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Alleviation of rolling contact fatigue on Sweden's heavy haul railway

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Abstract

A test has been undertaken on Sweden's Malmbanan, or iron ore railway, to reduce rolling contact fatigue (RCF) damage by developing a preventative maintenance regime involving routine grinding of the rails. In just the first 2 years of the test, the total cost of grinding plus rail replacements was reduced by almost 40%, while both the rail and track quality generally improved immensely. Although it may not be possible to reproduce such savings everywhere that RCF damage occurs, some lessons from the test are of general relevance. In particular, the development of even existing surface-initiated defects can effectively be halted by grinding and thereafter regularly reinstating, a profile which substantially removes loading from those cracks. In this test, the rate of metal removal by grinding was about 0.2 mm per 25 MGT. Methods were also developed for objectively monitoring the transverse and longitudinal profiles of the ground rail, and the depth of metal removed from the rail, i.e. the overall grinding "quality". It would appear that the desired benefits of grinding can be obtained even if deviations of the transverse profile from a desired reference profile exceed specified limits over a significant fraction of the track.

Keywords: Rolling contact fatigue; Routine grinding; Iron ore railway

1. Introduction

The "Malmbanan" is a heavy haul railway which carries iron ore from mines in the far north of Sweden, beyond the Arctic Circle, to ports and steel works on the coast in Norway and Sweden. It is essentially a single line with several passing loops, and was built almost 80 years ago specifically for the purpose of carrying iron ore. The line predated the road link across northern Sweden by several decades. The traffic is primarily in unit trains, with electric locomotives pulling a trainload of wagons that run on fairly conventional three-piece bogies with 25 tonne axle loads. There is typically about 23 MGT of traffic per annum on a line that is fairly highly curved, with a typical curve radius of 400 m. The main part of the Malmbanan, on which most of the work described here has been undertaken, is the line from the mine at Kiruna to the Norwegian port at Narvik. This is about 140 km long track from Kiruna to the Swedish/Norwegian border. There is a steady climb towards the border, followed by a rapid descent into Narvik. There are lines to other mines and also from Kiruna south towards the Swedish port and steel mill at Lulea.

The track itself is almost entirely BV50 section (50 kg/m) rail laid on timber sleepers with baseplates, with an elastomeric railpad. There are some sections of track (mainly in tunnels) with UIC60 rail laid on concrete sleepers. Almost all rail is to UIC 1100 specification: a relatively high strength alloy rail. The line south of Kiruna is almost entirely UIC60 rail, to UIC900 specification, laid on concrete sleepers.

For many years, the Malmbanan has suffered from problems of severe rolling contact fatigue (RCF): spalling, shelling and head checking (Figs. 1 and 2). RCF damage occurred primarily in switches and on the high rail in curves. South of Kiruna the rail was ground infrequently. This line suffered from corrugation and severe gauge-face wear, as well as RCF. The rail damage and rail breaks (which were more frequent on the line north of Kiruna) were a cause of considerable concern, not least because the line was ground every year or two (i.e. at an interval of about 23–46 MGT) and the received wisdom was that grinding should alleviate such problems. Yet, despite this relatively frequent grinding (by European standards) almost 10% of rail on the line plus several switches were renewed every year.

Considerable light was cast on this anomalous behaviour by a joint investigation between Banverket (BV, the Swedish National Railway Administration) and Loram Rail Ltd. (their rail grinding contractor at that time) that started in 1995. The original purpose of the test was to study the effect on

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Fig. 1. Example of severe localised spalling on Malmbanan.

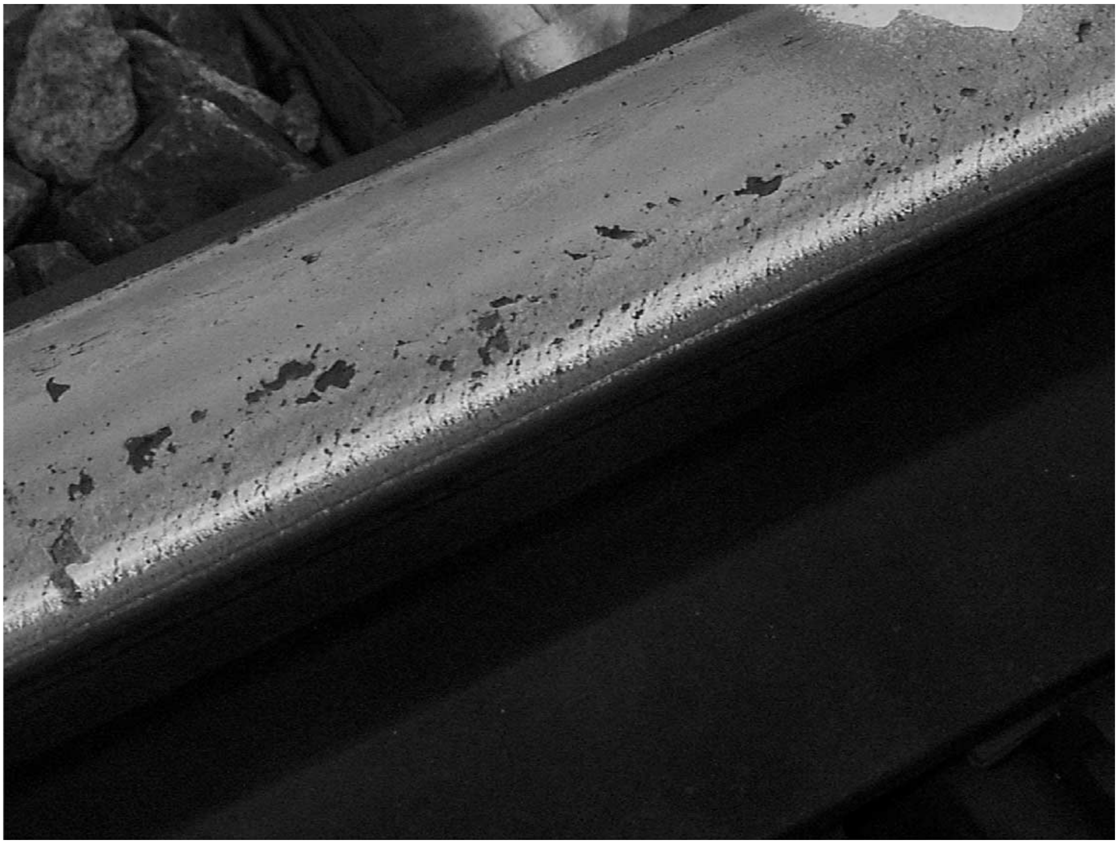


Fig. 2. Distributed spalling and headchecks.

RCF of the tolerance to which the transverse profile was ground [1]. This was a question of some contention at the time in Europe, where suggestions had even been made that rail should be ground to a tolerance of 0.050 mm. It is somewhat questionable whether rail could reliably be ground to such a tolerance let alone measured. It was, nevertheless, clear from the test that was begun in 1995 that the transverse rail profile that was specified was fundamentally incompatible with the prevailing wheel profile, particularly on the high rail. Moreover, in such circumstances the tolerance to which grinding had been undertaken was of no importance. It was accordingly recommended that a different transverse rail profile should be designed and adopted. It has not been possible significantly to influence the vehicles, the wheels on which tend to be hollow, as these are owned by a different company. As a separate and independent project, the train operating company is now testing vehicles with self-steering bogies, with which its wagon fleet may be replaced.

In 1997, a collaborative test began between the Banverket (BV) and Loram Rail Ltd. (later Schweerbau UK Ltd., who took over Loram's operations in Europe from the beginning of 1999). The principal objective of the test was to reduce RCF, and in particular replacements of rail and of switch and crossing work (S&C). At the time of writing, the test has been in progress for 3 years. Over this time the BV's purchases of rail and switches for the Malmbanan have decreased significantly (Section 6).

This paper describes what was done, how grinding was monitored and some detail of what has been achieved both technically and with regard to savings in costs.

2. The Malmbanan test

The effectiveness of grinding as a treatment of RCF problems has been widely demonstrated over a period of almost 20 years [2,3]. The critical reasons for the success of the treatment in alleviating RCF problems around the gauge corner, particularly on the high rail in curves, are

- a transverse profile is ground which partly "unloads" the cracked area of the rail and, thereby, removes the stresses which are causing any cracks to propagate,
- regular metal removal from the rail, particularly in the cracked area, so that embryonic RCF cracks are removed at an early stage.

In the present case, rail grinding was accepted by the owners of the track, the BV, as a critical component of their strategy for reducing costs on this line. The BV's goal in this respect was ultimately to achieve a so-called "preventative grinding" regime for the line, in which relatively little grinding would be undertaken relatively frequently. This grinding would be undertaken in such a way that problems would essentially be prevented rather than treated, or corrected, after they had occurred.

Nature on this line, north of the Arctic Circle, imposes its own constraints: the "window" for essentially all track maintenance is a mere few months in the summer before the snows return and after they have thawed. In the winter months, temperatures of −40 °C and below make it difficult for any fluid to flow, whether to lubricate the wheel/rail interface or to power a grinding train. Although there was already relatively frequent track-based lubrication on this line, this was further improved at the start of the test to ensure that there were lubricators at the entry to most of the curves of less than 1000 m radius: there are about 30 clicomatic lubricators in the 140 km track on the Swedish side of the border. Fortunately, there are also wheel flange lubricators on the locomotives, which should be less limited by the weather than the track-based lubricators. The clicomatic lubricators spray a jet of lubricant onto the gauge-face of the rail when the device senses vibration arising from a train, provided that the lubricant is sufficiently warm to flow!

The seasons also limit the grinding frequency to no more than about once per year, i.e. an interval of about 23 MGT. This is almost three times as long as the interval which has previously been recommended for preventative grinding of high rails in severe curves and much the same as the recommended interval for preventative grinding of tangent track [4].

While it was possible to adopt the principle of what had been done elsewhere to establish a preventative grinding, or more broadly a preventative maintenance regime, on the track, local factors made it necessary to apply these extremely flexibly. Local factors included not only weather and its attendant constraints, but also traffic and initial condition of the rail. The particular technical issues to be addressed in this test were accordingly.

- What profile(s) should be ground on the track in a preventative maintenance regime?
- To what tolerances should these profiles be ground?
- How frequently should grinding be undertaken? More directly, would grinding with a 23 MGT interval be satisfactory in severe curves? If so, what interval would be satisfactory for tangent track and for less severe curves?
- How much metal should be removed on each occasion?
- How should the transition be made from the existing to the new situation?

Both the BV and Loram/Schweerbau were keen to monitor this test closely. Because of the importance of the monitoring component of the test, this is treated separately in Section 5.

The standard profile for the high rail in curves was the so-called "Malmbanan" or "MB" profile. This is essentially the profile of a heavily worn high rail, found from measurements made in track, with addition of significant relief of the field side of the rail to avoid contact with the false flange of the extremely hollow wheels. This profile was ground on the high rail everywhere except in a short test section, where a profile with slightly more relief of the gauge corner was ground. Towards the northern end of the line the MB profile was ground also on the low rail and in curves. Our experience on the Malmbanan and elsewhere is that the steady-state worn high rail profile varies very little along a line that carries the same traffic, although it may differ considerably from one line to another. It is usually rather inappropriate to re-establish an artificial “reference” profile on such rail when this differs significantly from the worn profile as the reference profile inevitably increases contact stresses and wear. This problem is exacerbated on hard rail, whose profile changes relatively slowly.

Otherwise on the Malmbanan, the standard profile for the low rail and for tangent is a modified BV50 profile with the BV’s standard inclination of 1:30. The principal modification is for there to be heavy relief of the field side of the rail, again to avoid the false flange on the wheels.

Some consideration was initially given to grinding out the existing surface-breaking RCF cracks. However, this was not done for three reasons in particular.

- There was no means of knowing the depth of existing cracks with sufficient confidence to ensure that all cracks would indeed be ground out. For the same reason it would have been impractical to grind until there were no more detectable cracks. It is indeed still the case that satisfactory equipment is not yet commercially available for this purpose.
- Even if the crack depth were known, it was clear from the existing spalling on the line that it would have been necessary either to remove several millimetres of metal in the gauge corner and shoulder areas of the rail (Figs. 1 and 2), or to rerail much of the track. In either case, a great deal of grinding would have been required (if only, in the latter case, to establish the desired profiles).
- Intuitively, there was good reason to believe that if the areas with existing cracks were *un*loaded sufficiently, then the mechanism causing cracks to propagate would be greatly weakened. This mechanism is most likely to be hydrostatic compression of water and/or lubricant at the crack tip, combined with shear of the crack faces.

To achieve the desired objectives in the simplest possible manner, the tolerance on transverse profile of the high rail for the initial grinding campaign in 1997 was prescribed as +0/−1.0 mm. This ensured that the ground profile was always “under” the worn profile in the critical, cracked region. In the second and third years of the test, the tolerance was taken to be +0.3/−0.7 mm. There is general agreement that the high rail now *looks* in rather worse shape than it did after the initial grinding campaign. Although there is no quantifiable corroboration for this view, a return to a tolerance of +0/−1.0 mm is nevertheless likely in future years. For the low rail and on tangent track, the specified tolerance has been +/−0.5 mm.

In addition to achieving the transverse profile to the stated tolerances, a minimum metal removal of 0.2 mm was agreed. Although there has been some ambiguity in deciding for how much of the railhead it should be possible to show this minimum requirement, there is reasonable consensus that at least 0.2 mm should be removed between the 0 and 45° points in each grinding campaign, i.e. approximately every 23 MGT. This is again lower than has previously been recommended for preventative grinding of the high rail in tight curves, for which one recommendation has been 0.2 mm every 5–8 MGT [4].

In 1997 and 1998, almost all of the 140 km line from Kiruna to the Norwegian border was ground. In 1999, about 5 km of the tangent track was left unground to see if any defects would develop. At least the same amount of tangent track will remain unground in 2000, as a test to determine empirically how frequently the tangent must be ground to avoid RCF. In the meantime, the early success of the test has led to the extension of grinding over not only the full extent of the BV’s iron ore lines, but also into Norway.

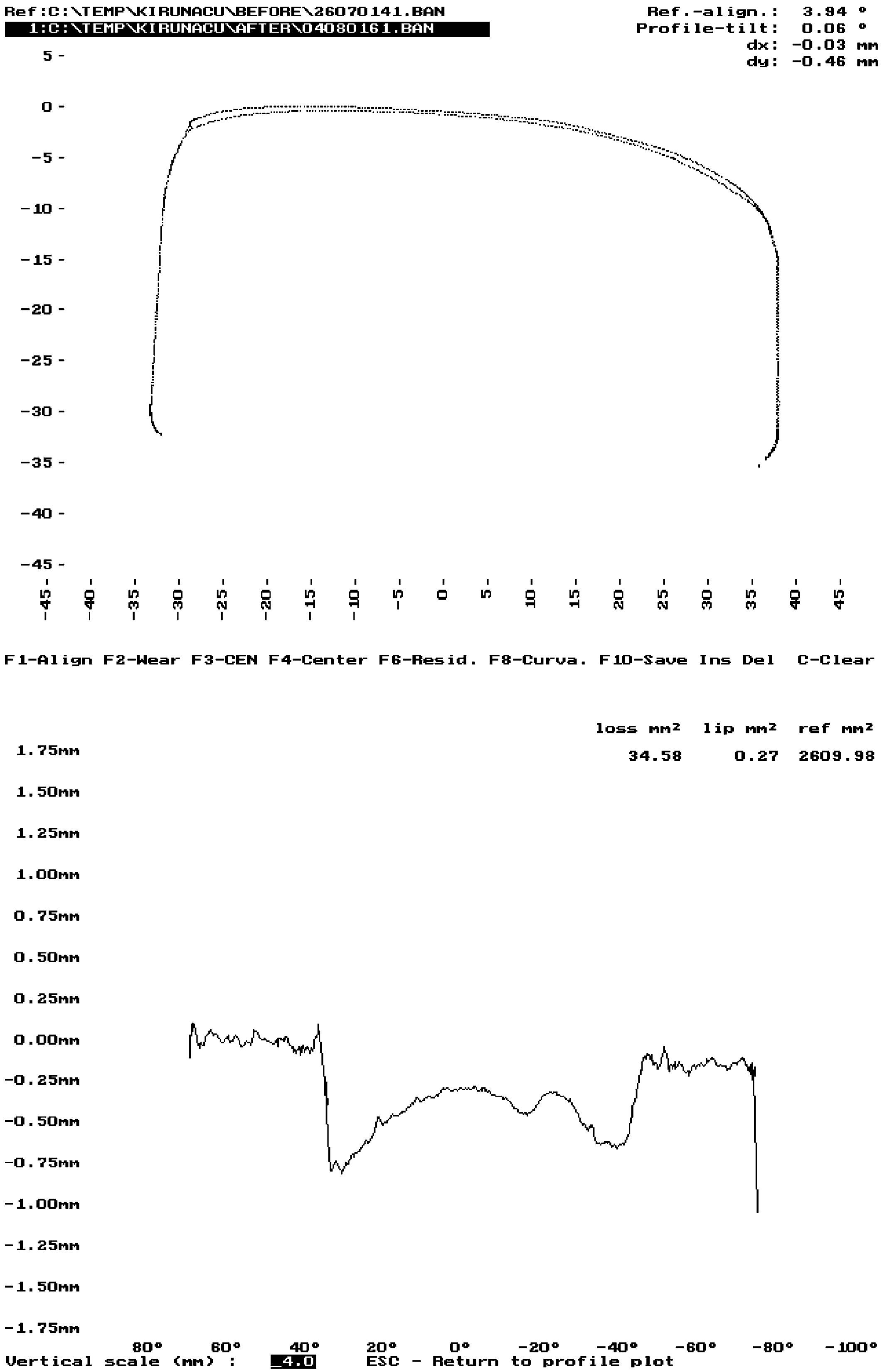
3. Results of the test

The most obvious superficial result of the test has been a clear improvement in the general railhead condition: spalling and gauge corner cracking are no longer of epidemic proportions throughout the line, and are now indeed almost eliminated. Inevitably the greatest improvement appeared to be in the first year. While the rail has generally remained in extremely good condition, some of those involved in the test feel that there has been a slight regression since changing the tolerance on the high rail to +0.3/−0.7 mm, thereby allowing some areas of the gauge corner and shoulder to rise above the worn reference profile (Section 2). Although the experienced eye can be an extremely sensitive instrument, there is no concrete evidence from conventional instruments that the rail condition has in fact deteriorated.

There has also been a substantial financial benefit (Section 6). The total cost of rail and grinding on this line was more than 11 million Swedish crowns (SEK) in 1997 (about US$ 1.5 million), and was less than 7 million SEK in 1997. While it may be difficult to sustain replacements at quite such a low level, there is every reason to believe that the bulk of the savings will be retained. A reasonable goal would be to aim for no more than 1% of the rail to be replaced per annum. This would be in accordance with current practice on CP Rail, where preventative maintenance of the rails is well advanced [6].

4. Operational issues

At the start of the test in 1997, there was a desire to put the MB profile on all rails: high, low and tangent. However, grinding to do this was extremely slow since more than 1 mm of metal had to be removed from the gauge corner and shoulder areas of the low rail and in tangent track where the rail was not initially worn to this profile. As a result, for



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                                                                dy: -0.46 mm

                                                 loss mm²  lip mm²  ref mm²
                                                  34.58      0.27   2609.98

Vertical scale (mm) :  4.0
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Fig. 3. Superposition of measured profiles before and after grinding, showing metal removed by grinding.

the later grinding during the first year, the modified BV50 profile was ground on tangent and on the low rail. Experience has shown that this does not change greatly in time, nor have there been significant problems on the low rail and in tangent. It would accordingly appear that this is a reasonable profile for these rails. In the second and third years of the test, the low rails and tangent were ground to the profiles established in the first year of the test. The high rail profile now also changes relatively little from the MB profile.

These findings are consistent with findings from the 1995 test, which indicated that the low rail profile changed relatively little from that which was ground, regardless of the tolerance to which the reference BV50 profile had then been ground [1]. The high rail profile did, however, change significantly from the reference BV50 profile in that earlier test.

The fact that there is now relatively little change in the profiles of the rails indicates that one condition for "preventative grinding" of the rails is now established. Grinding can now be undertaken primarily to restore the profile, which now changes only slightly from the desired profile, and to remove a fairly shallow depth of embryonic cracks. Miniprof measurements of a point along a high rail, before and after grinding, are superposed in Fig. 3, showing where metal has been removed across the rail. This is evidently fairly uniform across the railhead, with slightly more removed on the field side of the rail to maintain field relief and around the gauge corner to maintain the profile within the tolerance range (in this case) of +0.3/−0.7 mm. Metal has been ground off across to about 50° in Miniprof angles, which is beyond the area in which head checking and spalling used to occur (Figs. 1 and 2). In service, metal tends to be worn off sufficiently quickly at deeper angles around the gauge-face by the wheels themselves. If the tolerance range were returned in future years to +0/−1.0 mm, slightly more metal would typically be removed around the gauge corner than is shown here.

Now that the profiles of both rails change little from one year to the next, the required metal removal and re-profiling can be obtained with four–five passes of a Schweerbau grinding train with 32 grinding modules, each of 20HP. Where new rail has been installed, more passes are required to obtain the correct initial profile.

5. Monitoring of the test and quality assurance

Both client and contractor wanted to monitor this test closely. One reason for the monitoring was to ensure that there was sufficient understanding of what had been done for the recipe to be modified, if required, or adapted for use elsewhere, particularly on other parts of the Malmbanan such as that south of Kiruna towards the Swedish port of Lulea. A second reason was to ensure that the requirements that had been agreed with regard to profile, metal removal, etc. had in fact been achieved, and could be monitored by either party. This is essentially a quality assurance (QA) function. Two particularly novel features of the QA procedure (at least with regard to rail grinding) were:

- an explicit acceptance that not all measurements would show that the track had been ground to whatever "standard" was decided, and also, because the accuracy of even the best equipment available is similar to the tolerances typically demanded in European grinding specifications, the fraction of track actually within tolerance might be greater or less than that shown by these measurements;
- the equipment used for QA measurements should be available to both client and contractor so that both parties could take measurements, use data collected by the other, or even, in exceptional circumstances, check measurements taken by the other (to date this has been done only to ensure compatibility of results).

During the test, the "Miniprof" has been used for measurements of transverse profile. These measurements have in turn been used to calculate the metal removal. The corrugation analysis trolley, developed by Loram but now available commercially, was used for longitudinal profile measurements [5]. A Mitutoyo surftest 301 or 201 was used to measure surface roughness. The instruments have some acceptance as "reference" equipment for the purpose. In particular, the "accuracy" of the profile measuring equipment (not simply repeatability) has been established by reference to a higher standard. Any other instruments of similar accuracy could in principle be used for the QA function. This paper concentrates on the transverse profile and metal removal since it is these that most influence the RCF behaviour.

It is common in Europe for grinding specifications to be extremely detailed and (apparently) demanding. For example, it is not unusual for a limit of 0.010 mm to be demanded for the depth of residual short wavelength corrugation (typically the 30–100 mm wavelength range). However, there is no statement of essential things such as how is this measured? Indeed, does equipment exist of the required accuracy and reliability? Where on a rail should a measurement be taken? There is an implication that all measurements (whether accurate or not) should show that the requirements have been met. Is this indeed the case, or can some measurements be out of specification? If so, what fraction of non-compliant measurements is acceptable? Can satisfactory measurements be taken from a train to demonstrate that a specification has been met? The QA procedure agreed for the Malmbanan addresses many of these points, and has in turn helped to mould the development of a provisional European Standard (prEN) for rail grinding.[1] While some of the principles are of general relevance, the detailed manual

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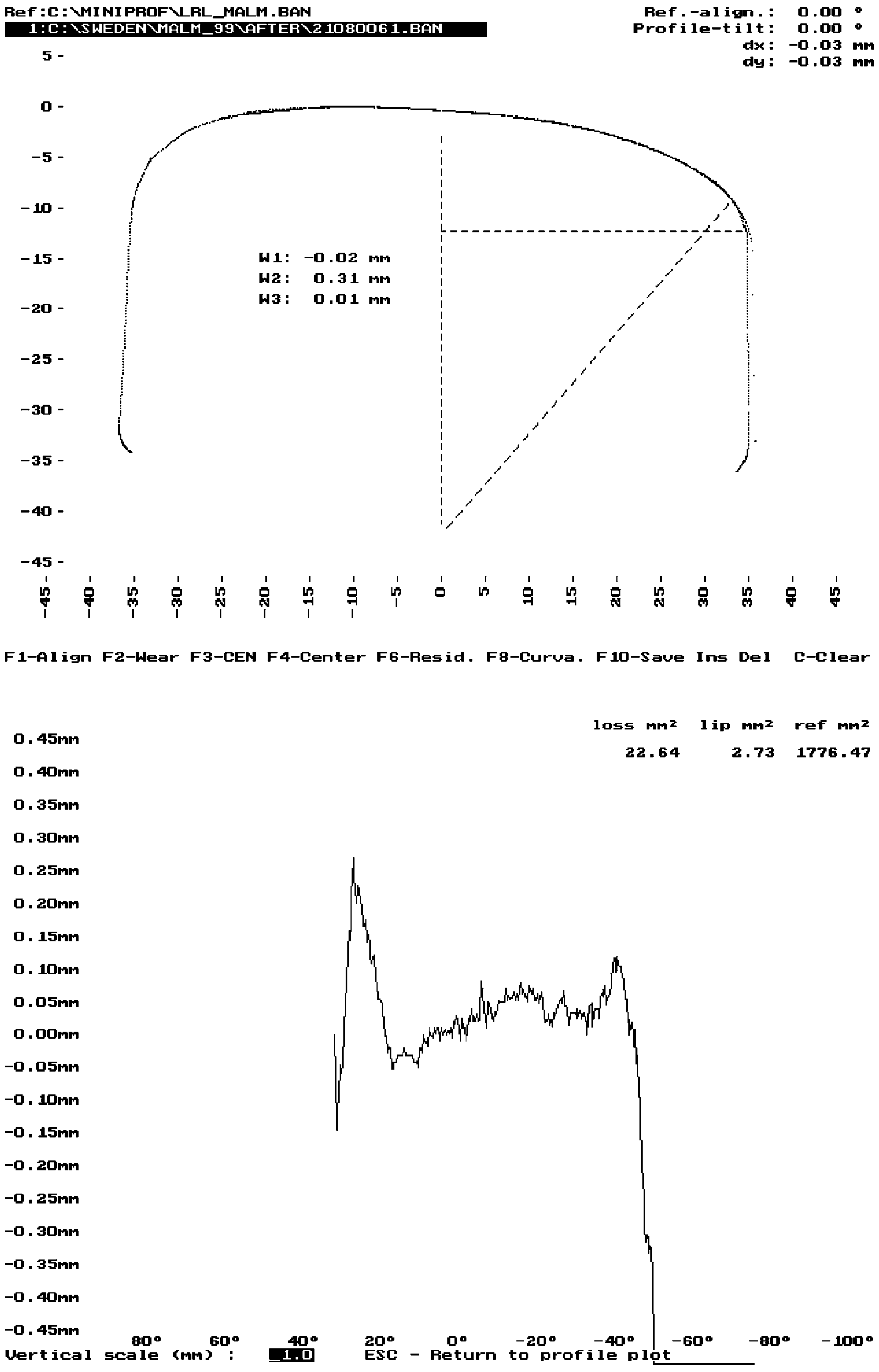
[1] The specifications under which Loram and Schweerbau have worked on London underground and that used for monitoring Loram's grinding work on the ARTC in Australia, both contain many similar features, to give an objective quantification of grinding "quality" that can be monitored by both client and contractor.



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                                                  dy: -0.03 mm

W1: -0.02 mm
W2:  0.31 mm
W3:  0.01 mm

                                        loss mm²   lip mm²   ref mm²
                                          22.64      2.73   1776.47
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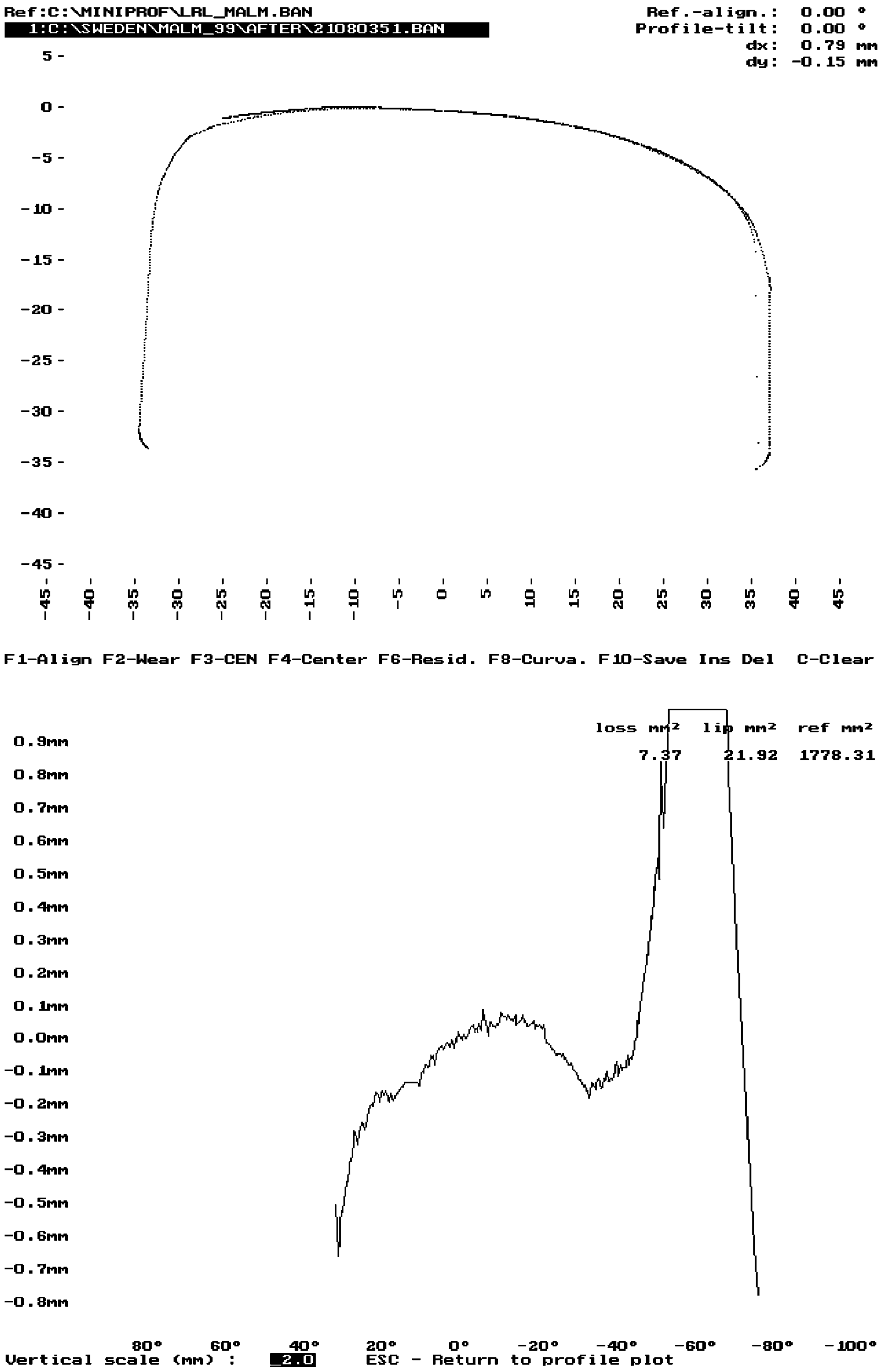
Fig. 4. Correlation of reference profile and low rail profile (ground to MB profile with ±0.5 mm tolerance).

monitoring undertaken here is clearly relevant only in exceptional circumstances, such as for a test.

To provide the relevant test data, a total of 69 measuring positions were established on each of the rails over the 140 km line from Kiruna to the border with Norway. Fifty-nine of these points were in curves, and the remaining 10 in tangent track. Measurements of transverse and longitudinal profiles and surface roughness have been taken at these points throughout the test. Initially, transverse profile measurements were taken at quarterly intervals, insofar as the weather allowed. Routine measurements now are not taken more often than before and after grinding.



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                                       Profile-tilt:  0.00 °
                                                 dx:  0.79 mm
                                                 dy: -0.15 mm
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loss mm²  lip mm²  ref mm²
    7.37    21.92  1778.31
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Vertical scale (mm) : 2.0        ESC - Return to profile plot
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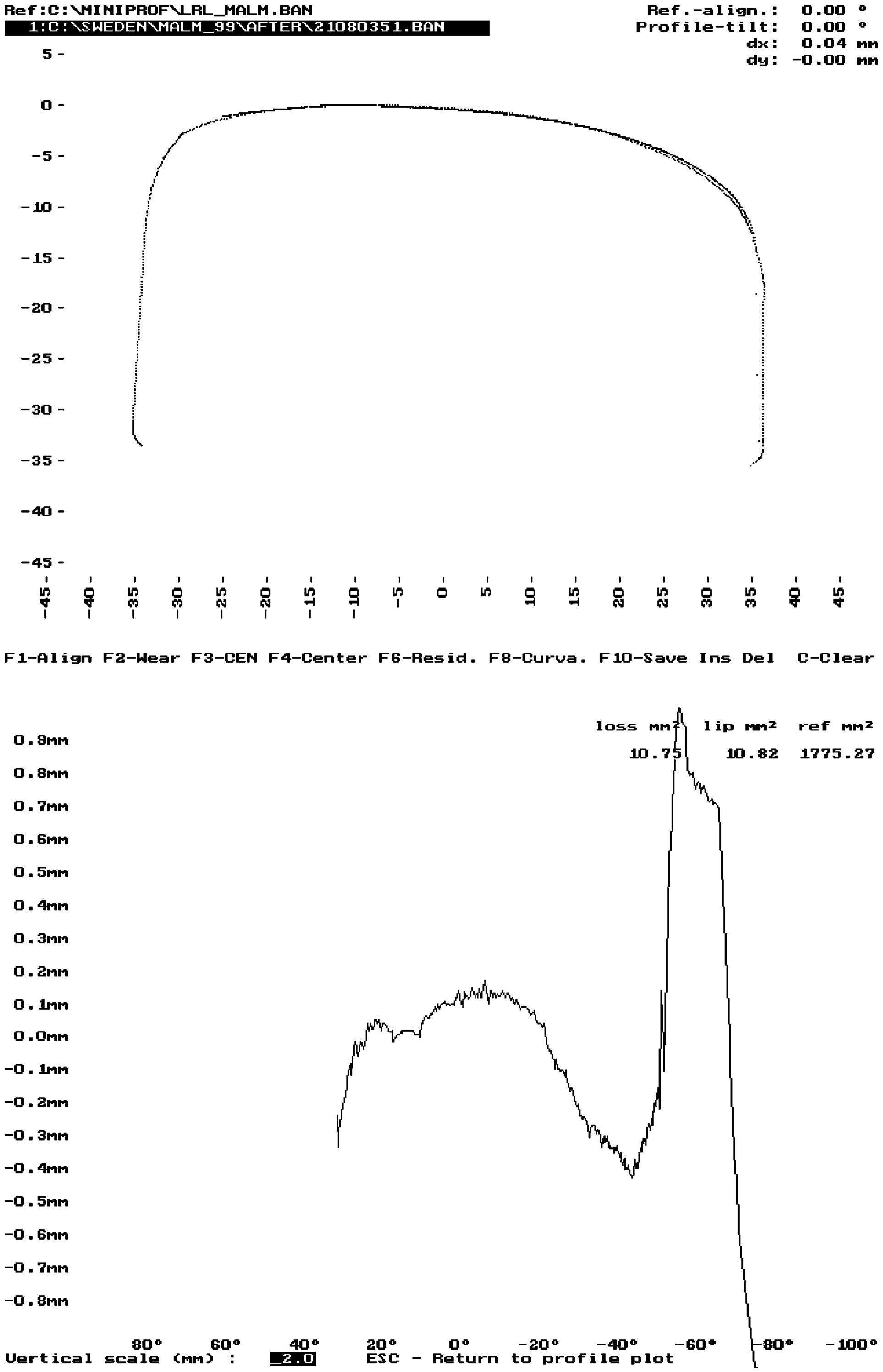
Fig. 5. Correlation of reference profile and high rail profile (ground to MB profile with +0.3/−0.7 mm tolerance).

The way in which a measurement of transverse profile is aligned with the reference profile can significantly affect the apparent "goodness of fit", or deviation of one profile from the other. Clearly, this can be rather critical in assessing the fraction of measurements that lie inside any particular tolerance band. It was agreed in 1999 to align a measurement at the 0 and 45° points on the reference profile. If a track were to have two rails with the reference profile, a tangent to the crown of both rails would touch the 0° point. This tangent is referred to here as the "reference line". The 45° point on the gauge corner of the reference rail is that point at which the tangent lies at 45° to the reference line. These two



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         dy: -0.00 mm
F1-Align F2-Wear F3-CEN F4-Center F6-Resid. F8-Curva. F10-Save Ins Del  C-Clear
loss mm²   lip mm²   ref mm²
 10.75      10.82    1775.27
Vertical scale (mm) : 2.0    ESC - Return to profile plot
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Fig. 6. Correlation of reference profile and high rail profile (illustrating the effect of different alignment procedure c.f. Fig. 5).

points of alignment, on the crown of the rail and around the gauge corner, have tentatively been accepted as valid points of alignment in the draft prEN for rail grinding (although at present for high rails only). They have several attractions, such as:

- they help to control the profile over that section of the rail where the profile is most critical: the crown, shoulder and gauge corner;
- they can be defined relatively simply and unambiguously for both symmetrical and asymmetrical reference profiles

at any angle of inclination, thus, simplifying their adoption in software;

- they are similar to the points at which a physical "bar gauge" would touch the rail, thereby simplifying comparison between manual measurements made with a bar gauge and those made with an instrument;
- the points are particularly relevant to side-worn high rails, where the use of an alignment point on the gauge-face of a reference rail (about 14 mm below the reference line in some current specifications) often makes it impossible to align measurements, even though the crown profile may be very close to that desired;
- the "goodness of fit" so found gives a good indication of the goodness of fit between a wheel and the rail, particularly a side-worn high rail; the use of an alignment point on the gauge-face of the rail has little relevance to how well a wheel fits on the rail since no wheel would ever touch such a point.

The use of these points of alignment and the type of monitoring of the transverse profile that has been undertaken are illustrated in Figs. 4–6. The upper part of each of these figures shows the measured profile aligned with the reference profile, while the lower part shows the difference between the two profiles (a negative difference indicates that the measurement lies "below" the reference). In Fig. 4, a measured low rail profile is aligned with the MB reference profile to which it has been ground, with a tolerance of ±0.5 mm.

Fig. 5 shows the same information for a high rail, ground to a tolerance of +0.3/−0.7 mm. Fig. 6 shows the measured profile of Fig. 5 aligned with the reference MB profile at about the 0° point and at a point 14 mm below the reference line. In Figs. 4 and 5 the measured profile is aligned with the reference profile approximately at the 0 and 45° points. These figures indicate that the profile has been ground quite closely, to a fit of within about +0.15/−0.05 and +0.1/−0.2 mm, respectively. We believe that the alternative alignment procedure illustrated in Fig. 6 (giving a difference of about +0.14/−0.42 mm c.f. +0.15/−0.05 mm) gives a misleading impression of how closely the measured profile corresponds to that desired over the area of the railhead that is in contact with a wheel.

A quantitative assessment of the "quality" of the transverse profile of the ground track is given by the cumulative probability distribution (CPD) of the deviation of measurements from the appropriate reference profile. The CPD of transverse profile for the 1999 grinding campaign on the Malmbanan is shown in Fig. 7 as a function of the range of deviation. This shows, for example, that 93% of the measured profiles (from the 138 measuring points) lie within a range of 1.0 mm (+0.3/−0.7 mm for the high rail, +/−0.5 mm elsewhere) about the reference profile, and 25% lie within a range of 0.4 mm (+0/−0.4 mm on high, +/−0.2 mm elsewhere). There are a few measurements that deviate in a range of more than 1.0 mm from the appropriate reference profile. These large deviations are on low rails or in tangent track.

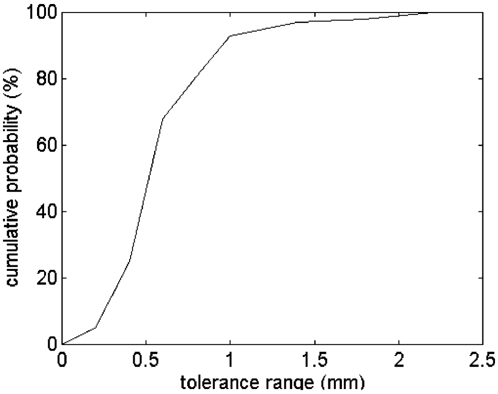

Fig. 7. CPD for maximum deviation of measured and reference transverse profiles, 1999 grinding.

CPD curves such as Fig. 7 (or their inverse, an exceedence curve) are a sensitive way of showing the condition of both the transverse and the longitudinal profile, whether for ground or for worn track. The rapid rise and relatively short "tails" in the CPD curve are typical of ground track. (An "ideal" CPD for ground track might show 0% of the track in tolerance just below the limiting tolerance range, and 100% in tolerance just above this range. The CPD for track with an ideal profile would show 100% within a tolerance range of 0 mm.) For unground track, the CPD curves for both transverse and longitudinal profiles are very much "flatter", indicating much greater variations in the standard of the transverse profile and of the corrugation depth.

6. Economic assessment

Preventative maintenance of the rail, particularly routine grinding to an appropriate profile combined with effective lubrication, has brought about a rapid and substantial reduction in the annual purchase of both rail and of S&C work for this line. Over the period of the test, both ride quality and the quality of track geometry, as measured by the BV's recording car, have improved, while the numbers of defects detected by their ultrasonic testing train have declined. These measurements are in accordance with a subjective assessment of the condition of the line. While each of these factors alone might be justification for the maintenance regime that has been adopted, the improvements taken together have been overwhelmingly beneficial.

The principal saving has been in the purchase of rail: this declined by two-thirds over the period 1997–1999, from over 6 million SEK per annum to about 2 million SEK, while the cost of grinding over the period of the test has remained roughly constant at about 5 million SEK (Fig. 8). These

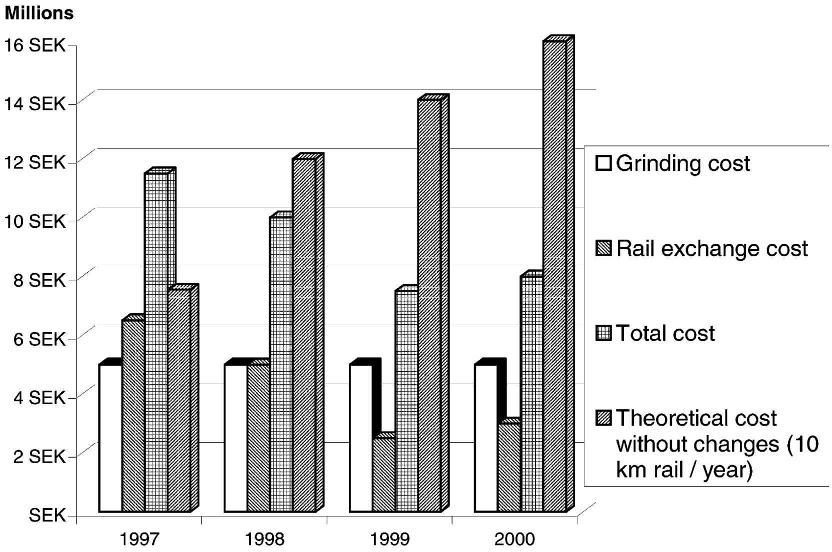

Fig. 8. Costs of grinding and rail for the period 1997–2000.

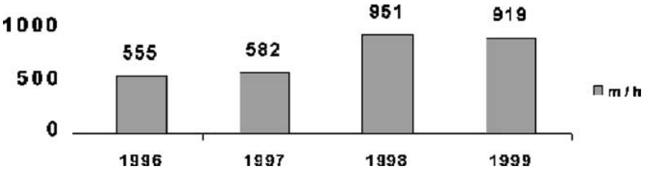

Fig. 9. Grinding productivity for the period 1996–1999.

figures in fact underestimate the benefits that have been obtained since the savings incurred from regular grinding of switches are not included and also the effective cost of rail to the BV has doubled over the period (from SEK 755 per rail metre to SEK1600 per rail metre). The total cost of rail and grinding in 2000 (Fig. 8) is accordingly *half* of what it would have been had the changes not been implemented and if 10 km of rail were replaced per annum. (This is significantly less than was replaced in 1997, hence the "theoretical cost" is less than the true "total cost" for this year).

While the cost of grinding and the length of track ground have remained roughly constant (the contract was for a price per finished kilometre of ground rail), the grinding productivity increased significantly: Fig. 9 shows the rate of finished metres of ground rail per operating hour during the test and immediately before it. This reflects the relative ease with which it is now possible to grind the rail, to profiles that are similar to those which nature prefers. By taking advantage of the unvarying profile, it should be possible further to raise the productivity.

7. Conclusions

A programme of improved rail maintenance and management on Sweden's Malmbanan, or iron ore railway, is currently entering its fourth year. In only the first 2 years of the test, rail grinding plus improved lubrication of the heavily curved railway combined to reduce the cost of grinding and rail renewal by about 40%, while nevertheless contributing to an improvement in the standard of track geometry and a reduction in the numbers of defects either measured or visible to the naked eye. Close monitoring of the test and excellent collaboration between the railway and the grinding contractor have contributed to the test's success.

Although rail grinding had previously been undertaken quite conscientiously on this line, the rail had been ground to a profile which brought about very high stresses around the gauge corner and shoulder area of the high rail and in S&C. There were also several places where the field side of the rail was badly damaged from the false flange on the vehicle wheels. These high stresses contributed to severe RCF defects and premature failure and renewal of the rails. This condition was probably exacerbated by the hard rail that was used since this wore very slowly to a more appropriate profile.

While the MB profile used on the Malmbanan is probably unique to this railway, there is every reason to believe that the principles adopted here could be used elsewhere to alleviate RCF damage in curves. The critical principles are that the high rail should be ground to a profile which is similar to that which wheels wear on the rail, and that this should be ground to a tolerance which ensures that there is relatively little wheel/rail contact in the area where RCF defects initiate, i.e. around the gauge corner and shoulder of the rail. Indeed Schweerbau UK Ltd are already grinding rail on relatively high speed lines elsewhere in Europe using these principles with the objective of alleviating RCF damage.

Currently, the rate of metal removal by grinding is about 0.2 mm across the railhead approximately every 23 MGT. Although this is a relatively low rate of metal removal compared to what is apparently practised in preventative grinding elsewhere, the early indications are that it is sufficient. We expect that an even lower rate of metal removal by grinding would be sufficient to alleviate RCF failures in curves if bogies are better maintained and are also designed to reduce the tractive forces required for curving.

Quantifications of “quality” were developed and used for both the transverse and longitudinal profiles of the ground track. These have enabled the quality to be assessed fairly objectively and in a manner that can be monitored independently by either client or contractor, with a good chance that both parties obtain the same results. These procedures are of general relevance in developing specifications and standards for grinding of track, and have already been used in the drafting of a prEN in this area.

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