TECHNOLOGY DIGEST

TD-06-021

©AUGUST 2006

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Measurement of the State of Imbalanced Loads

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Summary

Imbalanced loads and overloaded trucks cause increased stress on the railroad infrastructure and to various freight car components. In 2006, TTCI launched an Association of American Railroads' sponsored Strategic Research Initiative for the purpose of determining an acceptable level of imbalance for cars operating in interchange service. The first step, outlined in this report, is to quantify the existing state of imbalanced loads for freight traffic. Three categories of imbalance are defined: end-to-end (ETE), side-to-side (STS), and overloaded (OL). Future studies will include economic analysis of the effects of these imbalanced loads and overloads.

Random samples of five general car types were used to analyze the degree and scope of imbalance loads on the system. Data for measuring imbalance was queried from the *InteRRIS*® database using Wheel Impact Load Detector (WILD) technology. Preliminary findings from WILD sites throughout North America are as follows:

- Gondolas, open top hoppers, and covered hoppers have the highest occurrence of ETE imbalanced loads. Nearly 30 percent of gondolas and open top hoppers, and nearly 20 percent of covered hoppers, have end-to-end imbalances of 5 percent or more.
- Covered hoppers and box cars have the highest occurrence of STS imbalanced loads. Nearly 30 percent of covered hoppers and box cars have STS imbalances of 5 percent or more.
- Gondolas, open top hoppers, and covered hoppers have the highest occurrence of OL trucks. About 35 percent of gondolas and open top hoppers, and more than 25 percent of covered hoppers, have at least one truck overloaded by 5 percent or more.
- Cars with OL trucks (by 5 percent or more) travel a total of more than 2 million loaded car miles per year on the North American rail system.

Preliminary research suggests that imbalanced loads are an industry-wide issue causing accelerated deterioration of infrastructure and rolling stock with resulting economic implications. The imbalanced load project ultimately will determine a maximum tolerable imbalance and develop recommended guidelines based on its findings. The work in this report is limited to conventional four-axle, freight cars. While it is recognized that intermodal traffic represents a significant portion of North American rail traffic, the results reported here do not include this type of traffic. To keep the task at a manageable level and to accelerate the project, we will approach multi-platform car styles at a later time.

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INTRODUCTION

Recent efforts in the railroad industry have focused on reducing the stress state in the railroad system. Work done in 2005[1] demonstrated that imbalanced loads could increase the dynamic forces imparted to the rails. The present research initiative is to determine the maximum tolerable imbalance and to suggest a guideline based on these findings.

Economic implications will be considered in determining and establishing guidelines. Imbalanced loads can have many of the same effects as overloads on track, bridge, and vehicle components such as axles, bearings, side frames, and bolsters. There may also be an effect on fuel consumption. This first step of the research attempts to quantify the state of imbalanced loads that are currently operating on the system.

The state of imbalance is a direct function of how the lading is distributed in the car. Two types of imbalance are defined in this study, side-to-side (STS) and end-to-end (ETE) imbalances. A STS imbalance occurs when the measured wheel forces on one side of the car are much greater than on the other side. An ETE imbalance occurs when the total truck load on one end of the car is much greater than that on the other end. Excessive ETE imbalance may result in increased dynamic loads similar in effect to overloads.[1]

END-TO-END IMBALANCE RESULTS

Figure 1 shows sample population distribution of an ETE imbalance and illustrates that nearly 30 percent of all gondolas and open top hoppers and nearly 20 percent of covered hoppers are operating with more than 5 percent ETE imbalance. Only about 5 percent of all box cars have ETE imbalance of at least 5 percent. Tank cars show no ETE imbalance at the 5 percent level. This is reasonable and expected with liquid lading, assuming no slosh.

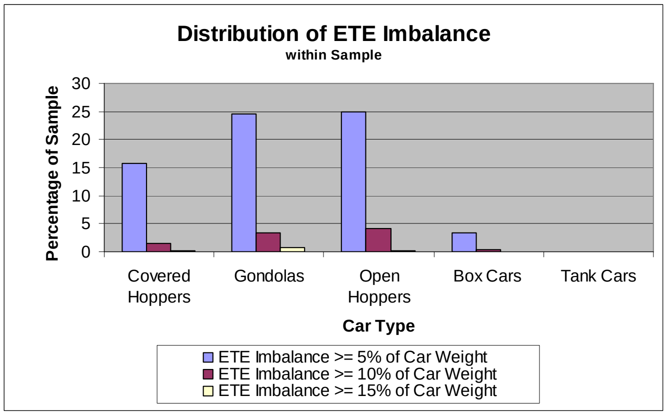

Figure 1. ETE Imbalance Levels

OVERLOADED TRUCKS

The ETE results should also be considered in terms of truck overload. A significant ETE imbalance may not itself be a problem if neither truck is substantially overloaded. Figure 2 shows the percentages of cars with overloaded trucks in the sample population.

The distribution of overloads has similar shape to the distribution of ETE imbalance, but does show some important differences. If a carbody type shows a higher percentage of overloads than ETE imbalances, it means that there are cars in the sample that are overloaded by at least 5 percent. This is true of covered hoppers, gondolas, and open top hoppers. It is also possible for the percentage of ETE imbalances for a carbody type to exceed the percentage of overloaded trucks. This happens if the cars are occasionally not loaded to capacity, as is the case for box cars. Box cars may fill to volume capacity with a low density lading before reaching their weight limit.

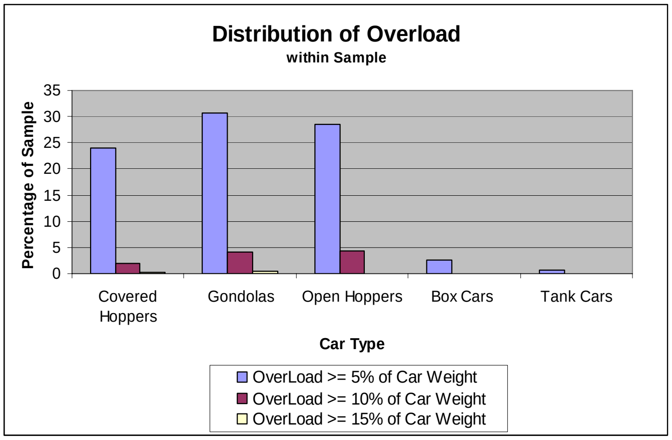

Figure 2. Overloaded Trucks in the Sample

SIDE-TO-SIDE IMBALANCE RESULTS

Figure 3 shows the sample population distribution of STS imbalance. All car types show an appreciable proportion of cars operating at over 5 percent STS imbalance. This is most likely due to external factors, such as a cross wind that side loads the carbody. The significant presence of Tank Car STS imbalance reinforces the external factor hypothesis.

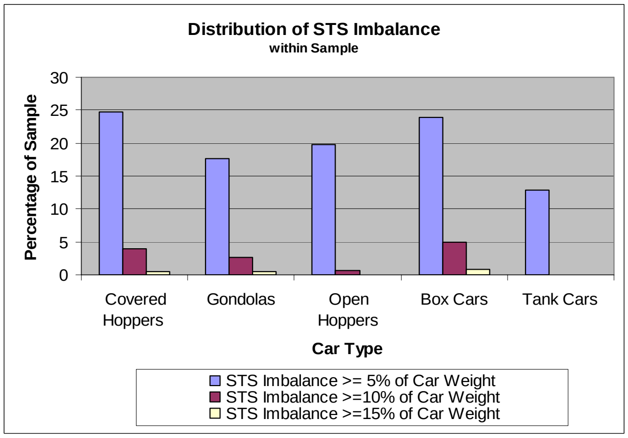

Figure 3. Imbalance Levels Side to Side

CAR MILES TRAVELLED WITH IMBALANCED LOADS

In order to understand the system wide effect of imbalance, loaded car miles per year were estimated for imbalanced loads.[3] Figures 4, 5, and 6 show the annual imbalanced loaded car miles traveled for each car type. There are nearly 2 million loaded car miles traveled annually with STS imbalance greater than 5 percent, and over 2 million loaded car miles traveled with greater than 5 percent overloaded trucks.

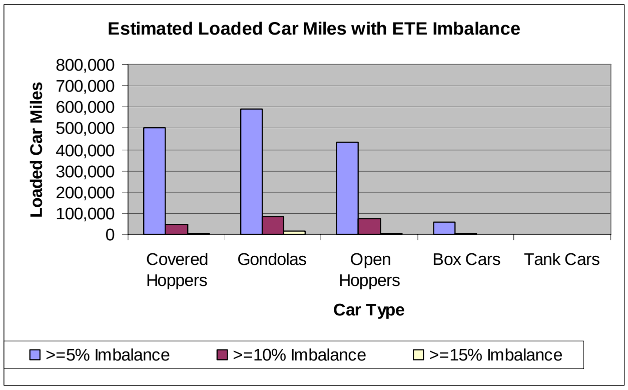

Figure 4. Estimated Loaded ETE Imbalanced Car Annual Miles

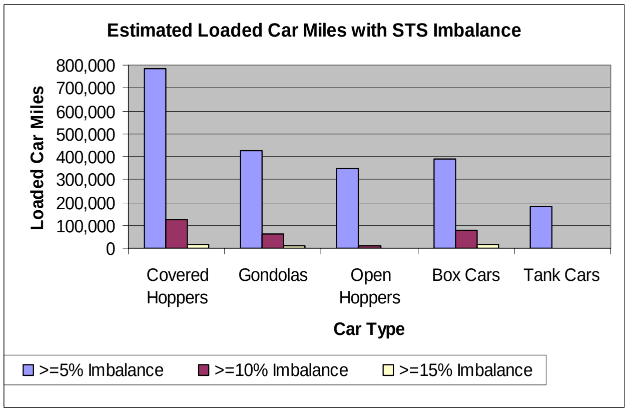

Figure 5. Estimated Overloaded Truck Car Annual Miles

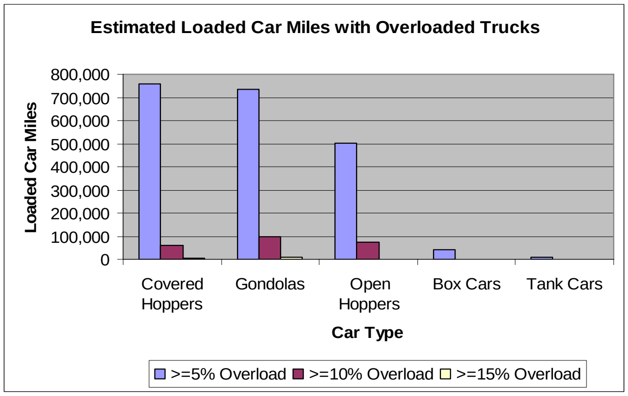

Figure 6. Estimated Loaded STS Imbalanced Car Annual Miles

DATA COLLECTION

Wheel Impact Load Detector (WILD) data from 2004 and 2005 was used for the results presented here. WILDs measure individual vertical wheel loads at locations throughout the rail network. The accuracy of measurement for a WILD is within ± 2 percent, 95 percent of the time for loaded cars.[2] While efforts are underway to improve the measurement accuracy, the existing information represents the current state of the art and is available through *InteRRIS*®. This study is the first look at the general population. For purposes of keeping this initial analysis manageable, only conventional four-axle car types, such as tank cars, hopper cars, gondolas, and box cars are considered. Imbalance of multi-platform vehicles will be considered later. The selected subset of car types represents 66 percent of the current traffic mix.[3]

SAMPLING METHOD

Categories of car types were defined based on the Universal Machine Language Equipment Register (UMLER) specification. From each category, a number of specific cars were randomly selected from a normal population to represent the car type. No special consideration was given to any given car in the sample population relative to type of service, load capacity, and region of operation. Each of the cars was tracked throughout the entire North American WILD system from January 2004 to December 2005. The car types were covered hoppers (UMLER Type C), open top hoppers (H, K), gondolas (E, J, and G), box cars (A, B), and tank cars (T). A population of 50 cars from gondolas, open top hoppers, and covered hoppers, and 20 cars for tank cars and box cars were traced.

Empty and loaded cars behave differently on track. They also present significant differences in measurement uncertainty. To account only for imbalance readings due to lading, we segregated the data to exclude cars that were not fully loaded. For this study, a loaded car is defined as having a car weight greater than 75,000 pounds at the WILD site, and carrying more than 40 percent of the UMLER capacity.

With the sampling process selected, seasonality issues such as commodity, weather, and track maintenance and structure were averaged. It is important to recognize that absolute measurements may vary by WILD site. This results in some variance in the sample population distribution.

STATISTICAL APPROACH

The average vertical load, in kips, for each wheel was used in the calculation of imbalances. By starting with the average vertical load for each wheel, calculating the total truck weight or total car side weight is straightforward. The appropriate vertical loads are summed for the desired result. The percent difference ETE or STS is calculated by taking the difference, dividing by the total car weight, and multiplying by 100 for percent.

The distributions were first categorized on a per-car-type basis. To quantify the sample sets, each sample point was categorized based on its deviation from the same-car-type mean. The total number of imbalanced loads for the entire population was estimated by summing the population imbalance counts per car type. The numbers for population imbalance per car type were extrapolated from the sample distributions. By considering the proportion of the entire population represented by each car type and applying an appropriate factor to correct for the number of loaded passes out of the total number of passes across all of the sites, we estimated that there are 9,100 ETE and 8,000 STS imbalanced loads introduced to the system per month. Recall this is the estimated number of imbalance outliers in the total population and is based on the individual distributions per car type. This estimate does not presuppose an absolute imbalance threshold.

FUTURE WORK

The next steps in this Strategic Research Initiative include modeling specific car types and routes and developing economic models to represent the cost of imbalanced loads. The end product is intended to be recommended guidelines for allowable imbalances based on the findings.

CONCLUSION

Based on the results of the statistical study of WILD data, the population and distribution of imbalanced loads on the North American railroad infrastructure have been estimated. Gondolas, covered hoppers, and open hoppers show a large number of imbalances occurring over a significant portion of time. Gondolas show the greatest average ETE imbalance, while covered hopper cars have the largest average STS imbalance.

REFERENCES

1. Rownd, Ken. August 2005. “Overloaded Trucks Increase the Stress State of Railroads.” *Technology Digest* TD-05-022, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
2. Tunna, John and Bill Sneed. April 2001. “Performance Tests of Overloaded and Unbalanced Load Detection at Track Speeds.” *Technology Digest* TD-01-008, Association of American Railroads, Transportation Technology Center, Inc., Pueblo, Colorado.
3. Analysis of Class 1 Railroads, 2004. Association of American Railroads, Washington, DC.