Depot-based CM for rail

Using vibration to identify a deterioration in bearing condition can be used as the basis of a predictive maintenance strategy to improve fleet reliability and reduce part repair/overhaul costs

By **S J Lacey**, consultant and **Richard Poulton**, managing director, both of T&RS Engineering

Today's highly competitive railway industry demands the need to reduce maintenance and operational costs without compromising safety and regularity standards, while at the same time meeting commercial objectives, in particular in-service reliability.

Operational reliability of railway rolling stock, in particular passenger trains, is key in maximising availability. That is highly dependent on the health of the drive system, which in this context includes the traction motor, gearbox and axlebox. Equipment degrades with age and usage.

The commonly-used preventative maintenance strategy involves equipment being overhauled on a planned schedule regardless of the condition of the parts. This normally involves the scheduling of trains into a depot where equipment is inspected, removed and replaced, irrespective of whether it is needed or not. This type of approach may cut down failures before they happen, but it also leads to increased maintenance costs as parts are often replaced or overhauled too frequently. There is also a risk of 'infant mortality' due to human error during the time the train is taken out of service for repair, adjustment or installation of replacement parts. In the rail industry, preventative maintenance is usually limited to inspection and lubrication, which is unlikely to identify a serious deterioration in equipment condition, for example deterioration of the bearings.

If key equipment on the train can be monitored in such a way as to obtain advance warning of a problem, significant costs savings can be obtained by avoiding unnecessary repair work/overhaul and resulting in increased availability of the number of trains in service. Optimising railway vehicle maintenance and overhaul plans to improve availability, reduce maintenance costs and increase reliability is becoming increasingly important.

Rail operators are increasingly adopting remote condition monitoring to monitor railway assets, including equipment condition onboard the train as it operates in service, to predict which parts are likely to fail and when. In this way,

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maintenance can be planned, and there is an opportunity to change only those parts showing signs of deterioration or damage. This means that problems can be detected in advance and maintenance is performed only when needed.

While the use of remote condition monitoring is receiving much attention, these types of systems are often expensive to retrofit. Vibration from the infrastructure (for example, track condition, rail joints), contact conditions at the wheel-rail interface and vehicle dynamics all make vibration data interpretation difficult.

And such interpretations are just as important, if not more so, than collecting data in the first place. A misdiagnosis can lead to the unnecessary removal of trains or rail vehicles from in-service operation, resulting in poor asset availability, lost revenue, high costs and customer dissatisfaction. A loss of confidence in such systems can be just as bad as not having the condition monitoring in the first place, and potentially can be more disruptive to in-service operation.

Instead, T&RS Engineering have been working closely with several train operators to extend maintenance and overhaul intervals, significantly reducing the overall maintenance costs for the train operators. One of the strategies adopts an off-line depot-based approach to condition monitoring using vibration measurements to assess the condition of the key assets (traction motor, gearbox and axlebox) of passenger trains without the need to remove equipment from the bogie. This is achieved by rotating the wheelset on a depot wheel lathe.

ADVANTAGES

The advantages of this type of approach are significant. It can be implemented quickly for a fraction of the cost of remote condition monitoring, without any additions or changes to the bogie; that is, no additional hardware, sensors or cables. Furthermore, the potential benefits of this approach are huge, enabling equipment faults and degradation to be detected at an early stage, maintenance planned, and costs reduced.

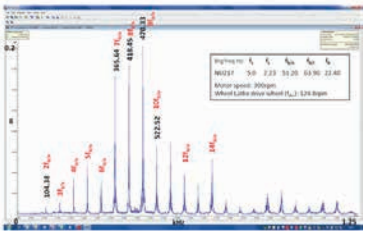
> **"Optimising railway vehicle maintenance and overhaul plans to improve availability, reduce maintenance costs and increase reliability is becoming increasingly important"**

Rolling bearings are a key part of the drive system of rail vehicles, and unexpected failure can result in serious damage to other components and equipment and loss of operation in-service. During operation, equipment reliability is very dependent on the type of bearing selected, correct installation, operation and maintenance.

Depot wheel lathes are used by fleet operators to maintain the condition of the wheel tread, allowing machining of wheel profiles without the need to remove from the vehicle. They generally operate in the range of 60-100m/min, so for a wheel diameter of 800mm this gives an axle speed of between 24 and 40rpm. For a typical reduction gearbox ratio of 4:1, the traction motor speed would therefore be between 96rpm and 160rpm respectively. The big advantage of this type of approach is that it allows the condition of the drive system to be easily assessed while the vehicle is on the wheel lathe for routine wheel turning. This makes the whole process extremely simple and cost-effective without the need for large capital investment, installation of equipment or extensive training. Vibration measurements are obtained at a constant speed and the effects of vehicle dynamics and the rail infrastructure minimised.

All vibration measurements are undertaken with the wheel tread unturned. Unturned wheel treads often have damage which often takes the form of wear and fatigue; consequently, the interaction between the wheel tread and lathe drive wheel can produce significant levels of vibration. While a turned wheel tread would result in significantly improved contact conditions at the wheel tread-drive wheel contact, the interval between wheel turning may be too long for trending of vibration. Therefore, all vibration measurements were carried out with the wheel tread unturned. This has the big advantage that trains can be brought into the depot at an optimum planned interval and the have the condition of the drive system assessed.

T&RS Engineering have been working closely with customers to extend and optimise overhaul intervals from light



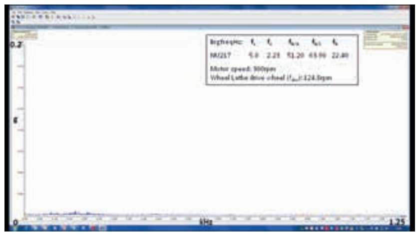


Figure 1, below, displays the extent of vibration in motors. Figure 2a, immediate left, is motor M3's vibration spectrum. Figure 2b, far left, is M2's spectrum. Figure 3, inset, shows bearing raceway pitting

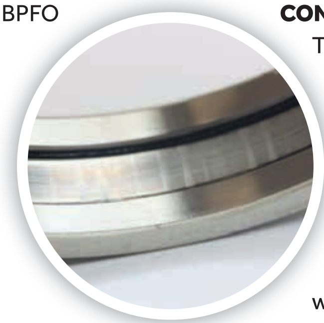
rail (such as London's Docklands Light Railway, pictured) to high-speed train fleets and freight. One example of a light metro system demonstrates how vibration monitoring can be used to detect an early deterioration in motor condition, enabling maintenance to be planned. Although this example shows a traction motor, the method has been extended to the gearbox and axle box.

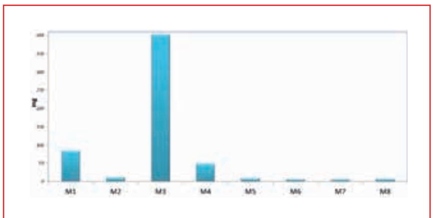
DATA COLLECTION SET-UP

A wheel lathe was used to rotate the wheelset and vibration measurements obtained from the traction motor housing. The wheel tread diameter was 715mm and rotated at nominally 100m/min, giving a wheel rotational speed of 44.5rpm (0.74Hz). The overall reduction ratio of the gearbox was 6.745:1, giving a motor speed of 300rpm (5Hz). The input and output gear mesh frequencies were 125Hz and 52.54Hz respectively.

Vibration measurements obtained at a rotational speed of 300rpm from the NDE of the traction motor housing are shown in Figure 1, below. This shows the characteristic vibration parameter Dsel (0-1kHz) obtained from eight traction motors (M1-M8) on a train. Some of the motors had completed around 530,000 miles. Notice how the traction motor M3 had significantly higher vibration levels than the other motors.

To obtain a more accurate picture of the motor condition, vibration analysis was carried out to give a more detailed diagnosis of what may have deteriorated. Figure 2a, above, shows the vibration spectrum obtained from motor M3, which is dominated by vibration at harmonics of 52.20Hz, which matches closely with the calculated BPFO (ball pass frequency outer raceway) for the motor cylindrical roller bearing of 51.20Hz. A large discrete peak is present at the ninth harmonic of BPFO (9fb/o = 470.33Hz), with high amplitudes of vibration present at the seventh and eighth harmonic of BPFO. In comparison to motor M3, the vibration spectrum from motor M2, Figure 2b, shows no significant vibration related to the BPFO or any other defect frequencies related to the cylindrical roller bearing.





From this, it was concluded that some major damage was present on the bearing outer ring raceway of motor M3, and all four motors (M1 to M4) were removed from the train.

The higher vibration was associated with a significant deterioration in bearing condition; that was used to initiate a replacement before a potentially serious failure occurred in-service.

After the motors had been removed from the bogie, the bearings were examined for signs of wear and deterioration (Figure 3, inset). Damage was present around a 90°-arc of the outer ring raceway, which took the form of surface depressions which could be easily felt with a fingernail. A further detailed analysis of the damage showed the cause to be electrical erosion.

Although some electrical erosion was found on the outer ring raceway of the bearing from motor M2, it was only visual and had not penetrated the surface. No significant surface deterioration had occurred and continued operation would have been possible.

CONCLUSION

The complexity and cost of modern-day trains means that condition monitoring is now becoming a much more cost-effective option. Vibration monitoring is still probably the most widely-used predictive maintenance technique and, with few exceptions, can be applied to a wide variety of equipment.

This example has demonstrated how vibration measurements can be used to effectively assess the condition of traction motors and identify faults before they lead to catastrophic failure resulting in high repair costs, service outage and loss of reputation. This technique has been successfully applied to traction motors from light rail to high-speed trains.

Vibration monitoring allows the condition of equipment to be determined as it operates, and detects those elements which start to show signs of deterioration before they fail, sometimes catastrophically. With this type of approach, unplanned downtime is reduced or eliminated, thereby increasing availability and efficiency.

Depot-based condition monitoring offers the potential to detect equipment faults and deterioration at an early stage, enabling maintenance to be planned and costs reduced. Optimum intervals for scheduling can be achieved, resulting in reduced costs and improved train availability, as well as predicting early failures enabling repairs to be planned.