Rail Defect Management

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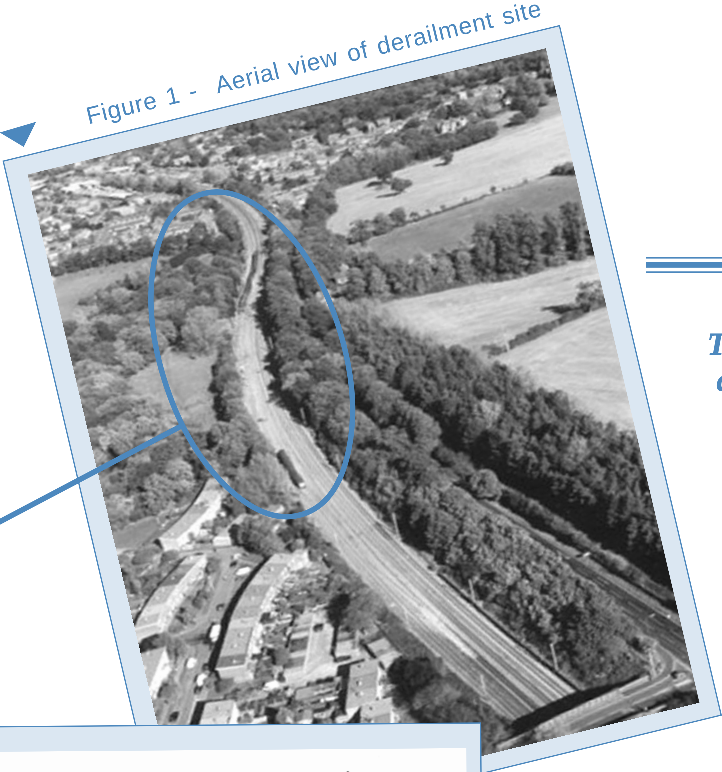
Figure 1 - Aerial view of derailment site



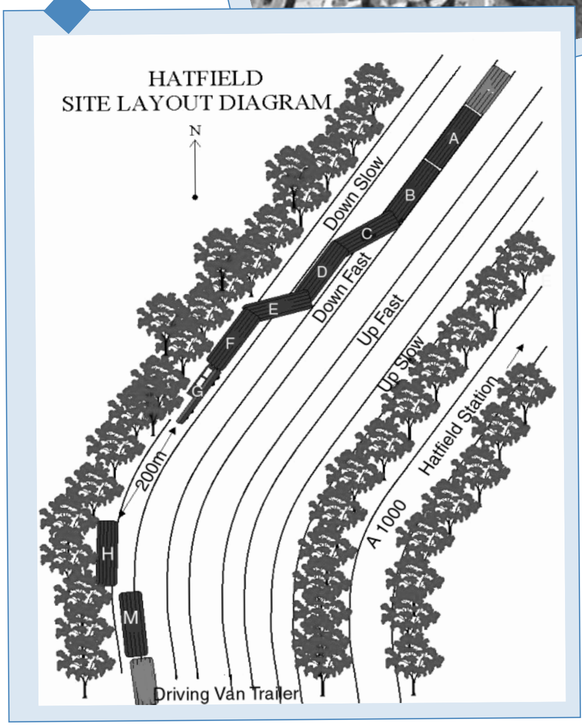


Figure 2 - Derailment site layout

(Source: http://www.hse.gov.uk/railway/hatfield/interim2.htm#annex1)

The Hatfield crash happened last October has alarmed the entire rail industry. There were investigation reports and news analysis covering what had happened, why it happened and who should be responsible. Will similar incidents happen to MTR? How good or bad we have been doing? What lessons can be learnt? This article provides you with some clues to these questions.

Hatfield Crash

Four people were killed on 17 October 2000 with 30 others injured when a 11-car Great North Eastern Railway train derailed at Hatfield Station, 16 miles north of London (see Figure 1). Set off at 12:10, the London King's Cross-Leeds Intercity 225 was carrying about 110 people, including 10 staff, and travelling at or close to the line speed of 185 km/h.

The train was heading North when the locomotive (see Figure 2) with coaches A and B passed over the site of the rail failure which had caused coach C to derail. As the train derailed, coach H was separated from the rest of the train with coach G slammed into an overhead line mast killing four passengers. All other passengers and staff escaped with injuries only.

Causes of the Incident

The followings are findings from the immediate investigation by the UK Health & Safety Executive (HSE):

- There is obvious and significant evidence of a rail failure.
- There is evidence of significant metal fatigue damage to the rails in the vicinity of the derailment.
- The only evidence to date of wheel damage is consistent with the wheels hitting defective track.
- There is no evidence of prior failure of rolling stock.
- The most extensive damage appears to have been caused by derailed carriages impacting line side structures.
- The signalling system appears to have played no part in the derailment.
- Parts of the rail and train components have yet to be recovered.

The report also stated that the matter of broken rails has been a concern for the HSE for some time.

Rail Defects

A 35 m section of the broken rail was recovered which had shattered into more than 200 pieces (see Figure 3). Such a failure was unprecedented and there was evidence showing the rail had developed severe gauge corner shelling prior to the derailment and had been weld repaired and identified for renewal. The rail was a premium "mill heat treated' (MHT) rail, commonly used in areas of high demand.

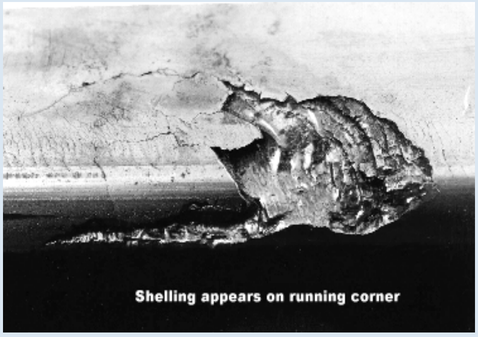
Figure 3 - Rail broken into over 200 pieces

(Source: http://www.hse.gov.uk/railway/hatfield/interim2.htm#annex1)

Findings of the derailment investigation had resulted in more than 500 temporary speed restrictions applied, bringing the rail system to a state of chaos. Over 500 km of rails were identified for replacement within a six month period. To put it into perspective, it is more than the total length of rail on the MTR System.

Investigation showed that the broken rail was due to rolling contact fatigue which is usually the result of high stresses at the wheel rail interface contact patch caused by poor matching of wheel and rail profiles. Micro cracking of the rail surface occurs and lubricant leaks into these cracks which has developed further due to induced hydrostatic bursting forces. This causes gauge corner shelling (see Figures 4 & 5).

Figure 4 - Gauge corner shelling



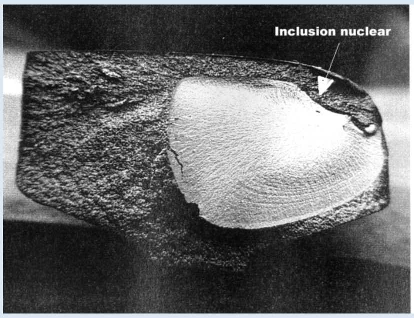
The demand on this contact patch is extreme with all the traction, braking and train loading forces transmitted from the wheel to the rail through a point about the size of a 10-cent coin.

MHT rail which is harder than standard grade rail can be more long-lasting if maintained effectively. MHT rail has been successfully used in the MTR System for at least the last 5 years and an effective rail grinding regime has been implemented through the application of MTR's Rail Management Model (RMM) to prevent RCF problem from occurring. Rail life of MHT rail in MTR shows a 40% increase over the standard grade rail.

Figure 5 - Shelling fracture surface

Another type of rail defect found in the Hatfield incident was "tache ovale" (see Figure 6). It is caused by the development of sub-surface shear cracking of the rail head, typically at 5-6 mm below the surface.

Figure 6 - Tache ovale, with nucleation point



The tache ovale can be developed from a nucleation point, either from surface shelling (see Figures 4 & 5) or from an inclusion in the rail. In Figure 6, there is a microscopic particle of slag in the rail acting as the nucleator. The only method of detecting tache ovale prior to any rail breaks is by means of ultrasonic testing.

Following the Hatfield derailment and the HSE's previous concern over the rising level of rail failures on Railtrack, the UK Office of the Rail Regulator appointed Track Technology Centre Inc. (TTCI) of Pueblo, USA to review whether Railtrack's failure to effectively manage its rail failures has breached its licence conditions. The review also examines whether Railtrack has tried to reduce rail failures to as low as reasonably practicable (ALARP).

From the TTCI's findings, reasons for continuing increase in rail failures on Railtrack were as follows:

- Reducing levels of rail replacement
- Reliance on manual ultrasonic testing
- Worsening track quality
- Increasing wheel flats

Wheel / Rail Interface Management in MTR

MTR adopts a holistic approach by having Permanent Way and Rolling Stock closely worked together in managing wheel / rail interface. It is strongly believed that the separation of responsibility for track (to Railtrack) and Rolling Stock (to the Operator) in the UK has worsened wheel / rail interface management.

MTR uses a sophisticated ultrasonic testing vehicle (UTV) (see Figure 7) to test all MTR tracks on a monthly basis, a frequency far exceeding international standards.

Figure 7 - MTR ultrasonic testing vehicle

The UTV incorporates sophisticated defect recognition software to assist technicians to detect and monitor defects (see Figures 8 & 9). This software enables a real time comparison with previous run and also off-line analysis for audit purposes.

In addition to the UTV, MTR undertakes a comprehensive manual non-destructive testing programme for sensitive components such as rail expansion joints, switch blades and bolt holes using ultrasonics, dye penetrant and magnetic particle inspection.

The recommendations of TTCI have been examined with respect to MTR:

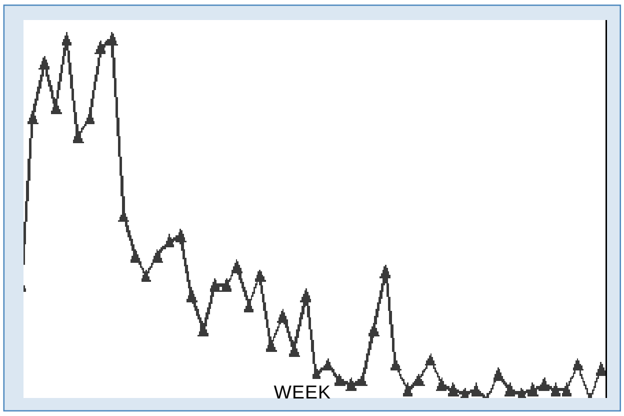
- **Reducing rail replacement on Railtrack** - MTR is increasing the life expectancy of its rail through effective wheel / rail interface management by using RMM. It also enforces rail replacement strictly in accordance with the minimum Action Code.

- **Reliance on manual ultrasonic testing on Railtrack** - MTR does not rely on manual ultrasonic testing. The Corporation's Infrastructure Maintenance Department (IMD) operates a state of the art UTV at a frequency exceeding international standards.

- **Worsening track quality on Railtrack** - MTR's tracks are predominantly non-ballasted which are highly resistant to deterioration. The ballasted track quality is regularly measured by IMD using the Track & Overhead Line Geometry Vehicle (TOV) and track tamping planned using a Ballast Management Model.

- **Increased wheel flats on Railtrack** - MTR has significantly reduced the incidence of wheel flats in the last 4 years (see Figure 10) through improved rail lubrication procedures, implementation of chopper control on EMUs and the introduction of SACEM signalling system.

Figure 10 - Wheel flat rate 1997 to 2000



As a result of its structured management and inspection regime the level of rail defects in MTR has continually reduced since 1992 (see Figure 11).

Figure 8 - Interior of ultrasonic testing vehicle

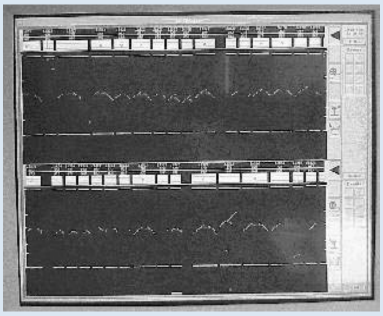
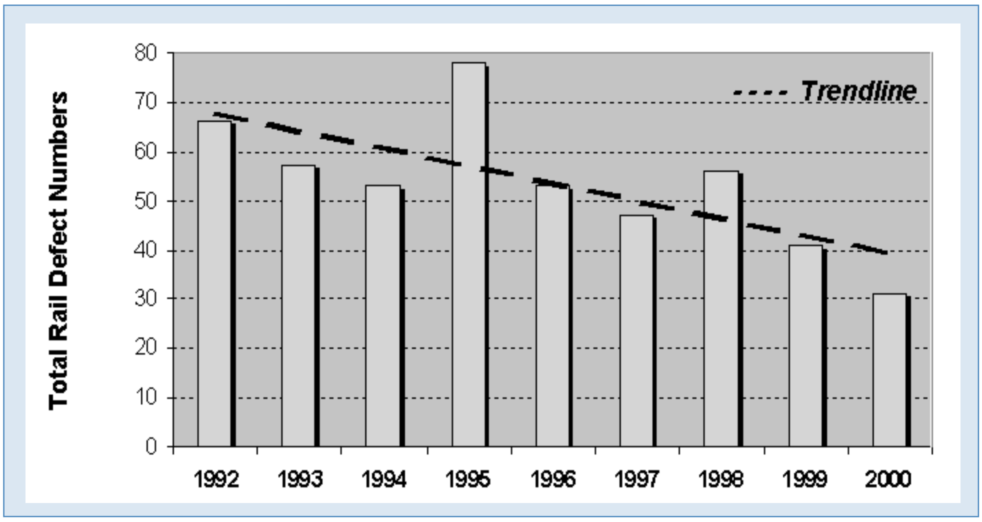


Figure 9 - Automatic defect recognition

Figure 11 - Rail defect trend 1992 - 2000



IMD has also examined benchmarking data from other railways but comparisons are often difficult due to difference in data recording. Major findings are highlighted in Figures 12 to 14.

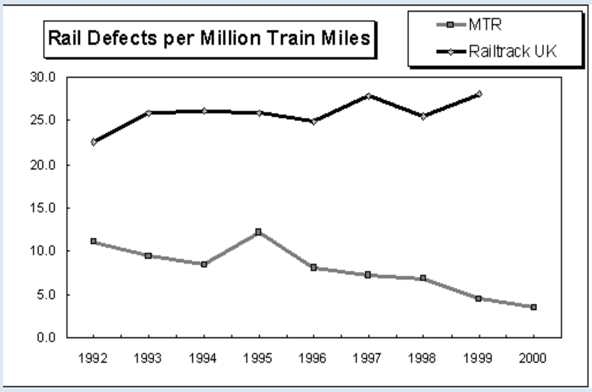
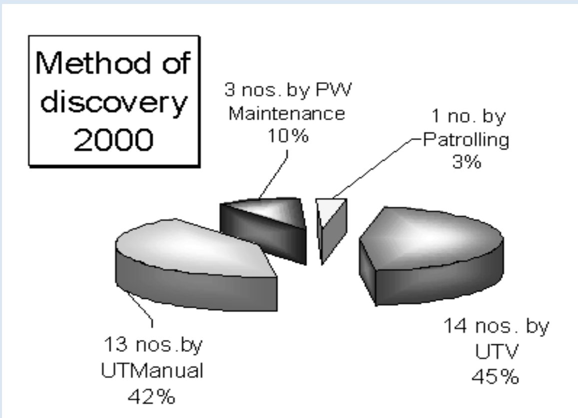


Figure 12 - Rail defects per million train miles

Figure 15 - Means discovering rail defects in 2000



These figures show that in all cases, MTR is achieving standards that are equal to or better than other international railways. One of the major contributing factors is the frequent inspection by IMD in detecting rail defects, hence few defects are able to become rail breaks. Last year, all rail defects were discovered by the P'Way Section during scheduled inspection or preventive maintenance (see Figure 15).

Figure 13 - Broken rails per million train miles

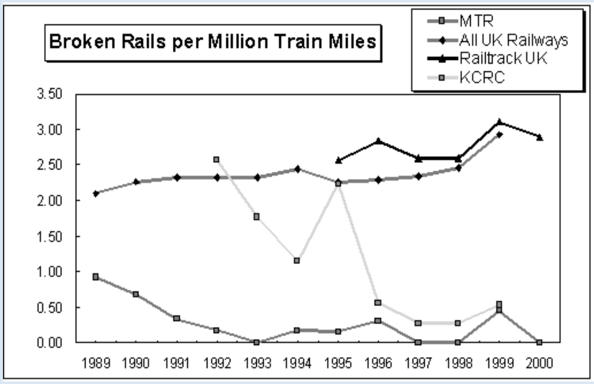
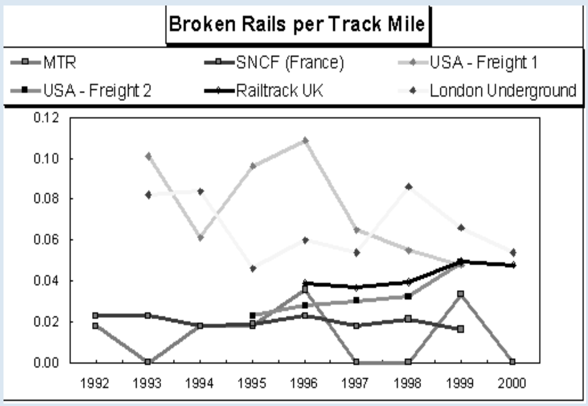


Figure 14 - Broken rails per track mile



Conclusion

To conclude, it is evident that MTR applies the world's best practice in its rail and rail defect management processes, particularly through continuous improvement in non-destructive testing technology, rail / wheel interface management and elimination of the root causes of rail defects.

Whilst rail defects are an inherent feature of railway operation, IMD places great emphasis on the application of world's best practice in defect management to ensure safe and reliable operation of the railway.