods (a total of seven), additional rail braces, and an assist rod (recommended).

Installation began with the removal of rail and hardware from the existing turnout, leaving only the switch machine, ties, and frog in place. Next, the ties were re-spaced according to the design. After laying down the straight stock rail, the curved closure and curved stock rails were located and installed according to the design



offsets. Lastly, the straight closure was installed based on standard gauge, and all rods and other hardware were attached. After final assembly, all throws and over-tees (switch rod adjustments) were rechecked.

Testing And Results

Before the crossover was rebuilt in its new configuration, tests were performed on the existing turnouts for later comparison with the new design. Strain gauges were installed at selected points along the diverging route, and forces from passing trains were determined from strain gauge readings. Accelerations were recorded from ride quality meters placed on NJT commuter trains. After rebuilding, a similar series of measurements was made for the new turnout design. In addition, acceleration measurements were taken with NJT's track geometry car. This allowed traveling through the diverging route at speeds up to 55 mph, which could not be done with commuter trains.

Table 1 shows a comparison of forces and lateral to vertical force (L/V) ratios from the tests. Of perhaps most interest here as a performance comparison, both the maximum and average lateral forces in the modified turnout are less than half of those in the original unmodified design.

Table 2 gives a comparison of lateral accelerations from trains. In this case, values for the AREMA No. 20 turnout include readings taken at the crossover, which was subsequently rebuilt, as well as those taken at another nearby No. 20 crossover. The average of maximum values is the sum of the maximum readings from the ride quality meter during the passage of each train divided by the number of passing trains. The average peak-to-peak values were similarly determined. For both measures, the accelerations from the new design are about 40 percent lower than from the conventional design.

Table 3 compares the lateral accelerations measured by NJT's geometry car traveling through a standard AREMA No. 20 crossover at 45 mph and the re-designed crossover at 55 mph. As shown, the average maximum acceleration for the two cases is about equal, while the average of maximum peak-to-peak values is about 15 percent lower for the re-designed crossover, despite the 10 mph higher speed.

SUMMARY AND CONCLUSIONS

A modified turnout geometry intended to provide a low-cost means to increase diverging route speeds through a turnout, without changing turnout length or frog angle, was installed and tested.

Table 1. Passenger Train Wheel Force Measurements

Data Description	Before Modification	After Modification
Number of Measurements	288	437
Number of Trains	9	13
Minimum Speed (mph)	18.98	27.87
Maximum Speed (mph)	43.92	42.95
Average Speed (mph)	36.05	38.55
Maximum Vertical Force (lbs)	21120	18885
Minimum Vertical Force (lbs)	10660	7110
Average Vertical Force (lbs)	15016	11943
Maximum Lateral Force (lbs)	7680	3436
Average Lateral Force (lbs)	2202	890
Maximum L/V Ratio	0.40	0.28
Minimum L/V Ratio	0.15	0.07

Table 2. Passenger Train Car Body Lateral Accelerations

Lateral Accelerations	AREMA Standard No. 20	Modified Crossover
Average of Maximum Values (g)	0.285	0.166
Average of Peak-to-Peak Values (g)	0.422	0.240



Table 3. Track Geometry Car Lateral Accelerations

Lateral Accelerations	AREMA Standard No. 20 at 45 mph	Modified Crossover at 55 mph
Average of Maximum Values (g)	0.39	0.40
Average of Peak-to-Peak Values (g)	0.68	0.57

Results indicated the ability to travel through the diverging route of a No. 20 crossover at 55 mph without exceeding the lateral forces, accelerations, or L/V ratios normally experienced at 45 mph through a conventional design.

This was achieved by first reducing the switch point angle, which simulations have shown is typically the cause for the highest lateral wheel/rail forces, along with realigning the closure curve to compensate for a longer switch point and the reduced switch angle.

This approach, which is applicable to the majority of existing turnouts, shows the potential to permit higher speed operation through turnout diverging routes or to enhance ride quality at current speed limits.

FOR FURTHER RESEARCH

Performance of the modified No. 20 crossover on NJT will be monitored for at least 2 years following its installation. Monitoring will include measurements of switch point and rail wear, along with periodic ride quality measurements. A full report on this project will be prepared upon conclusion of the monitoring period.

ACKNOWLEDGMENTS

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REFERENCES

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