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# Experimental modelling of lipping in insulated rail joints and investigation of rail head material improvements

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## Abstract

An insulated rail joint is a component used to join two abutting rails whilst keeping them electrically separated from one another. This allows for the construction of track circuits and train detection within signalling systems. Electrical failure of the joints can be caused by plastic flow of the rail steel over the insulating gap, known as lipping. In the following paper this failure mode has been experimentally modelled using twin disc testing and indicative conclusions have been formed. It has been found in this testing that endpost thickness does not have an effect on the rate of lipping, but the endpost and rail material do. An endpost with higher compressive strength will perform better while tougher / harder rail steel will also improve performance. The application of a laser clad layer of tougher material on the running surface, however, gave the greatest resistance to lipping.

Keywords: Insulated block joint, lipping, twin disc test

## 1. Introduction

### 1.1 Background

An insulated rail or block joint (IBJ) forms an integral part of the signalling system of the railway network and insulates two abutting pieces of track. The IBJ splits the track up into blocks so that track circuits can be used and the signalling system can ascertain where a train is on the network. The joint is generally constructed using two insulated fishplates that are bolted through the web of both rails which forms a double lap joint. As well as the use of mechanical fasteners IBJs are also commonly fixed into the rail using an adhesive bond. The space between the two adjoining rails is filled with an endpost constructed from an insulating material, commonly a plastic or epoxy composite. A typical IBJ construction can be seen in Figure 1.

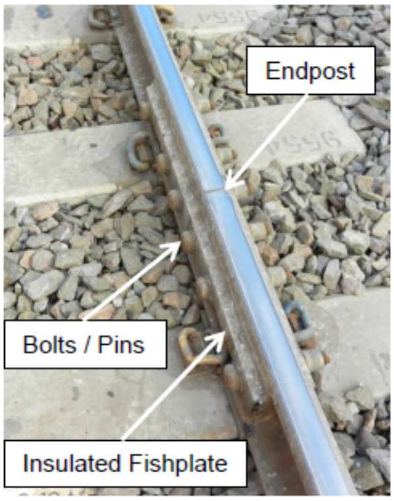

Figure 1: Standard UK IBJ

The failure of an IBJ, which can occur in many different ways, can generally be split into one of two categories, mechanical and electrical failure. Mechanical failure includes failures such as fatigue cracking of the fishplates or the rail and fractures of the mechanical fasteners. Mechanical failures do not always lead to the breakdown of the signalling system as the adjoining rails may still be isolated from each other. Electrical failures, on the other hand, always lead to the failure of the signalling system because the electrical insulation between the two rails is lost. This could be because of contamination over the endpost, de-bonding of the glue layer in a joint or lipping. Lipping can be defined as the plastic deformation or material flow of the rail head over the endpost of the IBJ. If this material flow is severe the gap between the two rails closes up and eventually the two rails become connected, causing electrical failure.

Lipping of the rail head can be seen in Figure 2 where the plastic deformation of the steel has caused the endpost to become damaged. Lipping is a major problem for rail networks worldwide where IBJs are used. In the UK lipping accounts for 17% of all recorded IBJ failures [1] and is also a noted problem on the Australian heavy haul network [2]. Failures due to lipping can be expensive to the railway operator due to the cost in repairing the damage but also in the fines received because of a failure in the signalling system which causes delays.

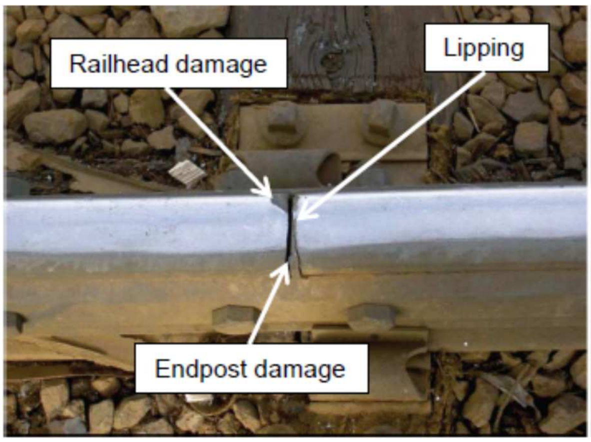

Figure 2: In situ IBJ showing material deformation of the railhead (lipping), endpost damage and railhead damage

## 1.2 Current Research

Field testing, full scale laboratory testing and numerical modelling have all typically been used to investigate and study the plastic flow of rail head material at an IBJ. A three year field study was carried out recently that monitored deterioration at the endpost of IBJs [3] [4]. This has provided information on hardening and damage of the surface of the rail head which is useful reference data. The subsurface effects could not be monitored, however, due to the IBJ needing to stay in service. Microstructural analysis has been achieved on in-service IBJs. This, however, has provided a limited amount of data on the patterns of lipping or material flow [5]. Various methods have been trialled in an attempt to reduce the lipping seen at insulated joints including the use of tapered or angled cuts in the rail [6]. This method aims to aid the wheel transfer between the two rails and therefore reduce the contact forces between the wheel and rail which may lead to lipping. Other methods include the application of a tougher secondary material to the rail head which has been trialled in service to try and reduce the lipping at an IBJ [5]. Field testing and full analysis of in service IBJs is the ideal approach to gaining a full understanding of the problem, however, testing of this nature takes too long and is also costly.

Full-scale rig tests have been developed to study the strain accumulation in the rail end [6]. Although this method provides useful data for validating numerical models it does not manage to replicate the lipping mechanism that is seen in the field. Alternative full scale testing carried out analysed the benefit of changing the shape of the rail head in order to reduce strain accumulation and therefore lipping [7]. It was found that the strain in the rail head could be reduced by introducing a dipped profile at the end of the rail. In practice, however, this approach would be unadvisable due to the increased dynamic forces on the rail from passing wheels created by a localised dip that would damage the track form.

Analytical and numerical approaches using computer modelling have focused on the development of understanding of the contact between the wheel and rail around the endpost of an IBJ [8] [9] . These studies show that higher contact forces are seen at the rail ends which would be a contributing factor in why lipping occurs.

Investigations on the effect of the thickness of the endpost (the width of the gap between the two rails) on the contact forces have been carried out using numerical methods and finite element analysis [3] [10] [11]. It was shown that the effective strain and the plastic strain magnitude both increase when the endpost is thicker. This suggests that damage to both the endpost and the rail steel will occur more quickly when the endpost thickness is increased, although there will be a bigger gap for a lip to form over and therefore the overall effect on lipping is hard to ascertain.

Scaled experimental simulation of ratchetting, the accumulation of plastic deformation of the rail head, has been performed using twin disc testing [12] [13]. The image in Figure 3 shows the material flow that is accumulated because of the slip between the rail and the wheel. The mechanisms of lipping could be tested using this method, but to date twin disc testing has not been used to investigate this.

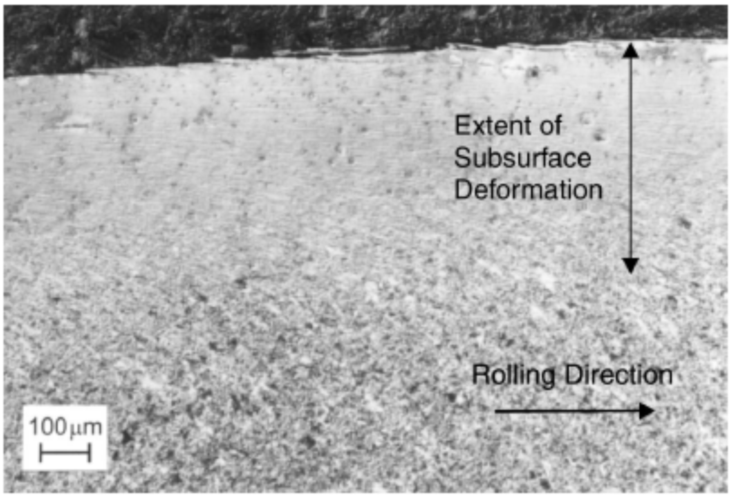


Figure 3: Steel ratchetting after twin disc testing with 3% slip [12]

Twin disc testing has also been used to investigate the benefits of improved rail steels and laser clad layers of tougher material on wear and rolling contact fatigue performance [14] [15]. The laser cladding of some materials onto the running surface of the disc has been found to improve the fatigue strength and reduce ratchetting which has been backed up by numerical analysis [16]. These methods could be utilised at the rail ends at an IBJ to limit the extent of lipping and increase the service life of an insulated joint.

### 1.3 Hypothesis

Lipping of the rail head over the insulating endpost of an IBJ is mainly caused by two mechanisms. The first being high contact forces and stress concentrations at the rail ends and the second being the longitudinal creep forces caused by traction and braking which lead to ratchetting and plastic flow. The test method in this paper aims to experimentally model both of these mechanisms in a scaled environment to provide a quick and efficient way to replicate lipping and then rank possible solutions.

## 2. Experimental Method

The contact between the wheel and the rail can be modelled experimentally using twin disc testing. The SUROS (Sheffield University ROlling and Sliding) twin disc test machine has previously been used to model wear and rolling contact fatigue problems [12] [13]. The discs are cut from the rail head and wheel steel to ensure that the correct materials are used and are then slotted on the running surface. The slots are filled with an endpost material to simulate the middle of the IBJ. This test machine gives the ability to generate the high contact forces seen in the field and can also simulate the ratchetting of the steel, giving the chance to test both mechanisms mentioned in the above hypothesis. The testing set-up does have limitations, however, as high dynamic loads are not introduced which are normally present around an IBJ. Even so, the high contact forces generated give a good representation of the real life scenario. An image of the rail disc with slots can be seen in Figure 4.

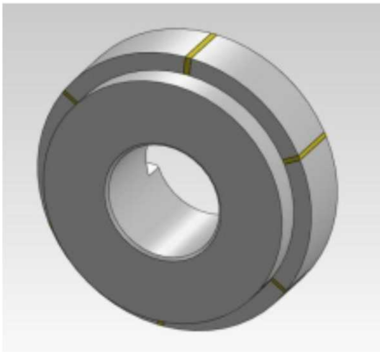

Figure 4: Rail disc with endpost inserts

The discs that were tested measure 47mm in diameter and have a contact width of 10mm. The twin disc testing was conducted using a maximum contact pressure of 1500MPa which corresponds to a load of 7.19kN. The contact pressure is a standard value used for rolling contact fatigue testing on the SUROS test rig which is higher than the value generally used to model the tread contact, 900MPa. The higher value was chosen in order to accelerate the testing regime. These contact conditions create a contact width of approximately 0.6mm between the two discs. The contact between a wheel and rail normally has a width of around 12mm and therefore the endpost inserts used in the rail disc were scaled down to match (1:20). In the UK endposts installed into insulated joints usually have a thickness of 6mm or 9mm. However, there was found to be a practical limit to how small the endpost inserts can be made for the disc and therefore the smallest insert was made to a thickness of 0.5mm. Inserts of 0.75mm and 1.0mm were also created to assess the difference that endpost thickness might have on the lipping performance. The other parameters that were altered to assess their lipping performance were the endpost material and the rail material. Two common endpost materials in the UK, polyamide6 (PA6) and epoxy glass composite, have been compared. Standard grade rail steel has been tested against head hardened and US premium rail steel (grade DHH 390) and also rail steel with a laser clad layer of tougher material (Stellite 6) on the running surface. US premium rail steel is a head hardened rail with a tested surface head hardness of approximately 390 Brinell [17].

The SUROS rig was used to run the tests at a speed of 400rpm with a slip of 0.5%. The slip value was chosen to represent tread contact conditions of a driven wheel. Tests were run at first for 2000 cycles and further testing was carried out to a total of 96000 cycles.

# 3. Results and Discussion

## 3.1 Experimentally Modelling Lipping

The first testing was carried out to prove the concept of modelling lipping using the twin disc test rig. The rail disc used was manufactured from steel grade R260, the standard grade of rail used in the UK. The discs were run for periods of 400 cycles before the test was stopped and the rail disc was checked for signs of any lipping. After a total of 2000 cycles lipping could be seen where the gap that the endpost occupies was closing up. This can be seen in Figure 5 where the endpost is shown before and after testing for 2000 cycles. In Figure 5(b) the gap that is more apparent in Figure 5(a) has closed up due to metal flow.

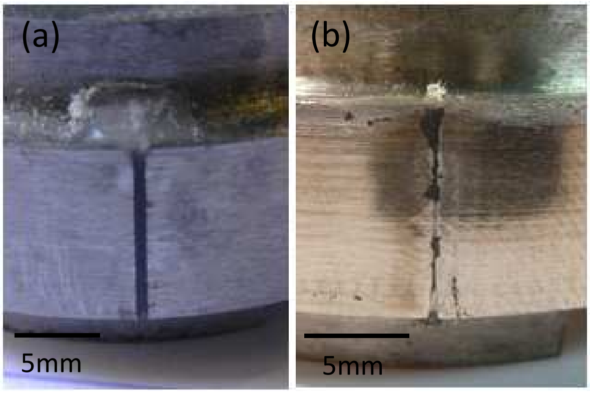


Figure 5: Surface image showing endpost in a rail disc: (a) pre-testing; (b) post testing

Once lipping had been seen on the surface of the joint the discs were then cross sectioned so that a better understanding on the depth of the steel deformation could be gained. An image of the sectioned disc can be seen in Figure 6 where material flow is clearly visible at the running surface of the disc.

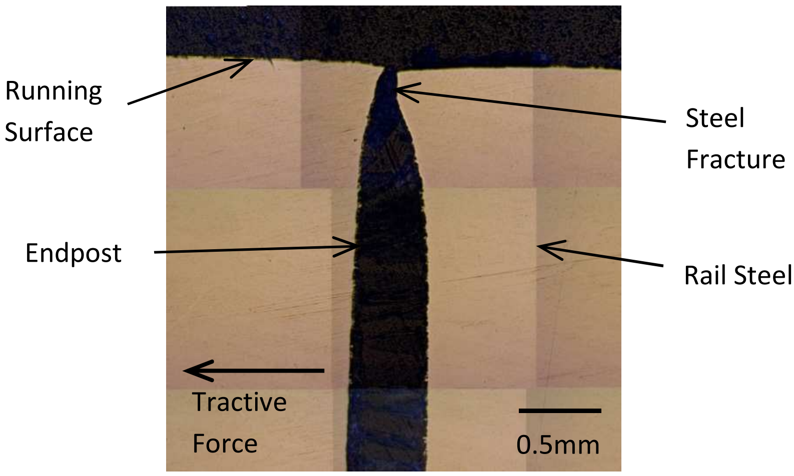


Figure 6: Sectioned view of 0.5mm epoxy/glass endpost in 260 grade steel disc (note that the wheel disc is driving and rolling towards the right hence the traction force is to the left)

The steel fracture that is indicated in Figure 6 is part of the running surface of the disc that has broken off after lipping has formed. It is thought that this is due to the high contact pressure of the wheel disc on the rail disc which is greater than the lip can support and therefore the lip has fractured.

The sectioned discs have been etched so that the grain boundaries of the steel can be seen and therefore the hypothesis that lipping is due, in some part, to ratchetting behaviour can be tested. The etched steel at the running surface of the rail disc can be seen in Figure 7. From this image it can be seen that there is no deformation of the rail steel in the direction of the tractive force, this suggests ratchetting has not occurred. This is most likely because the discs have only been run for a total of 2000 cycles at a low slip of 0.5%, which is not long enough for ratchetting to become visible. It has therefore been concluded that the lipping generated in this testing, which can be seen in Figure 6, is due to the bulk deformation of the steel caused by the high contact pressures between the wheel and rail discs. It is possible, however, that if ratchetting were to have occurred during this short test period and very thin layers of material flowed over the endpost, they would have been easily broken off or worn away after a few cycles. More cycles are required to accumulate greater strain and more surface flow.

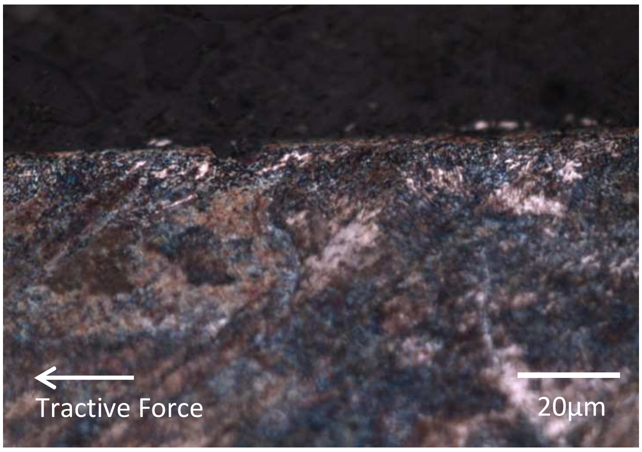


Figure 7: Etched cross section of 260 grade rail disc after testing

The lack of ratchetting that is seen in these discs can be explained by analysis of a shakedown plot, shown in Figure 8. This is a plot of the coefficient of traction against the load factor. The R260 grade discs falls into the lower left side of the graph which represents a subsurface elastic condition and therefore ratchetting is unlikely to occur in these discs with test parameters that have been applied. It should be noted that the reason for the spread in values for coefficient of traction could be the test length. As will be discussed later, the tests that ran for longer had a higher value than those run for 2000 cycles.

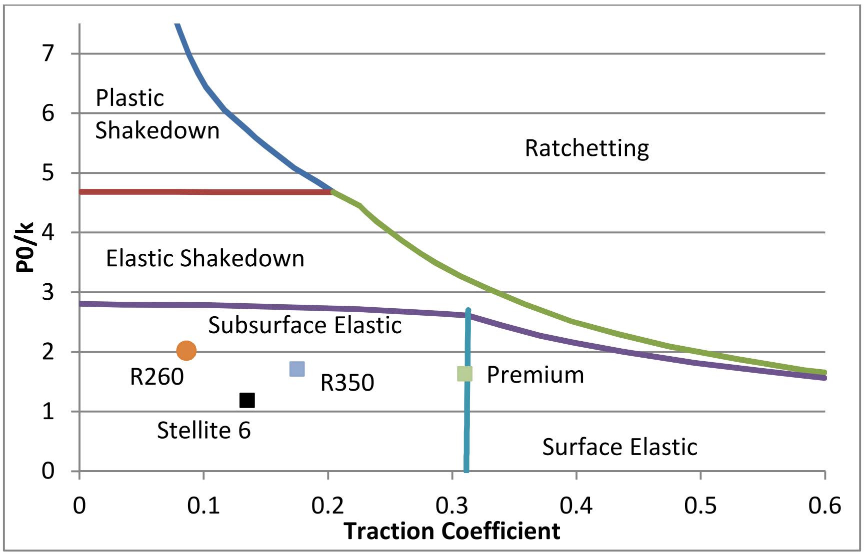


Figure 8: Shakedown plot with different rail materials

The bulk deformation of the steel below the running surface can be explained by the shear stress distribution in the disc. The highest shear stress is below the running surface of the disc as is shown in Figure 9. The graph, a plot of equation 1 which calculates the shear stress in the disc, shows the maximum shear stress at a depth of approximately 0.25mm. This plot does, however, assume no friction in the contact which is not true, the friction involved would decrease the depth of the maximum shear stress slightly. The level of the coefficient of friction required to bring the peak shear stress to the surface is 0.3 as seen in the plot in Figure 8, the R260 disc contact had a coefficient of friction of 0.08, and therefore the peak shear stress would still be below the surface. The peak shear stress at a depth of 0.25mm, or slightly less than this when taking friction into account (which equation 1 does not account for), corresponds well with the deformation seen in Figure 6.

$$\tau_1 = \frac{p_0}{a}\{z - z^2(a^2 + z^2)^{-0.5}\} \quad (1)$$

where $\tau_1$ is the principal shear stress in the direction of deformation, z is the depth, a is the contact half width and $P_0$ is the maximum contact pressure. More details on the type of analysis and its limitations can be found in Johnson [18].

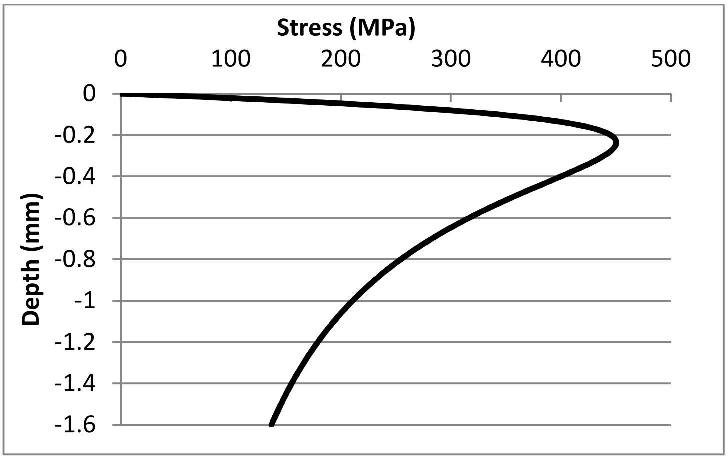


Figure 9: Shear stress distribution in the rail disc below the running surface

A comparison of the testing in the twin disc machine and studies of in-situ joint studies can be made by comparing the two images in Figure 10. In addition to the fracture of the steel due to high contact pressures discussed above, damage is apparent on the running surface of the disc. This can be compared to shelling that has been noticed to occur around the endpost of IBJs in the field. Similar shelling or cracking can be seen on the surface images of the disc in Figure 5.

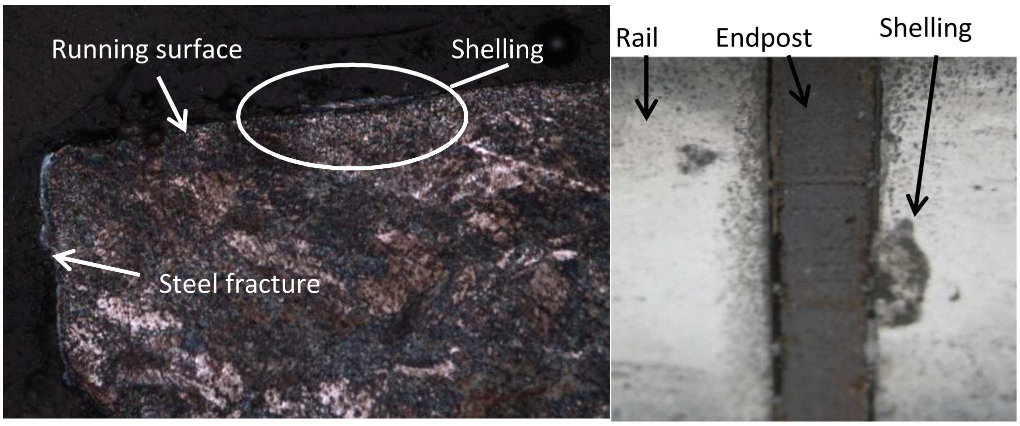


Figure 10: Comparison of shelling in a) the twin disc test and b) in the field [4]

## 3.2 Effects of Changing the Endpost Thickness

As discussed above, the practical limit for the smallest endpost inserted into the rail disc is 0.5mm. To assess the effect of endpost thickness a disc was manufactured with endpost slots of 0.5, 0.75 and 1.0mm in thickness. The test was run for 2000 cycles again. In Figure 11, images of the sectioned disc with the three endpost thicknesses can be seen; (a) shows a 0.5mm endpost, (b) a 0.75mm endpost and (c) a 1.0mm endpost. The lipping that occurs on the left side of the endpost, opposite to the direction of the tractive force, has been marked. It can be seen that the magnitude of the lipping is similar in each case at 0.25mm.

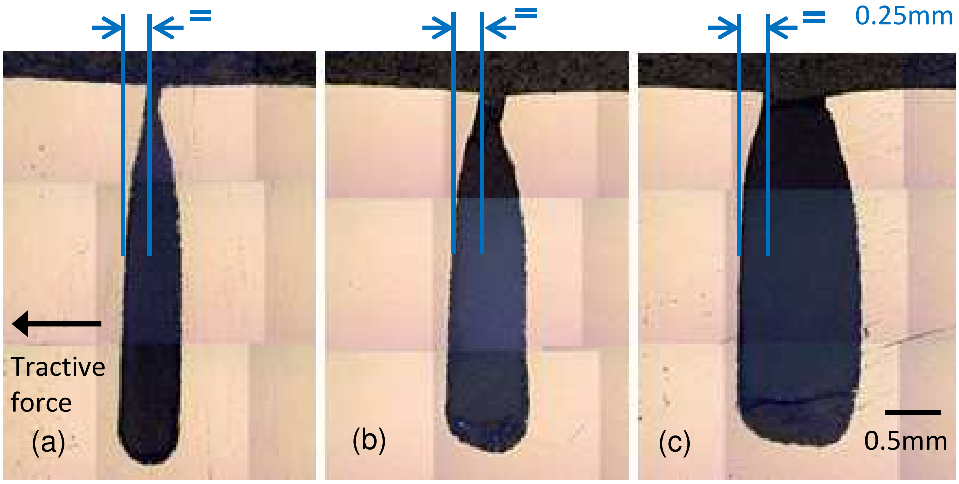


Figure 11: Varying endpost thickness showing similar amounts of lipping of the left side of the endpost.

Looking at the right side of the endpost, lipping in the direction of the tractive force, it is easy to see that the magnitude of the lipping varies and appears to be greater when a thicker endpost is used. However, when analysed more closely in Figure 12 it can be seen that in two cases the steel has fractured in a similar manner to that described in section 3.1, this occurs in (a) and (b), the 0.5mm and 0.75mm thick endpost samples. If this fracture had not occurred during the testing process it can be estimated that the magnitude of lipping would have been similar in each case as shown by the dashed lines in Figure 12. This leads to the conclusion, therefore, that the thickness of the endpost in this test set-up does not affect the rate of lipping in the direction of the tractive force.

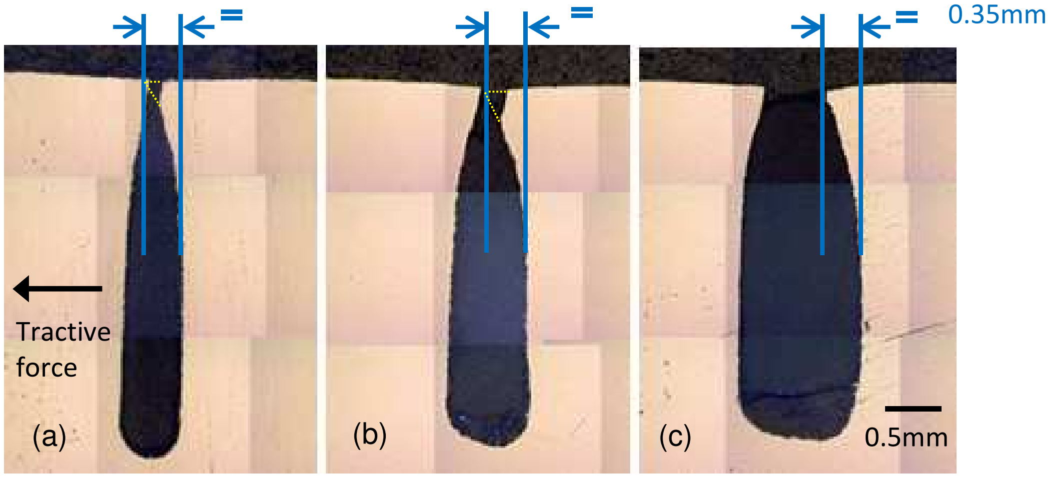


Figure 12: Varying endpost thickness showing varying amounts of lipping of the right side of the endpost.

The result that endpost thickness does not affect the rate of lipping of the rail head would lead to the conclusion that a thicker endpost would be beneficial as a steel lip would take longer to bridge the gap between the two rail ends. A thicker endpost can lead to other issues within the IBJ though, the wider the gap between the two rail ends the weaker the joint becomes and consequently this could lead to other failure modes associated with the IBJ or the support structure.

This result goes against current research in this area where computer modelling has shown that an increase in the endpost thickness may lead to an increase in lipping due to a higher plastic strain magnitude [10] [11]. There are limitations in both computer modelling and twin disc testing. In twin disc testing the limitations include the relative endpost sizes compared to real life situations and the curvature of the disc. There is also a difference in the dynamics between the twin disc test and the computer models. Dynamic loading could have, for example, caused higher impact loadings with larger gaps. Further research should focus on in-situ field testing of IBJs with varying endpost sizes to determine what the true outcome of this design change is.

### 3.3 Effects of Changing the Endpost Material

The two most common endpost materials used in the UK are an Epoxy-glass composite material, used mostly in glued IBJs and a polyamide (PA6) used more commonly in non-glued IBJs. These two materials were inserted as endposts into the rail disc and the same testing procedure was followed to assess the effect these materials have on lipping performance. The effect of changing the endpost material can be seen in Figure 13 where the epoxy-glass composite is used in image (a) and the PA6 material is used in (b). It can be seen that the steel of the disc deforms more and closes more of the gap in image (b), suggesting that the PA6 material is less able to resist the steel and more lipping occurs as a consequence. This is most likely because of the higher compressive strength of the epoxy-glass composite material.

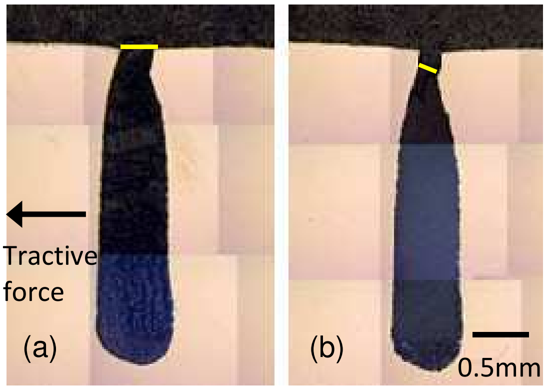


Figure 13: The effect of endpost material on lipping a) epoxy/glass b) PA6 (0.75mm endpost thickness)

The lines shown in Figure 13 mark the height of the endpost after testing has been carried out. From this it can be seen that the PA6 material has worn more than the epoxy-glass material and therefore a gap is present between the steel on either side of the endpost. The wear debris that this created built up on the disc and can be seen in Figure 5. This gap left between what would be the rail ends in a full IBJ could cause problems as it may fill with rail wear debris or other conductive material and lead to electrical failure due to contamination.

## 3.4 Effects of Changing the Rail Steel

Differing rail steels have been tested so a comparison could be made between them on their lipping performance. UK standard R260 grade rail steel has been compared with R350 heat treated rail steel. R350 grade rail steel is advertised as having a tensile strength of 1175MPa, higher than R260 grade at 880MPa [19]. The hypothesis is that tougher rail steel will reduce lipping of the rail head. Hardness measurements of the two types of steel were taken and can be seen in Figure 14, this has confirmed that the R350 grade steel has a higher hardness than the R260 grade.

The graph in Figure 14 shows the hardness of the discs after 2000 cycles. The plots show very little or no evidence of work hardening. This would further the conclusion that no ratchetting has occurred during this short test time.

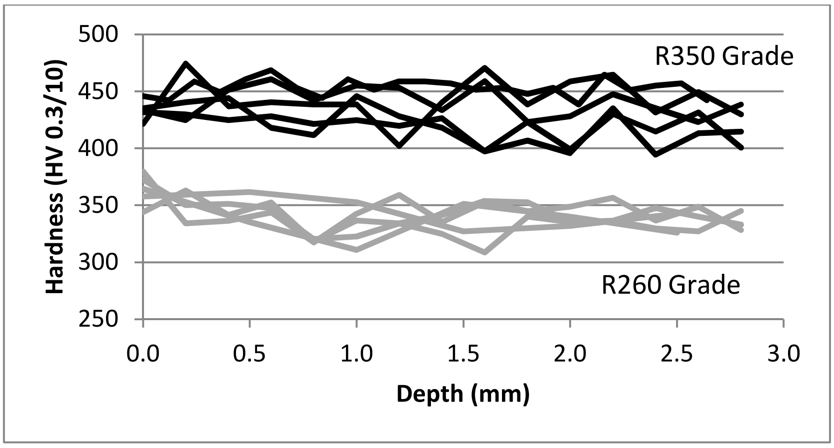


Figure 14: Hardness trace of R260 and R350 grade discs after 2000 cycles

Figure 15 shows a cross section image of the endpost in both a standard R260 grade rail disc and in a heat treated R350 grade rail disc. It is clearly seen that the heat treated rail steel lipped much less than the standard rail steel. This is thought to be because of the tougher rail steel being able to better withstand the high vertical and tractive forces exerted on it by the wheel disc.

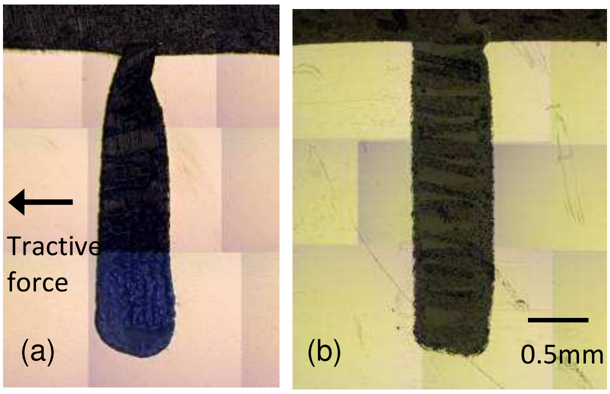


Figure 15: The effect on lipping of harder / tougher rail steel R350 grade (b) and R260 grade (a)

The tested R350 grade discs were also etched for comparison with R260 grade discs, an example of which is shown in Figure 16. It can be seen that no ratchetting was present as in the R260 grade discs. This is again backed up by the information provided by the plot in Figure 8 where the R350 grade disc is also in the subsurface elastic region where no ratchetting is expected. No shelling of the running surface near the endpost is observable where it was in the case of the R260 grade discs.

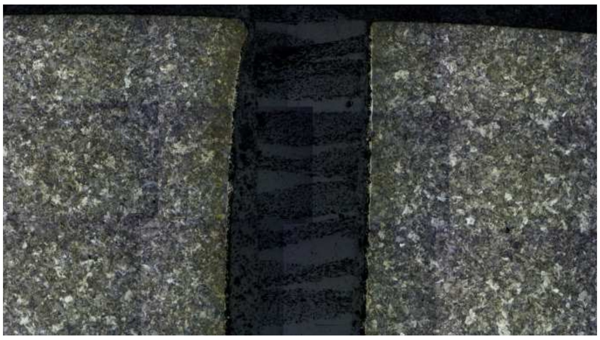

Figure 16: Etched R350 rail disc, no ratchetting or shelling is present

Further measurements were taken to assess the performance of the two rail steels in comparison with one another. A profilometer was used to measure the surface of the discs so that the vertical plastic deformation of the steel could be evaluated as well as the longitudinal lipping effect. Figure 17 shows profiles of the head hardened and standard grade steel in comparison to the profile of an ideal disc. It was seen that the deformation of the standard grade steel was much greater than that of the head hardened rail. The discrepancies in the centre of the graph are the locations of the endpost.

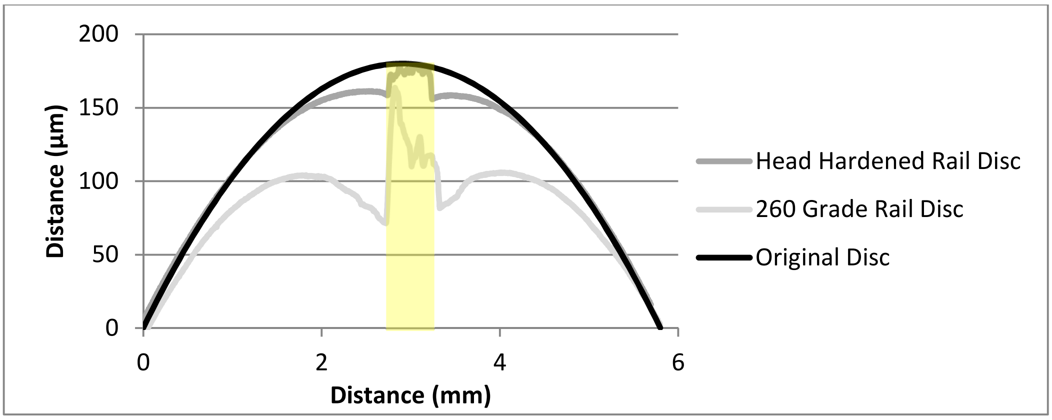


Figure 17: Profiles of the two different rail steels tested in comparison to the ideal disc profile, the shaded area denotes the endpost location

The vertical plastic deformation of the steel around the centre of an IBJ leads to dip in the track. Dipped joints are usually associated with track structure degradation and are problematic because they cause the passing wheels to exert high dynamic forces on the IBJ and the surrounding track structure leading to further damage and premature failure of the system as discussed in the introduction. Dipping of the joint because of material flow could be one cause of initial structural degradation.

## 3.5 Investigating Laser Clad Materials on the Rail Surface

In addition to testing different rail steels, materials that have been laser clad onto the test samples have also been assessed for their performance benefits. A tougher material, in powder form, can be welded onto the running surface of the disc using a laser. This creates a layer on the surface with enhanced properties to that of the bulk rail steel. This technique is generally used to improve the wear performance and life of components such as drills and machine tools without having to change the bulk material, also making the process more cost effective.

To begin this testing a grade R260 rail disc was clad with Stellite 6 material, a cobalt based alloy commonly used for hard facing and wear protection of components. Stellite 6 has a higher hardness and strength than the R260 rail steel, the hardness of the laser clad layer of the samples being approximately 600HV whilst the grade R260 rail steel measured at approximately 350HV. This can be seen in Figure 19. Stellite 6 material was chosen due to previous investigations seen in the literature where different materials laser clad onto twin disc specimens were tested. Stellite 6 showed the lowest wear and good RCF performance [14].

The samples were tested using the same parameters as previous tests so that comparisons could be made between them. It must be mentioned, however, that the pressure between the two discs may not be 1500MPa as used for the previous tests. The force applied to the discs was kept at the value of 7.19kN, but because of the discs differing material properties it is likely the contact patch was smaller and therefore a slightly higher pressure was experienced between the two discs. It is difficult to assess the change in contact pressure, especially in the laser clad disc that has a layered structure and this is outside of the scope of this current research. The applied force between the two discs was kept constant as would be the case in the field if the rail head material was changed. After 2000 cycles the laser clad specimens showed little to no sign of lipping, very similar to the results gained from by using grade R350 discs. Cross section images of these discs can be seen in Figure 18.

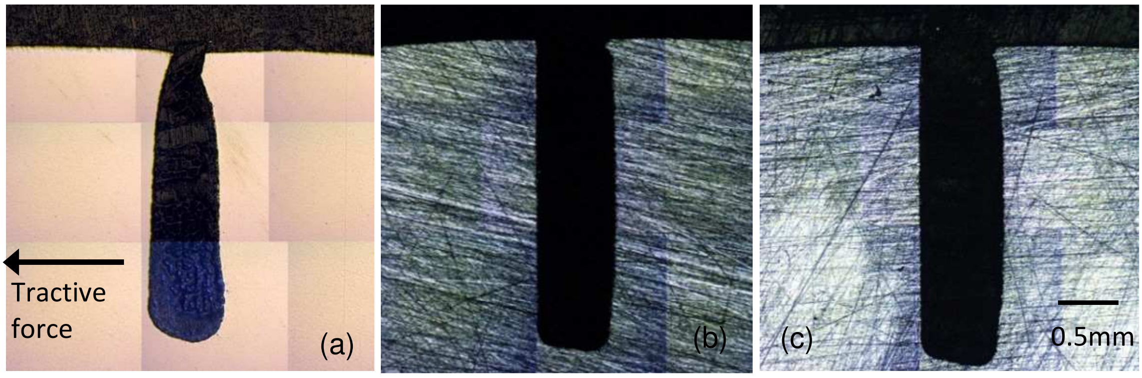


Figure18: Different disc samples tested under the same conditions (a) R260 rail steel (b) R350 rail steel and (c) R260 rail steel with laser clad layer of Stellite 6

The reduction in lipping of the laser clad sample compared to the R260 sample can clearly be seen in Figure 18. The improved lipping performance is for the same reasons that the R350 grade discs show better qualities, the laser clad layer is harder and tougher and so resists the high contact pressures better. The increase in hardness between the different materials can be seen in Figure 19. From this graph it can be seen that the laser clad layer has a higher hardness than the R350 and R260 discs and the layer is around 0.5mm in thickness. Underneath the laser clad layer the hardness of these discs is increased over the bulk material from a depth of 0.5 to 1.5mm. This is the heat affected zone where the properties of the R260 material have been changed by the laser cladding process and are roughly the same hardness value as the R350 discs. Beyond this heat affected zone the hardness is similar to that of the R260 grade disc. For the full-scale, the clad layer thickness would be chosen to avoid the peak shear stress being near the interface or in the HAZ much as it has been for the twin disc tests.

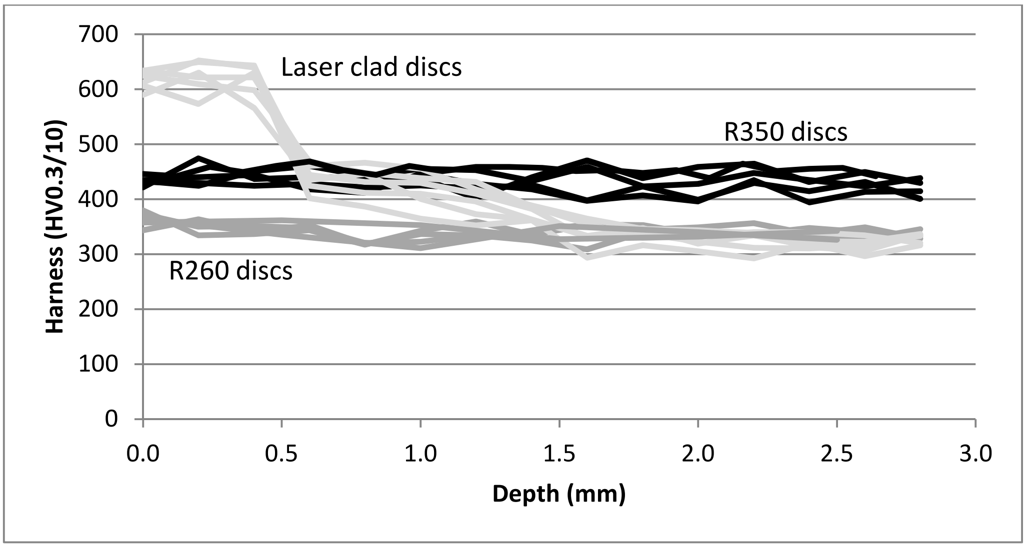


Figure 19: Hardness of grade R260, R350 and laser clad twin disc samples

The tests above were run for 2000 cycles, which was not enough to cause severe lipping in either the R350 rail disc or the laser clad rail disc. Therefore, further tests were carried out for a greater number of cycles so that an assessment can be made of possible benefits of laser clad rail over hardened rail steel. For this testing samples of premium rail steel from the US were used. This rail steel is very similar in properties to that of R350 grade rail steel used above. The laser clad material that is used is kept as the same material as in the above tests, Stellite 6 cobalt alloy. The tests in this case have been run for a total of 96000 cycles at the same slip value as previous tests of 0.5%.

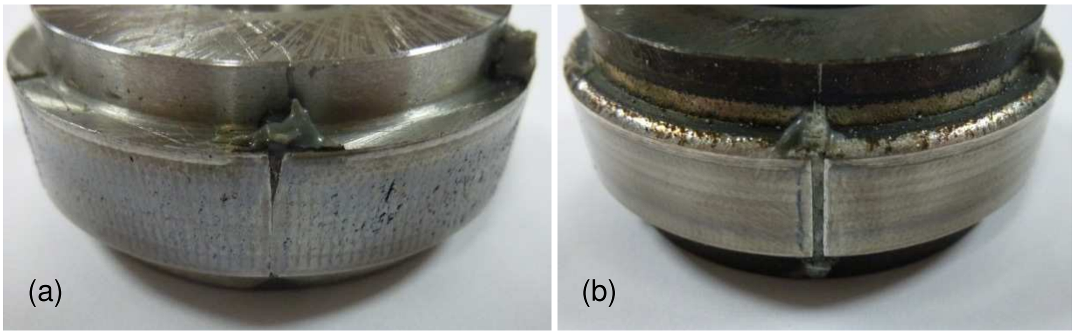


Figure 20: Surface images of the premium rail (a) and laser clad (b) twin disc samples after 96000 cycles

From image (a) in Figure 20 it can be clearly seen that a full lip has formed over the endpost gap in the premium rail steel sample. In comparison, the laser clad sample in image (b) shows endpost is still visible and no or very little lipping appears to have occurred. This is further highlighted by the cross section images in Figure 21.

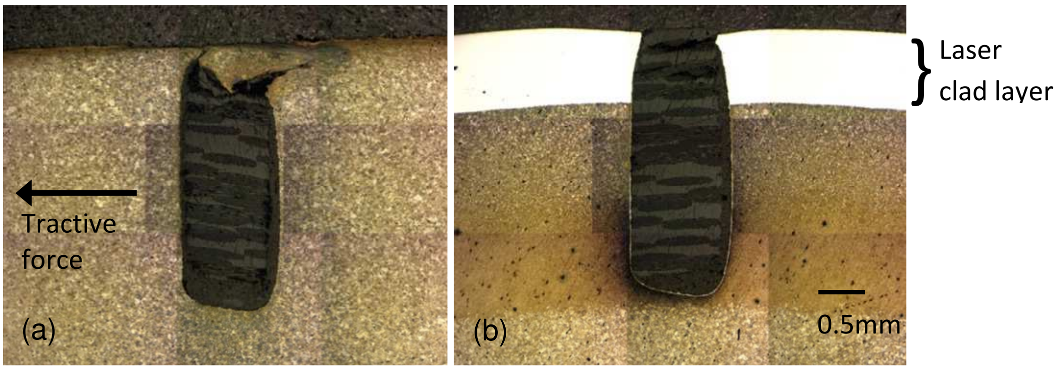


Figure 21: Cross sectional images of premium rail steel (a) and laser clad (b) twin disc samples after 96000 cycles

In Figure 21 the laser cladding layer can clearly be seen in image (b). The steel in these images has been etched to display the grain boundaries and the Stellite 6 layer is visible because of this process. A closer image of the surface of the premium rail disc in cross section can be seen in Figure 22. This image shows the ratchetting behaviour of the disc to a depth of around 0.3mm. The total depth of deformation of the steel in Figure 21 (b) is around 0.7mm, this would suggest that bulk deformation is still occurring, as was displayed in the previous results. However, the bulk deformation is heavily influenced by the tractive force as there is a much greater lip formed in this direction than is formed against the direction of the tractive force.

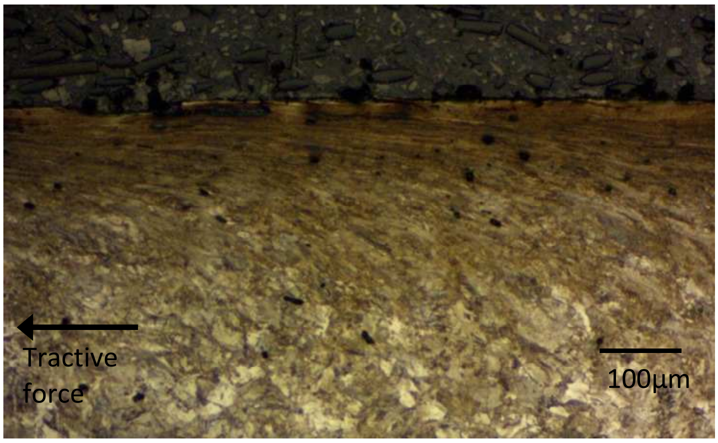


Figure 22: Image of the running surface of the premium rail disc in cross section displaying ratchetting behaviour

In Figure 23 a plot of the coefficient of traction can be seen of the premium rail disc test. This shows that the traction coefficient is highest at around 10000 cycles and higher than values shown in Figure 8 for other rail materials. The coefficient then slowly drops throughout the test. This helps to explain the ratchetting seen in these discs as the increase in friction brings the maximum shear stress in the disc towards the surface. It also explains why ratchetting was not seen in the R350 grade rail. The R350 grade discs were only run for 2000 cycles meaning that the traction coefficient did not reach the value required to cause ratchetting.

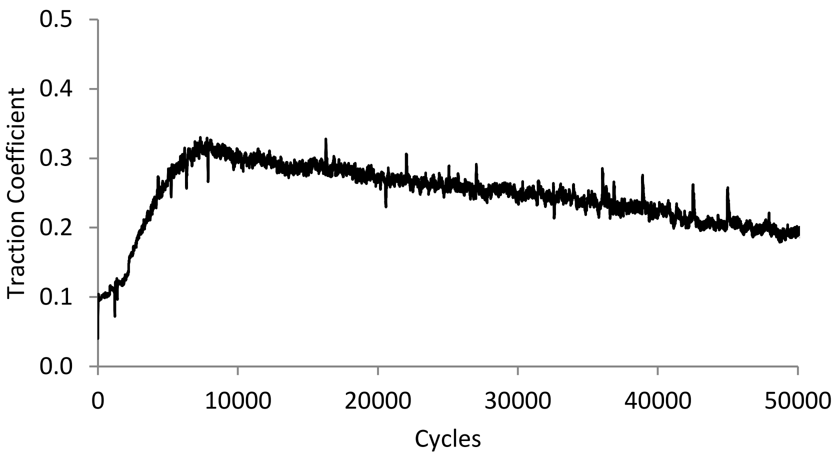


Figure 23: Graph showing the coefficient of traction for the premium rail steel disc

Profile measurements were also taken of the discs used in this test which can be seen in Figure 24. The results are similar to that shown in Figure 17, the laser clad rail disc which shows an increased performance in lipping also displays less vertical deformation at the running surface than the premium rail disc.

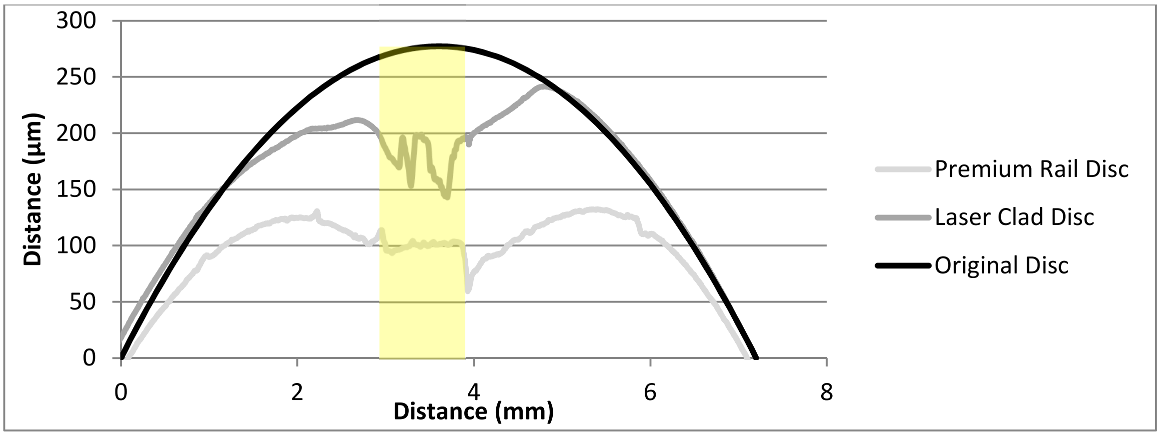


Figure 24: Graph showing the different profiles of the tested rail discs in comparison with a new disc, the shaded area denotes the location of the endpost

Laser cladding of the rail head around the area leading up to an IBJ seems a positive step to take to guard against lipping when considering the above results. Care must be taken, however, to ensure that the laser cladding itself and the interface between the laser clad layer and base rail steel does not become an issue in itself as seen in previous work [5].

## 4. Conclusions

The testing that has been carried out has led to a number of indicative conclusions being drawn.

- Lipping of the steel rail head over the endpost has been simulated successfully using the Sheffield University ROlling and Sliding twin disc test machine.
- The effect of changing the endpost thickness was investigated. The thickness was not found to affect the extent of lip formation. A thicker endpost provides a greater distance between the two rail ends and should therefore lead to a greater time before electrical failure due to lipping. However, the effect of overall joint deformation also needs to be considered.
- Changing the endpost material from PA6 to epoxy glass altered the lipping / plastic deformation seen over the endpost. The PA6 endpost led to more lipping of the steel. A higher wear rate was apparent in the PA6 endpost than the epoxy glass.
- Increasing the hardness and strength of the rail steel was found to reduce the lipping over the endpost. The vertical deformation of steel at the endpost position was also reduced. The performance was increased further by using a tough laser clad Stellite 6 layer on the running surface of the disc.
- Lipping in these tests has been caused by both the bulk deformation of the steel at the endpost and influenced by the tractive force and ratchetting of the steel at the running surface.

It is suggested that further work be carried out in full scale for the laser cladding application. In service IBJs should be clad and monitored in order to assess the life cycle benefits of this methodology.

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