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Publisher's version / Version de l'éditeur:

International Heavy Haul Association Conference, IHHA 2011, June 19-22, Calgary, Alberta, Canada, 2011

Winter Railroading in Canada - A Review of Track and Rolling Stock Challenges

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Abstract

Railways operating in Canada face extreme winter weather conditions including cold temperatures, snow and ice. These conditions affect the safety of employees and the public in general, while reducing the overall efficiency of operations.

With the sponsorship and participation of the Canadian railway industry, a study was performed to review and prioritize winter issues affecting railroading in Canada. The study consisted of a literature review, interviews with key railway personnel, and site visits to several train yards. Several issues stand out as being especially problematic and widespread in Canada: frozen switches, broken rails, wheel shelling, air brake performance, hump yard performance, and the performance and reliability of distributed power.

1 INTRODUCTION

Railways operating in Canada face extreme winter weather conditions including cold temperatures, snow and ice. These conditions affect the safety of employees and the public in general, while reducing the overall efficiency of operations. Challenges due to winter weather reduce capacity and cause shipping delays, which negatively impact customers, reduce the profitability of Canadian railways, and negatively affect the movement of goods which has a detrimental effect on gross domestic product (GDP).

Fuel is one of the largest operating costs for railways. The amount of diesel fuel used and the associated costs with purchasing the fuel have increased steadily in the past, as shown in Table 1. The consumption of fuel during winter increases due to dragging brakes, idling locomotives, reduced adhesion, and the increased car weights due to snow accumulation. With the escalating cost of fuel, fuel efficiency and fuel conservation are becoming increasingly important.

Table 1: Diesel fuel consumption on Canadian railways 2003-2007 [1].

	Total Diesel Fuel (thousands of litres)	Total Diesel Fuel Cost (thousands of dollars)
2007	2,193,684	$1,486,001
2006	2,119,082	$1,299,572
2005	2,130,224	$1,153,591
2004	2,097,070	$846,489
2003	2,007,813	$761,278

Each year, railways spend a considerable amount of money maintaining infrastructure and equipment. A large fraction of total maintenance costs for the Canadian roads are attributable to winter conditions such as snow and cold temperatures. As an example, Figure 1shows the percentage of annual infrastructure maintenance costs for the Canadian Pacific Railway (CP) by month. Since the bulk of regular rail replacements, track levelling, brush cleaning signal maintenance and the like are done during the summer period (May-September) the high costs through the winter months can be largely attributed to preparation for winter and dealing explicitly with winter problems such as broken rails, snow removal, frozen switches, avalanches, etc.

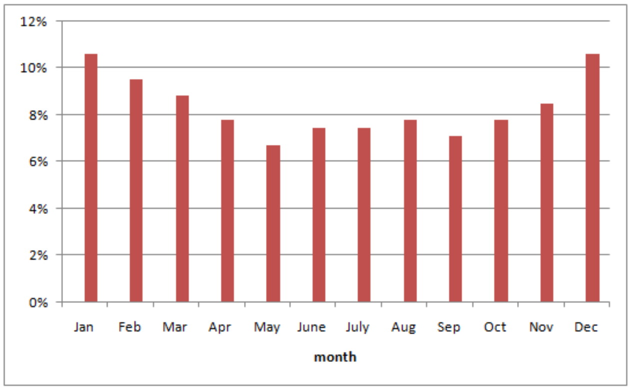

Figure 1: Percentage of annual infrastructure maintenance costs, by month, for CPR.

Cold temperatures are a strong contributor to problems such as broken rails and air brake malfunctions. Snow creates and contributes to many problems including wheel shelling, decreased locomotive reliability, decreased adhesion, and sticking brake beams. In addition, a significant amount of resources are allocated to snow removal. Snow creates difficulties for virtually every aspect of running a railway, such as managing large snowfalls, clearing switches and mechanical issues with locomotives due to snow ingress.

Ice can cause switches to become inoperable, reduce wheel rail adhesion, and create safety hazards, especially in tunnels. High winds create snowdrifts that require clearing and in yards impair movement of inspection, maintenance and refueling crews and equipment. The cold temperature, wind and snow also make it increasingly uncomfortable and unsafe for inspection and maintenance crews to work outdoors.

While many issues are common within Canada, different regions do face some unique issues. Certain geographic areas are more prone to the environmental effects of winter. Mountainous regions, for example, face challenges of especially heavy snowfalls and steep grades, while prairie regions must deal with high winds that create significant snowdrifts.

It is the goal of railways to continually operate longer, heavier trains in order to increase efficiency, but in the wintertime train lengths must be reduced [2], [3] because of several factors. Supplying sufficient air pressure in cold temperatures can be difficult due to frozen moisture in the air lines and increased leakage through couplings and fasteners, resulting in dragging brakes, increased fuel usage and possibly increased wheel shelling.

While many issues were identified from a study that assimilated many relevant research themes related to winter railroading in Canada [4], several stand out as being especially problematic and widespread in Canada: frozen switches, broken rails, wheel shelling, and poor performance of the air brake system.

2 METHODS

The National Research Council of Canada Centre for Surface Transportation Technology (NRC-CSTT) was contracted by Transport Canada Transportation Technology and Innovation Directorate (TC-TTI) to assess the needs and priorities of a research program addressing winter railway issues, with sponsorship and participation from Canadian railways. The goal of this study was to identify and prioritize winter issues affecting the railway industry in Canada. In order to accomplish this, NRC-CSTT performed the following tasks:

1. Set up a steering committee to provide industry guidance that included representation from Transport Canada (TC), CP and CN.
2. Obtained approval of the steering committee regarding the project plan.

3. Performed a literature review of over 100 references that identified a broad range of winter issues from countries including Canada, United States, China, Sweden, Finland, Norway, Russia, and Japan.
4. Interviewed railway personnel regarding winter issues.
5. Visited CP and Canadian National Railway (CN) operations and conducted informal interviews during yard visits and train rides.
6. Analysed and summarized the gathered information to identify research priorities.

The winter preparedness plans for CN and CP were examined and are discussed in this report. Interviews were conducted with key personnel in the railway industry to understand the most critical problems that the railways face in the winter. The interviews complemented the literature review, validated the relevance of several well-known winter issues and brought attention to several issues that were not found in the literature review. Tours of CN and CP facilities and train rides on CP's operations in western Canada provided NRC-CSTT a first-hand experience of winter railroading in Canada. The tours also provided the opportunity for informal discussions with railway staff about winter operations. This was supplemented with notes and email communications from several winter strategy meetings that NRC-CSTT and CP conducted between 2005 and 2008.

3 RESULTS

This section serves as a discussion of what was learned concerning the current state of Canadian winter railway operations. Current issues faced by the various railways and suggested paths to solutions or mitigating actions are discussed. This section is divided into two parts, one: mechanical (vehicle) issues and engineering (track) issues.

3.1 Mechanical (Vehicle) Issues

3.1.1 Air Brakes

Air brakes were one of the most commonly mentioned problem areas for railways in the winter. The cold temperatures cause brake pipes to contract and couplings to lose their integrity. Small leaks in air pipes, which may be manageable in moderate temperatures, can become significant in cold temperatures, making it difficult for trains to develop sufficient air pressure to fully release brakes. This limits the practical length of trains in the winter - while summer train lengths are typically between 7500 and 12000 feet, CP limits the length of bulk trains to 7000 ft at -25ºC and 5500 ft at -35ºC. CN sets its limits for bulk trains at 8000 ft at -25ºC and 4500 ft at -35ºC. Improved leak detection technologies would be welcomed by the Canadian railways, as current techniques, while effective, are difficult to perform in the winter.

Trapped moisture in the air lines can freeze in cold temperatures leading to frozen and stuck brake valves and brake cylinders. Furthermore, frozen moisture in air lines restricts air flow and may clog brake valves. Brake valves require replacement at an increased rate in the winter. Trains moving between different climates can be especially vulnerable to air brake problems. In a warmer climate, a long train may have no problem generating sufficient air pressure in the brake line (to fully release the brakes) and the humidity may be manageable. However, when the train moves into a colder climate, freezing of moisture laden air may contribute to insufficient air pressure and result in dragging brakes. For this reason, trains are typically sized based on the coldest climate they are expected to encounter during their trip.

A train's inability to generate full pressure in the line to fully release air brakes has many consequences. Dragging of brakes contributes to heating of the wheel tread and possibly to wheel shelling. When a hot or severely shelled wheel is detected, the car has to be set off for repair, which requires the brake line to be cut and subsequent recharging of the air brake line.

Dragging brakes impair the train's ability to climb a grade and can lead to a train stall, especially when coupled with poor wheel/rail adhesion that occurs when snow, frost and freezing rain accumulate on the wheel. Train stalls are naturally most common in areas of steep grades Train stalls are a large concern for some railways, but only a minor one for others.

Cold temperatures make the hoses stiffer, which not only increases stress on the connectors but also makes hoses difficult to connect. In passenger trains, falling ice from the train has caused air hose separations. Research into more appropriate rubber compounds for the Canadian winter may be helpful in this regard. However, any hose material would have the requirement of not becoming too flexible at higher temperatures.

Snowfall, particularly when it accumulates above the top of rail, can interfere with braking. Snow can accumulate on brake riggings and reduce the braking force available for a sudden stop. In addition, the snow accumulation can impede the changing of brake shoes. Together with reduced air pressure, snow accumulation contributes to reduced braking forces at a train's tail end.

3.1.2 Wheel Shelling

Increased wheel shelling is a common winter problem among railways. This was identified in the literature review and confirmed by those interviewed. Examples are shown in Figure 2.

Shelled wheels are associated with heavy wheel/rail impact loads that damage the track and break rails. This is especially true during the cold temperatures when the ballast is frozen and rails are under tension due to thermal contraction. The increased occurrence of wheel shells in the wintertime necessarily results in a greater number of wheel changes and increased workload for the maintenance shops. It is essential that railways ensure that they have sufficient stockpiles of wheelsets. The elevated rates of wheel shelling (up to five times the summer rates) and concomitant winter replacement of wheelsets is a very large cost for the railways, estimated as $85 million per year [5].

There are two main causes for wheel shelling. The first is the formation of martensite, which is a phase of steel that is characterised by its high hardness and brittleness. It forms as a result of high temperatures incurred by a sliding wheel that is followed by rapid cooling [6]. The second cause is rolling contact fatigue. In the mid 1990's, the latter was determined to be the governing mechanism for wheel shelling on Canadian unit train (grain and coal) operations [6].

There is a significantly higher occurrence of wheel shelling in the winter, but the severity of the problem is very climate and terrain dependent. For example, a railway that has many steep downgrades can expect to suffer greater rates of wheel shelling associated with hot wheels and high shearing of the surface material (so-called thermo-mechanical shelling [7]). But even in the absence of heavy grade, high rates of shelling can occur. One reason for this is that blowing and swirling snow can lead to moisture entering pre-existing surface cracks on the wheel tread and propagating them hydraulically, increasing the rate and severity of shell growth. Another contributor may be air brake problems and dragging brakes, which can cause skid flats and the formation of martensite, or simply heat the wheels enough to degrade the strength of the wheel steel, making it more susceptible to rolling contact fatigue. Wheel slides in the fall due to leaves on the track, or in winter from frost on the rail can also initiate shells, which progress into visible shelling in the winter months.

Figure 2: Examples of shelling on coal car wheels.

In order to solve the wheel shelling problem or to constrain it to a more manageable level there are several key areas for future research:

- Review the causes of wheel shelling in Canada, since the last significant work done in Canada to understand wheel shelling dates back more than a decade [6]. With improved suspensions, friction management and rail profiling practices, it is possible that the root cause of wheel removals is no longer predominantly wheel shelling due to rolling contact fatigue. Recent anecdotal evidence from CP's Golden shop suggests that wear is responsible for an increasing number of wheel change outs.
- Improved metallurgy – Tests with several trial pearlitic steel alloys show the potential for reduced martensite formation, but the metallurgy needs fine tuning [8]. Bainitic steels have superior resistance to rolling contact and thermal fatigue [8], [9]. Bainitic steel has been tested in service on an iron ore line in Sweden and shows positive results [9]. Unfortunately, bainitic steels have poorer wear properties compared to pearlitic steels, so this is one issue that needs to be addressed before bainitic steel usage in wheels becomes more widespread. Future work, described in [9], is aimed at a grade of bainitic steel appropriate for heavy haul with improved wear characteristics.
- Improved wheel and rail profiles – minimize contact stresses in both the initial and worn profiles to establish and retain good curving performance and avoid stress concentrators.
- Optimizing friction levels – on both the gauge-face (i.e. lubrication) and top of rail (i.e. friction control) [10] should be contributing to reductions in both wear and shelling of wheels. This should be analysed and validated.
- Operating/maintenance practices, such as wheel retruing practices, WILD threshold settings and the use of single versus multi-wear wheels are examples of practices that could be tuned to address the seasonal wheel shelling problem.

Wheel shelling is especially critical as it not only affects the number of wheelsets that need to be changed out, but it also impacts rail defect growth, broken rails, and wear and tear on rolling stock components due to increased vibrations. Any reduction in wheel shelling would benefit the mechanical side as well as the engineering side.

3.2 Engineering (Track) Issues

3.2.1 Broken Rails

Broken rails are a frequent occurrence and can lead to derailments. The problem is magnified in the winter due to the tensile thermal stresses induced in continuously welded rail. The magnitude of the stress increases with decreasing temperatures and especially when combined with unfavourable residual rail stresses, the resulting tensile forces produced in the railhead due to wheel impacts can be enough to fracture the rail. Broken rails often occur at locations where a transverse defects already exists in the railhead.

Rail defects occur more frequently in the winter and thus the frequency of track inspections for rail flaws is typically increased, thereby reducing track availability. Extreme cold temperatures may also reduce the fracture toughness of rail steel, making it easier to break the rail at a transverse defect [10], [11], [12], [13]. Rail defects that occur in the transverse plane of the rail are major contributors to broken rails. In addition to transverse defects in the rail, other defects such as crushed heads also occur more frequently due to the higher wheel impacts and stiffer track. Rail pull-aparts at joints and broken joint bars occur more frequently in the wintertime in jointed track.

It has been reported by several of the people interviewed that broken rails seem to occur with an increased frequency during sudden changes in temperature (from warm to cold), especially early in the winter, an observation that is also found in the literature [14]. Rapid drops in temperature are thought to create higher localized thermal stresses and thus zones of increased risk of breakage. With time, the thermal stresses become equalized along the length of the rail as additional traffic passes over and the temperature stabilizes.

The neutral temperature of the rail is a critical factor in determining the thermal stress induced at a given temperature. The neutral temperature of the rail is initially the temperature it was installed at, but can change significantly with time for a variety of reasons such as local track work (e.g. surfacing and realignment), addition of nearby rail plugs and rail running due to traction or braking. The precise longitudinal stress at any piece of rail at a given time is unknown. The development of a simple and cost effective system for monitoring rail neutral would provide tremendous benefits to Canadian railways concerning broken rails (and rail buckles). Various researchers around the world are trying to tackle the problem. In Germany, a system using magnetic fields has been developed to measure rail neutral temperature and the stresses in a rail [15]. Field test of remote monitoring of the rail neutral temperature is described in [16].

In dark territory (where there are no track circuits), there is an increased risk of broken rails going undetected and thus resulting in a derailment. Since there is no circuit to be broken, a broken rail can go undetected until it is noticed by an inspector or passing train. Technology to detect broken rails in dark territory would be extremely valuable to the industry. One example of such technology is an ultrasonic broken rail detector [17]. This system was developed in South Africa and requires very little additional infrastructure to implement. Broken rail detection capability on locomotives would be useful for trains travelling in dark territory [18].

Impact forces have been demonstrated to be highly speed-dependent [19], [20], [21], [22]. In order to mitigate broken rails, it is common to set slow orders at various low temperature thresholds. Depending on the track temperature and location of a train, the train speed may be restricted in order to reduce broken rail and derailment risk. Train speed is therefore a key parameter used to manage broken rails. Additional research is needed to develop practical, optimized train speeds (cold slow orders) that balance the risk of derailment with the need for efficient operation of the railway.

It was suggested by one interview candidate that the rail break problem could be addressed by inducing an artificial expansion (thermal gap) using heated and insulated sections of track to induce compressive forces in adjacent sections of track. This would presumably offset some of the tensile stresses caused by low temperatures. The sections would be heated only when temperature drops below some predefined level. The practicality and the economics (especially energy requirements) of this idea remain to be quantified.

3.2.2 Snow-clogged and Frozen Switches

In reviewing literature and talking with railway personnel, one of the most common winter engineering problem areas is switch operation. Switches can become sufficiently frozen or clogged with snow that the throwing of switches is prevented. Inoperable switches often occur during heavy snow, where switch heaters and blowers cannot keep up with the falling snow.

Snow accumulation between fixed and moving rails can also lead to derailments. Freezing rain can also cause switches to become stuck in one position. A frozen switch disrupts operations and most often requires manual clearing.

On mainline tracks, switch heaters or blowers are often used. Switch heaters (melters) apply heat in the areas of the points to keep them free of ice and snow (Figure 3a). Blowers direct either hot or cold air at the switch points to keep them clear of snow (Figure 3b). The most common types of switch blowers are hot air blowers, which can be gas, propane, or electrically powered. Too much heat can burn ties and lead to fires.

Figure 3: a) Switch heater. b) Hot air blower.

In yards, switches often are not heated or kept clear with hot or cold air. Since yards are typically built in low-lying areas, pooling water can collect near switches and freeze, resulting in inoperable switches. Often and especially in yards, switches must be cleared manually using shovels and brooms. Backpack blowers and shovels are often used by personnel to clear switches. In extreme conditions snow jets, which are essentially jet engines mounted on high-rail trucks are used to clear snow from switches. It was mentioned during the interviews that the industry needs something less expensive than a jet engine for mounting on a high rail truck to effectively clear snow from switches.

It is apparent that increased switch reliability is a strong need of railways operating under winter snow and ice conditions and that significant future research should be directed towards this goal. Research in this area can take several paths. First, new switch designs could potentially be produced that are less sensitive to snow and ice build-up. This was attempted in the 1970s but the developed switch, for whatever reason, never caught on with the railways [23], [24], [25], [26]. Perhaps this idea could be revisited and other potential designs examined. A second approach, and one that is more likely to produce results quicker (although more modest improvements) is to improve the performance of switch heaters / blowers. The energy costs of running switch heaters/blowers are significant. In addition to energy costs, there is also the initial purchase cost, and ongoing labour and parts for maintenance, as well as the labour cost for freeing frozen or clogged switches.

In the Nordic countries, various types of spoilers have been tested to prevent snowdrifts from accumulating in switches [27]. Spoilers are mounted outside the rail and reach a height of about 100 mm above the top of the rail; they have been made using rubber and vertical brushes placed alongside the switches.

4 SUMMARY

Railroading in Canada presents many challenges during the winter. The environmental conditions associated with winter may vary across the country, but in every region winter interferes with Canadian railways' ability to operate. Each of the major parts of a railway: mechanical, engineering and operations must deal with the obstacles that winter presents.

Several issues stand out as being especially problematic and widespread in Canada: snow-clogged and frozen switches, broken rails, wheel shelling, and air brake performance. These are seen as the biggest roadblocks to efficient winter railroading from the mechanical and engineering departments perspectives, and thus should be priorities for further research.

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