

# Managing rail degradation on the Malmbanan



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An upgrading programme started in 1998 and due to be completed by 2010 is allowing the introduction of heavier axleloads on Sweden's heavy haul iron ore line, permitting gross train weights to be increased to more than 8 000 tonnes. But the transition requires careful management if degradation of the infrastructure is to be kept under control

**T**HE INFRASTRUCTURE upgrade of the century-old Malmbanan has focused on strengthening bridges, the stability of embankments, and the lengthening of passing sidings. Even so, the higher axleload and gross tonnage moved is expected to increase the rate of track degradation by 20% over the next 10 years.

The higher vertical wheel load has forced changes in maintenance strategy as it directly affects the economic life of rails, sleepers and ballast. Investment in new track components is aimed at raising standards so that less maintenance is required despite the heavier axleload, minimising an expected increase in maintenance and renewal costs.

UIC 60 kg/m rail has now been

installed on the northern part of the Malmbanan. Extra ballast has been added, and the cross-section of embankments has been adjusted to ensure good drainage. An extensive grinding programme was initiated in 1997 to achieve a specified rail profile, and to control surface-initiated rolling contact fatigue cracks.

Today's challenge is to undertake successful renewal of track components, and to design a new concrete sleeper for 30 tonne axleloads. The arctic conditions, with a short summer and a long cold winter, demand good frost isolation for the substructure. Any such system will tend to be compressed and degraded by heavier axles, so new technology needs to be explored in this area too.

In heavy haul applications, rail grinding and lubrication are routinely used as maintenance tools in curves to reduce friction, wear, and RCF. However, proper lubrication can reduce wear rates by a factor of 20 while grinding programmes can also produce significant cost savings for both train operator and infrastructure owner.<sup>1,2</sup>

*The 18 IORE Co-Co electric locos supplied by Bombardier's Kassel plant in 2000-04 are rated at 5.4 MW. The 180 tonne locos operate in pairs hauling trains of 68 wagons to carry 6 600 tonnes of ore per trip, giving a gross train weight of 8 160 tonnes*

On the Malmbanan, a large portion of the operational budget has been spent on the maintenance and replacement of rails, mainly because of rail breakage, RCF and both wheel/rail and track geometry. On a heavy haul line, wheel/rail contact and rail condition are major factors and must be managed correctly.

## Grinding strategy

Banverket's maintenance strategy for the Malmbanan includes yearly maintenance grinding including rail head reprofiling, and extensive rail lubrication in curves below 600 m radius. The main objectives in grinding are reducing surface-initiated RCF and also rail head wear. Grinding is currently being carried out under contract by Speno.

A grinding programme was initiated by Banverket in 1997 between Kiruna

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and the Norwegian border. This was an important step in increasing the axleload to 30 tonnes, and was also one of the main strategies used to prolong the life of existing 50 kg/m rail.

A new target profile was introduced at this time. It is a typical worn rail profile called MB1 (Fig 1) that was expected to conform better to the somewhat hollow worn wheels of the ore cars. At first, the MB1 profile was only ground on the high rail in curves. The standard BV50 profile is still ground on the low rail.

As the contact path in the MB1 is wider than previous standard profiles, the onset of RCF was expected to be delayed. Early results fulfilled these expectations to a great extent; the

decrease in RCF defects like head checking, spalling and shelling was quite pronounced.

Fig 2 shows the consequent reduction in grinding and rail renewal costs, which is significant when the years before and after the initiation of the grinding programme are compared.

The payback of the cost for rail grinding was very rapid. Over the first two years of the rail grinding programme, the total cost of grinding plus rail replacement was reduced by almost 40%, while both the rail and track quality generally improved immensely.

However, after several years of grinding the track may degrade, and an

*LKAB has signed a framework contract with K Industrier for the supply of 680 new iron ore wagons, with firm orders for 222. After a year's testing with a 70-strong pre-series build, regular deliveries began in December 2006 and are due to ramp up to five wagons per week in 2008*

accumulated volume of rail will probably need to be replaced. It is likely that the future cost level will be slightly higher than values shown in Fig 2.

Today, Banverket is convinced that the strategic rail maintenance programme has helped spread renewal costs. Optimising the grinding process and further development of the rail profile are possible steps towards an even longer rail life.

Neither the grinding campaigns, nor objective measurements to increase wheel life using a new rail profile, seemed to affect the total wheel/rail system in a negative way. Although it may not be possible to reproduce such savings everywhere that RCF damage occurs, some lessons from the test are of general relevance.

Today curves on the Malmbanan southern route are ground every year, which equates to 26 million gross tonnes including the mass of locomotives and empty trains. Tangent track is ground every third year after about 80 million tonnes.

Some curves might need to be ground more frequently. As grinding on the Malmbanan takes place in the summer to autumn period, grinding at more frequent intervals might require an additional machine.

Evaluation of the MB1 wear profile has been followed by more optimised target profiles on the Malmbanan. MB3 is a further development characterised by a slightly modified gauge corner shape, resulting in an optimised gauge corner relief.

Switches are also ground in the same way as plain track. The presence of corrugations, wear, RCF defects and out-of-geometry rail head are parameters which decide when and how to grind a specific switch.

On the Malmbanan almost every switch is ground annually, at least the rails in the main track and most often both the main and diverging rails. At the beginning, the target profile was Banverket's standard BV50 with an inclination of 1:30 instead of the vertical profile with which the switches are installed. However, with this standard profile the result was the same as in plain track, unacceptable wear and the presence of RCF defects, so the MB4 target profile was tried. This profile also has gauge corner relief but not to the same extent as MB1.

The reason for not grinding directly to MB1 was mainly due to the reduced production capacity of the switch grinder. To grind MB1 from a deformed profile would have been very time-consuming. Grinding in steps was adopted for this reason. However, in

## IHHA comes to Kiruna

THE INTERNATIONAL Heavy Haul Association's Specialist Technical Session on June 11-13 is being hosted in northern Sweden by LKAB, which produces and transports iron ore and pellets to the ports of Narvik and Luleå, and Banverket, the national rail infrastructure manager responsible for the track that carries LKAB's trains.

The focus of technical interest in Kiruna for IHHA delegates will be the long-established heavy haul operation that links iron ore mines around 200 km from the sea to the ice-free port of Narvik in Norway, and also in the opposite direction to Luleå at the head of the Gulf of Bothnia. The railway between the two ports is 473 km long, and apart from 39 km in Norway, the line in Sweden for which Banverket is responsible is known as the Malmbanan.

This single-track line was originally constructed between 1898 and 1902 to standards that would not be considered appropriate for heavy haul as the term is used today. There are 25 tunnels and 125 bridges in rugged terrain requiring numerous sharp curves and steep gradients, and the axleload when it opened was only 14 tonnes.

Subsequent improvements include electrification at 15 kV 16 $\frac{2}{3}$  Hz completed in 1915. After the pioneering separation in 1988 of rail infrastructure from train operations in Sweden, LKAB sought to control directly the transport by rail of its principal product. This was achieved by setting up a subsidiary train operating company in Sweden called Malmtrafik i Kiruna AB (MTAB).

In 1996 Norway followed Sweden's example and established Jernbaneverket to own and manage the national rail infrastructure, including the isolated line to Narvik. Iron ore trains to Narvik are now managed within Norway by Malmtrafik AS, a subsidiary of MTAB.

LKAB had two objectives: one was to control the cost of the operation, and the other was to develop the Malmbanan into an efficient heavy haul railway, raising the axleload from 25 to 30 tonnes, procuring new wagons and locomotives, and operating longer and heavier trains to improve productivity. Loading and unloading arrangements had to be replaced by new facilities.

Banverket's task was to meet LKAB's future requirements. Increasing capacity for higher traffic and heavier axleloads takes time, so planning and construction started well in advance of introduction. This work started in 1998, and the project will be completed in 2010.

For LKAB, the benefit from 30 tonne axleloads that became available to Luleå on October 1 2000 is that the payload per car is increased by 25% from 80 to 100 tonnes. The extension of sidings on the southern section of the Malmbanan to accept 750 m long trains means that the standard train formation to Luleå is now 68 cars, rather than 52 cars still being hauled to Narvik today. Together these changes allow the gross train weight to be increased from 5200 to 8160 tonnes.

The upgrade of the line to Narvik is still in progress and will be completed by 2010. ■

2007 most of the switches will be ground to the MB1 target profile.

## Lubrication pays off

Three methods of lubrication are widely used today in heavy haul lines: wayside, on-board or hi-rail. On Malmbanan both wayside and on-board lubrication are applied to reduce gauge face wear of rails and flange wear of wheels. Based on the failure history of lubricators, it is essential that Banverket establishes a strictly enforced maintenance routine for lubricators to ensure reliability and safety.

When lubricators need to be removed for preventive maintenance activities such as rail grinding and tamping, they are reinstated immediately after these operations to avoid excessive wear. Lubricators need to be adjusted for seasonal changes in ambient temperature to compensate for the viscosity change of the lubricant.

An analysis of lubrication effectiveness on Malmbanan has been undertaken as a PhD thesis. As well as curves where rail wear was occurring, it was also applied where there was evidence of flange contact. Results from that project showed the importance of allocating enough resources for maintenance of those lubricators once installed. It is also important to consider the impact of weather changes during the operation.

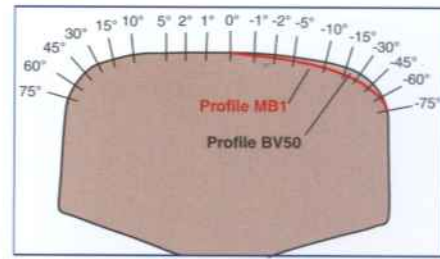
Maintenance of wayside lubricators involves replacing spare parts, refilling grease tanks, cleaning contaminated ballast, changing the position of lubricator nozzles and adjusting the height of nozzles and grease distribution units to achieve proper lubrication.

## Malmbanan rolling stock

Currently trains are a mixture of DM3 electric locos hauling 52 ore cars with a 25 tonne axleload built between 1960 and 1974, and the more modern IORE locos hauling 68 cars with a 30 tonne axleload.

At the moment, the 217 km southern route between MalMBERGET mine and Luleå port has changed over completely

Fig 1. The MB1 target profile compared to the Swedish BV50 standard profile



to the new 30 tonne format.

Two IORE train sets have replaced five of the old DM3 sets. This has become possible not only due to the 65% increase in payload for the new trains, 6 600 compared to 4 000 net tonnes of ore, but also to the fact that one IORE train makes two complete round trips per day instead of 1-3 trips.

The speed has been raised by 10 km/h from 50 to 60 km/h in the loaded direction, and from 60 to 70 km/h when empty, but the real improvement was in the terminal and the harbour. Electrification of the loading and unloading yards and new, more efficient, loading and unloading equipment cut the cycle time to make possible two round trips per day, despite the greater train length. As a bonus the terminal locos could be eliminated since the IORE loco remains attached to the trainset during both loading and unloading.

Important factors that ensure double trips are achieved reliably are that IORE trains get a high priority on the line, and that enough passing sidings have been extended for 750 m trains. A delay of around 1 h means that the train misses its path and LKAB loses 6 600 tonnes of transport capacity. This places stringent requirements on the reliability and maintainability of the rolling stock, loading and unloading facilities as well as on the infrastructure managed by Banverket.

The same work that was carried out on the southern route is now in progress on the northern route and is scheduled to be completed by 2010. It includes a new electrified loading yard and station in Kiruna and a new harbour in Narvik, together with the delivery of more new ore cars and locos.

## Future expansion

For the last 20 years the objective has been clear: the total transport cost must go down. One powerful way to save transport costs on existing assets is to increase the axleload even further.

Last year LKAB ordered a new fleet of cars that will be able to carry even heavier loads, and hence we might

expect an increase in axleload from 30 to 32.5 tonnes quite soon. This will also increase gross train weight from 11.7 to 12.6 tonne/m, which affects bridges in particular. The gross train

## Faire face à la dégradation de la voie du Malmbanan

L'achèvement de l'amélioration majeure de la ligne vieille d'un siècle qui achemine le minerai de fer vers les ports de Narvik, en Norvège, et de Luleå, en Suède, est attendue pour 2010. Les voies de garage en ligne vont être allongées pour accueillir des trains de 750 m de longueur et la charge par essieu va être augmentée jusqu'à 30 tonnes, les 32.5 tonnes pouvant être atteintes bientôt, ce qui rendra possible la circulation de trains de 9 200 tonnes brutes. La durée de vie des rails va être allongée grâce à une attention accrue du meulage des profils et à un graissage intensif dans les courbes de rayons inférieurs à 600 m. Des nouvelles technologies sont également explorées afin d'isoler l'infrastructure des effets du gel

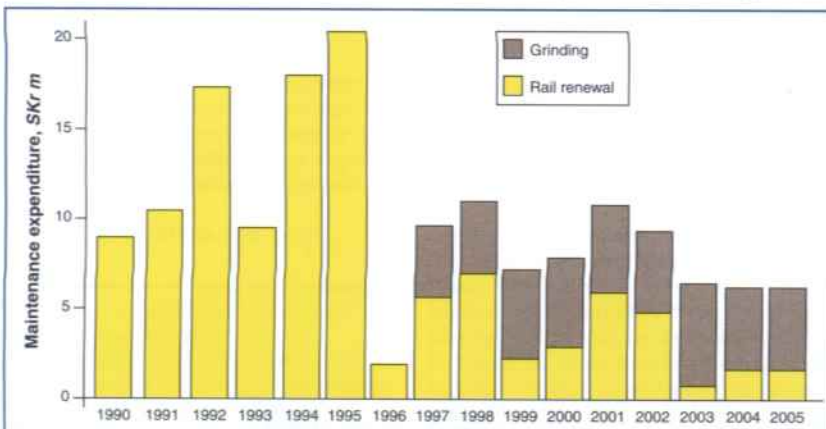
## Den Verschleiss des Gleises auf der Malmbanan in Griff bekommen

Ein wesentlicher Ausbau der ein Jahrhundert alten Bahn, welche Eisenerz in die Häfen von Narvik in Norwegen und Luleå in Schweden transportiert wird 2010 abgeschlossen sein. Ausweichstellen werden verlängert, damit 750 m lange Züge aufgenommen werden können, und die Achslast wird auf 30 Tonnen (und demnächst 32.5 Tonnen) erhöht, was es erlauben würde, Züge von 9 200 Bruttotonnen zu betreiben. Die Lebensdauer der Schienen wird durch eine genaue Kontrolle des Profils und intensive Schmierung in Kurven mit unter 600 m Radius verlängert. Neue Technologien zur Isolation des Unterbaus gegen Frost werden untersucht

## Gestión de la degradación del carril en el Malmbanan

Se espera que en 2010 finalice una importante renovación del ferrocarril centenario que transporta mineral de hierro a los puertos de Narvik en Noruega y Luleå en Suecia. Se están ampliando los apartaderos para admitir trenes de 750 m de longitud y se está aumentando la carga por eje a 30 toneladas. Además, cabe la posibilidad de que se alcancen en breve las 32.5 toneladas que permitirían la circulación de trenes de 9 200 toneladas brutas. La duración de los carriles va en aumento debido a la rigurosa atención prestada al amolado de los perfiles y a la intensiva lubricación de las curvas con un radio inferior a 600 m. Se está explorando una nueva tecnología para aislar la infraestructura del suelo helado

Fig 2. This financial evaluation of the impact of grinding on rail renewals demonstrates that the overall cost has reduced substantially from 1997 onwards





LKAB's Head-of Technology Thomas Nordmark inspects one of the newly-delivered ore wagons being built in Malmö by K Industrier

Photo: Kjell Törnä

With this rather long cycle time per upgrade step, both LKAB and Banverket need to set the long-term strategic vision to axleloads even higher than 32.5 tonnes. In that way, the organisations responsible for both infrastructure and rolling stock can plan and invest in new technology to permit higher loads.

If this is done in small steps every time we change or choose a new component, in the long run we might have a transport system that manages higher axleloads than 32.5 tonnes.

New challenges have to be dealt with in the years to come. Today, LKAB is dispatching each year 16 million tonnes of pellets and ore to Narvik, and a further 8 million tonnes to Luleå, together with 4.5 million tonnes of ore moving from the mine in Kiruna to the pellet plant at Svappavaara. In addition, the empty trains returning from the ports are used to convey fuel and additives for the pelleting process (coal, olivine, calcium) totalling 5000 tonnes. The line is carrying a total of 29 million tonnes of freight, which is expected to grow to 32 million tonnes in the near future.

The world market for iron ore is booming. Increasing traffic on the

Malmabanan means the continuation of work to optimise wheel and rail profiles. Testing of modified profiles will be monitored closely, and depending on the results, the grinding, wheel profile and lubrication strategy may be changed. Other areas for improvement lie in the field of conditioning monitoring and improved maintenance of both rolling stock and infrastructure.

Some early steps and a pilot project have also been conducted to automate the rail transport process. The philosophy here is to see trains as a part of a process that can be monitored, controlled and optimised like the rest of the mining operations.

A project called Computer-Aided Train Operation has shown that both the capacity of this single track and energy consumed can be improved substantially. Implementation of a system like this could also open the door for running the ore trains without a timetable or train plans, increasing capacity even further. ■

weight will then increase from 8 520 to 9 200 tonnes.

The last two upgrades each took us 10 years to fully adopt new technology for traction power systems, signalling and track components. We also had to consolidate the substructure for heavier loads, and complete the necessary investments in new infrastructure components, new maintenance strategies and safety procedures.

## References

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