TECHNOLOGY DIGEST

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Tread Buildup on Railroad Wheels

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Summary

Tread buildup (TBU) is the accumulation of metallic material on the tread surface of railroad wheels. Transportation Technology Center, Inc. conducted 90 wheel slide tests over distances ranging from 4,000 feet to 27 miles using three different gross axle loads and speeds between 5 mph and 40 mph. A water spray system was used to test three different rail conditions: dry, wet, and lubricated. During testing, TBU was found on most, but not all, slid wheels.

Based on literature sources,[1,3] inspections of failed wheels, and wheel sliding tests, TBU is caused by wheel slide events due to excessive brake force. While TBU is not uncommon, on rare occasions it accumulates to a sufficient height to become an issue. The railroad industry is currently poised to reduce TBU through the increased use of data from wayside detectors to identify cars with brake problems, hand-brake training and design improvements, and an improved air brake test. In the future, technological advances in hand-brake control could further reduce the incidence of TBU.

In some cases, during the tests at the Transportation Technology Center, the TBU flaked off leaving no evidence behind. The dry rail condition generally produced the most TBU during the wheel slide tests irrespective of the other test variables. No consistent differences were observed in comparing the results on wet rails to the results on lubricated rails. In cases of excessive braking forces, slide distances on the order of 27 miles or greater can produce TBU heights of concern. Dry conditions and train speeds in the range of 20 mph and 30 mph appear to optimize TBU height.

No TBU was created when the wheels were rolling. Based on these tests, transfer of metallic material from brake shoes has not been shown to be a source of significant TBU. The chemical content in the TBU samples indicates that they are most likely composed of a combination of wheel and rail material.

Twenty-one service worn wheelsets with TBU were inspected. For all but one wheelset, evidence of a slide was observed. Three wheelsets had TBU heights greater than 1 inch and the highest measured 3 inches radially off the tread surface.

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INTRODUCTION

This *Technology Digest* describes testing to explore the mechanisms of buildup on the tread of railway wheels. The Federal Railroad Association (FRA), Office of Research and Development, has teamed with the Association of American Railroads (AAR) to fund research conducted by Transportation Technology Center Inc. (TTCI) regarding the root cause of wheel related accidents.

BACKGROUND

While the buildup of material on wheel treads is not uncommon, it rarely accumulates to a sufficient height to become an issue. Between 2004 and 2011, 98 total accidents reported to the FRA involved TBU. The weather was categorized as clear or cloudy during 86 of these accidents, with only 12 accidents occurring during precipitation (rain, fog, sleet, or snow). A wheel with TBU at a radial height of 1/8 inch or greater is condemnable under AAR rules. This rule is in place to prevent impact loads and the reduction in relative flange height that can result in broken rails and train derailments.

Though many sources agree that problems with the braking system are involved,[1] the mechanism that causes the material to build up is still not well understood and agreed upon. Metal from brake shoes has long been suggested as a source of the TBU material.[2] In fact, the metal in brake shoes has been found in at least one case to be a source of small amounts of TBU.[3] Historically, brake shoes were made of cast iron, but this is no longer the case, because high friction composition brake shoes began to replace cast iron shoes in the 1960s.[4] There are only two major sources of metal in today's shoes: particles that are embedded from the wheel surface, also known as "pickup," and, in the case of tread conditioning shoes, iron inserts or high metal powder content. The industry has migrated away from the use of iron brake shoes and the movement of hot wheel steel during wheel slides likely causes the current problems with severe TBU.

INSPECTION OF SERVICE WORN WHEELS

In an effort to increase the knowledge base regarding TBU, TTCI inspected 21 service-worn wheelsets with TBU. For all but one wheelset, evidence of a slide was observed. The largest mass of buildup was not necessarily directly adjacent to the slide location for all wheels.

Varying amounts of TBU were found. Three wheelsets had TBU heights greater than 1 inch, the highest measured 3 inches radially off the tread surface (see Figure 1). The circumferential length of the TBU was also measured, and TTCI observed that the highest TBU measurements occurred on the wheels with some of the shorter TBU lengths. This fact combined with large flat spots immediately adjacent to the TBU and heat discoloration on the wheel plates indicated that the wheels with the highest TBU were the result of a wheel slide event. Figure 2 shows the TBU dimensional data.

Figure 1. Wheelset with TBU Extending 3 Inches Radially from the Tread Surface

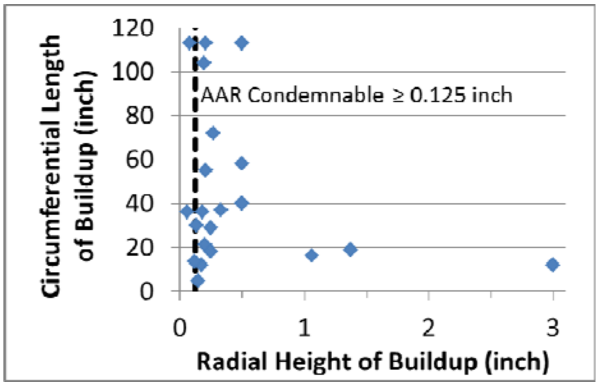


Figure 2. TBU Dimensional Data

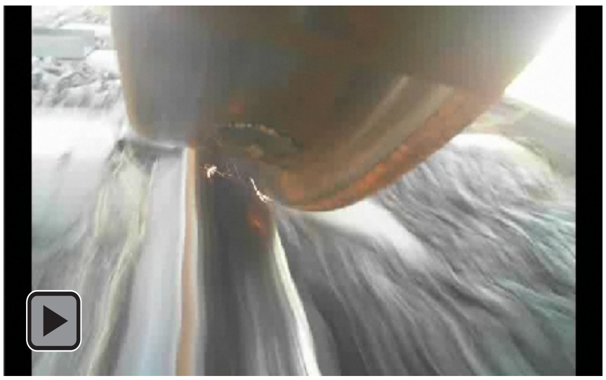
TESTING AT TRANSPORTATION TECHNOLOGY CENTER

To further the understanding of the conditions necessary to create TBU, TTCI conducted wheel slide tests at the Transportation Technology Center (TTC) including variations of railcar speed, gross axle load, and moisture at the wheel/rail interface. Each test covered a specific distance on the track and began by applying the brakes to a stationary car, accelerating to the test speed, maintaining the test speed, and decelerating to a stop. The hand brake and air brake were applied to the B-end truck only, and the wheelsets in this truck were slid the entire test distance. Upon completion of a test run, the brakes were released and the wheels were rotated to allow measurements and photographs of the slide areas and TBU.

After documenting the damage, the car was moved enough to position an undamaged portion of each wheel in contact with the rail in preparation for the next test. A series of 54 short slide tests were conducted at a slide distance of approximately 4,000 feet. An additional 36 slide tests, using an empty aluminum hopper, were conducted at distances ranging between 9 miles and 27 miles.

SHORT SLIDE TESTS

Three wheel/rail friction conditions and three car weights were tested during the 54 short runs at speeds ranging from 5 mph to 30 mph. The three different friction conditions included: dry, wet, and lubricated. A water spray system was used to continually cover the rails with either water or a mixture of water and soap. The system was fixed to the leading end of the test car and aimed at a position on each rail immediately in front of the leading wheelset. Video 1 shows an example of a test in progress as viewed from a video camera mounted on the test vehicle at a position immediately behind one of the sliding wheels.



Video 1. TBU Generated from Wheel Slide

Figure 3 shows the average TBU height from the short slide tests. The average TBU was highest when the rail was dry and the car was loaded to its heaviest test condition (72,200 pounds gross rail load). This is a logical trend because the heat at the contact patch is related to the wheel/rail normal force and the friction conditions. Figure 4 shows the maximum TBU height for the short slide tests. This data follows the same trend as the average TBU height, although the test with the lightest car weight and wet rail produced a higher maximum TBU measurement than expected based on the trends of the other tests.

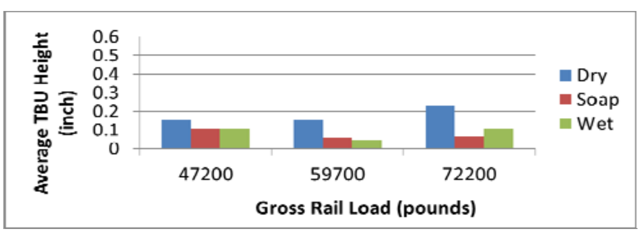


Figure 3. Average TBU by Gross Rail Load for the Short Slide Tests

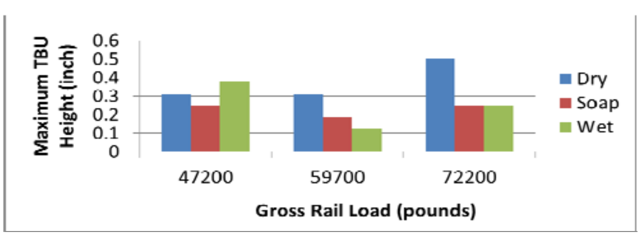


Figure 4. Maximum TBU by Gross Rail Load for the Short Slide Tests

LONG SLIDE TESTS

Thirty-six test runs were conducted with an empty car (47,200 pounds gross rail load) over longer distances to investigate the effect of increased slide distance. Between one and three laps were completed on a track loop approximately 9 miles long. The laps were made at four different speeds: 10 mph, 20 mph, 30 mph, and 40 mph. The water spray system was used to control the wheel/rail friction conditions.

Figures 5 and 6 show the average and maximum TBU separated by speed and wheel/rail friction condition. The highest average values of TBU height occurred during the 20 and 30 mph runs. The maximum values also occurred during the same speeds.

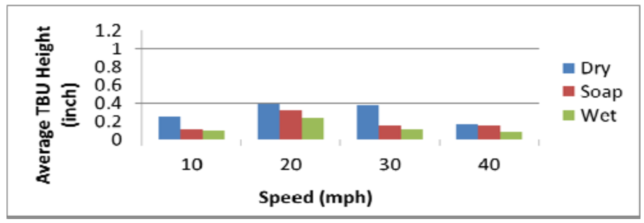


Figure 5. Average TBU by Speed for the Long Slide Tests

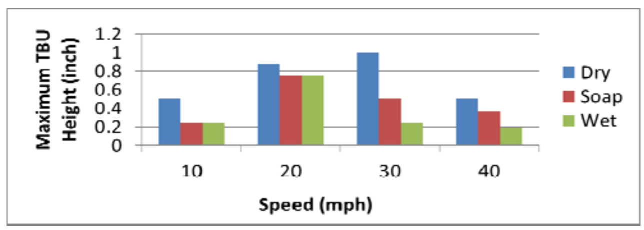


Figure 6. Maximum TBU by Speed for the Long Slide Tests

Figures 7 and 8 show the average and maximum TBU heights that were recorded at each wheel slide distance. In general, the TBU heights were greatest when the rail was dry and after the longest wheel slide distance (27 miles).

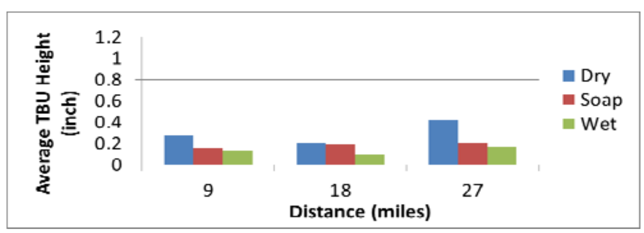


Figure 7. Average TBU by Distance Traveled for the Long Slide Tests

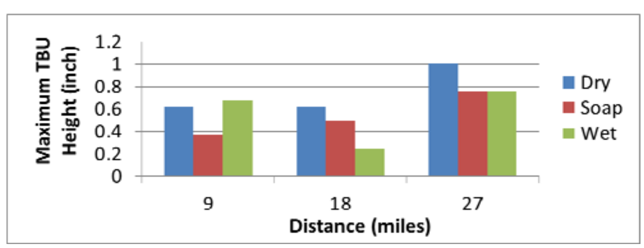


Figure 8. Maximum TBU by Distance Traveled for the Long Slide Tests

RATCHETING TEST

In the past, TTCI created TBU all around the circumference of wheels by purposely dragging an empty car with the hand brake tightly applied. The wheelsets alternatively slid and rotated (ratcheted) until a small amount of buildup material covered the majority of the tread circumference. In the current work, TTCI attempted to recreate TBU around the circumference of the wheel. The hand brake was tightly applied, but the air brakes were released. During this testing, the wheels were sliding on the rails at intermittent times as desired and the test crew could see TBU on the wheel from their location on the instrument coach coupled to the test vehicle. However, after a significant distance of ratcheting, the wheels ceased sliding and began to roll. After this rolling began, any evidence of TBU began to disappear. By the end of the test, the only evidence remaining on the wheel was a slight bluing near the flange and all TBU was gone.

BRAKE SHOES WITH METAL PICKUP

Brake shoes with metal pickup have been theorized as a possible source of TBU. TTCI ran three tests with brake shoes containing metal pickup. A light hand brake application was used to keep the brake shoes in contact with the wheels as they rotated. Test speeds were 20 and 40 mph, and the test distance was 9 miles. The results of these tests showed no measurable signs of TBU, and, in most cases, the pickup metal in the shoe had decreased in size.

DESTRUCTIVE ANALYSIS

A chemical analysis of TBU samples indicated that the source of the material is likely a combination of wheel and rail steel. The TBU material from two wheels removed from revenue service and eight wheels that were dragged on the tracks by TTCI was evaluated for chemical content.

The percent carbon in the TBU material was in the range of Class C wheel steel (0.67 to 0.77) for six of the TTCI-created samples and one of the revenue service samples. Two of the TTCI-created samples had carbon content between the maximum for wheels (0.77) and the maximum for standard rail steel (0.84). One of the TBU samples from revenue service had a carbon content of 0.89, which is higher than the maximum for wheels or standard rail steel, but within the range of premium rail steel (approximately 1 percent). The percentages of other elements in the TBU samples were generally within the specified limits for wheel steel.

Evaluation of the microstructure of several TBU samples showed a pearlitic microstructure with a notable absence of any martensite, indicating that any heating of the steel from sliding either did not reach the austenitic transformation temperature (approximately 727 °C) or more likely did not cool at a sufficient rate to form martensite.

CONCLUSIONS

Based on literature sources,[1,3] inspections of failed wheels, and wheel sliding tests, TBU is caused by wheel slide events due to excessive brake force.

During testing at TTCI, TBU was found on most, but not all, slid wheels. Based on video evidence from testing, some TBU material did not stick to the wheel, but instead flaked off leaving no evidence behind. The dry rail condition generally produced the most TBU during the wheel slide tests irrespective of the other test variables. Wet rails and lubricated rails produced similar results. In cases of excessive braking forces, slide distances on the order of 27 miles or greater can produce TBU heights of concern. Dry conditions and train speeds in the range of 20 mph and 30 mph appear to optimize TBU height.

No TBU was created when the wheels were rolling. Based on the testing at TTC, transfer of metallic material from brake shoes has not been shown to be a source of significant TBU.

The chemical content in the TBU samples indicates that they are most likely composed of a combination of wheel and rail material.

FUTURE WORK

The railroad industry is currently working on efforts to improve brake system performance, many of which could reduce the incidence of TBU. Increased use of data from wayside detectors, hand-brake training, design improvements, and an improved air brake test are all potential benefits for brake system performance. In the long term, technological advances in hand-brake release control would provide an opportunity to dramatically reduce the incidence of TBU.

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