Holland®

Identifying Potential Areas Prone to Rail Rollover Derailment With Holland's Products and Services

RMSS White Paper Series

Introduction

According to the FRA accident database wide gauge (FRA Code T110, T111) constitutes 20% of all track-caused derailments. [1, 2] Wide gauge derailments can be classified as lateral translation and rail rollover.

When railway trucks negotiate a curve, steering forces are generated. The gauge is widened by high rail wheel flanging action and lateral creep forces on the low rail. The magnitude of lateral forces depends on many factors, such as: vertical load, friction coefficient, degree of curvature, wheel and rail profile geometry, over/under balance speed, track geometry, in-train forces (coupler force and angle), truck steering properties, etc. The rail can be laterally translated on the tie, resulting in gauge widening and possible wheel drop. Another mechanism is the rail roll due to the moment of lateral and vertical force when the resultant force falls outside the base of the rail.

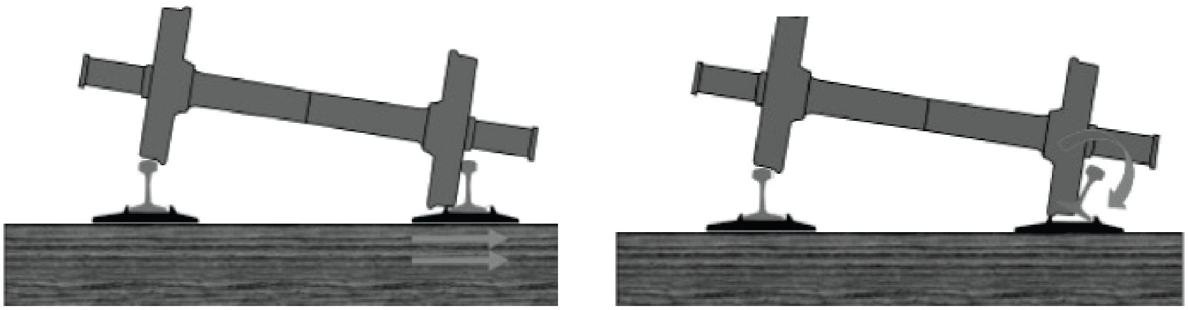

Figure 1 Gauge Widening and Rail Rollover

This paper investigates rail rollover derailment from the perspective of base-to-height ratio (B/H). The effects of gauge face wear, wheel tread wear, rail cant angle, and railhead slope on the B/H ratio are explained. Holland's track analysis software, ***Rangecam***™, allows users to identify and report track sections with a critically low B/H ratio.

B/H Ratio for Rail Rollover Initiation

When the force and moment equilibrium diagram of wheel and rail interaction is analyzed, a simple relationship that explains rail rollover initiation is revealed. When the wheel pushes the rail outward with a lateral force L, it creates a clockwise moment about the field corner of the rail base by leveraging the contact height (shown in Figure 1). At the same contact point, vertical load creates a counter-clockwise moment by leveraging the base distance. To initiate the rail rollover, the lateral-to-vertical load ratio (L/V) ratio must be greater than the base-to-height (B/H) ratio. Instead of a single wheel, truck side L/V was found to be more correlated to the railhead movement from the field tests[3]. In reality, there is a fastening clip or cut spike factor, so there is some room for safety, but a direct comparison of truck side L/V to B/H is a conservative and safe practice.

[1] *Wolf G., May 2015, "Origin and Dynamics of Wide Gauge Derailments", Wheel Rail Interaction Heavy Haul Seminars*

[2] *Liu X., Barkan C. et. l., "Analysis of Derailments by Accident Cause", Journal of the Transportation Research Board, DOI:10.3141/2261-21*

[3] *Wu H., Kerchof B., 2014, "Management of Wheel/Rail Interface to Prevent Rail Rollover Derailments", Journal of Rail and Rapid Transit, Vol. 228(6) 673-686*

Today, L/V values are commonly measured by instrumented sites (rail-mounted strain gages), trackside measurement technologies, and instrumented wheelsets. B/H ratio is generated from rail profile measurements. Holland's ***Argus***® track measurement technology suite offers different options to measure full track geometry and rail profile from ***TrackSTAR***® vehicles, track inspector hi-rails, track geometry cars, freight cars, and locomotives. Once the rail profile is measured, the B/H ratio can be generated by ***Rangecam***™ software.

Figure 2 shows a typical new wheel and rail flanging scenario on the left-hand side. The B/H ratio is found as 0.64. When the same wheel engages heavily worn rail (~5/8" gauge face wear), the B/H ratio drops to 0.48.[4]

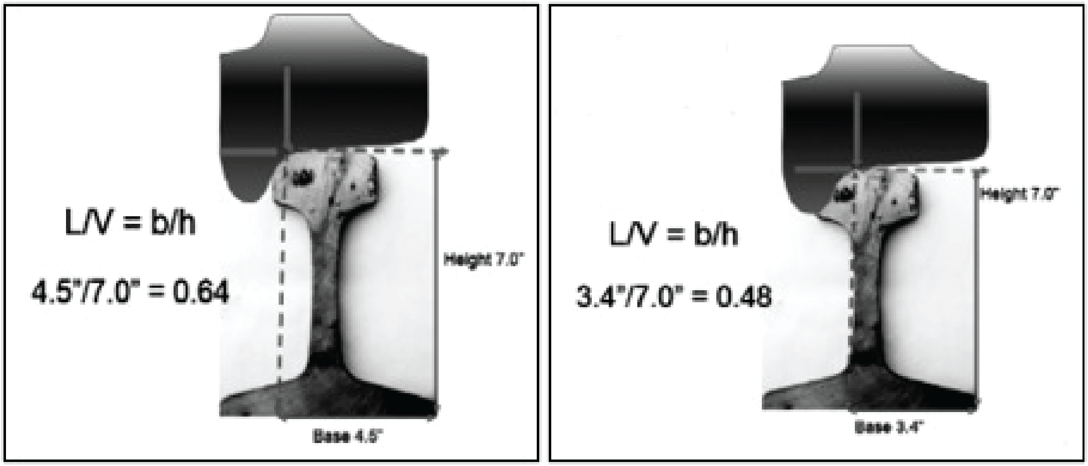

Figure 2 Reduction of B/H Ratio With Gauge Face Wear – High Rail

Low rail can also be rolled over under certain conditions. Figure 3 shows an example of a hollow wheel interacting with a flat head low rail profile. Contact point naturally occurs on the field side of the railhead, and the B/H ratio reduces to 0.38. With the assumption of 36,000 lb. of vertical load over a moderate or sharp curve, 0.38 or higher friction coefficient can result in sufficient lateral creep forces to initiate rail rollover. Unloaded wide-gauge exacerbates the situation and further reduces the B/H ratio. After the rail starts to roll, the problem is further compounded, and rollover becomes progressively easier.[5]

[4] *IHHA, June 2015. "Chapter 8, Guidelines To Best Practices For Heavy Haul Railway Operations"*

[5] *Wolf G., May 2015, "Origin and Dynamics of Wide Gauge Derailments", Wheel Rail Interaction Heavy Haul Seminars*

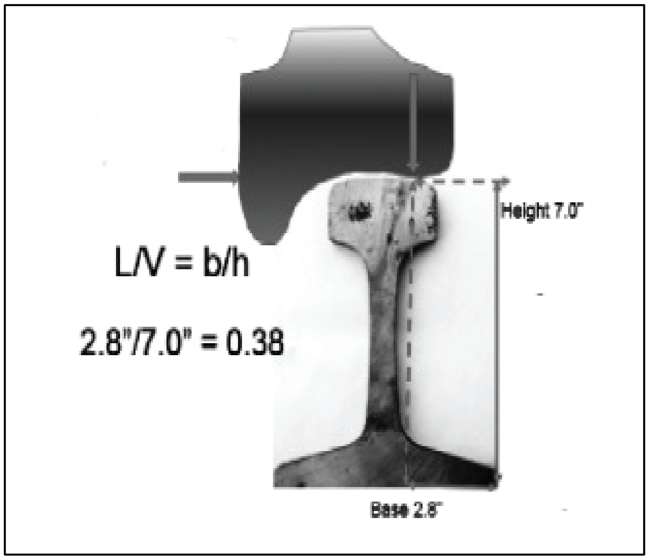

Figure 3 Reduction of B/H Ratio with Hollow Wheel Field-Side Contact - Low Rail

Reverse rail cant angle is another critical parameter that reduces the B/H ratio. Figure 4 shows how 3 degrees of reverse cant angle reduces the B/H ratio from 0.64 to 0.45 since the base distance drops dramatically due to the new geometry positioning. Wu and Kerchof provided an excellent article that mapped out B/H ratio as a function of rail cant angle and lateral contact position (Figure 5)[6]

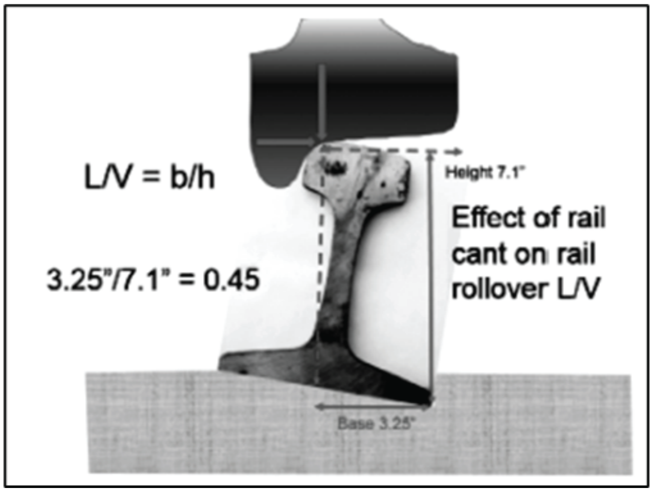

Figure 4 Reduction of B/H Ratio with Reverse Rail Cant

Holland's ***Argus***® track measurement technology provides real-time rail cant angle measurement reported with track geometry strip charts. In addition, loaded cant measurements are provided by Holland's ***TrackSTAR***® vehicles' gauge restraint measurement systems (GRMS).

[6] *Wu H., Kerchof B., 2014, "Management of Wheel/Rail Interface to Prevent Rail Rollover Derailments", Journal of Rail and Rapid Transit, Vol. 228(6) 673-686*

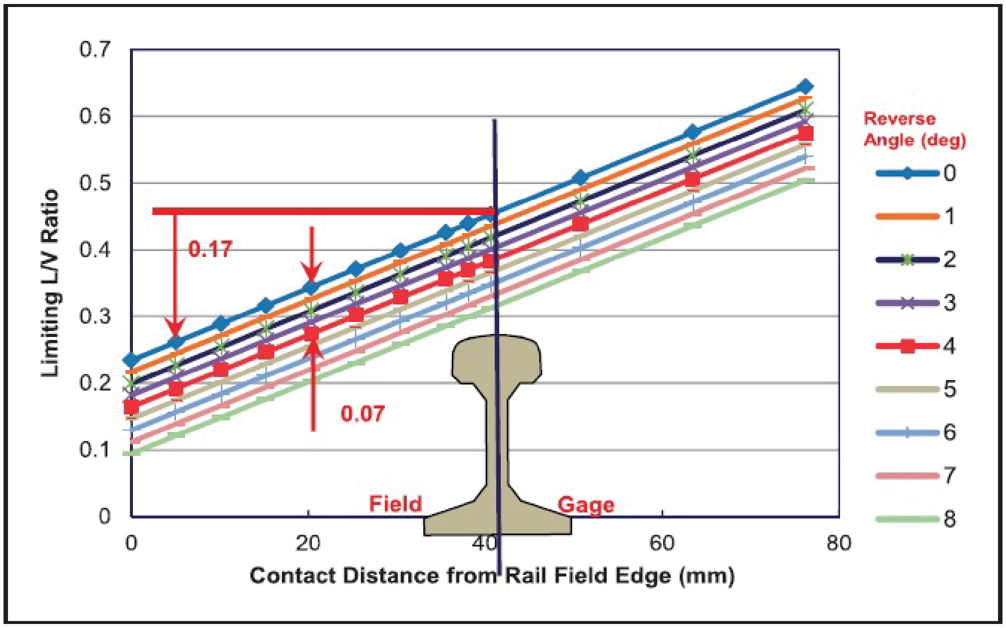

Figure 5 L/V to Initiate Rail Rollover as a Function of Rail Cant Angle and Lateral Contact Position (Wu & Kerchof)

Railhead slope is another factor that reduces the B/H ratio. It is the angle between the top-of-rail surface and horizontal track planes. Two points that are an inch apart are defined about the rail centerline, and the top-of-rail surface plane crosses these two points. ***Rangecam***™, Holland's track analysis software, can calculate this parameter from rail profile data. ***Rangecam***™ users can identify spots with undesired railhead slopes along the testing route with detailed querying features.

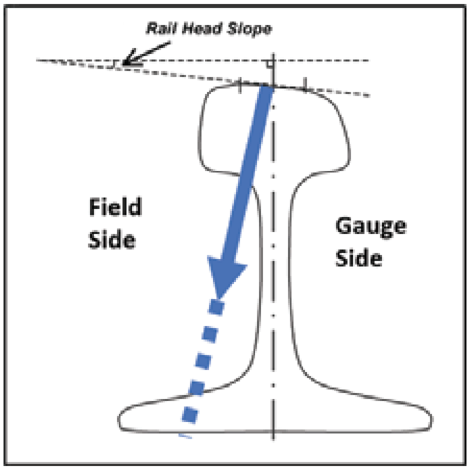

Figure 6 Railhead Slope

As shown in Figure 6, similar to rail cant angle, a higher railhead slope moves the orientation of the resultant wheel force vector unfavorably and reduces the B/H ratio. A Class I railroad adopted a 5^0 railhead slope threshold along with a 0.35 B/H ratio to identify areas of concern.[7]

[7] *Kerchof B., 2018. "Case Study : Investigating a Rail Rollover Derailment", WRI 2018 Principle Courses*

Additionally, excessive railhead slope can reduce the internal rail flaw detection quality. High railhead slope can change the normal angle refraction of the ultrasonic beam from the transducer to such a critical level that the ultrasonic signals do not penetrate at the expected angle or to the anticipated location of the specimen. Thus, reflected sound beams generally associated with internal rail flaws may not be identified by the test systems.

Figure 7 shows a typical ***Rangecam***™ profile analysis with B/H ratio calculations. ***Rangecam***™ provides rich query options to subset interested division, sub-division, track, particular test run, degree of curvature, a high or low rail, and thresholds for B/H ratio and railhead slope.

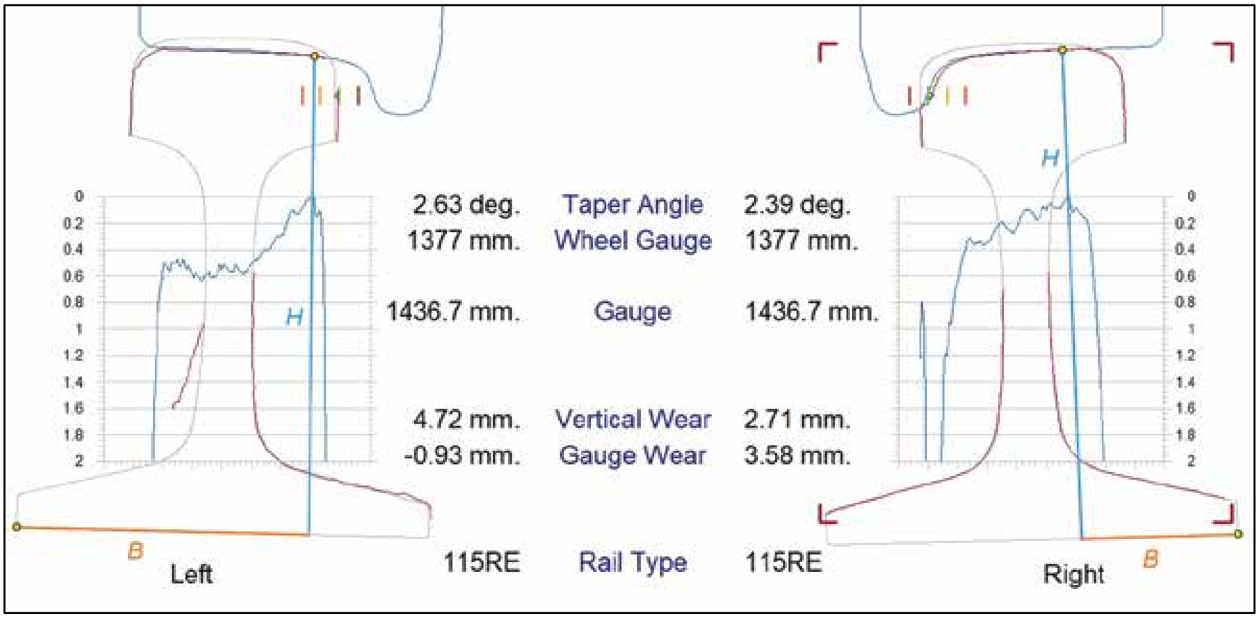

Figure 7 Rangecam B/H Ratio Calculation Example

Holland's Rail Measurement Systems and Services (RMSS) team provides track testing, geometry, and rail measurement products and services. RMSS served more than 150 railroads, including Class I, short and regional lines, and transit agencies with ***TrackSTAR***® services, ***Argus***® track measurement technology suite, and ***Rangecam***™ track analysis software for more than 25 years. Don't hesitate to contact us at sales@hollandco.com and let us keep your rail operations safe.

[8] *Guidelines To Best Practices For Heavy Haul Railway Operations – Infrastructure Construction and Maintenance Issues Chapter 4, International Heavy Haul Association, 2009.*