



Line 2 (Bloor-Danforth) Wheel Flats Update

Date: July 10, 2019

To: TTC Board

From: Chief Vehicle Officer (Acting)

Summary

This report is in response to the TTC Board motion to provide an update on the ongoing investigation of noise complaints related to wheel flats on Line 2 (Bloor-Danforth).

Recommendations

It is recommended that the TTC Board:

1. Receive this report for information.
2. Direct staff to report back in Q1 2020 on:
 - a. The status of the number of wheel flats on Line 2 and the overall trend; and,
 - b. Results, conclusions and lessons learned from the investigation.

Financial Summary

This report is being provided as an update to the Board on the wheel flats noise issue on Line 2 (Bloor- Danforth) only. There are no financial impacts associated with the Board's receipt of this report.

The Chief Financial Officer has reviewed this report and agrees with the financial summary information.

Equity/Accessibility Matters

As a proud leader in providing accessible public transit in the city of Toronto, TTC is committed to ensuring reliable, safe and inclusive transit services for all our customers. The continued work of investigating and remediating Line 2 noise complaints related to wheel flats will positively affect the community.

Decision History

At its April 11, 2019 TTC Board meeting, the Board adopted a motion moved by Commissioner Brad Bradford to:

1. Request TTC staff report back to the July 10, 2019 TTC Board Meeting on noise complaints and repair/replacement processes related to wheel flats on Line 2, further to and/or including the ongoing investigation being conducted by the National Research Council of Canada (NRC) and TTC in partnership:
 - a. Include counts on wheel turnover and timelines for repairs vs. replacement for wheel flats
 - b. Include decibel readings on noise from wheel flats
 - c. Root causes of the noise, including aspects of the subway vehicle braking system

[http://www.ttc.ca/About the TTC/Commission reports and information/Commission meetings/2019/April 11/Reports/24 Notice of Motion Wheel Flats Noise Issue Brad Carroll.pdf](http://www.ttc.ca/About%20the%20TTC/Commission%20reports%20and%20information/Commission%20meetings/2019/April%2011/Reports/24%20Notice%20of%20Motion%20Wheel%20Flats%20Noise%20Issue%20Brad%20Carroll.pdf)

Issue Background

In October 2018, the T1 subway vehicles on Line 2 experienced a higher than normal number of wheel flats. A normal spike in wheel flats is expected during autumn weather due to foliage falling on the tracks and seeping natural oils that reduces the friction between the vehicle steel wheels and the rail. The result is increased sliding between wheel and rail during braking, which is a major contributor to the experienced autumn wheel flats. The number and duration of wheel flats this autumn exceeded the previously experienced seasonal wheel flat trend. The vibration generated from the wheel flats raised concerns from residents along Line 2.

The TTC has a wheel flat detection system (AURA) on both Line 1 and 2. The AURA system identifies wheel flats and classifies them in terms of severity so that the most severe flats can be prioritized and removed from service first. On Line 2, the AURA system is located along the westbound direction from Kennedy to Warden Station.

Historically, TTC has been able to cope with seasonal wheel flat spikes and prevent vehicles with significant wheel flats from entering service. In October 2018, however, the number of wheel flats generated was unusually high. A second and unexpected spike in the number of wheel flats occurred again in late December 2018. These two incidents overwhelmed the maintenance facility and corrective maintenance activities were no longer able to keep pace with the high volume of new wheel flats being generated each day.

The number of new wheel flats continued to remain high throughout January and February 2019. Given the large backlog of flats experienced, to ensure subway service requirements were met, trains had to be placed into service with this defect. As a result,

in mid January 2019, staff initiated an in-depth investigation to resolve the unexplained wheel flat issue. A task team was formed, comprised of various TTC operations and engineering teams and chaired by the National Research Council of Canada (NRCC). Regular task team meetings were conducted to study the issue.

Discussion

Since the number and duration of wheel flats being generated was abnormal, TTC initiated an extensive investigation, chaired by the NRCC. As part of this investigation, numerous tests were conducted to rule out potential root causes. These tests included both infrastructure and vehicle operations. Chart A below illustrates the number of most severe new wheel flats generated by month while Chart B illustrates the percentage of trains generating high vibration passes on the Line 2. Included below is a chronology that summarizes the number of wheel flats being generated, observations at the time and the actions taken as part of the investigation.

Chart A – Wheel Flats Generated by Month

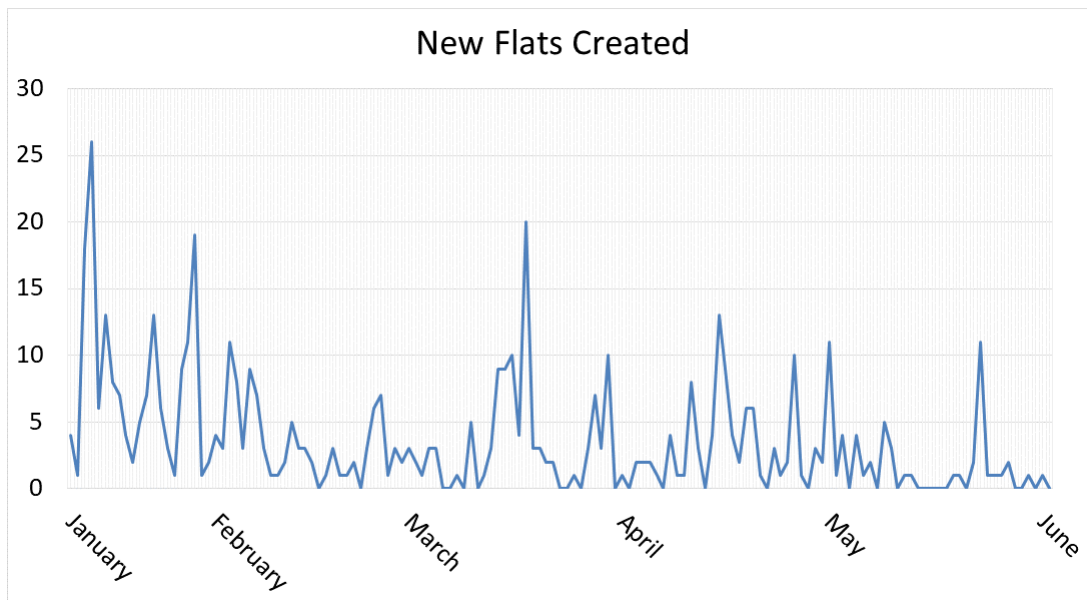
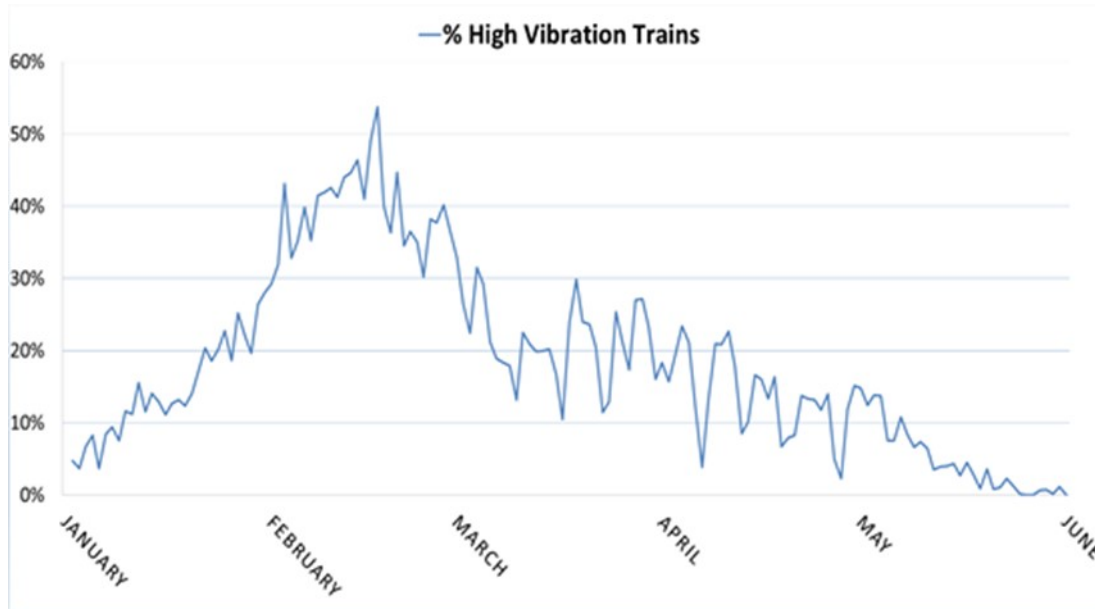


Chart B – % Trains Exhibiting High Vibration



Chronology

Prior to October 2018

Observations:

- Speed Control and Operator Emergency Brake (EB) were on average 225 applications per month on Line 2;
- A batch of wheels produced metal flakes which dropped to track level causing signal problems.

Corrective Actions:

- Conversion of fleet to a different manufacturer of wheels continued. Note – program started in 2016;
- New brake shoes with different material composition were also being introduced to reduce and eliminate metal flakes from being deposited onto the rails;
- On-board wheel flange lubricator sticks were being tested to reduce the use of rail lubricators.

October 2018

Observations:

- More than 80% of the T1 fleet cars had moderate to severe flats. This percentage is higher than normally expected for seasonal wheel flats.

Corrective Actions:

- The home location for maintaining the T1 vehicles on Line 2 is Greenwood Carhouse, while Wilson Carhouse maintains the TR fleet for Lines 1 and 4. To keep pace with the number of wheel flats being generated, Wilson Carhouse supplemented wheel truing (machining) operations at Greenwood Carhouse.

The combined effort of both Carhouses machined on average 80-100 axles per week;

- Speed control group introduced a temporary reduced speed supervision mode on Line 2 in open cut areas that is activated and deactivated by the placement of Unequipped Equipment Mode (UEM) tags on the guideway. This reduced the number of emergency brake applications from 364 in October 2018 to an average of 280 per month.

November 2018

Observations:

- The number of T1 cars that had wheel flats remained high;
- Excessive grease was observed on both the wheels and the rail at Greenwood Yard.

Corrective Actions:

- Machining at full capacity continued into November of 2018;
- Rail lubricators at Greenwood Yard were turned off due to the high level of grease found on the wheel/rail interface. The level of grease found made brake rating of the vehicles difficult.

December 2018

Observations:

- By December, the efforts made by the Greenwood and Wilson Carhouses started to reduce the overall number of cars with flats. In addition, the number of new wheel flats being generated started to level off to expected levels, consistent with historical numbers.

January 2019

Observations:

- Two (2) large spikes of wheel flats experienced on Line 2 negated the progress made in December for wheel truing and again overwhelmed the Carhouses' abilities to keep pace with machining.

Corrective Actions:

- All rail lubricators on Line 2 were turned off indefinitely except between Islington and Kipling stations as a result of excessive noise complaints caused once the lubricators in this area were isolated. Lubricators were turned off to rule out excessive grease on the main line as a contributor;
- The National Research Council of Canada was retained as consultant to assist and lead the investigation and chair the regular task team meetings with various TTC staff.

February 2019

Observations:

- Machining operations continued at both Wilson and Greenwood Carhouses to maximum possible output. The number of new wheel flats being created daily however remained higher than the Carhouse could sustain

Corrective Actions:

- Speed restrictions applied to open cuts along Line 2 to minimize high speed braking applications;
- Vehicle acceleration and brake rate testing conducted as part of investigation;
- Greenwood Carhouse reconfigured trains each day to minimize the number of trains on the main line with severe wheel flats.

March 2019

Observations:

- Another large spike in March resulted in a peak of 105 cars being affected with flats;
- Low amount of precipitation experienced in March further challenged the task team;
- Excessive wheel squeal on the main line commenced due to low lubrication of rail. Complaints of wheel squeal were being received throughout Line 2 – including in the west end around Islington, while TTC attempted to commission a Top of Rail Friction Modification Unit, to replace the outdated grease dispensing side rail units between Islington to Kipling.

Corrective Actions:

- Machining operations continued at maximum output;
- Two lubricators at Islington which were found to be non-functional were replaced with new, proven units that do not utilize the grease dispensing system to more effectively reduce squeal;
- Information campaign rolled out to operators as a reminder of proper acceleration and braking techniques.

April 2019

Observations:

- Large number of new flats created during service continued;
- Machining operations continued at maximum output;
- Low amount of precipitation for April.

Corrective Actions:

- Top of rail friction modifier dispenser was installed and commissioned west of Islington Station to reduce wheel squeal without the use of grease.

May 2019

Observations:

- Increased amount of precipitation and periods of heavy rain fall in May;
- The number of new flats being created in service dropped;
- Machining operations continued at maximum output.

Corrective Actions:

- NRCC provided 13 recommendations to control the cause of wheel flats: low rail adhesion and EB applications;
- Network Rail Consulting (NRC) hired as a consultant to lead the investigation into wheel flats, once the contract with NRCC had ceased and recommendations received.

The number of wheel flats being generated started to decline in May 2019. By June 2019, the number of new wheel flats being generated reached a manageable level and allowed wheel machining operations to get ahead of the problem. A low of 27 cars (or 7% of the T1 fleet) had experienced severe wheel flats during the week of June 16, 2019.

Wheel Flats - Technical Discussions

Wheel flats refers to a flat spot on a metal wheel. When the wheel rotates to this flat spot, it creates a “thumping” sound and generates vibration in the rail. The larger the flat spot, the larger the thumping sound.

Wheel flats are a known phenomenon in the rail industry. Though there are various ways to generate wheel flats, in simple terms, it is the sliding motion between the steel wheel and the steel rail that will induce a flat spot on the round wheel diameter.

Methods of Generating Wheel Flats:

a) Excessive oil or grease on the wheel / rail interface

Spikes in the number of wheel flats can be expected during the fall season. These wheel flats are attributed to naturally occurring oils in the leaves that fall onto the tracks. When wheels crush the leaves, the oils are released and spread to the wheels and the rails. Excessive oil will create low wheel to rail adhesion resulting in potential for sliding and thus the wheel flat(s).

While excessive oil and grease are unfavourable for wheel flats, small amounts must be applied to reduce “wheel squeal” and to extend the life of the rail around curves. Wheel squeal is the sharp noise heard when steel and steel rub against each other in curved sections of the track. To combat wheel squeal, “lubricators” are used to apply small amounts of grease to the track to lubricate the wheel and rail interface. A correct amount of grease will mitigate squeal and extend the service life of the rail while having little effect on the wheel rail interface. Incorrectly set, poor dispensing

units or damaged lubricators can however result in excessive squeal (not enough grease) or poor adhesion (too much grease).

b) Wet or snow weather conditions

Poor weather conditions can create a layer of moisture on the track and reduce available traction. Open cut sections of both Line 1 and Line 2 create the greatest potential for wheel flats.

c) Other factors causing poor wheel/rail adhesion

Other methods of reducing wheel/rail adhesion include changes to material properties in either the rail, wheel or brake shoes. In 2016, changes to the material composition of the wheels was noted. Increased “pitting” and “shelling” of the wheels was observed which deposited metal shavings from the wheel to the rail. These shavings reduced wheel to rail/wheel adhesion. As a result, new wheels with improved properties were installed on the fleet.

While wheel changes started in 2016, in 2018 there was an introduction of new brake shoes (V-631), along with a 10% increase in brake cylinder pressure to achieve OEM brake rates. NRCC has indicated the possibility of brake dust from new brake shoes affecting traction. 28 cars have been reverted back to previous designed brake shoes (V-830) for testing purposes.

d) “Speed Control” software induced emergency braking

To supervise drivers in operating the vehicles at prescribed speeds and compliance to signal aspects on the line, TTC added a Speed Control system onto the T1 vehicles. This equipment, designed by Thales, sends a command to the onboard equipment for the application of Emergency Braking (EB) when the vehicle is operated under a number of conditions that include:

- i. spin/slide conditions;
- ii. over speeds conditions; and/or,
- iii. signals violations

Since its full implementation onto the T1 fleet, the number of emergency brake applications increased. On average, Line 2 operations experience approximately 280 emergency brake applications per month.

When the vehicle experiences insufficient traction during braking, normally the flat-preventing “Spin Slide” system is engaged, preventing wheel lockup. Speed Control sends a command to the train onboard equipment to activate emergency braking when wheel spin/slide occurs, effectively bypassing the flat prevention system in insufficient traction areas.

e) Operator applied emergency braking

Train operators may also induce emergency braking during service. These applications can either be intentional or in error.

The master controller on the T1 vehicles has a “service brake” position. When applying service brakes, the train will not experience wheel lockup due to the Spin/Slide system. The next level of braking on the master controller is Emergency Brake (EB). EB applications are the most aggressive braking on the train. Operators are trained to only use this application in emergencies.

While there is a physical detent between the full service brake position and the EB position, an inattentive operator or aggressive operator can mistakenly pull through this detent to trigger EB application. EB application can also be mistakenly triggered by activating the “dead man” protection circuit. To ensure the operator is not suffering from medical issues, the train control system is equipped with a “dead man” feature which monitors a driver’s input. If certain inputs are not sensed, the train will apply EB braking.

Corrective Measures for Wheel Flats

Preventative and corrective maintenance on the infrastructure and vehicle side help to minimize the creation of new flats, and to prevent vehicles with wheel flats to operate in service. Foul weather operator driving techniques also assist to minimize and prevent new wheel flats.

Infrastructure Maintenance activities include:

- Pruning foliage that overhang open cut rail sections;
- Removing foliage from outdoor track sections in as expedient a manner as reasonably possible; investigate supplementing foliage removal with seasonal rail cleaning activities;
- Grinding top of rail to maintain optimal rail wheel interface and assist in braking
- Maintaining and replacing obsolete rail grease type lubricators to ensure proper operation and prevent excessive grease on the rail; replacing rail grease type lubricators, where possible with top of rail, non grease type units; and
- Consistently reviewing the Speed Control (SCS) system for performance and operational trends and work with the original equipment manufacturer (OEM) to upgrade system to more reliable levels, if and as required.

Vehicle Maintenance activities include:

- Monthly inspections of brake shoes and wheels to ensure no defects that could lead to low rail adhesion and/or locking of brake system;
- Brake rating at set intervals of trains to ensure brake pressures are within specifications;
- Monitoring the AURA system and removing trains with wheel flats from service; and
- Machining wheels to remove the flats before vehicles are allowed to return to service.

Transportation Initiatives include:

- Operator Awareness Campaigns are performed to reduce unnecessary use of Emergency Brakes (EB);
- Operator Awareness Campaigns are performed to reduce Speed Control intervention.

Investigation & Root Cause Analysis

The investigation into this prolonged event of wheel flats involved the efforts of three departments:

1. Subway Infrastructure,
2. Rail Cars and Shops, and
3. Subway Transportation.

In order to obtain independent oversight of the investigation, the TTC retained the services of the National Research Council of Canada (NRCC). In addition to the NRCC, TTC also hired Network Rail Consulting (NRC) in May 2019.

The investigation focused on potential causes for creating wheel flats and included:

- Review of vehicle and track data;
- Inspection and testing of vehicle condition and performance;
- Inspection and testing of track equipment;
- Systematic elimination of potential contributors to the problem;
- Consultation with peer agencies.

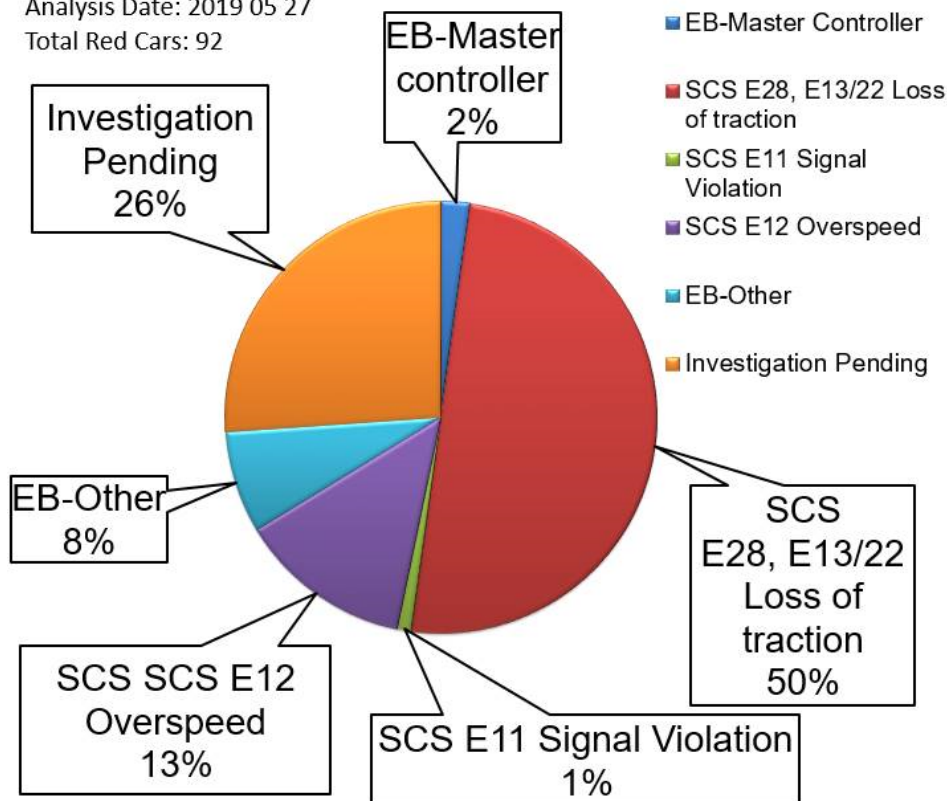
Data Review

Data from the AURA system and the SCS system were reviewed to identify patterns in wheel flat locations on the train. For example, wheel flats identified along one side of a train, would suggest wheel/rail interface problems on one side of the track. Similarly, flats generated to the west or east of the AURA system would help to narrow down potential problem areas geographically. Patterns in wheel flat locations however was difficult to identify. Wheel flats appeared on both sides of the trains and were not consistent from axle to axle. Geographical location of wheel flats being generated along Line 2 could also not be determined.

Data from the Speed Control System was also analysed. This data highlighted instances of EB application and potential reasons for the application. The graph below is an example of the data analysed weekly. From this data, the investigation team would determine tests and investigations to perform in attempts to reduce the number of wheel flats generated. For example, operator information campaigns were implemented when it was identified that the number of EB applications due to over speed and signal violations increased. In addition, speed restriction zones were implemented in the open cut sections during inclement weather to minimize wheel slip.

RED FLAT CARS BY EB EVENTS, APRIL 2019

Analysis Date: 2019 05 27
Total Red Cars: 92



Inspection and Testing of Vehicles

Various inspections and tests were performed on the vehicles as part of the investigation. While subway trains are inspected monthly as part of TTC's preventative maintenance program, an audit of inspection results was performed to ensure inspection crews were correctly identifying and reporting technical issues. In addition, engineering staff performed random testing of vehicle acceleration and braking rates to ensure vehicle performances are within specifications. Results of these inspection audits and tests did not identify deficiencies that would contribute to the wheel flat problem.

Inspection and Testing of Infrastructure

Similar to the inspection and testing of vehicles, subway infrastructure crews performed similar inspections and testing of track side equipment. This included lubricators, rails and speed control systems. From these inspections, the following actions were taken:

- Adjustments of lubricators were performed to ensure the correct amount of grease is being applied to the rails; and,
- Testing of top of rail friction modifiers to replace traditional lubricators. Top of rail friction modifiers do not apply typical grease but use a special lubricant to mitigate wheel squeal while at the same time increasing wheel to rail adhesion

Systematic Elimination of Potential Contributors

In conjunction with the inspection and testing of the vehicles and infrastructure, maintenance crews systematically attempted to eliminate potential contributors to the wheel flat problem. This included temporarily turning off of the rail lubricators, and then conducting temporary by-passes of the speed control system.

While the track maintenance crews inspected and adjusted the rail lubricators, this equipment was also temporarily turned off to ensure greasing of the rail was not the primary cause of the wheel flats. When turned off, there was a small improvement to the number of wheel flats being avoided, however the number of wheel flats being generated remained high.

The speed control group then introduced a temporary reduced speed supervision mode on Line 2 in open cut areas that is activated and deactivated by the placement of UEM tags on the guideway. This reduced the number of certain types of emergency brake applications from 350 in October 2018 to an average of 280 per month. Again, although this initiative helped, the number of wheel flats being generated still remained high and it could not be concluded with any confidence that the speed control system was the primary contributor to the problem.

To further reduce the number of emergency brake application when slippery conditions are experienced, additional tags were installed in the outdoor sections and a software upgrade has been requested from Thales to take advantage of the new tags. The software update is due to be in service before Fall 2019.

Consultation with Peer Agencies

Staff contacted several peer agencies to determine if similar experiences were seen elsewhere. Agencies such as the MTA, Metra, WMATA and the MBTA were contacted. While all agencies acknowledged having seasonal flats, staff at each location could not recall having wheel flat issues similar to the problem faced at the TTC.

Results to Date

The number of new wheel flats generated each day has significantly declined. As a result, vehicle maintenance crews have been able to get ahead of the problem and reduce the number of cars with wheel flats. As of the second week of June 16 019, the total number of cars with wheel flats was reduced to 27.

Although the number of cars with wheel flats have been greatly reduced and the number of new wheel flats being generated appear to be under control, no root cause has been identified to date. A number of initiatives from the investigation have been implemented and/or are ongoing which staff believe is helping to gain control of the problem. The following is a summary of the actions taken and results to date:

Actions taken to date include:

- 1) Rail near curve lubricators was cleaned to remove excess grease;
- 2) Grease lubricators near Islington were replaced with new, and turned back on;
- 3) Additional (grease-less) “Top of Rail Friction Modifier” dispensers were installed;
- 4) Vehicles were thoroughly investigated to ensure all equipment meets specifications. Vehicles with flats were subjected to additional detailed technical inspections with no trouble found;
- 5) Vehicles were brake rated under varying track and weather conditions;
- 6) Transportation performed Operator Awareness Campaigns; and the
- 7) Speed Control group installed Unequipped Equipment Mode (UEM) tags in open cut areas to reduce Emergency Brake activations in case of over speeds or spin/slide in the proximity of a signal.

Results of investigation to date:

- a) During wet weather events, the traction at wheel/rail interface drops to below minimum required levels for Emergency Braking without skidding. TTC is seeking a reliable way of measuring traction at this interface;
- b) Application of Emergency Brakes in service remains high. Technical solutions will be required to reduce the number of unnecessary Emergency Brake applications during operation;
- c) Vehicle condition has been found to be within specifications. Wheel hardness, brake pads, brake system pressures, brake rates, and vehicle acceleration were found to be within OEM recommendations.

Community Relations

Communication with TTC Chair and Local Councillors

TTC’s Community Relations team kept an open line of communication with the TTC Chair and Line 2 councillors. Updates via e-mail were provided in October 2018 (previous council term), January 2019, February 2019, April 2019 and late May 2019.

TTC staff also corresponded with residents who were put in touch by local councillors.

Communication with Residents

TTC's Community Relations and Customer Service teams received upwards of 60 unique complaints related to wheel flats since October 2018. Complaints were received via phone calls, e-mails, online form submissions, social media and through local councillors.

To meet subway service requirements on Line 2, trains were unavoidably placed into service with wheel flats. This affected some residents residing above, adjacent or near Line 2. Residents who contacted the TTC generally reported an increase in noise and vibration felt within their homes. When communicating and following up with residents, a high-level summary of the wheel flat issue and TTC's approach to resolving the issue was provided.

In some instances, track inspections were also conducted by TTC subway staff to confirm if other issues (other than wheel flats) contributed to an increase in noise and vibration. Community Relations staff also visited some residents' homes along Line 2 to make observations of the noise and vibration they were experiencing. All observations were then shared with TTC subway staff for information and consideration.

Wheel flat related noise and vibration concerns were received from the following areas:

- Islington to Royal York (Ward 3)
- Royal York to Old Mill (Ward 3)
- Old Mill to Jane (Ward 3/4)
- Jane to Runnymede (Ward 4)
- High Park to Keele (Ward 4)
- Dundas West to Lansdowne (Ward 4/9)
- Dufferin to Ossington (Ward 9)
- Bathurst to Spadina (Ward 11)
- Bay Station area (Ward 11)
- Broadview to Chester (Ward 14)
- Pape to Donlands (Ward 14)
- Donlands to Greenwood (Ward 14)
- Greenwood to Coxwell (Ward 14)
- Woodbine to Main Street (Ward 19)
- Main Street to Victoria Park (Ward 19)

Updates on the wheel flat issue was also posted online via TTC's website:

http://www.ttc.ca/Service_Advisories/Construction/Subway_noise_vibration.jsp

A fact sheet on wheel flats was provided online in late February 2019:

https://www.ttc.ca/PDF/Transit_expansion_PDFs/Information%20on%20Wheel%20Flats.pdf

An overview of wheel flats and TTC's efforts was provided online in April 2019:

http://www.ttc.ca/PDF/Transit_expansion_PDFs/Reducing%20Subway%20Noise%20and%20Vibration%20April%202019%20%20Update.pdf

TTC's Community Relations team is currently in the process of following up with residents across Line 2 to request feedback on the noise and vibration felt within their homes. As the number of wheel flats has significantly been reduced, there should be an improvement in noise and vibration related to wheel flats.

TTC will continue to keep an open line of communication with local councillors and residents, and report noise and vibration concerns as

Next Steps

Staff will continue to work with the National Research Council of Canada to investigate this problem and to improve operations to better avoid future unexpected spikes in wheel flats.

In order to reduce the wheel flats being created, a reduction in Emergency Brake activations and/or improvement in wheel/rail traction will be required. The following are planned initiatives moving forward:

For the goal of reducing Emergency Brake activations:

1. On a short term, Speed Control software and tag changes will be implemented to prevent Emergency Brake activation in areas of low traction. Speed Control group is currently working with the OEM, The Thales Group on these software updates;
2. On a long term, TTC is pursuing the modification of Speed Control to activate service brake (not Emergency Brake) and therefore maintain Spin Slide wheel protection during stops. Rail Cars and Shops has engaged vehicle OEM Bombardier to study the feasibility of vehicle software and hardware changes to achieve this goal;
3. Rail Cars and Shops is working with Transportation on proposed changes to vehicle controls to reduce Emergency Brake actuation by operators.

For the goal of improving traction at wheel/rail interface:

1. Subway Infrastructure is testing the effectiveness of Top of Rail friction modifiers as an alternate to grease lubricators.

Additionally,

1. Staff is reviewing recommendations made by NRCC and the feasibility of implementing these recommendations to further reduce emergency braking applications;
2. Rail Cars and Shops is investigating vehicle mounted accelerometer sensors, and on-board data monitors to collect flat creation parameters for further analysis.

Comments

With a recent seasonal reduction in new wheel flats being created, the effects of wheel flats on Noise and Vibration on Line 2 has been nearly restored to historically normal amounts. National Research Council of Canada has provided TTC with action items to reduce formation of flats, which will be reviewed and acted on where feasible. Ongoing investigation under the guidance of Network Rail Consulting will review vehicle operations and rail maintenance.

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