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Environmental Effects on Brake Beams

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Summary

Research efforts have been ongoing to identify the brake beam operation environment to facilitate the authoring of a fatigue specification.

In 2005, the Transportation Technology Center, Inc. (TTCI) conducted performance tests in revenue service and in a controlled environment to establish the fatigue environment for brake beams and to establish the required parameters for a laboratory fatigue test that could be used to evaluate new designs.

` Test results showed that a fatigue test must replicate the conditions present when brakes are applied. Stresses in a brake beam are most significant when high impact wheels are installed in the truck; therefore, loading should be consistent with this condition.

Over the last few years, Union Pacific (UP) has collected field performance data from car repair billing data. UP observed a relationship between high impact wheels and the brake beams from the same truck. To confirm this research, the UP donated four wheelsets to TTCI to be used in brake beam tests.

This digest highlights the analysis and results from controlled and revenue service tests with information from previous tests.[1]

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INTRODUCTION

Using information from previous tests[1] and direction from the Association of American Railroads' Brake Committee, a supplier developed a laboratory test and proposed a brake beam fatigue specification. The specification requires that the brake beam be excited at its resonant frequency for 2-million cycles. The specification was not adopted "as is" because there was no backup for the 2-million cycle requirement. Representatives of the UP pointed out that this might only amount to 72 hours of 50 mph revenue service with wheel flats. Further development of the specification trailed off when the industry experienced an economic downturn.

In 2005, the issue was revisited and previous data was gathered from available sources. This information was used in the design of a revenue service test. Fortunately, the brake beam service test was able to piggyback onto a non-related revenue service test involving a 110-ton coal hopper car. The hopper car's brake beams were equipped with instruments to quantify the beams' environment. Because the car's condition, including the wheelsets (had minor tread damage), was good, the test data provided a sound baseline for comparison.

UP offered data from its research that highlighted the relationship between high impact wheels and damaged brake beams. To measure the effect of high impact wheels on brake beam stress, the UP provided four axles taken out of service due to wayside detector alarms, and a test program was conducted by TTCI. This digest highlights the analysis and results from controlled and revenue service tests. The objective is to provide a resource that will facilitate the development of a fatigue test specification.

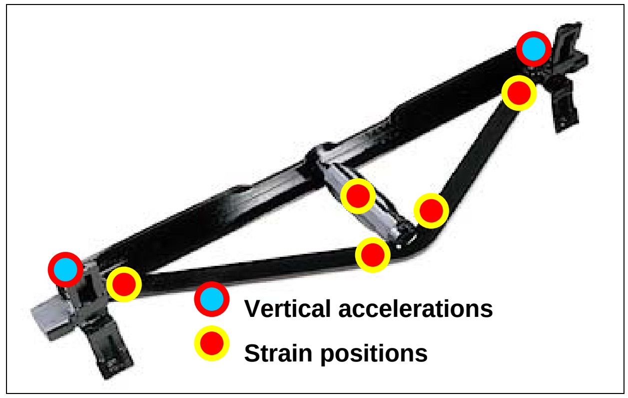

Figure 1. Positions Instrumented on Two Brake Beams on the Leading Truck of a Coal Gondola

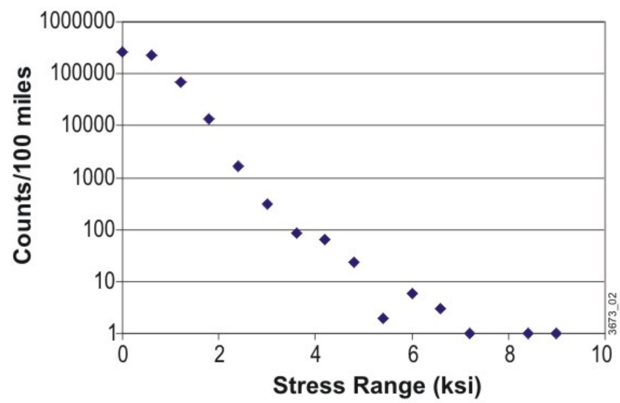

Figure 2. Cycle Counts from Revenue Service Test with Instrumented Brake Beam

2005 Over the Road Revenue Service Test

In February of 2005, a revenue service test was conducted using a 286,000-pound coal hopper from the Wyoming coal fields to northern New York State. The loaded car had two brake beams each instrumented with five strain gages and two accelerometers. Figure 1 is a diagram of a sample brake beam showing the locations of the instrumentation.

Results from the over the road test provided similar findings regarding the natural frequencies as found in previous studies.[1] From a fatigue perspective, the highest stress ranges were approximately 9 ksi (see Figure 2). While this is high enough to cause fatigue damage to a welded structure, the low number of cycles at this level will probably result in a relatively long life.

A comparison was made between two 100-mile sections comparing acceleration counts between concrete and wood ties. The concrete ties did show a slightly elevated acceleration signature, which implies that the wood ties provided more damping than concrete ties.

Union Pacific Results

Over the last few years, the UP has collected field performance data from car repair billing data. UP observed a relationship between high impact wheels and the brake beams from the same truck. UP findings showed a strong correlation between the two conditions, which is displayed in Figure 3 (used with permission from the UP mechanical engineering department).

Two things are interesting about Figure 3: (1) the relationship between wheel impacts and broken beams and (2) the wide range of impact loads associated with the broken beams.

The same dataset was evaluated with respect to time in an effort to quantify how long a beam must be subjected to the wheel impacts before breaking. Unfortunately, the data did not provide any definite trends given that the time when the beam failed is unknown. All that is recorded is the time the beam was discovered and removed and the wheel impact history. Potentially, a laboratory test method may help provide a relationship between time, impact level, and brake beam fatigue life.

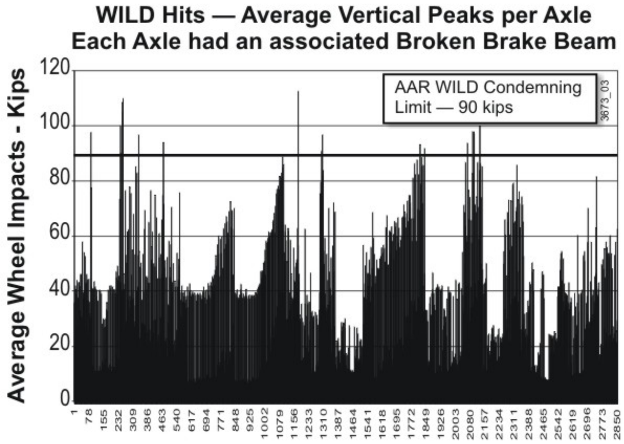

Figure 3. Broken Beams Associated with Average Wheel Impact Load Values

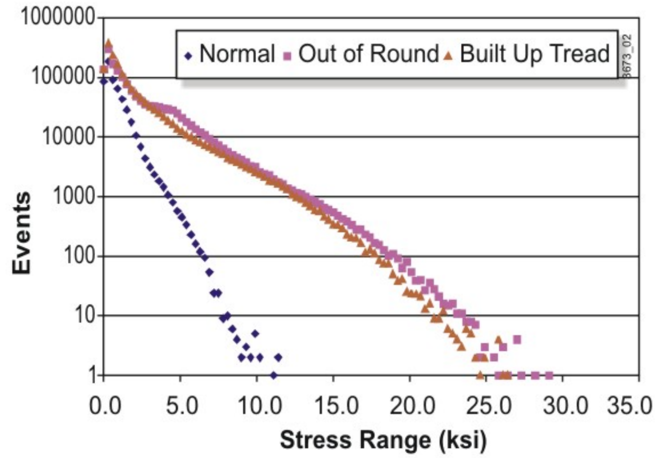

Figure 4. Histogram of Stress Range Counts from the Three Wheel Conditions

Controlled Tests and Results

To investigate the relationship between high impact wheels and brake beam damage, TTCI developed and performed a controlled test. The UP provided four high impact axles (see Table 1).

Table 1. Maximum Wheel Impact Loads Recorded by a Wheel Impact Load Detection Site

Max. WILD Alarms	Lead Axle	Trail Axle
Out of round	54 kips	80 kips
Built up tread	94 kips	108 kips

Using the test wheelsets and the original pair from the over the road test, three days of testing were performed. Each day a pair of wheels was run for 7 hours on the Transit Test Track at speeds between 40 and 60 mph, while random braking loads were applied. In addition to the same instrumentation used over the road, a pressure gage was added to the brake cylinder to indicate the braking levels. In Figure 4, a cycle count summary is provided which confirms the following:

- The cycles from the baseline wheelsets match those measured in revenue service.
- The two pairs of high impact wheels produced a significant increase (2.5 times) in the stress range as well as an increase in the number of cycle counts.

During testing, it was observed that higher stress cycles were associated with brake applications. In fact, after quantifying the differences, the stress cycles of the high impact wheels when *brakes were not applied* were equivalent to the baseline wheels when *brakes were applied.*

The range and counts of these cycles become significant when the brakes are applied. The time history shown in Figure 5 illustrates the relationship between stress cycles and brake applications. The blue trace is from wheels in good condition, and the red trace highlights the same beam responses when high impact wheels are used. The third data plot is the cylinder pressure, which in this dataset represents a minimum brake application.

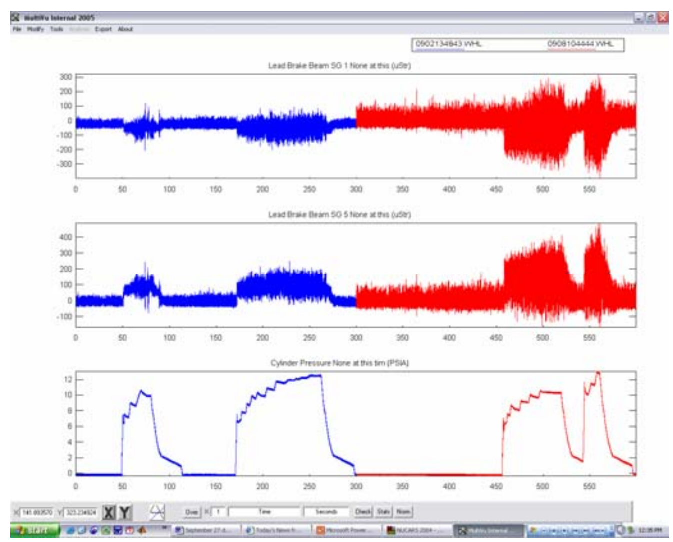

Figure 5. Time Histories Comparing Stress Ranges Produced by Good Wheels and High Impact Wheels

As Figure 5 shows, each time the brakes are applied, the strain ranges shown in the first and second plot increase dramatically. Looking at the strain cycles from 300 to 450 (sec) in the red area, where the brakes are not applied (0 brake cylinder pressure), notice that the range is approximately equal to the regions in blue (good wheels), when the brakes are applied. This relationship is quantified in Figure 6 where the cylinder pressure is broken down into low, medium, and high levels. There is a significant increase in stress range and counts with a minimum service application. With increased braking force, there are only smaller gains in the stress ranges, but the trend certainly highlights this. Further, wheels having higher levels of damage also tend to produce higher stress cycles. But the increase is small between the two damaged wheelset pairs. This correlates with information from the UP (Figure 3), where even small impact loads were related to broken beams.

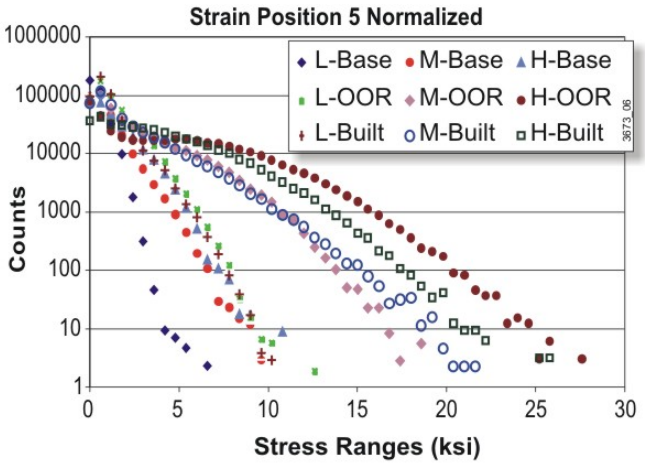

Figure 6. Comparison of Stress for Three Wheelset Conditions and Three Braking Levels

Recommended Laboratory Test

Figure 7 illustrates how TTCI believes the forces are being transmitted into the beams. When the beam is disengaged (as in the upper part of Figure 7), it free floats in the guide and the beam remains decoupled for two reasons:

- There is clearance in the brake guides so the motion of the beam is not tied directly to the side frame or high impact wheel.
- The brake guides are between the two axles. This has the effect of "averaging" out the effect of track roughness between the two wheelsets of a truck.

This is why the stresses are lower when the brakes are disengaged.

The lower part of Figure 7 demonstrates the condition when the brakes are engaged and the highest stresses occur. In this condition, the motion of the brake beam is tied directly to the motion of the axle though the brake shoe.

A laboratory test should meet the following conditions:

- Loading of the brake beam through the brake head as though the brakes were engaged.
- A loading environment that includes the effect of flat wheels.

Such a test could serve as a design tool for manufacturers to help them produce brake beams with better fatigue resistance.

CONCLUSION

Designing stronger beams in fatigue prone regions could reduce brake beam failures. Research findings could help facilitate a standardized field or laboratory test that would facilitate development of improved designs. Research has identified the primary factors that cause brake beam fatigue failures — those being high impact wheels coupled with applied brakes. Because wheel impacts excite all natural frequencies, it is unnecessary to focus on any particular frequency range if the laboratory test is designed to replicate the effect of high impact wheels.

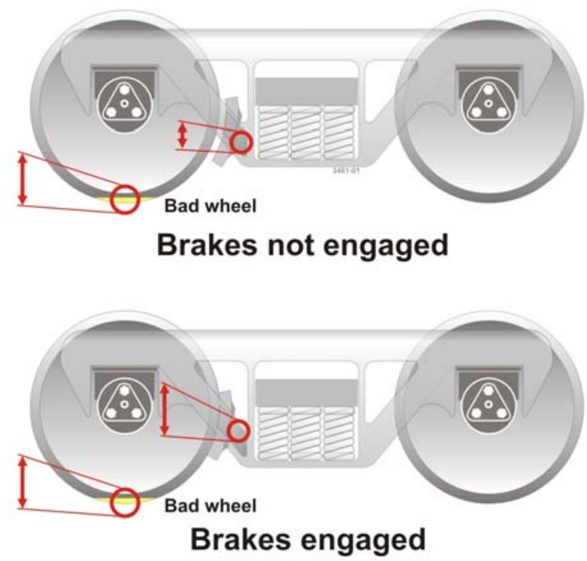

Figure 7. Indication of How Vibration from the Wheel-Rail Interface is transferred to the Brake Beam

FUTURE WORK

Additional tests with truck mounted brakes were performed in 2006 (see TD06-031). The stresses measured in these tests should be compared to those produced in the AAR dynamic test and/or a proposed fatigue test specification. This would involve the following steps:

- Determine the acceptable life of brake beams
- Calculate the fatigue life based on the actual revenue service test data.
- Estimate the proportion of time brake beams experience high impact wheel conditions and low, moderate, and heavy brake applications. Determine the effect of these variables on fatigue life.
- Confirm that passing a proposed fatigue test would indicate acceptable life of brake beams. This might involve testing some beams to demonstrate that the applied loads are producing the appropriate stresses.

REFERENCE

1. "Vibration Test Specification for Brake Beams." June 11, 2002 presentation given by Jorge A. De la Fuente, Acertek, to AAR Brake Systems Committee. Chicago, IL.