Vehicle Hunting & Its Effect on North American Railroad Operations

Summary: In North America, hunting vehicle derailments have been cited for more than 10% of the equipment related derailments each year. The lateral truck/bogie oscillation from one rail to the other induces excessive lateral wheel forces, increases fuel consumption, promotes damage to lading and causes excess damage to vehicle components and railroad infrastructure.

To reduce the stress state of the North American railroads, both vertical and lateral wheel force alarms have been developed and implemented over the past twenty years. In the most recent four years, truck/bogie hunting (lateral oscillation) has become an industry focus to prevent lading damage as well as unsafe operating conditions. Salient Systems, Inc. (SSI) developed the Hunting Index (HI), which is currently being adopted by the railroad industry, and is becoming a North American interchange rule.

This paper will discuss the evolution of the Hunting Index and describe how the HI can be used to evaluate mechanical components, reduce fuel costs and monitor individual vehicle stability as well as fleet performance. All of which will improve safety, reduce vehicle and infrastructure damage, and thus reduce operating costs.

Index Terms: Truck hunting, bogie hunting, Hunting Index.

INTRODUCTION

To achieve the ultimate goal of zero tolerance for railroad-related accidents, injuries and fatalities, railroads and suppliers have spent millions of dollars in innovative trackside technology to improve railroad safety and efficiency, and to detect problems before they occur [1]. According to the Railroad Safety Statistics published by U.S. Federal Railroad Administration (FRA), American railroads have made significant progress reducing the number of derailments over the past six years. SSI’s Hunting Truck Detector (HTD) is one of the key wayside detectors that has been widely adopted by the North American railroads over the past four years.

Rail operations have and will continue to shift to heavier cars, longer trains, and higher speeds because of the increased performance demands in today’s transportation marketplace. As more high-speed trains come into service, the ability to insure stable, higher speed performance becomes more critical. Hunting condition, which is more prevalent at higher speed, causes a rail car to weave down a track, usually with the flange of the wheel striking the rail. A 1995 derailment investigation of train No. 306-05 verified that the train was moving faster than the maximum prescribed speed for the loaded covered hopper cars it was pulling. Track irregularities induced oscillations and a wheel climb derailment of...
covered hopper car 253034 destroyed the track and derailed seven other cars [2].

HTD measures a parameter called Hunting Index and identifies the lateral instability of a truck/bogie. With the AAR’s interchange Rule 46 in place, it is necessary to understand how the HI evolved and how to use the HI to monitor the truck/bogie performance.

1. BACKGROUND

In 1979, the DOT/FRA funded Battelle Memorial Institute to research concrete ties failure after limited service. Mr. Harold Harrison discovered that the root cause of the problem was excessive impact caused by defective wheels, and high impact forces being transferred through the rail to the ties. To measure the impact of the wheels, the Wheel Impact Load Detector (WILD) was invented. WILD systems use strain gauges mounted on both sides of rail web at the neutral axis to identify wheel defects such as shelling, spalling, and/or slid flats.

In 1994, with the proven reliability of WILD measuring dynamic wheel impacts, the AAR set wheel replacement criteria in Rule 41 of the Field Manual of the AAR Interchange Rules. When the impact of a wheel is 400kN (90Kip) or greater, based solely upon measured WILD data, the car can be pulled from service until the wheel is replaced. To date, there are more than 150 WILD installations in North America and about 180 worldwide.

In 1990, lateral strain gauges were installed on the base of the rail at the Union Pacific (UP) Gothenburg WILD site to measure the lateral forces of the wheels, along with the web-mounted gauges that were measuring vertical force. Most WILD installations since that time have been implemented with both lateral and vertical gauges.

1.1 Truck/Bogie Hunting and Hunting Index

Truck/bogie hunting is an unstable lateral oscillating movement of a wheel set or a truck/bogie. The wheelset or truck/bogie continuously oscillates from one rail to the other while traversing down tangent track. This phenomena is also observed in curves, but is much less likely to occur. Figure 1 illustrates the wheelset behavior in a hunting situation. Truck/bogie hunting can be caused by low warp restraint, reduced shear stiffness, worn wheel profiles, and/or other worn truck/bogie components [3-5]. Track irregularities can also induce truck/bogie oscillations [6].

Hunting occurs when the wheel set of a truck/bogie shifts toward one rail causing a rolling radius difference. The wheel set then “hunts” for rolling radius equilibrium by oscillating back and forth from side to side. Worn or improper functioning truck/bogie components allow this to occur.

Truck/bogie hunting results in excessive wheel lateral forces, and can cause excessive wear in the vehicle and truck/bogie components. This creates a potentially unsafe operating condition, increases fuel consumption, promotes damage to lading and causes excess damage to railroad infrastructure. It can also result in a dangerous wheel climb derailment. For freight vehicles, the phenomenon occurs primarily with empty or lightly loaded cars with worn wheel sets. Hunting truck/ bogie derailments have been cited for more than 10% of the equipment-related derailments in recent years.

A low cost alternative to individual vehicle testing of the hunting propensity is to use a HTD detector. A typical SSI HTD monitors the health of freight and passenger trucks/bogies as they pass by the instrumented zone. The HTD has 32 dual-channel front-end processors monitoring 16 vertical circuits and 16 lateral circuits per rail. In 1998, Tom McCanney of SSI developed an algorithm to compute a value called the Hunting Index (HI), which describes a truck/bogie’s hunting behavior. The instrumented zone is
approximately 15 meters long and is capable of seeing two to three cycles of a typical hunting truck/bogie’s behavior. The algorithm uses correlated lateral and vertical data from each circuit to minimize the response to random flanging.

HTD processes real-time data and forwards actionable information to railroads. It is also capable of alerting the locomotive engineers of excessive truck/bogie hunting. If severe hunting does occur, reducing speed is the only immediate option until the cause of the hunting can be determined and corrected.

For the past four years, North American Class I railroads have adopted more than 100 HTDs. The hunting index is scaled from 0 to 1. The optimal threshold that distinguishes the troublesome car is above 0.4–0.6. This method has been proven to reliably detect and alarm the hunting trucks/bogies. On September 1, 2006, in AAR’s Circular Letter C-10354, a revision to Rule 46 about truck/bogie performance was stated. In this letter, the AAR set up a condemnable truck/bogie criteria based solely on the HTD-measured HI. A single HI reading above 0.65 and two absolute HI readings above 0.5 in a twelve-month time period for a single truck/bogie is cause for condemning a vehicle. Although the Hunting Index is derived from forces measured throughout the HTD measurement zone, it has been shown to approximate car body accelerations in g’s.

Figure 2 shows an example of a hunting truck/bogie exception report following the above AAR rule. Truck/bogie B of vehicle ATW 113134 had two occurrences of hunting indexes exceeding 0.5 in the past 12 months; therefore it was alarmed and reported.

### 1.2 Data Analysis

A large quantity of data has been produced in the past four years. Figure 3 shows 17,525 trucks/bogies hunting at normal operating speeds, which accounts for less than 0.1% of the truck/bogie populations of all trucks/bogies that passed by the HTD detectors on the UP main lines between July 2005 and September 2006.

![Figure 3. Hunting Freight Trucks/Bogies at Normal Operating Speed](image)

As readers may know from various publications [7-8], speed is a critical factor in truck/bogie hunting. When train speeds increase, there is a higher tendency to hunt. Figure 4 shows both trucks/bogies of freight car RTTX 970410 hunting at a speed of 112km/h (70 mph) and performing within acceptable limits when the speed is below 80km/h (50 mph). Figure 5 illustrates that track irregularities contribute to vehicle hunting and show that HI is site specific. The onset of hunting tends to increase with speed, often within the 55-80km/h (35-50 mph) range [5]. Figure 3 illustrates that severe hunting occurs at speed above 65km/h (40 mph).

![Figure 4. Truck/Bogie History Report](image)
Figure 6 shows the measured vertical force and lateral force over a 15-meter length of track as well as the L/V ratio. As with the lateral forces, the range of the L/V values are not extreme; they are within 27kN (6 Kips). However in Figure 7, the lateral forces from crib to crib are a very large 90kN (20 Kip) difference. Vertical forces shown in both Figure 6 and 7 demonstrate the motion of the truck roll and the irregularities of the track. The L/V ratio in Figure 6 shows a maximum of 0.3 and a minimum of –0.3 and in Figure 7 shows a maximum of 1.2 and minimum of –0.75. Five cribs have a L/V ratio > 0.8. A wheel climb derailment scenario is possible in the later case.

By further examining the bad-actor trucks/bogies beyond the 99.9th percentile at all UP HTD sites, Figure 8 shows 15 months of UP car types with truck/bogie HI >= 0.4. About 80% of the vehicles are conventional freight cars with ~10-12m bogie centers, 14% are 27m long cars, and 6% of the cars are multi-platform intermodal cars with 143 3 Paks and 923 5 Paks. Results show that the middle trucks/bogies of articulated vehicles do not hunt. Almost all of all the hunting trucks/bogies were the leading trucks/bogies and the remainders were the trailing trucks/bogies. Worn trucks/bogies have proven more likely to hunt than new or well-maintained trucks/bogies. It is worthy of note that only one loco and no passenger cars had a truck/bogie HI >= 0.4.

As expected, Figure 9 shows empty cars are more prone to hunting than loaded cars. The lighter the tonnage routes, the more hunting trucks/bogies were seen on those routes [6].
Wheel climb is a condition where the wheel flange rolls up and onto the top of the railhead. This normally leads to a derailment. The primary factors that influence wheel climb are: L/V, friction coefficient, wheel angle of attack, and flange contact angle. A wheel climb derailment criterion of L/V >= 0.88 was established in 1908, formulated by Nadal of the French Railways [9].

More recent research into the effects of wheel and rail profiles, angle of attack, and severe hunting have further advanced the understanding of wheel climb derailment conditions [10-13].

Wheel L/V force ratio is the dominating factor in calculating HI for a truck/bogie. Figures 10 and 11 show the relationship between the HI and L/V. Over 4,000 trucks/bogies were used in the study of HI>0.5 and 2291 trucks/bogies of HI<0.4. The average L/V in the case of HI>0.5 is 0.126 vs. 0.0197 in the case of HI<0.4. Both min and max L/V are greater in HI>0.5 case than in HI<0.4 case. At the 95% cut off point, HI>0.5 exhibits an L/V of -0.64 to 0.76 and HI<0.4 exhibits an L/V of -0.41 to 0.55. The higher the HI, the higher the absolute value of L/V ratio. Obviously, negative L/Vs do not contribute to wheel climb, but are indicative of large lateral velocities and the corresponding creep forces.

On the Northeast Corridor, Amtrak has installed SSI’s HTDs to monitor two main tracks at their Edgewood, Maryland and Mansfield, Massachusetts detector sites. Although the freight railroads also use these tracks, 90% of the traffic is high-speed commuter traffic. Given the high speed of the Acela trains and all the hunting issues those train sets suffered from, both sites have a unique 40-circuit layout instead of the typical 32-circuit layout to make for a longer zone. The operating speed of the commuter trains are between 160 ~ 240 km/h. A typical passenger truck/bogie wheelbase is about 228 ~ 330 cm long vs. a typical freight truck/bogie wheelbase of about 152 ~ 183 cm. Generally, the longer the truck/bogie wheelbase, the more stable. When a longer bogie hunts, it generates a longer wavelength, which are identified by the HTD.
Eight months of HTD data from both Edgewood and Mansfield have been analyzed in Figure 12. About half a million two-bogie cars were identified in this analysis. Figure 12 shows the distribution curve of the hunting index. Even though the passenger cars were much lighter than the freight cars and were running at a much higher speed compared to the freight cars, the passenger cars hunted much less. Due to the major differences in truck/bogie design and the better maintenance practices on passenger equipment, 99.97% of the passenger bogies have a HI less than 0.2.

In severely worn bogies, side frames and bolster will need extensive repair, as well.

2. CONCLUSIONS

This paper discussed the evolution of the Hunting Index and described how the HI can be used to evaluate mechanical components, reduce fuel costs, monitor individual vehicle stability, and improve fleet performance, all of which will improve safety, reduce vehicle and infrastructure damage, and thus operating costs. Salient Systems Inc’s HTD along with the high impact WILD data will aid the railroad in their proactive maintenance of both infrastructure and rolling stock.

3. ACKNOWLEDGEMENT

The authors would like to acknowledge the Union Pacific Railroad for their continuing cooperation and use of data, as well as Yan Li for her help in data mining.

4. REFERENCES

2. Railway Occurrence Report, Report Number R95M0027, Transportation Safety Board of Canada, Gatineau, Quebec, Canada, 1995


