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## Seasonality of Wheelset Removals: Repair Data and Inspections

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### Summary

Transportation Technology Center, Inc (TTCI) recently inspected 75 wheelsets removed for tread damage causes at a Canadian wheel shop as part of the Association of American Railroads' Strategic Research Initiatives Program to prevent wheel failures. In Canada, there exists a substantial seasonal wheelset removal disparity with 58 percent of all tread damage wheelset removals during the four coldest months of the year. Seasonal trends in wheelset removals are much less pronounced in the United States and Mexico, presumably due to the milder winters.

The primary objective of the inspections was to determine the high level root cause of the tread damage. While spalling from wheel slides was noted on some wheels, an overall predominance of shelling was found to an extent not reported previously from wheelset inspections conducted in the United States. This is a strong indicator that the Canadian winter seasonality is tied to shelling problems rather than spalling from wheel slides.

The duration of the service lives of the inspected wheelsets varied dramatically based on car type. Wheelsets removed from the double stack cars typically had short service lives: 75 percent of these wheelsets were removed from service after 3 years or less. Service lives of tread damaged wheelsets removed from other car types were typically much longer. For reasons not well understood, some wheels reach condemnable impact loads within weeks of developing shells while other wheels can survive multiple winters after developing shells.

Several plausible explanations for the seasonality of the wheelset removals have been offered. TTCI plans to begin further investigation into this issue by analyzing wheel temperature data and measuring wheel/rail coefficient of friction.



**INTRODUCTION**

Seasonal trends in wheelset removals were investigated by TTCI through the analysis of repair data and an inspection of removed wheelsets to determine a high-level root cause for any visible tread damage. This work was conducted as part of the Association of American Railroads’ (AAR) Strategic Research Initiatives Program to prevent wheel failures.

**BACKGROUND**

Wheelset removals due to tread damage increase each winter with a corresponding decrease each spring.<sup>1</sup> AAR Car Repair Billing (CRB) data shows that other wheel-related causes for wheelset removal show substantially less seasonality. For the purposes of this digest, tread damage causes are considered any of the following Why Made Codes (WMC): 61, 65, 67, 69, 74, 75, 76, 77, and 78. The majority of the tread damage wheelset removals are billed as WMC 65 for impact loads greater than or equal to 90,000 pounds.

In the CRB data, the AAR classifies every repair location into one of ten different geographical regions. Canada and Mexico are each considered a region, and the United States is divided into eight regions. Region 0 (Canada), Region 3 (Illinois, Indiana, Michigan, Ohio, Wisconsin), and Region 4 (Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee) will be considered in this analysis because of their variety of winter weather. Figure 1 shows these regions.

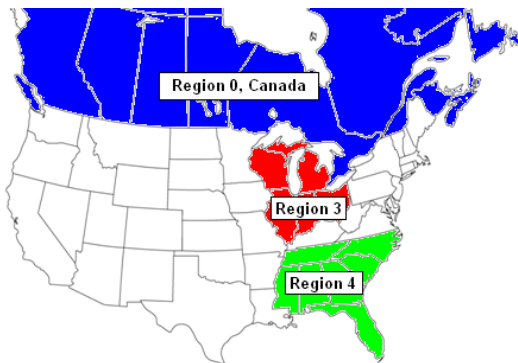


Figure 1. AAR Regions under Consideration

Winter wheel tread damage is a problem particularly in Canada. Figure 2 shows the percentage of wheelset removals between 2008 and 2010 due to tread damage during the four coldest months compared to the eight other months of the year. If no seasonal effect was present, it would be expected that 33 percent of the removals would occur in the coldest four months and 67 percent of the removals would occur in the other eight months. This is nearly the case for the United States and Mexico as well as U.S. Regions 3 and 4, implying minimal seasonal influence. However, in Canada there exists a substantial seasonal effect with 58 percent of all tread damage wheelset removals during the four coldest months.

A comparison of the weather between the different regions will be helpful. It is recognized that Canada encompasses an enormous geographical area and smaller regions within Canada experience much variation from the data shown here.

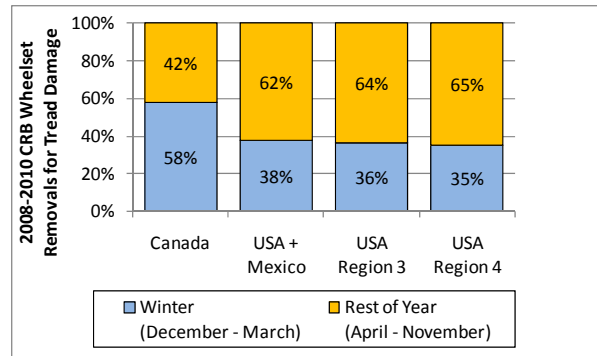


Figure 2. Seasonality of Tread Damage Wheelset Removals

Figures 3 and 4 show the average monthly temperatures and precipitation, respectively, for the different regions. The data for U.S. Regions 3 and 4 in these plots is based on an average of individual state values between 2008 and 2010 available from the U.S. National Oceanic and Atmospheric Administration.<sup>2</sup> The data shown for Canada is a rough estimate of the southern portion of the country based on historical temperature and precipitation maps from the National Atlas of Canada.<sup>3</sup>

U.S. Region 3 has a much colder winter compared to U.S. Region 4. The average monthly temperature in January is 22°F colder in Region 3 than Region 4. Canadian winter temperatures are approximately 10°F colder on average compared to U.S. Region 3. U.S. Region 4 has the wettest winter on average of the three regions. Both of the U.S. regions have more average precipitation throughout the year compared to Canada.

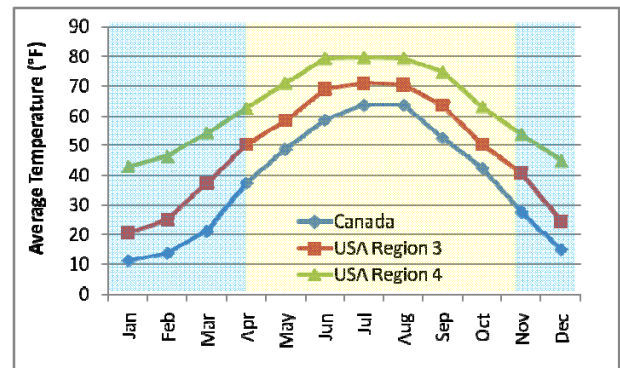


Figure 3. Monthly Average Temperature

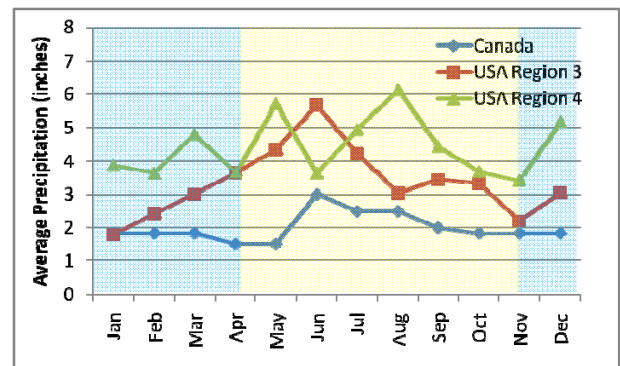


Figure 4. Monthly Average Precipitation

**WHEELSET INSPECTIONS**

Seventy-five wheelsets removed because of tread damage were inspected at a Canadian wheel shop in March 2011 to investigate the root cause of the seasonal tread damage problem. Tread damage on wheelsets in the United States is typically due to one of two root causes: shelling from rolling contact fatigue or spalling from wheel slide events.<sup>4</sup> The type of tread damage has been found to be dependent on the type of car from which the wheelset was removed. For example, shells are predominant on wheelsets removed from coal cars while spalls are more common on wheelsets from cars that are subject to more individual handling such as tank cars and covered hoppers. Martensite is a hard and brittle microstructure that forms on the wheel tread surface from sliding events and can be used to identify wheel spalls. After cleaning the area around each shell or spall, an etching solution was applied to each inspected wheel to reveal any martensite. Figure 5 shows martensite on a spalled wheel tread after etchant has been applied. Surface hardness measurements were also used to verify the presence of martensite.



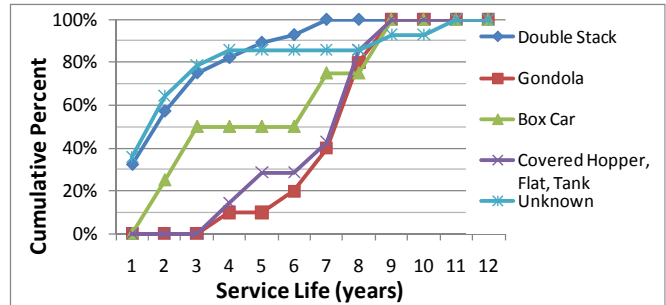
**Figure 5. Photo of Wheel Tread Surface after Applying Etchant** Martensite can be seen as the light gray areas between the spalls.

Table 1 shows the results of the Canadian wheelset inspections. Some relationship can be seen between the type of tread damage and the car type from which the wheelset was removed, but an overall predominance of shelling was found to an extent not reported previously. This is a strong indicator that the winter seasonality is tied to shelling problems rather than spalling from wheel slides. Car types were determined based on the car numbers written on the wheel plates. The wheelsets with an “unknown” car type were inspected after the chalk markings on the wheel plates had been removed and the car number was no longer visible. Wheelsets in the “out of round” category had no visible shells or spalls.

**Table 1. Inspected Wheelsets**

Car Type	Wheelset Count	Percent Shelled	Percent Spalled	Percent Out of Round
Double Stack (End Trucks)	29	93%	3%	3%
Gondola (for Wood Chips)	17	82%	18%	0%
Boxcar	6	67%	33%	0%
Covered Hopper, Flat, Tank	9	78%	22%	0%
Unknown	14	86%	7%	7%

Figure 6 shows the cumulative distribution of service life for the wheelsets inspected. The service life was estimated as the difference between the bearing locking plate date and the wheelset removal date. Wheelsets removed from the double stack cars typically had short service lives: 75 percent of these wheelsets were removed from service after 3 years or less. The similar service life curve of the wheelsets from the unknown cars may be an indication that many of these wheelsets were also removed from double stack cars. Service lives of tread damaged wheelsets removed from other car types were typically much longer.



**Figure 6. Service Life of Wheelsets Segregated by Car Type**

Historical impact load data from the inspected wheelsets was analyzed. A dynamic load greater than 20,000 pounds is considered by at least one Class I railroad to be a good indicator of tread damage. Many of the wheels removed from double stack cars did not exceed 20,000 pounds dynamic load until just weeks prior to their removal from service. On the other hand, many of the wheelsets from other car types survived multiple winters after reaching dynamic loads greater than 20,000 pounds.

**DISCUSSION**

Water has been shown to increase the rolling contact fatigue crack growth rate.<sup>5</sup> Water in a crack can be compressed into the crack tip, driving the crack deeper into the material. Water can also promote crack growth by lubricating the crack faces. However, precipitation quantity alone cannot explain the seasonal effect seen in wheel tread damage removals. U.S. Regions 3 and 4 both have more precipitation than Canada yet experience only a minor seasonal winter increase in wheel tread damage removals. Canada and U.S. Region 3 have more precipitation in the summer than the winter

The nature of the precipitation in the winter, rather than the quantity, is one possible explanation that has been offered regarding Canada’s seasonality in wheelset removals. Accumulated snow near the track has a tendency to swirl into the air in the presence of a passing train if the snow has not attained an outer “crust” from one or more freeze/thaw cycles. This airborne snow could then act to continuously wet the wheel surface, providing a sustained source of moisture for hydraulic crack propagation. Canada’s colder weather would presumably provide longer durations for accumulated snow to remain on the ground before experiencing a freeze/thaw cycle..

Another possible explanation for the seasonal tread damage effect is a higher wheel/rail coefficient of friction (COF) in Canada during the winter compared to warmer months. Blowing snow may provide sufficient abrasive action on the wheels and rails to remove lubricant or contaminant that is acting to limit the COF. Additionally, it is possible that wayside lubricators may not function as effectively during periods of extreme cold. Higher wheel/rail COF could act to promote rolling contact fatigue by allowing greater frictional forces at the wheel/rail contact patch.

Wedging action during the expansion of water as it freezes is yet another possible explanation for the seasonal tread damage issue.<sup>6</sup> The state of water (solid, liquid, gas) is dependent on both temperature and pressure. Water can take a liquid state at temperatures of nearly -8°F when under pressure. At temperatures between -8°F and 32°F, the cyclical pressure from wheel/rail contact could produce a freeze/thaw cycle on water in a wheel tread crack on each wheel revolution. The expansion of water freezing could force the mating surfaces of a crack farther apart and accelerate the shelling process.

Ironically, cold winter operations may result in more wheels reaching sufficiently warm temperatures from braking to reduce the tread resistance to fatigue and accelerate the shelling process (thermal mechanical shelling). Snow and ice can build up on the brake shoes during cold winter conditions. To ensure that trains have reliable braking during the wintertime, train operators periodically apply the train brakes to remove any buildup of snow or ice. Each time the brakes are applied and released, there is a possibility of inducing a stuck brake situation where a car does not release its brakes as desired. Figure 7 shows the average monthly brake shoe removals between 2008 and 2010. This data indicates that brake shoe consumption (an indicator of brake use) is also subject to seasonality and to a much larger degree in Canada than U.S. Regions 3 and 4.

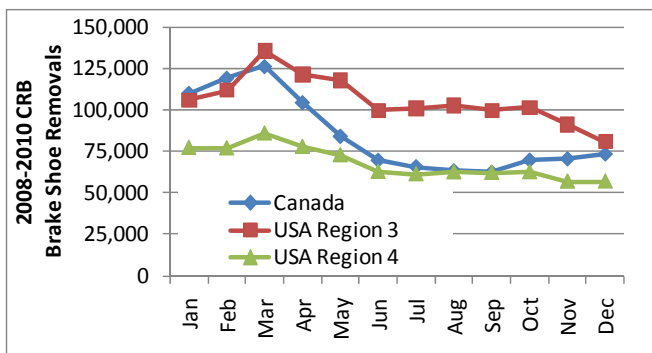


Figure 7. Brake Shoe Removals

## CONCLUSIONS

- In Canada, 58 percent of all wheelset removals for tread damage occur during the four coldest months of the year.
- The seasonality of tread damage wheelset removals is far more pronounced in Canada compared to the United States and Mexico.
- Shelling was disproportionately found on the treads of 75 wheelsets inspected recently at a Canadian wheel shop. Shelling appears to be the mechanism driving the seasonal wheel tread damage issue in Canada.
- Wheel service lives less than 3 years were found on many of the wheelsets removed from intermodal double stack cars.
- For reasons not well understood, some wheels reach condemnable impact loads within weeks of developing shells while other wheels can survive multiple winters after developing shells.

## FUTURE WORK

The seasonality of tread damage wheelset removals will be further investigated by analyzing wheel temperature data and measuring wheel/rail COF.

## ACKNOWLEDGEMENTS

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