Effective management of risk from slipstream effects at trackside and on platforms

Introduction
In Britain, the risk associated with train slipstreams is small; however train slipstreams can have a significant effect on the safety of passengers on platforms and trackside workers if the risk from them is not managed effectively.

Since 1972, twenty-four incidents have been reported in mainland Britain which involve airflow induced forces mainly on wheeled items on station platforms (pushchairs, wheelchairs, trolleys), but also on passengers and their belongings. Cross winds can amplify the effect of slipstreams but significant scatter exists in the results and experimental data is difficult to reconcile with actual operating experience. Such uncertainty makes it difficult to manage the risk in an optimum way and impedes investigating opportunities to increase freight train speed as slipstreams are one of the determining constraints.

The forces induced by airflow are proportional to the square of the slipstream velocity of the train which itself is proportional to the train speed; so any significant increases in train speeds have the potential to increase the accident risk at platforms and at the trackside. In high wind speed conditions, the risk is intensified due to the combined effects of high winds and vehicle slipstream resulting in very high slipstream and wake velocities.

Figure 1: Vortex structures in the wake of an idealised train vehicle (Mair and Stewart (1985) and Copley (1987), Chiu (1991))

Aims
This project sought a greater understanding of the mechanisms by which risk from train slipstreams manifests itself, enabling mitigation measures to be optimised along with the opportunity to alleviate operating constraints on freight traffic in particular.

Methodology
The work comprised the following elements:
- A commentary on the existing situation in Britain.
• An analysis of an existing large body of experimental data on train slipstreams including the effects on pushchairs/baby buggies.
• Theoretical modelling of the effects of train slipstreams on a standing person.
• A review of the effect of cross-winds on slipstreams.
• A review of existing data of gust effects on standing people.
• An appraisal of potential mitigation measures.

As an extra investigation, laboratory experiments measured the stability of pushchairs. These tests were performed on one double and two single pushchairs to determine the coefficient of friction, centre of gravity and toppling force, with the force applied either longitudinally or laterally. Using this data, and data for the physical dimensions and mass, the slipstream force model was used to predict the pushchair stability.

Findings

The findings of the individual elements of the study are as follows:

(i) A commentary on the existing situation in Britain

The risks associated with slipstreams are small compared with overall railway risks in Britain. The estimated value of loss (VoL) is £45.6k for the whole network based on 1.86 events per year. \(^1\)

However, if there was a fatality, then the value of loss would increase by a factor of just over four to £192.4k per year. Occurrence of a fatality could result in a severe adverse reaction from the public resulting in loss of confidence in the railway and a very significant commercial loss which is difficult to quantify. A fatality has occurred in Germany so, although the different operating factors need to be considered, the risk of a fatality occurring in Britain is real.

(ii) An analysis of existing experimental data

Between 1972 and April 2005, there were twenty four slipstream related incidents reported on station platforms. Thirteen of these involved a pushchair, ten being caused by freight trains and three by ordinary passenger trains. Very few trackside incidents have been reported over the last eleven years. In Great Britain, some injuries have occurred but to date there have been no slipstream related fatalities.

Full scale tests have indicated that the peak 1s moving mean flow velocities \(^2\) generated at the positions of safety on platforms and at the trackside are 20m/s and just over 25m/s respectively. The data exhibits significant scatter due to the random nature of the flow and is insufficient to establish firm dependencies on the main dependent variables of:

- Train type
- Train speed
- Clearance from the platform edge
- Clearance on open track from the line
- Crosswinds

Freight trains generated the largest slipstream velocities at a given train speed.

At the trackside, significantly higher slipstream velocities were produced at the minimum position of safety stated in

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1. The VoL is based on the value of preventing a fatality of £1.5M at the time of this study.
2. A 1s moving mean flow velocity is the average flow velocity over the previous second. 1s moving mean flow velocities for the full slipstream velocity excursion are determined successively by stepping in time from one flow velocity sample to the next. The peak 1s moving mean flow velocity is then extracted from the results of the stepping process.
the Rule Book for train speeds up to
100mph (1.25m from the nearest rail)
than at that for train speeds up to 125mph
(2.0m from the nearest rail). This
suggests that the minimum position of
safety for train speeds up to 100mph
requires review.

Instrumentation for measuring slipstream
velocities at full scale is shown in Fig 2.

Figure 2: Trackside measurements at full
scale, anemometers for measuring
slipstream flows

(iii) Theoretical modelling of the
effects of train slipstreams on a
standing person

The basis of a model which could
potentially be used to assess the
response of a standing person to a
passing train has been developed. The
initial results demonstrate that the model
is capable of generating realistic
slipstreams corresponding to passenger
trains, which can be converted into a
force experienced by a person standing
near the train and used to model their
response.

(iv) A review of the effect of cross-
winds on slipstreams

The review was conducted using the
results of full scale tests, reduced scale
tests performed on a moving model rig,
wind tunnel tests and Computational
Fluid Dynamics (CFD) modelling.

Figure 3: CFD simulation of flow velocity
contours for train subject to a crosswind.

In very broad terms, the moving model
experiments and the CFD calculations
show that the presence of the train tends
to shield the lee side from the effects of
cross winds, Figure 3, but under some
circumstances, an amplification of the
cross wind velocity was seen as the train
passes that can be associated with the
presence of longitudinal wake vortices.
This latter trend of velocity amplification
is also clear from the analysis of
maximum slipstream velocities from the
full scale experiments, although the
scatter in the data makes the scale of this
effect difficult to quantify.

The idealised model train wind tunnel
tests clearly illustrate that at low yaw
angles of attack the primary lee side flow
mechanism is a system of inclined trailing
vortices.

(v) A review of existing data of
gust effects on standing people

The results of tests conducted on people
in a large wind tunnel suggest that a gust
speed of 15m/s is sufficient to displace a
significant proportion of people
regardless of age, weight, or orientation.
Measurements conducted on platforms
and at the trackside, at locations that are
designated as being safe, indicate that
short duration flow velocities significantly
greater than this can occur. There is no
indication, however, that these gusts are unsafe.

One possible reason for this could be linked to the duration and structure of the gusts. Another reason could be the actual behaviour of personnel eg adopting greater clearance distances or easily re-establishing their balance by a change of stance. Both issues require investigation to confirm that an underlying safety problem does not exist. The rate of application and duration of gusts, together with the varying response rate of people are aspects which are being examined as part of a PhD study presently underway.

(vi) An appraisal of potential mitigation measures
The VoL for a slipstream incident is relatively low compared with other types of incident on the railway system. As a result, only relatively low cost mitigation measures are justified, such as disallowing unattended wheeled equipment, increased clearance and warning signs, auditory warnings and posters or similar media.

An incident involving a fatality, however, could undermine public confidence in the railway and encourage greater usage of the roads which are significantly less safe. This may justify the adoption of more expensive mitigation measures such as platform barriers in stations in exposed locations where crowding occurs on platforms.

(vii) Experimental investigation to establish the stability of pushchairs
The results suggested that, under the conditions tested (pushchair designs, and pushchair orientations to the slipstream force), destabilisation was more likely to involve the pushchair moving along the ground than toppling over even with its brakes on. The model also confirms that increasing train speed and decreasing distance from the platform edge increase the likelihood of destabilisation, with container freight trains presenting a higher risk than passenger trains; and that a pushchair is considerably more likely to be destabilised than a standing person. The tests undertaken were preliminary, and a more extensive study will be needed to determine pushchair stability to an appropriate level of reliability.

Next Steps
This work has consolidated the understanding of the issue of train induced slipstreams and management of the risks. It has identified where further work needs to be undertaken in order to reduce risk and uncertainty, and thus enables management of the risk to be optimised.

Although the incident statistics suggest that the safety risk to public and railway personnel is not high, the continuing trend towards increased traffic (particularly freight), and greater crowding on platforms, implies some increased risk. Further work is therefore proposed to examine the causal factors of incidents due to slipstreams and consider the need for further mitigation measures to manage the risk associated with existing operating conditions (ie. for
a maximum freight train speed of 75 mph).

There is substantial subjective experience but little firm measured data that slipstream velocities on the train leeside are significantly augmented in the presence of ambient crosswinds. There is, therefore, a need to obtain reliable measurement of these characteristics from aerodynamic testing in order to derive worst case criteria. The economic justification for such testing will be based on the demand for faster freight traffic.

The following work has been identified for reducing risk and producing a case for increasing the speed of freight trains:

1) A study into the behaviour of people on platforms and at the trackside as trains pass at speed.

2) Development of recommendations for the collection and analysis of data on, and reporting of, slipstream incidents.

3) Review of existing station management procedures and production of a code of practice for guiding station managers in the management of slipstream risk, noting the greatest perceived risk is to pushchairs.

4) Development of an economic justification for increased freight traffic speed.

A business case for justifying an increase in the speed of freight traffic is being developed by Rail Safety and Standards Board (RSSB) in discussion with the Aerodynamics GB Working Group, a sub-group of the Rolling Stock and Infrastructure Standards Committees.

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