EXECUTIVE SUMMARY

Objectives

On 2 June 2015 a collision involving two trains occurred on the Smiler Ride at the Alton Towers Theme Park, Staffordshire. A train, fully loaded with passengers, struck a stationary, empty train in the double loop portion of the track known as the "Staffordshire Knot". Several passengers sustained serious injuries as a result of the collision. Following the incident [redacted] requested that the Health and Safety Laboratory (HSL) assist in the investigation of the mechanical aspects of the incident as follows:

1) Recovery of the entire empty train (Train 3) from Alton Towers to HSL.

2) Recovery of the front section of the passenger train (Train 4) containing the front two passenger rows.

3) An inspection of Train 3 with a view to identifying any aspect of the train condition or design which might have caused the train to slow down.

4) An assessment and test of all wheel bearings on Train 3 with a view to identifying if the condition or type of any of the bearing(s) may have caused the train to slow down significantly.

5) An assessment and test of the ball joints between cars 2 and 3 and cars 3 and 4 on Train 3 with a view to identifying any aspect of the joint condition or design which could have caused the train to slow down significantly.

6) An assessment and test of the rotary joint between cars 1 and 2 on Train 3 with a view to identifying any aspect of the joint condition or design which could have caused the train to slow down significantly.

7) A theoretical analysis of the likely forces exerted on Train 3 caused by wind loading over a range of wind speeds between 0 and 50 mph (0 and 22.5 m/s) and over a range of applied angles to the longitudinal axis of the train of +/- 30 degrees in 5-degree increments.

8) An assessment of whether the likely wind loading on Train 3 at the time of the incident was sufficient to cause it to slow down sufficiently to prevent it "making" the loop.

9) An assessment of available CCTV footage to determine (if possible) the speed of Train 3 as it entered the loop and the deceleration as it travels around the loop.

10) A comparison of Train 3 speeds and decelerations (see (9) above) with HSL video footage made post incident, of empty and loaded trains, successfully negotiating the loop.

11) A detailed laser scan of both trains.

12) Establish from available CCTV footage a "timeline" of events including train, passenger and technician movements within the relevant time period immediately prior to the incident.

13) Produce a simple video animation showing the events established in (12) above.

Main Findings

1) Tests carried out on all of the wheels on the empty train (Train 3) and on the first and second chassis of the full train (Train 4) indicated that the bearings were performing normally.

2) Apart from the incident damage, the general condition of the trains recovered to HSL was good. They are substantially constructed, and a visual inspection indicated that they have been well maintained. Some dismantling of selected components supported this view.

3) Tests carried out on the centre bearing between the first and second chassis of Train 3 indicated that the bearing was rotating freely and functioning correctly.

4) Measurements of the moments required to rotate the ball couplings connecting the second, third and fourth chassis on Train 3 indicated that they were functioning as intended. The stiffness of the ball couplings did not contribute significantly to slowing down the train.

5) A track inspection carried out by Jacobs UK Limited found no evidence of damage. Several track joints had gaps that were larger than would normally be expected. In the opinion of the Jacobs engineers, the gaps would not contribute significantly to reducing the speed of a train.

6) An analysis of local wind data carried out by [redacted] of the Building Research Establishment Limited concluded that the wind was gusting to 17 m/s up to and around the time of the incident.

7) An analysis of the behaviour of the two trains, based on data drawn from CCTV footage and laser scanned imagery of the track indicated that the empty train (Train 3) stalled at the second loop of the Staffordshire Knot primarily because of energy losses caused by the high gusting wind. This conclusion is supported by the behaviour of test trains that were sent around the track following the incident.

8) Both of the trains involved in the incident were subject to additional energy losses attributable to geometric misalignment between the train wheels and the track. The misalignment is a feature of the design, and is accommodated by springs mounted in the wheel carrier. However some skewing, transient redistribution of forces, and vibration can be expected as the trains negotiate the bends and loops in the track.

9) The energy absorbed during the initial impact was estimated at 384 kJ.