MEETING REPORTS

THE AUTUMN CHALLENGE – THE LEAVES ON THE LINE SAGA

by Gilbert Rowe, Project Engineer – Central Line Leaf Fall

A report of the LURS meeting at All Souls Club House on 14 October 2008

Our speaker has worked with LU for over thirty years, being the Chief Brakes Engineer from 1990, and the project engineer for wheel slide protection on the 1992 Tube Stock from 1998, leading on to the Central Line leaf fall project from 2001.

The aim is to operate a normal timetable throughout autumn. But leaves on the rails can result in poor adhesion leading to platform overruns or signals passed at danger, and even to a loss of train detection with the risk of train collision or derailment. So the normal, apparently minor, autumn fall of leaves could possibly result in a major incident.

BRAKING AND ADHESION

On the Central Line under automatic operation, trains in tunnels brake at 1.15 metres/second^2 (m/s^2), around 2.5mph/second,which requires an adhesion factor of 0.13. In the open this is reduced to 0.75 m/s^2 requiring a factor of only µ0.09. Cautious manual driving may only brake at 0.3 m/s^2 requiring only µ0.05. Maximum acceleration can achieve 1.3 m/s^2 with adhesion of 0.15.

A chart of rail adhesion factors showed that clean dry rail offered over µ0.20, which could deteriorate under heavy rain to µ0.13, so these conditions were not challenging. Clean rail under light rain could reduce the adhesion factor down to µ0.08, the same as dry leaf film. Oily or greasy rails are a concern, with a factor between µ0.11 and µ0.05, but damp leaf film can reduce adhesion below µ0.07 to virtually nil, and this can happen within minutes. Normal operations on the open sections require a factor above µ0.10.

Over the past fifty years many factors have led to a deterioration in performance during the leaf fall season. In the time of steam operation, the lineside was trimmed of vegetation for fear of fires but this was considered unnecessary with the advent of diesel and electric traction. As tree growth returned, the design of trains was also radically changing. Newer light-weight materials and designs were matched with increased speeds, acceleration and braking rates. Improved bogie designs tracked better, rather than hunting which tended to scrub rail surfaces clean.

Train performance improved over this time, and defensive driving has been promoted to adapt to autumn conditions, together with autumn timetables to allow additional running time, and train borne sanders have been reintroduced, particularly on short multiple unit trains. Cast iron brake blocks made less demand on the wheel/rail interface, with a rising friction characteristic applied to the wheel tread. Disc brakes have a more constant friction characteristic, and braking rates have generally increased. This means that braking commences later, with less latitude for poor adhesion and therefore greater consequences if it is encountered. Disc brakes were originally adopted for high speed trains, where friction braking with brake blocks resulted in high wheel tread temperatures that caused metal damage. However, they (disc brakes) were later widely adopted by the main line rail industry. LU has remained with brake blocks given its lower speeds, and avoids the cost and weight penalties of fitting brake discs.

Wheel slide protection was developed in the 1960s to try and avoid the problem of damage caused by flat spots worn on wheels (due to wheelslide), but early systems performed relatively poorly – failing to prevent wheelset damage and extending braking distances. In the mid-80s British Rail Research measured real rail adhesion profiles, and developed a computer simulation which allowed test repeatability, leading to improved WSP systems which did protect wheels with minimum braking degradation. This was the situation when the 1992 stock was constructed.

Dynamic braking makes use of traction equipment to slow trains, whilst brake blending interfaces this with the conventional friction braking system, especially at lower speeds. These systems reduce use of the friction brake, and lead to increased life of both wheelsets and brake pads or blocks, with less dust. The power produced is dissipated as heat in rheostatic systems, or can also be returned to the line in regenerative systems. There is a risk, during wheel slide, that the dynamic and friction brakes may 'fight' each other for control. Cross blending is a technique which uses any excess dynamic braking capability (on a motor car) to help brake an adjoining trailer car. This makes increased adhesion demands on the motor car, and therefore increases slip risk in adverse rail conditions.

LEAVES ON THE LINE

Compressed leaves on the rail head form a hard Teflon-like coating which, in damp conditions, leads to low adhesion which extends braking distances, risking station and signal overruns. All LU wheels are braked, but not all are motored leading to even greater risk of reduced motoring performance and increased journey times. In dry conditions, compressed leaves on the rail head can form an electrical insulation between the rail and the wheel, leading to non-detection of trains through track circuits. This can be mitigated by extending signal overlaps, monitoring sequential operation of track circuits, and by use of axle-counters.

The problem is one of the interface between the wheel and the rail, and sometimes the contamination is carried by the wheel rather than the rail. The best rail condition is in dry weather, and the worst is light rain, drizzle or dew, but the difference between the two is hard to detect.

Living with ‘leaves on the line’ led to autumn timetables that allow increased journey times for defensive driving, braking lighter and earlier and reducing top speeds. They have been used on the Metropolitan Line and on the main lines. Defensive driving requires drivers to have been trained and assessed, and they must remain competent through refresher training and practice.

Mitigation of the problem can involve prevention of contamination by removal of trees near the railway. However, tree roots may strengthen lineside earthworks, and vegetation can help ameliorate neighbours' noise problems. It is not all situated on rail property. So mitigation will also involve removal of contamination. This can be done by train-borne application of treatments such as Sandite, a mixture of sand and stainless steel which improves conductivity, and high pressure water jetting. Network Rail have trains carrying 16,000 litres of water which they blast at the rail at a pressure of over 1,000 bars. It can be effective particularly with slow speed application, but any contamination remaining is left damp, and therefore presents a high risk of low adhesion. HPWJ has since been developed so that it can be applied at 60mph, higher than the recommended 30mph limit for Sandite, which is also used by Network Rail. Traction gel applicators are also used to spread Sandite for a distance on the rail head, in the fashion of rail lubricators, and are used mainly to aid motoring away from platforms. There are also manual applicators used by lineside gangs with Sandite, scrapers and liquid sprays, but these are laborious and time consuming, and therefore expensive.

In 1994 at Slough a train ended up on the platform after failing to stop in a bay road, although there was no vegetation nearby. The train data recorder showed a near nil adhesion factor. In response an emergency sander was developed, essentially a button on the driver's desk that set off a fire extinguisher that sprayed sand onto the rails. This was a drastic last chance device that could be used only once. From this was developed an automatic sander that operated based on detected wheel slide on the leading bogie, and this is now fitted to the trailing bogie of the leading car of most National Rail multiple-units. However, signal engineers were worried about sand on the railhead possibly insulating short trains from detection, so the amount of sanding was restricted.

Leaf fall mitigation is costly, but cheaper than the consequences of no action. There is a danger that success can lead to complacency, but a sustained effort is required in pre-season preparation, and then implementation and monitoring. It is an organisational challenge, affecting several different departments and areas.

In Autumn 2005 there were two serious overruns, at Esher and Lewes, both in excess of a kilometre and both near misses! The Railway Accident Investigation Bureau report found the limitations on sanding capacity on both trains was of serious concern, and there has been widespread modification to equipment in consequence.

LU has particular problems with leaf fall north and west of Harrow-on-the-Hill and east of Leytonstone, particularly east of Woodford. On other lines there are localised problems, such as around Sudbury Hill and Sudbury Town, Ealing Broadway and Ealing Common, near Osterley, and Hendon Central.

CENTRAL LINE UPGRADE – WHEELSLIDE PROTECTION MODIFICATION

The objective of this line upgrade, when planned twenty years back, was to deliver 33tph through a new signalling system providing automatic train operation of the new 1992 Tube Stock, with upgraded power supplies, a new communication system and track replacement as required. Of course nothing goes exactly as planned, and there were problems with the performance and reliability of the new trains, and with the automatic train protection (ATP) signalling and the automatic train operation (ATO) system. A particular problem with the new trains was the traction based slip control, which resulted in excessive wheel flatting.

As delivered, the new trains featured wheelslip control in the dynamic brake during service braking. Unfortunately, this resulted in a major reduction in braking effort and drivers would regularly go straight into emergency braking when poor adhesion was encountered, causing major wheel flats up to a foot long (e.g. wheel lock up at 90-100 kph). The ATP system was confused by the locking of tachometer wheelsets, and serious overruns occurred during early ATO tests, which were therefore banned during the autumn. Under these circumstances, it was not possible to implement the ATO system throughout the line as planned. Over 1,000 wheelsets were removed for turning annually, although over 50,000 wheelsets were damaged each year. Noise and vibration complaints were received from nearby residents, especially those living over tunnel sections, and impact damage to train bogies and track was extensive.

It was decided to fit a comprehensive per-axle wheelslip protection system to the 1992 Tube Stock, with the intention of delivering the optimum practical braking performance for the prevailing conditions. When slip is detected, the dynamic brake is released on the unit affected, allowing the friction brake to reapply. There is then per-axle wheelslip protection through the friction brake, with a control unit on each car. This control allows 20% limited slip, which means the wheelset is allowed to slip to a maximum 20% below the speed of the train. In consequence, there is minor heating of the rail which improves adhesion for subsequent wheelsets. The bogie-mounted 3-stage dump valve introduced a hold stage to both inlet and vent valves, reducing air consumption to manageable proportions.

With the new system fitted, wheel flatting was effectively eliminated. Poor adhesion braking performance was dramatically improved, and emergency braking performance could be increased by 10%. It was now possible to commission ATO, a key objective of the £800 million Central Line upgrade, after spending £10 million on installing the new WSP system. ATO was commissioned in the tunnels in 1999. In April 2001 it was agreed on the open sections excluding leaf fall season. A separate case for autumn ATO had to be made, and was accepted in October 2001.

CENTRAL LINE LEAF FALL AND ATO

The problem with ATO running in open sections is that trains are always driven as hard as possible to provide a consistent and intensive service. There can be no adjustment for conditions, so no defensive driving, and brake rates of more than double those used in manual driving are applied. This results in a ten-fold increase in risk of leaf fall incidents, which requires enhanced measures. It was originally considered essential to determine if conditions were suitable for ATO before any trains ran, and when this had been achieved it was also considered essential to update the assessment throughout the operational day.

The decision process was aided by development of a software tool called the ‘Adhesion Controller’s Condition Assessment Tool’ (ACCAT). This considers the source of leaves, falling or fallen, the cause of leaf litter mobility, wind or train induced, and rainfall or railhead moisture levels. Leaves may fall from overhanging trees or from lineside vegetation. In severe weather, leaves can be carried significant distances, even being ripped from the trees and forming a carpet of leaves across the rails. Heavy, sustained rainfall is good for rail conditions, softening and removing leaf film from rails, and damping down fallen leaves with its weight. Conversely, light rain and drizzle moisten fallen leaves and leaf film on the railhead, generating low adhesion.

A survey of lineside vegetation was shown. At the east end of the Central Line, there is linear forest (continuous lineside trees) with a significant amount of mature trees, most of which shed leaves in early/mid November. Between Woodford and Epping, this linear forest is oak-rich, giving a further leaf shed in late November/early December. At the west end, there are intermittent patches of heavy vegetation in 100- to 250-metre stretches. North Acton to Hanger Lane westbound is a particular problem, with the cutting providing constant shade which prevents drying of the track.

Leaf fall mitigation on the Central Line involves vegetation management; the operation of two Sandite trains; the use of track-based staff for site inspections and hand-Sanditing, also providing a rapid response to detected problems; leaf fall and weather prediction data from the Weather Office; an Adhesion Controller at Wood Lane control centre who monitors the condition assessment process; lineside railhead moisture sensors; and the ATO risk prediction software (ACCAT). Prediction data and site inspection data are entered into ACCAT, which can then determine fitness for ATO and whether Sandite trains are to be run for mitigation. The sandite trains are limited to 30 mph and are not run unless required because they can hold up service trains, and Sandite is bad for the railhead if used in excess. Service performance feedback is also entered into the ACCAT program.

ACCAT provides a six-hour look ahead, and at least a one-hour warning to allow preventative action to be taken. It must be credible and reliable in its predictive ability. The display shows a level of risk for each direction of travel between consecutive station pairs. In 2007, the system lacked automatic, real-time feedback from lineside sensors and from trains, being reliant on manual reporting and data entry.

Since then, eight railhead moisture sensors have been connected to provide real-time data to ACCAT when a threshold is triggered. These sensors use a half-metre section of dummy rail beside the track, and feature a battery-powered sensor, rain gauge, processor and communication unit. Also twenty cabs are being trialled to report direct to ACCAT any wheelslip activity on the leading car, together with the last station location. Drizzle and fine rain detection has been poor in the past, providing an under-stated risk level until sudden change on detection. This has led to late use of the Sandite trains, but improvement is now possible.

The objective of ACCAT is to provide a three to six hour prediction of risk to allow Sandite train operation, a one-hour risk to allow track-team inspections, and an immediate risk with the possible need to suspend ATO. These must consider different factors, and are in potential conflict, so the current ACCAT provides four assessment levels, “time now”, next hour, next three hours and next six hours. The short term predictions use local, up-to-date data, whilst the long term predictions are area based data and are updated less often.

ACCAT is now being further developed for use on the Metropolitan Line for leaf fall, and perhaps for year round use on the falling gradient in cuttings from Amersham to Rickmansworth. It will be needed for the introduction of ATO with the line upgrade.

The Jubilee Line new automatic train control system also needs a “year round” adhesion management system. Although the line is not significantly affected by leaf fall, the adhesion issues presented by general weather conditions (rain, dew, drizzle, fog etc.) need to be managed so that the appropriate brake rate can be applied. The main line railways have been trialling the system on Chiltern Railways to Aylesbury, for performance benefits which could improve line capacity. The European Rail Traffic Management System is also coming, which requires a low adhesion setting to be input.

QUESTION TIME

During question time, it was reported that Network Rail research worked with a laser railhead cleaning train for five years. Whilst effective at low speed, reduced performance at higher speeds could not be overcome to provide a practical tool.

In response to concern over the introduction of S Stock on the Metropolitan Line, it was explained that, as a result of the Central Line/1992 Tube Stock experience, the requirements and design proposals for signalling and rolling stock have been significantly modified. These include the provision of train-borne sanding equipment, a first for modern LU rolling stock.

One member queried the possible use of magnetic track brakes. These require a mechanical linkage between the two sides of the train, which the centre current rail impedes. Motor bogies have no space for this equipment, and so they are usually mounted on trailer bogies, a problem for all-motored 1992 Stock and S Stock. They are heavy, which would add to the unsprung weight and, if reserved for emergency use only, would have little use for the weight penalty. With regular use they can damage the track, especially on Metro-style services which feature frequent heavy braking. British Rail Research detected no improvement in braking performance, although Continental railway research has been more favourable. In our speaker's view, sanding offers a greater benefit. For ATO lines, the need to define a “low adhesion brake performance” is increasingly necessary and this requires brake, WSP and adhesion improving (e.g. sander) systems to be considered as a complete system

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