Wheel/rail hardness and total ‘system’ wear

Mark Burstow  
Principal Vehicle Track Dynamics Engineer  
V/T SIC Permanent Project Group  

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Summary

It is a common perception that reducing the wear rate of the material on one side of the wheel/rail interface will result in an increase in wear on the other side of the interface. A review of research and published papers has been undertaken to determine if this view is supported by experimental or experiential evidence.

It has been found that increasing the hardness of one material has little or no effect on the wear rate of the other material, and many researchers have actually observed a reduction in the wear rate in both materials when the hardness of one of them is increased. It is therefore concluded that there is no justification for a belief that harder wheels or rails will result in an increase in wear of the opposite side of the wheel/rail interface.

Harder materials can also provide a benefit in reducing whole system maintenance costs: provided a ‘good’ wheel/rail profile is used then the lower wear rate of the material will maintain the wheel or rail profile in that shape for longer.

Introduction

There is often concern about the impact that changes to one side of the wheel/rail interface will have on the opposite side of the interface. This is particularly true where wear of either wheels or rails is desired to be reduced through using harder, more wear-resistant, materials. For example, it is a common perception that “harder rails cause an increase in wheel wear”, it being assumed that the total amount of wear from wheels and rails must be the same, and that reducing the wear rate of one will increase the wear rate of the other.

This paper reviews published data from wheel and rail wear tests to consider whether it is true that increasing the hardness of the material on one side of the wheel/rail interface will result in an increase in wear on the opposite side of the interface.

Experimental evidence

Laboratory tests using a small-scale roller rig (or twin disc testing) are a simple way to test the wear characteristics of different materials under a range of load conditions, and have been widely used for many years. In 1993 an internal British Rail Research report, “Effect of differential hardness on
wheel/rail wear- literature survey” [1], reviewed available sets of test data and published papers on wheel and rail wear. One of the main conclusions was that “the belief that an increase in the hardness of the rail, while giving a decrease in the rail wear rate, will give an increase in wheel wear is not generally felt to be justified”. This conclusion was based on a review of a large number of studies from different organisations and researchers in the UK and abroad.

Laboratory twin-disc tests conducted on pearlitic rail steels by BR from 1981[2] showed that the wear rate of the wheel steel was practically independent of the steel against which it was run for a wide range of load conditions (covering both the mild and severe wear regimes). Graphs of the total ‘system’ wear showed that this dropped as the rail hardness increased.

BR also undertook tests on a full-size wheel/rail rig[3] which found that both rail and wheel wear were reduced as the rail hardness was increased. Similar effects were reported in a large number of research papers, for example [4, 5]. Although not all the papers described a reduction in wheel wear with increasing rail hardness, they all showed a reduction in total system wear and none reported an increase in wheel wear. It was suggested by some (for example [5]) that the reduction in wheel wear with high strength rails may be associated with a reduction in the surface deformation damage on both the wheel and rail samples: the reduced volume of wear debris from the harder rail material resulted in less abrasive wear occurring on the wheel material. Some tests (for example, [6]) found that increasing rail hardness resulted in a clear tendency for wheel wear to decrease.

In summary, the review of laboratory wheel/rail wear tests[1] concluded that the wear of one component is either unaffected or is decreased by changes in hardness of the other. The actual effect is dependent on the metallurgy (which affects the nature of the wear debris produced) of the harder component, but a reduction in wear debris volume (due to the increased hardness) might be expected to be less abrasive to the softer material.

More recently, a series of tests were undertaken by DB Systemtechnik[7] to determine the effect of increasing rail hardness (to resist RCF) on wear of both the wheel and rail. A series of laboratory and track tests were undertaken to test these rail materials, but due to the relatively short sections of rail being tested it was not possible to determine the effect of the rail materials on wheel wear from the track tests. In the laboratory tests no significant difference in wheel wear was obtained for any of the rail steels tested, apart from a head-hardened material, for which a drop in the wheel wear rate was obtained. They concluded that higher strength steels for both wheels and rails had a favourable impact on wear of the system as a whole and helped sustain profile stability.

One of the workstreams in the InnoTrack project undertook twin-disc tests on premium grade rail steels to test their RCF resistance[8]. During the tests wear of the wheel material was also measured. The tests were undertaken in both dry and wet conditions. The results showed no clear relationship between rail
hardness and wheel wear under dry contact conditions but a drop in wheel wear rate for an increase in hardness when ‘wet’. They also observed that increasing the rail hardness did clearly show a significant drop in total system wear under all contact conditions.

Should we expect wear to increase?
Wear of either wheel or rail material is a result of a combination of i) the forces generated in the contact patch and ii) the response of the material to those forces. If the material on one side of the contact patch is made more wear resistant, then its own characteristic material response to wheel/rail forces has changed. However, if the wheel/rail profiles are the same then the location of the contact point between wheel and rail, and the total force which needs to be transmitted will be the same, irrespective of the rail material hardness. The wheel material will therefore be required to transmit the same force through essentially the same contact patch area (changes in rail material hardness may affect the size of the contact patch due to plastic deformation, but these changes will mostly be small and most of the contact force is transmitted through the centre of the contact patch) and its own wear rate is driven by the forces it needs to transmit: the material on the opposite side of the contact patch will see no significant change in the contact forces and does not ‘know’ what the hardness of the other material is. Therefore it should not be expected for the hardness of one material to have an effect on the response of the other material.

The only exception to this, and this was discussed in some of the research papers[5], would be if the change in material properties were to change the nature of the wear debris, causing more debris to become entrained in the contact patch, making the contact conditions more severe, and increasing wear by abrasion. This may be the reason for some materials having a bigger impact on the wear rate of the other material than others. However, when the rail material hardness is increased then the lower wear rate will produce less wear debris, so it might be expected that the wheel material wear rate would also go down. Therefore, it should not be a surprise that increasing the hardness of the material on one side of the contact patch should help reduce the wear rate on the other.

Other considerations
In contrast to the test results it could be possible for the wear rate of wheels to increase in the presence of harder rails if the rail (or wheel) profile is not optimal, resulting in more severe contact forces. With normal grade rail a more aggressive contact condition would cause the wear rates of both the wheel and rail to increase, for a short time, until the profiles had become more ‘conformal’ and more ‘friendly’. However, a rail with a more wear-resistant characteristic would retain its ‘unfriendly’ shape for longer, causing increased wheel/rail forces and more wheel wear before it wore to a better shape. Therefore, in the presence of harder grade rails it is important to ensure that rail profiles are managed and maintained to control the contact forces better.
Conclusions
A review of a wide range of research and published papers and test results has shown that there is no basis to conclude that an increase in material hardness on one side of the wheel/rail interface will result in an increase in wear rate on the opposite side of the interface. No evidence has been found to support the notion that the total ‘system’ wear rate is constant. In addition, many researchers have observed that an increase in hardness on one side of the interface can actually be beneficial in reducing wear on the opposite side.

References