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Optimisation of Grease Application to Railway Track

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Abstract

Trackside lubricators are designed to deliver grease to passing wheel flanges to reduce wheel and rail wear on curves. Ensuring that they are set up to deliver sufficient grease for the range of vehicles passing a site can be a challenge. For example, vehicle dynamics modelling and site investigations have shown that the wheels of passenger vehicles do not run as close to the rail face as those of freight vehicles, meaning that they are less likely to contact the grease and lubricate subsequent curves.

To investigate the effects of different trackside devices, and the influence of parameters governing grease pick-up, including lateral wheel displacement and pump durations, a bespoke test rig was built at the University of Sheffield. The rig used a scaled wheel, a short section of rail and a modern trackside lubricator set-up. Experiments involving different lateral wheel displacements and pumping durations were carried out, as well as visualisation of grease bulb sizes. This showed how a grease bulb grows. It also indicated that a worn profile is likely to require greater wheel displacement to cause contact with grease bulbs than a new wheel profile. The experimental results showed that increasing pick up of grease can be expected where using an additional component called a GreaseGuide™ fitted to a regular grease dispensing unit (GDU) on the rail. The efficiency of grease pick up was investigated and test results exploring increasing pump durations indicated a relationship between pick-up and bulb size. To validate the use of the scaled rig, similar tests were carried out using a full-scale test rig. The full-scale results were compared to the experimental results from the scaled-wheel rig. This showed that whilst there were differences between the two test-rigs in absolute values and anomalous results, overall trends were the same on both test scales. The effect of temperature on bulb size and pumpability of grease was also investigated. This work can be extended further by using the same method to investigate other parameters affecting the lubrication of curves. This can lead to optimised lubricator setup to ensure the track is fully lubricated all of the time.

Keywords: wheel rail contact, grease, pick up, lubricant modelling, bulb size, temperature, pumpability

1 Introduction

1.1 Background

High rates of sidewear of rails can result from the high stress and slip conditions where there is contact between the wheel flange and the rail gauge corner, and is most common in curves. In such situations some form of lubrication is normally applied to control wear to an acceptable level. As part of a project to better understand the performance of trackside lubricators on the GB network, Network Rail [1] are currently investigating situations where some vehicles appear not to pick-up grease from these lubricators. It is concerned with whether vehicles are able to adequately lubricate the subsequent curve(s). Lack of adequate grease pick-up may be due to the siting of the lubricators; historically, a lubricator would be placed in the entry transition to a curve where flange contact is first likely to occur and hence pick-up of grease by the wheel flange will take place. Recent developments in trackside lubrication have led to the increased use of electric lubricators which provide enhanced performance and reliability over traditional mechanical lubricators. Consequently, a single electric lubricator is expected to deliver sufficient grease to lubricate longer sections of track, with a reduction in the total number of lubricators required. Electric lubricators have also tended to be placed on sections of straight track, where lubricator blades can deliver grease to the wheel flanges passing on both rails, and the siting of the lubricators can be positioned to ease access arrangements for the maintenance teams. Figure 1 shows a typical lubricator set-up where two grease delivery units (GDUs) are utilised to lubricate one rail.

Figure 1- Typical GDU layout

However, recent work [1], using vehicle dynamics simulations to predict the extent of wheel-rail relative displacement when running on a section of track, has shown that the wheels of some vehicles may not move close enough to the gauge face of the rail to pick up grease from lubricators installed on straight sections of track. This is due to differences in vehicle suspensions and wheel profiles, and has been corroborated by measurements from vehicles in the field. This leads to a subsequent risk that the rail/flange contact on the following curves may not be adequately lubricated. Figure 2 compares the simulated movement of a wheel relative to the rail for two different vehicles, with different wheel profiles, running over two different pieces of straight track with different lateral alignment quality. The red and blue dotted lines indicate the amount of relative movement between the wheel and rail required for the wheel flange to pick up grease from the lubricator GDU for the two different wheel shapes. The results show that, because of the higher wheel/rail conicity and stiffer yaw suspension, the wheels of the passenger vehicle (red line) exhibits very little movement relative to the centre of the track and are therefore unlikely to get close enough to the lubricator to pick up grease from the GDU. On the other hand, the freight vehicle (blue line) shows much larger lateral movements and might, therefore, be expected to be better at picking up grease from lubricators located on straight sections of track.

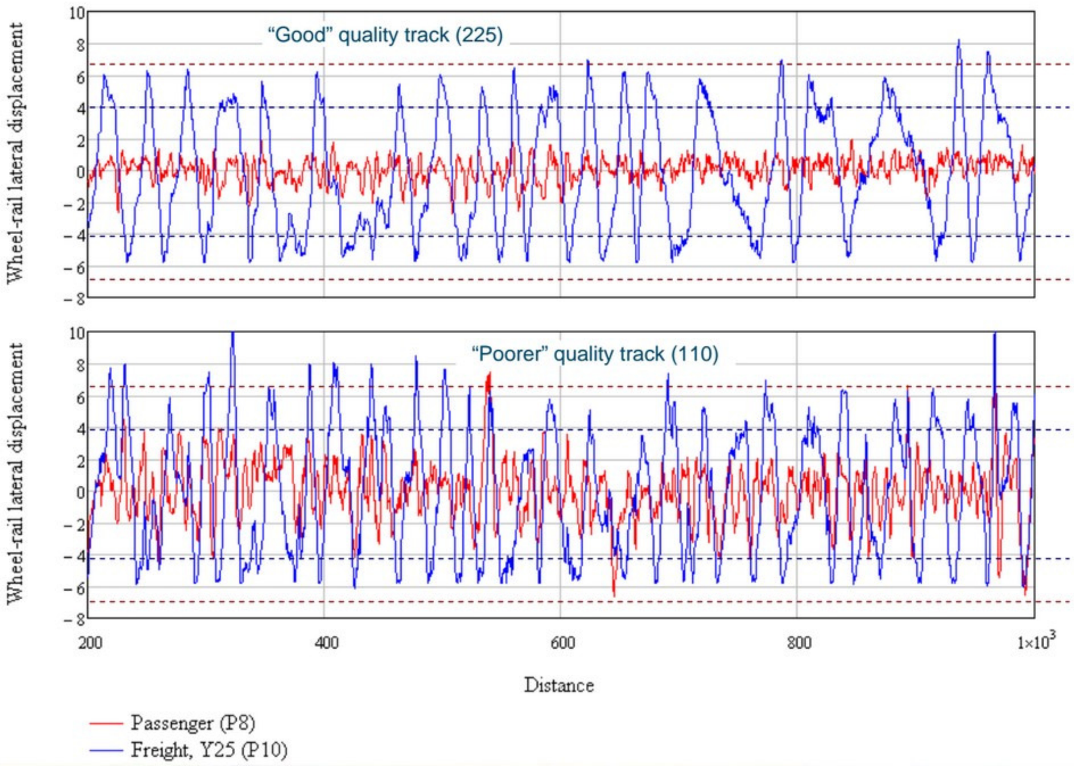

Figure 2- Predictions of wheel-rail lateral displacement for example freight and passenger vehicles on differing quality track, showing that the wheels of passenger vehicle with P8 wheel profiles exhibit much less lateral motion than a freight vehicle with P10 wheel profiles [1]

The data above illustrates observations from the field, that some vehicles did not consistently pick up grease from lubricators on straight track because of vehicle/track interaction. Developing a better understanding of the relationship between grease output from a GDU, wheel/rail lateral position and the ability of the wheel to pick up grease could improve the application of components and controls to increase the effectiveness of the trackside lubricators and therefore have considerable benefits to the industry.

1.2 Aims and Objectives

The aim of this project was to investigate the optimum conditions for grease pick-up by the wheel flange from track based Grease Distribution Units (GDUs). This was achieved by studying the interaction between the wheel and 'bulbs' of grease dispensed from the GDU using two approaches. The first was to take measured sizes of output grease 'bulbs' from the field and compare the theoretical interaction with wheel/rail position in a computer model. Then experiments were undertaken with a scaled wheel-on-rail test apparatus with a GDU fitted. This enabled measurements of grease pick-up with a range of controlled parameter settings. Further tests were also carried out using a full-scale linear test rig to validate the findings.

1.3 Grease Lubrication Research

Currently there are very few published papers that focus on the subject of grease pick-up, although there are papers which deal with flange lubrication in general. The effect of lubrication is well documented: wear rates of dry wheel/rail contact can be as much as twenty times higher than lubricated wear rates in sharp curves, which illustrates the importance of proper flange lubrication [2]. The American Association of Railroads estimates that wear caused by ineffective lubrication costs in excess of $US 2 billion per year and Eurostar estimate that lubrication saves £ 1,000,000 per year in maintenance and wheel replacement [3].

Work carried out in 2014 at the University of Sheffield [4] developed the test apparatus or rig that was also used in the work described in this paper. In that work grease pick up was measured in terms of mass at two different vertical mounting positions in clean and dirty conditions. Tests were carried out at four different lateral positions of the wheel relative to the rail, but there was found to be a large spread in the data recorded, making conclusions difficult to draw. Some of the variation was attributable to difficulties in controlling pump output volumes since a hand pump was used.

There have been a variety of field based studies looking at flange/gauge face lubrication (for example [5-6]). However, laboratory experiments provide more control over key variables as it is easier to isolate a particular parameter of interest. Twin disc testing with greases simulating flange/gauge face contact has shown that an increase in retentivity causes a decrease in wear rate [7]. Retentivity is defined as how long a fixed amount of grease provides lubrication. These tests also found significant differences in wear rates when using different greases. Uddin *et al*. [5] carried out a variety of field studies in Australian heavy haul lines. They found that longer (by circa 50%) applicator bars performed better, and in some cases increase the distance the lubricant was carried through curves by up to 60% compared with shorter GDUs. Tests also showed that 'splash' of grease, which corresponds to wastage of grease, varies greatly depending on bar height, type of bar, rail size and type of grease.

2 Methodology

2.1 Test Apparatus

2.1.1 Scaled-Wheel Rig (SWR)

A bespoke rig designed for pick-up assessment (from [4]) was used in the work (see Figure 3), with some adaptation to improve operation and adjustment. A reduced diameter wheel is mounted on a trolley, which is mounted on a T-section bar to provide a parallel controlled motion, with the tread of the wheel thus rolling along a section of real rail inclined at 1:20. The trolley is in two parts, the lower with roller bearings interfacing with the bar and the upper part able to be adjusted to set the wheel position laterally with respect to the rail. The neutral position of the wheel is found from analysing standard track gauge and wheelset back-to-back measurements for the GB network; the distance from wheel flange back to rail gauge face is 37.5mm. The size of the wheel was determined (approximately 1/5-scale, 180mm diameter) so that it was large enough that the circumference was longer than the GDU and the length of rail was sufficient to allow the wheel to pass the GDU. The wheel profile used was that of a new P8 profile [8], commonly used for passenger rolling stock in Great Britain. For this test rig, the wheel/rail surface contact is in nominally pure rolling and there is no speed control, slip or angle of attack applied.

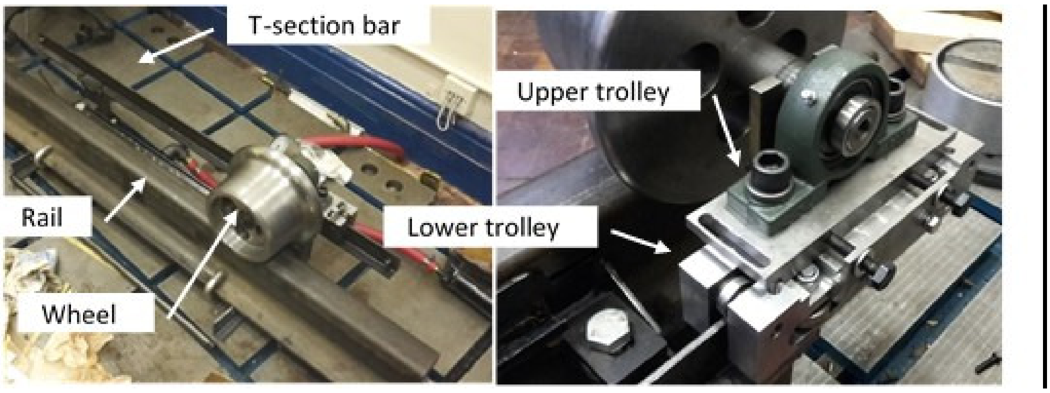

Figure 3- set up of test rig

2.1.2 Full-Scale Rig (FSR)

The Full-Scale Rig (FSR) [9] uses a full size P8 profiled wheel that is loaded and rolled along a section of rail which slides on a slide bed beneath it. Figure 4 is a diagram showing how the FSR operates. Normal load and wheel/rail creepage (slip) can be controlled using three separate actuators (labelled 1, 2 and 3 in Figure 4). Normal load is applied vertically above the wheel, rail velocity is controlled by moving the slide bed and slip is applied via a chain attached to the rim of the wheel that moves at a set velocity relative to the slide bed. Figure 5 is a photograph showing the attachment of the standard GDU to the FSR. Other aspects of the FSR can also be seen in the photograph.

The lateral position of the wheel is set by lifting the wheel off the rail and manually moving it to the desired position. The wheel is only fixed on the 'field' side of the rail (opposite side to the GDU). During operation, and due to a small angle-of-attack of the wheel to the rail, the wheel was sometimes observed to move laterally, varying the gauge face to wheel flange back distance. This movement could vary from one wheel pass to another and could lead to some increased variance in the results.

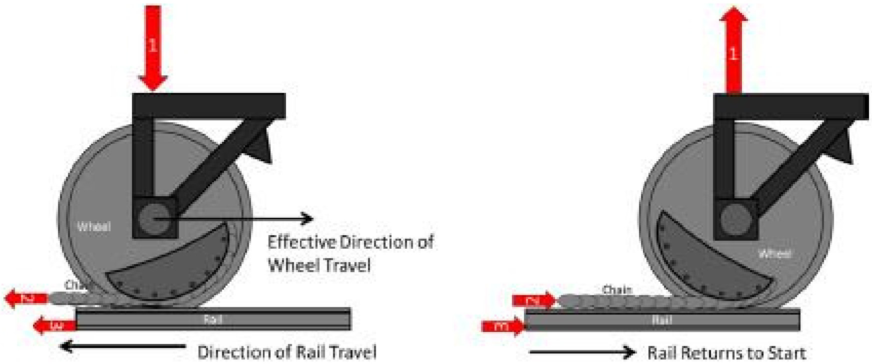

Figure 4- FSR diagram

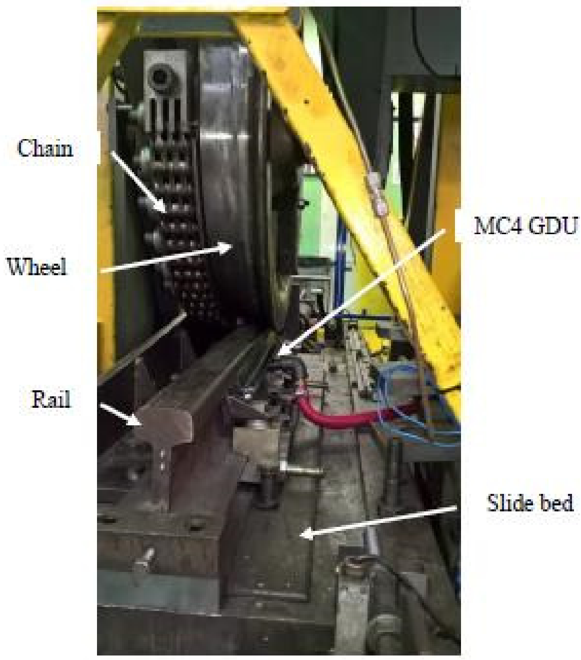

Figure 5- Set-up of MC4-GDU on FSR

2.1.3 Lubrication Equipment

A L.B. Foster supplied "Protector IV" lubricator cabinet with pump, motor and controller was used to control grease supply during the experiments. The grease used in these tests has properties shown in table 1:

Temperature range	-40°C to 120°C
Pour point (IP15)	<-30°C
4 ball wear scar (IP220)	0.5mm
4 ball weld load (IP239)	450kg
Penetration (IP50)	280-295
Flash point (IP34)	>250°C

Table 1- Grease properties

It is important to note that the tests carried out in this paper focus on how the wheel position and pump characteristics affect pick-up/carry-down rather than an assessment of the grease properties.

The investigation made use of two variants of GDU manufactured by L.B. Foster. The standard MC4 (Figure 6) is a bar type GDU with 18 outlet ports, through which grease is pumped forming separate bulbs which are available to be picked up by passing wheels. The second variant is of the same base design, but is supplemented by the patented GreaseGuide™ (GG) (Figure 7). This additional element comprises a foam pad which forms a ledge alongside the bar. Both GDUs were mounted at the height specified by the manufacturer.

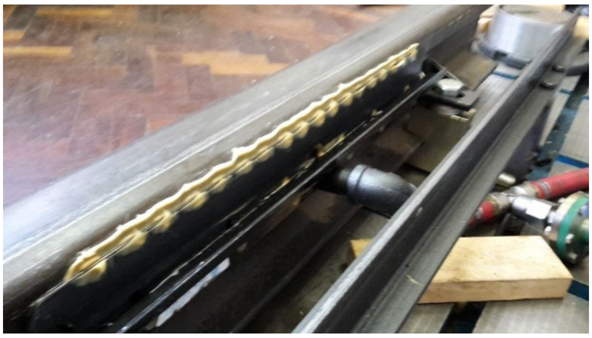

Figure 6- MC4 GDU

Figure 7- MC4-GG GDU

2.2 Visualisation of grease interaction

Visualisation of the interaction of the grease bulbs and wheel flanges was carried out using real measurements of grease bulb sizes from the MC4 GDU in the lab and importing them into proprietary drawing software. As the size of the bulbs produced at each port may vary along the GDU, measurements were taken of bulbs at three equally spaced locations along the GDU produced by pump intervals of 0.1s up to 1.0s and for a maximum pump duration of 1.4s after which the bulbs were found to start to collapse and fall. The depth of the bulbs was measured at 2mm intervals from the top of the bulb to the base of the bulb and the mean dimensions determined to build up a typical 2D model of the bulb shape for each pump duration. To reduce the effect of scatter in the model, three repeats at each pump duration, including two ports at each measurement location, and including a minimum and maximum bulb size were used.

These measurements of bulb size were then fitted to electronic drawings of the rail and GDU assembly and overlaid with new and worn wheel profile shapes to determine the required lateral displacement of the wheel for contact between the wheel flange and grease bulb to occur. The modelling of a worn P8 profile was considered important as the pick-up tests would only use the new P8 profile, whereas in the field a GDU would be expected to deliver grease to a wide range of worn profile shapes. Although this comparison only used one worn wheel profile, it was useful in assessing the applicability of laboratory results to wider field performance. The worn profile was lightly worn as seen in Table 2, the values for new and maximum/minimum were taken from the Railway Group Standard for wheelsets [8].

	Flange Thickness (mm)	Flange Height (mm)
New Profile	28.5	30
Worn Profile Used	27.83	31.22
Minimum/Maximum Allowed	24	36.5

Table 2- Details of worn profile used

2.3 Pick-Up Tests

Tests were carried out using the SWR at a range of lateral wheel displacements that approximated those found from vehicle dynamics simulation for freight and passenger trains undertaken by Network Rail [1], an example of which is presented in Figure 2. Those simulations showed that the wheelset with a P8 wheel profile on a passenger vehicle generally experienced a lateral displacement relative to the track of approximately 2-4mm, depending on the quality of the lateral track alignment. However, the P10 wheel profile on an example freight vehicle exhibited variations in lateral shift of up to 6-8mm.

Figure 8 shows the difference in lateral movement required for two common GB wheel profiles to be able to approach the lubricator GDU. The P10 wheel profile (shown in red) has a thicker flange than the P8 wheel profile (shown in blue), and therefore needs approximately 2.5mm less lateral displacement from the track centre line to be able to interact with likely grease position. These results were made use of to approximate the proximity of different wheels to the gauge face of the rail without requiring a second scaled wheel with a different flange profile. Lateral displacements of 2-4mm, with measurements at 1mm intervals, were therefore used in the tests to represent a typical range of 'passenger' wheel displacement, and displacements of 5.5-8.5mm at 1mm intervals were used to represent typical 'freight' wheel displacements.

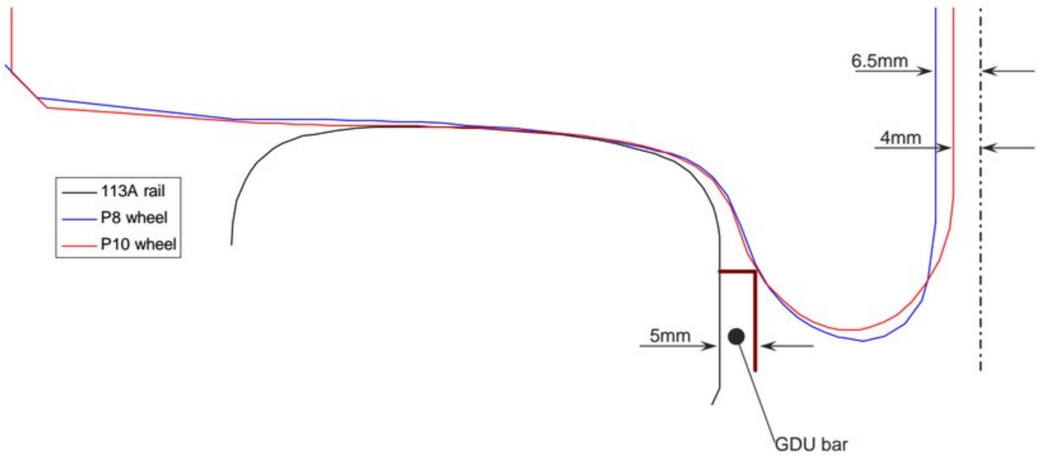

Figure 8- Differences in the lateral displacements required for different wheel profiles to be able to interact with the lubricator GDU, for typical passenger (P8) and freight (P10) wheel profiles [1]

A standard pump duration of 0.1s was used at every wheel lateral displacement setting. In order to investigate the effect of pump duration on pick up, tests using pump timings of 0.2s and 0.3s were also investigated for certain cases of wheel displacement. Each individual test was repeated three times. Grease pick-up was measured by mass of the grease adhering to the wheel and photographs were taken to capture the pattern of grease pick-up. The grease was removed from the wheel using cotton pads and its mass recorded using a set of scales accurate to 0.005g. Grease was also removed from the rail and GDU and weighed using the same process.

It was necessary to establish a base level of grease on the GDU/rail that was considered to replicate a standard established state in service. This was to replicate field conditions as much as possible, where a GDU will already have an amount of grease present on it before a wheel runs past it. Whereas in the laboratory tests all the grease had been removed for weighing after the previous test. Whilst this inevitably introduced a degree of variability, it was considered important to enable the test to represent a comparison in service rather than always using a clean rail. For the MC4 GDU this was achieved by rolling a wheel three times at a lateral displacement of 8.5mm through grease that was pumped for 0.3s. The amount of grease thus established on the rail was weighed and was found to be consistent, while additional wheel passes removed no significant further grease. Due to the design of the MC4-GG a normalised level of grease comprises a more consistent layer of grease and greater volume along the length of the bar. A similar process of normalisation was therefore not practical so a modified method was devised to achieve the equivalent effect. The normalised levels of grease are shown in Figure 6 and Figure 7.

2.4 Validation of Pick-Up Tests

Tests were carried out using the FSR at lateral displacements and pumping durations to match the SWR study, with each parameter tested three times. This was done in order to validate the use of the scaled wheel. Grease pick-up was measured using the same equipment and procedure as in the SWR study. For this study the following parameters were used:

- Constant vertical load was 86kN. This equates to a contact pressure of roughly 1000 MPa
- Rail velocity was 100 mm/s
- Slip was 0.5%

Due to the design of the FSR, the normalisation procedure for the standard MC4 had to be modified. The bar was not wiped between each measurement, but to return the grease level to ‘normal’, one pump of 0.3s was added to the existing layer and one pass at a lateral displacement of 8.5mm was carried out. This same normalisation procedure was used for the MC4-GG as well.

2.5 Temperature Effects on Bulb Size and Pumpability

To investigate what variations of temperature will have on the grease bulbs the standard MC4 GDU was put into an environment chamber. The pump cabinet was too large to fit into the chamber so a standard hand pump was used. The test set up is shown in figure 9.

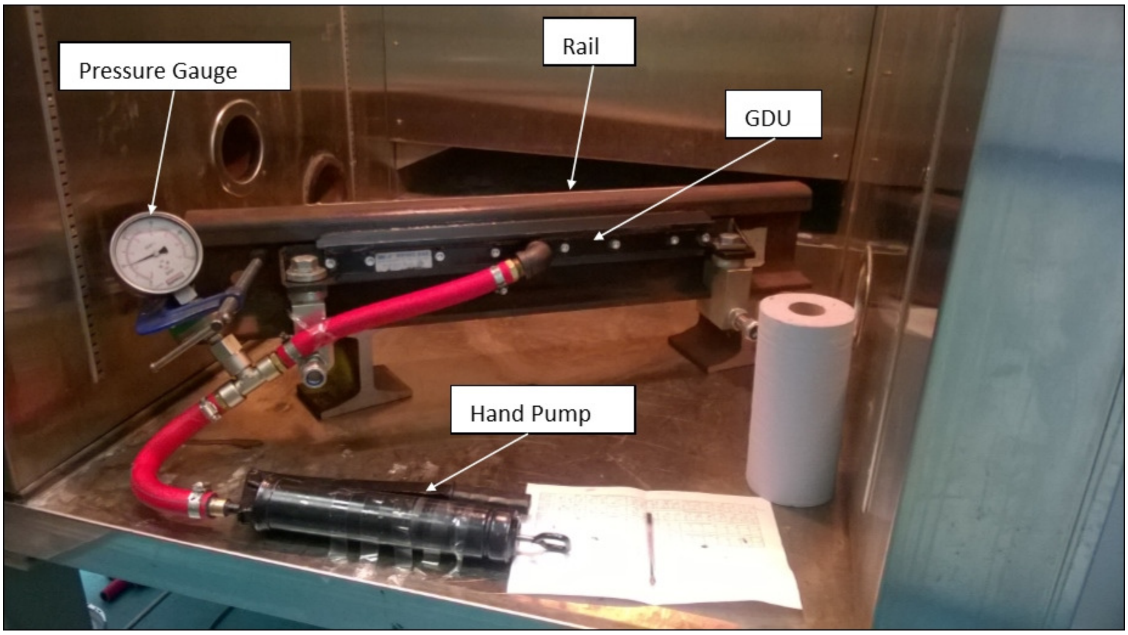

Figure 9- Pumpability test set up

The grease bulb size was measured for all 18 ports of the GDU at four different temperatures: -20°C, 0°C, 20°C, 40°C. The maximum pressure required to pump the grease was also recorded except at -20°C as the pressure gauge had a working temperature range of 0-70°C. The grease and environment chamber was left for 30 minutes once it had reached the required temperature to allow the grease to reach the same temperature.

3 Results and Findings

3.1 Visualisation and Modelling

The modelling was used to show how an untouched bulb can form and grow. Figure 10 illustrates an example of this with a new P8 profile making contact with the mean shape of a 0.5s pump duration grease bulb. Three different grease bulbs are shown: the minimum, mean and maximum are shown by the different colours of bulb.

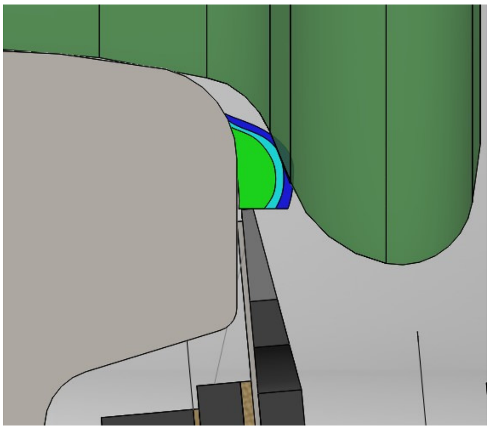

Figure 10- A new P8 profile wheel modelled with a 0.5s pump duration grease bulb

Similar analysis using a worn P8 wheel profile showed that the worn profile required a greater lateral displacement for contact with the grease to occur, see Figure 10. This is because the worn profile has experienced some flange wear, so more movement is required for the flange to contact the grease bulb. Figure 11 shows how this movement varies with bulb size.

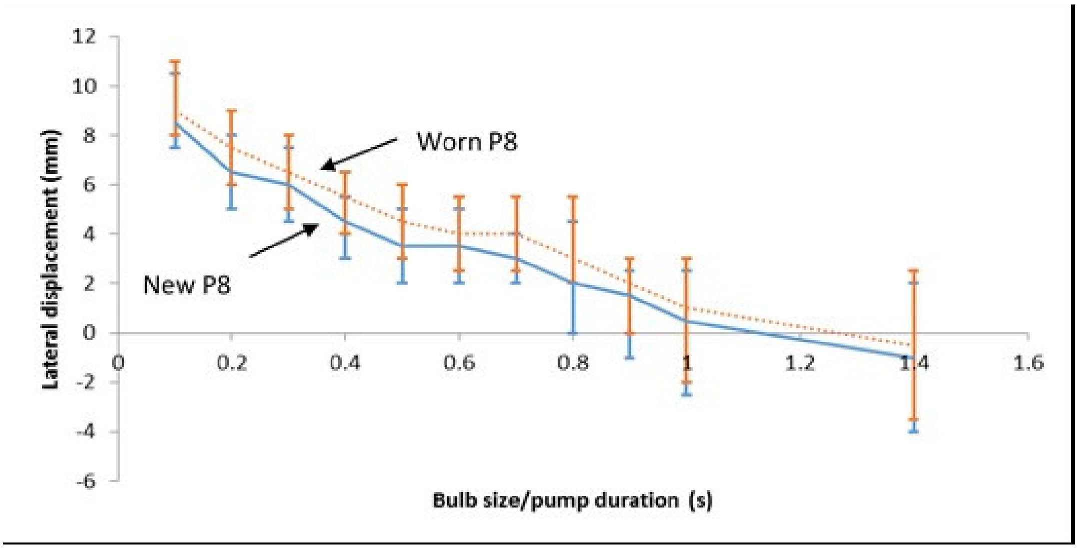

Figure 11- Bulb size vs lateral wheel displacement required for contact with a grease bulb

Figure 12 shows how the grease bulbs grew as the pump duration increased (the wheel shown is a new P8 profile at zero lateral displacement). The different colours show the average size of the grease bulbs at pump durations of 0.1s to 1.0s at 0.1s intervals and a final pump duration of 1.4s. As one would expect, it can be seen that the larger the bulb, the smaller the lateral displacement of wheel for contact to be made with the grease bulb as the bulb grows outwards from the gauge face as well as growing up the side of the rail towards the gauge shoulder.

It should be noted that this visualisation only provides information on contact between the grease bulbs and the wheel, it does not provide any insight into how much grease is picked up by the wheel. This was investigated using the test rig as further described below.

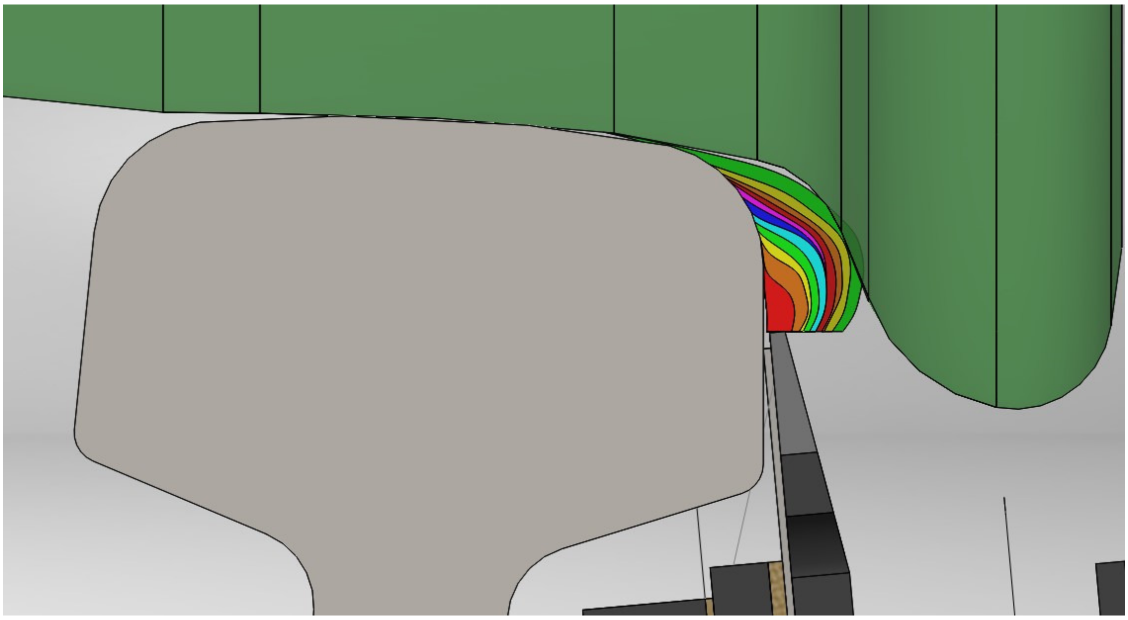

Figure 12- growth of an untouched grease bulb from pump duration 0.1s to 1.0s at 0.1s intervals and a pump duration of 1.4s

3.2 Testing

3.2.1 Results from Pick-Up Tests Using SWR

The key findings from the laboratory testing consisted primarily of data on the amount of grease picked up at different displacements for a range of pumping times. Most of the work was undertaken using the MC4 GDU, with a subset undertaken using the MC4-GG to compare different GDUs.

Photographs of the results were taken as well as mass measurements of the amount of grease picked-up. This allowed the location on the wheel flange where grease was picked up, as well as the quantity of grease, to be identified: both important parameters. Further investigation of the grease pick-up position on the wheel is merited to improve the definition of useful grease pick-up, rather than just the amount of grease found to adhere to the wheel.

The standard MC4 GDU was observed to deposit discrete beads of grease onto the wheel (Figure 13). This was in contrast to the MC4-GG GDU which provided a more continuous “strip” of grease onto the wheel flange (Figure 14). In both cases, there is a ‘tail’ of grease which forms as the wheel pulls away from the grease as it passes.

Figure 13- Pick up of grease onto wheel from one pass through the standard MC4 applicator

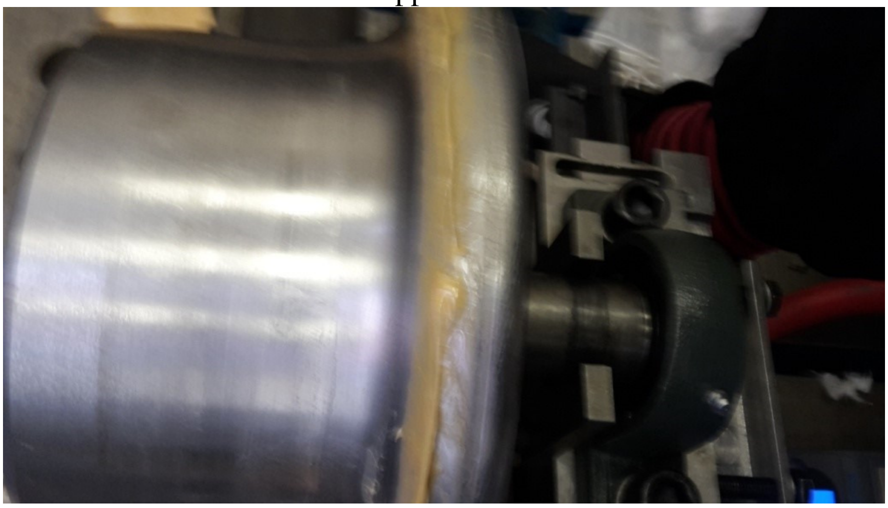

Figure 14- Pick up of grease onto wheel from one pass through the MC4-GG applicator

At a small lateral displacement of the wheel, i.e. the wheel further from the rail, the grease was observed to have been picked up much closer to the wheel flange tip as seen in Figure 15. This is not optimal since contact between the wheel and rail usually occurs closer to the flange root area of the wheel, and in this position it is unlikely that the grease would be able to transfer to the rail effectively to lubricate the contact area. This characteristic was found to be less prevalent in the tests with the MC4-GG GDU.

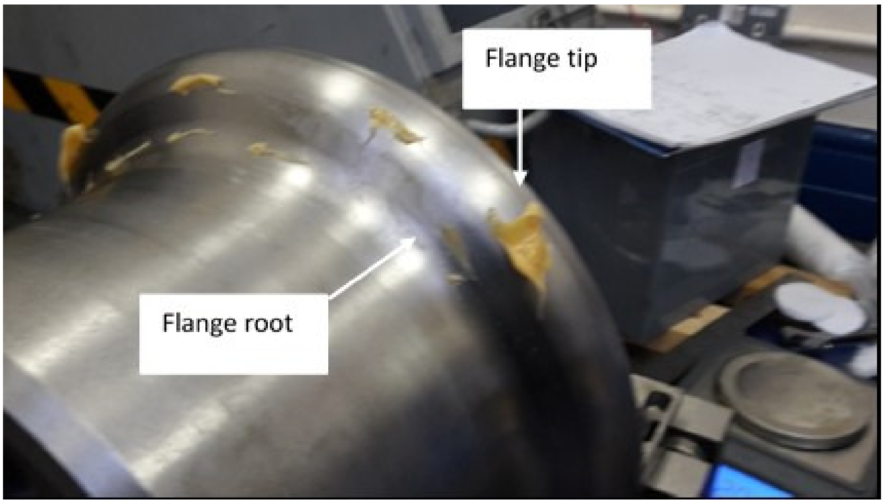

Figure 15- Pick up of grease onto wheel from one pass through the standard MC4 applicator at a small lateral displacement

Figure 16 shows the relationship between wheel displacement and mass of grease picked up with the 0.1s pump time, for both GDU arrangements. The trend of increased pick up with increasing wheel displacement is clear and to be expected. The MC4-GG was found to result in greater grease pick up when compared to the standard MC4 for all lateral displacements tested. The non-linearity of the graph appeared, by observation, to be the result of the complex geometries involved.

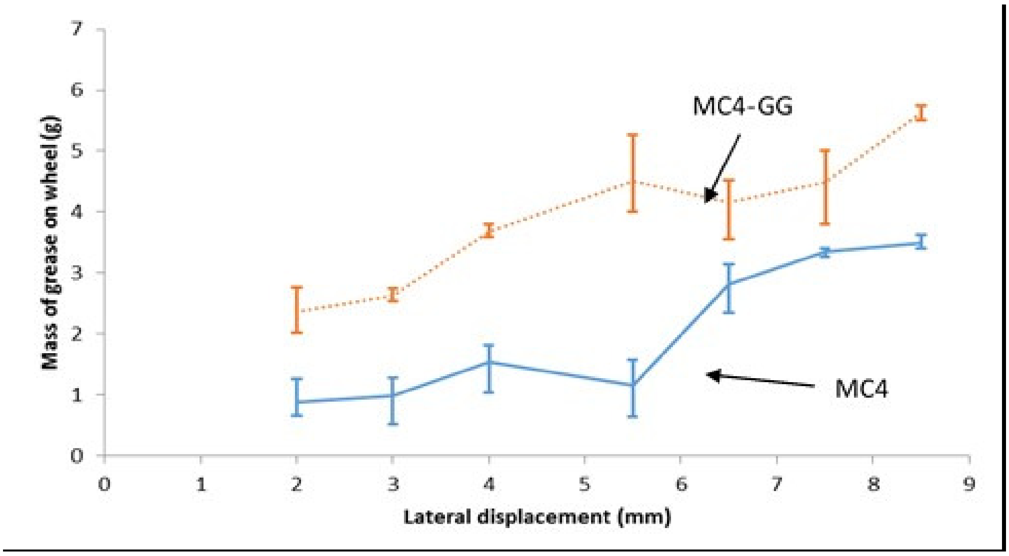

Figure 16- Lateral wheel displacement vs mass of grease pick-up for both GDUs with pump duration of 0.1s

As in both GDU arrangements the same amount of grease is being delivered per test. What was clear from the various parts of the grease weighing was that a proportion of the grease on the plain bar was effectively lost at each wheel pass as it was squeezed down below a point where it could ever be picked up.

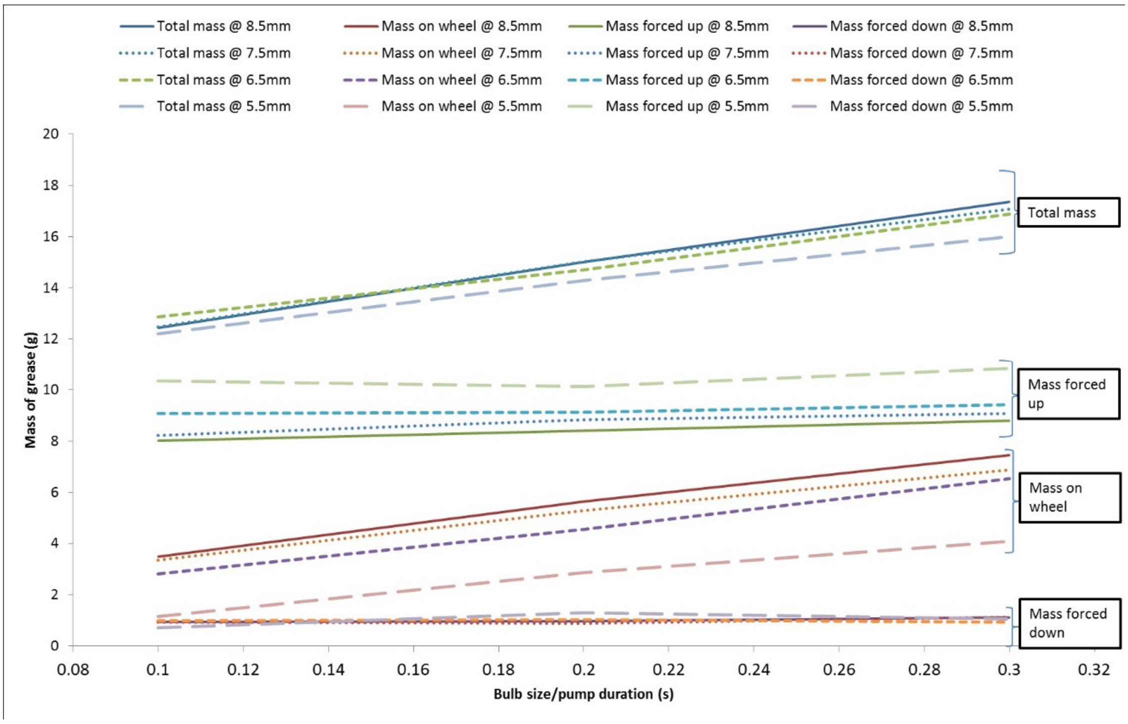

Figure 17- Bulb size vs mass of grease measured in total and as found on wheel and parts of the bar/rail (displacements of 5.5 to 8.5mm, MC4 GDU).

Figure 17 shows (for the MC4 GDU bar), for different positions of the wheel relative to the rail and pump durations, how the grease ends up being distributed on the wheel and rail. Where grease is not picked up by the wheel but remains on the rail it can either be squeezed out of the bottom of the contact towards the rail foot ("Mass forced down" in Figure 17) or spread up the side of the rail towards the gauge shoulder of the rail ("Mass force up" in Figure 17). The total mass of grease increases as pump duration increases, as would be expected, and is reasonably constant for any specified pump duration. The amount of grease lost ("Mass forced down") is similar, regardless of pump timing, and as bulb size increases more grease is picked up. It is interesting to note that, although the amount of grease picked up by the wheel increases as the wheel gets closer to the rail, it remained below 50% of that pumped, even with the larger wheel displacements. The evidence here does not provide insight into how this would change where full flange root to rail gauge corner contact is made. However, pump timings used in the field are most commonly set at the lower end of the range used in these tests.

For the MC4-GG, all grease either remains on the bar or is transferred to the wheel. Also, the long time required to normalise this bar for each measurement meant that a similar graph as in Figure 16 was not produced.

Figure 18 compares the amount of grease picked up by the wheel for each of the two GDU types at the reference and two longer pump times. This shows that the amount of grease picked up from the MC4-GG GDU was more consistent, almost independent of the pump duration, than for the GDU without the grease guide. The increase of pick-up with an increase in pump duration for the MC4 GDU suggests that there is a strong correlation between the amount of pick up and the amount of grease that the wheel contacts. The key points to note from the tests were the actual location of grease on the wheel and the amount picked up at the lowest pump setting. Whilst the mass of the grease picked up from the MC4 bar increased as pump duration increased, the grease was observed to have been closer to the flange tip, which means that it is less likely to be transferred into the contact area. Therefore, although the amount of grease picked up increased the useful proportion of grease picked up did not necessarily increase to the same degree. Secondly, as noted above, the more normal pump duration time for lubricators in the field is at the lower end (0.1s or less) and for these cases the amount of grease picked up from the MC4-GG was significantly higher.

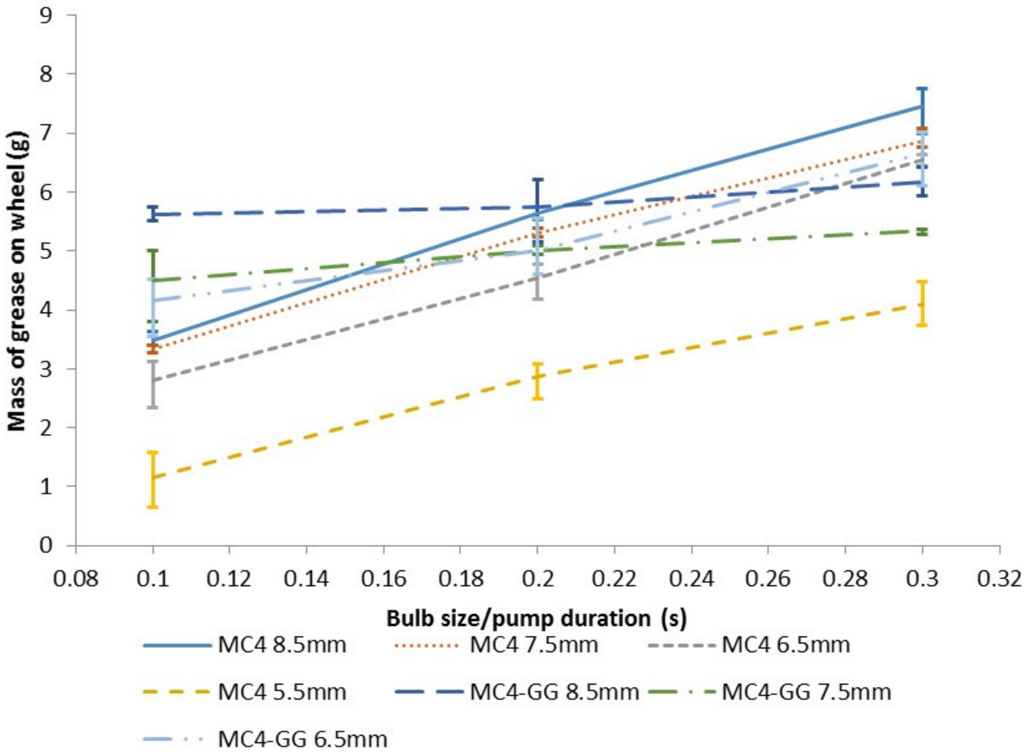

Figure 18- Bulb size vs mass of pick up by wheel for both GDUs at a range of lateral wheel displacements

3.2.2 Results from Validation Tests Using FSR

Figure 19 shows how the FSR results compare to the SWR for the standard MC4 applicator. The graph shows that, for the SWR, there is an increase in grease pick-up as wheel lateral displacement and pump duration increases. For the FSR results there is not a significant difference in pick-up for different pumping durations. However, there is a reasonably good correlation between the SWR and FSR results for a pump duration of 0.1s. It is unclear why the FSR results for the higher pumping durations were considerably different to the SWR results although the different normalisation procedure between the two test rigs will have influenced the results. Data was not collected from the FSR on the amount of grease forced up or down. The larger flange on the full size wheel could have been responsible for dragging down more grease, and not wiping the grease bar between test runs exacerbated this effect. This would explain why the higher pumping durations did not show an increase in pick-up as more grease was pulled down rather than transferred to the wheel.

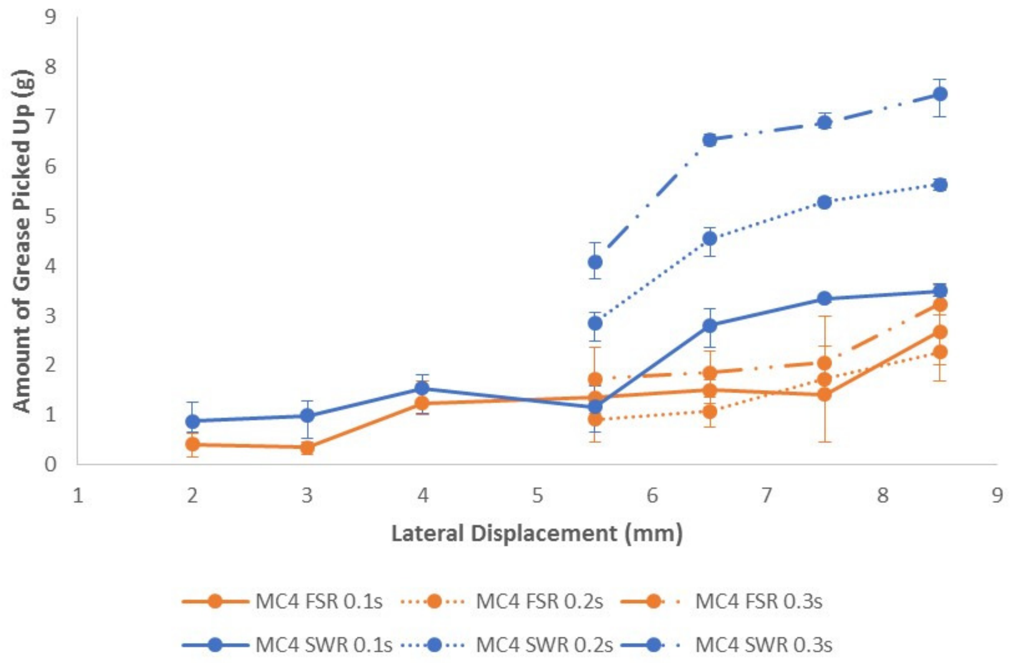

Figure 19- Lateral displacement vs mass of pick up for both the SWR and FSR, for different pump durations using the standard MC4 applicator

Figure 20 shows how the FSR results compare to the SWR results for the MC4-GG applicator. Overall, there is general trend for a small increase in grease pick-up for increasing lateral displacement using both rigs, although there are anomalies within the data which show the opposite effect. In contrast to the standard MC4 data, there is a clear increase in mass pick-up for increasing pump duration for both test rigs.

The error bars showing the maximum and minimum repeat values in Figure 19-20 display an increase in scatter within the results for the MC4-GG applicator. This could account for some of the anomalies within the general trends described above, particularly as the range of pick-up values is smaller with the GG installed when compared to the standard MC4 applicator. Increasing the number of repeats would help improve analysis of the data as anomalies would have less effect on the average values.

The absolute values of mass pick-up are different between the FSR and SWR with the FSR always producing less grease pick-up. The increased size is likely to have an influence as well as the inability to lock the wheel on the FSR at a particular lateral displacement. Although the absolute values are different, overall the same trends are observed on both test rigs.

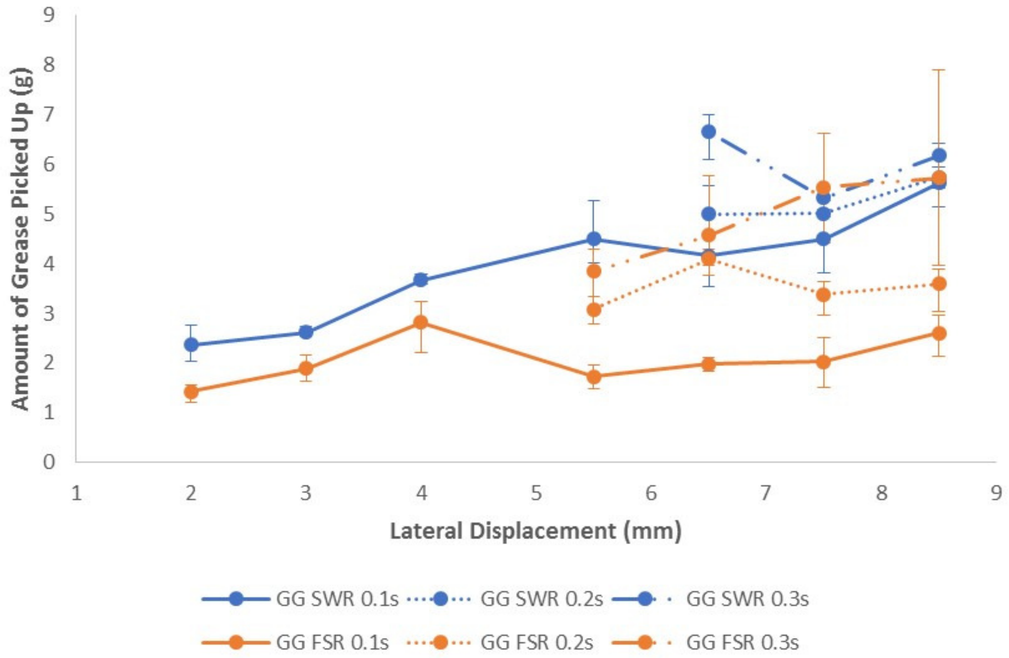

Figure 20- Lateral displacement vs mass of pick up for both the SWR and FSR, for different pump durations using the MC-GG applicator

Figure 21 shows photographs taken after one wheel pass through the two different GDUs. The pumping duration and lateral displacement was the same for both photographs. It can be seen that the GG (Figure 20b) provides a larger smear of grease across more of the flange face than the standard MC4 (Figure 20a). These findings are typical of the observations across the different lateral displacements and pumping durations.

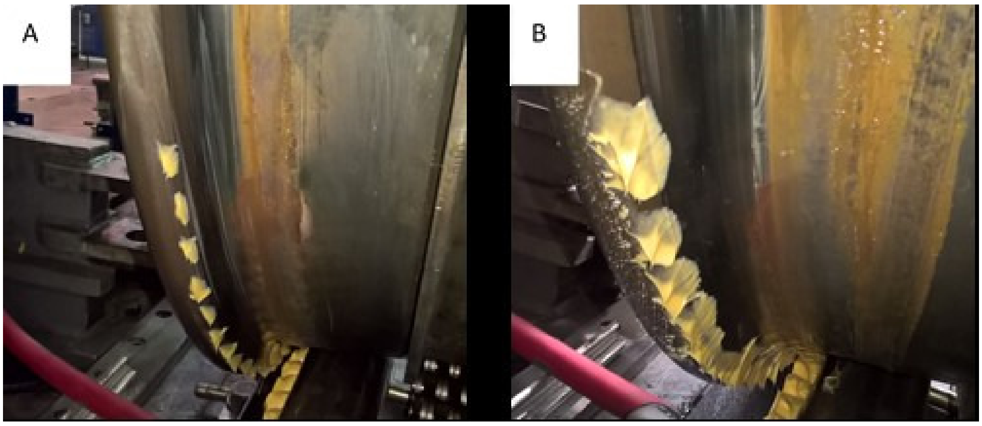

Figure 21- Pick-up of grease onto wheel from one wheel pass at lateral displacement 6.5mm using A) standard MC4 GDU, B) MC4-GG

3.3 Results of Temperature Effects on Bulb Size and Pumpability

Figure 22 shows how the bulb size varies along the GDU in height (figure 22a) and depth (figure 22b). The figure shows the 2 point moving average for each temperature to show the relationship between temperature and bulb size more clearly. It shows that in general the grease bulbs are larger in the middle of the GDU compared to the bulbs at either end of the GDU. The grease bulbs are largest at 20°C. As temperature decreases from this point, the bulb size also decreases due to grease becoming slightly more viscous and does not flow through the GDU as well. Increasing temperature from 20°C to 40°C also results in a decrease in bulb size. This is because the grease becomes sligtly less viscous and hence does not form the bulb as well as at 20°C.

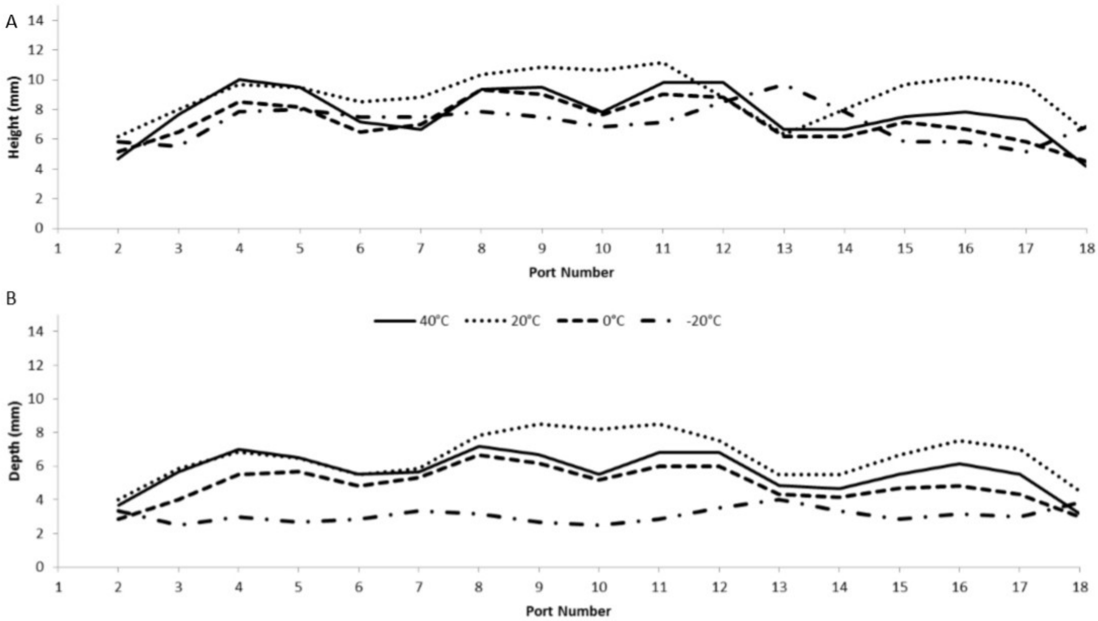

Figure 22- How temperature affects bulb size along a GDU

Figure 23 shows the maximum pressure to pump the grease through the GDU. It clearly shows that the pressure decreases as temperature increases which supports the results in figure 22.

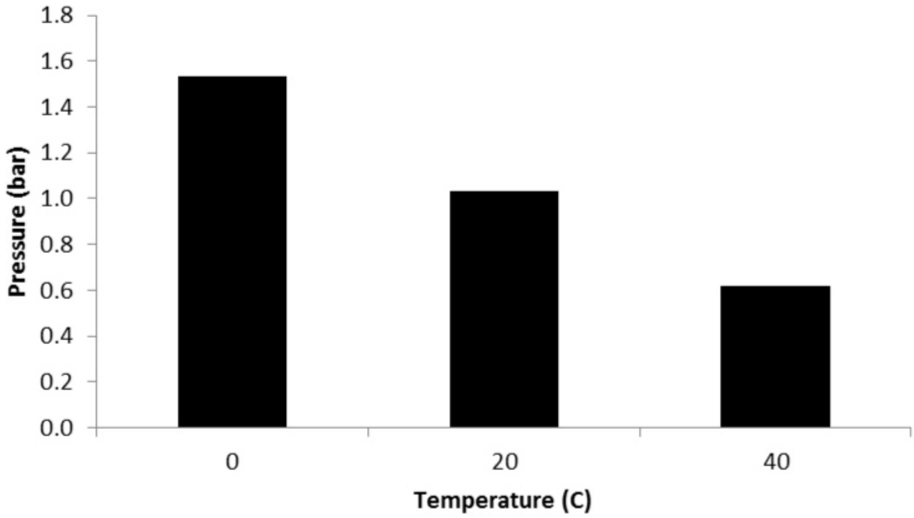

Figure 23- How temperature affects pressure required to pump grease

3.4 Transfer of Results to Field Operation

The lab environment is significantly different to the environment the GDU operates in during normal operation in the field:

- The temperature and humidity is constantly changing throughout the day as well as seasonal fluctuations. It has been shown in these tests how temperature affects the bulb size, but the temperature will also affect the grease properties, changing how it interacts with the wheel.
- Precipitation changes the contact conditions of the wheel-rail interface and could influence how a wet wheel interacts with the grease. There is currently no data on how (or if) it affects the pick-up of grease.
- Contamination of the site (by leaves, ballast dust, old grease etc.) does not occur in the lab. Again there is no data on how this would affect pick-up of grease.
- The grease reservoir is left by the side of the rail exposed to all the environmental changes occurring. This can lead to the grease separation which will change the properties of the grease when it is pumped through the GDU.
- Speed of the wheel in operational circumstances is significantly faster than in lab tests.

These factors will combine to give a different pick-up in the field than is found in the lab. It would be expected that the pick-up is lower in the field compared to lab measurements as the lab environment is relatively clean and controlle. However, it is difficult to quantify the difference with current available data so further field testing is required in to quantify the relationship between lab measurements and field operation.

4 Conclusions and Recommendations

Grease bulb modelling work has shown the relationship between bulb size and lateral displacement needed for contact. It was found that a worn wheel required a greater lateral displacement for contact. Models of the grease shapes based on measured bulbs also confirmed that it is to be expected that modern passenger trains require a much larger grease bulb for contact to occur when compared to freight trains due both to the wheel profiles used and the vehicle's dynamic behaviour.

From experimental work it was found that several logical relationships were demonstrated:

1. Mass of grease picked up increased with wheel displacement toward the rail for a given grease output.
2. Mass of grease picked up increased with increasing output for a given wheel displacement.
3. Although absolute values differ between using the SWR and FSR, the same relationships do hold for both test rigs.

More importantly it was found that there is a not insignificant amount of grease lost from conventional bars compared with the amount picked up, at least at regular output settings. This loss was practically eliminated when the GreaseGuide™ was fitted as the grease cannot be forced down and away, it remains on the foam pad where it contributes to the usable grease reservoir on the bar arrangement. It also increased the effective pick up of grease compared to the traditional MC4 GDU.

The testing of the GDU at different temperatures has shown that the temperature has an effect on the bulb size and there is an optimum temperature at which the grease bulb is at its largest. Further work to evaluate what effect the change in bulb size has on pick-up, and if the temperature has an effect on the grease adhering to the wheel should be carried out to help relate these lab tests to field operation.

These findings have been shown to be influenced by scale and could further be influenced by wheel speed. Field-work on track to investigate and validate the findings reported in actual operational conditions is considered worthwhile, not least due to the improvements that have been indicated as a result of the addition of the GreaseGuide™.

It is recommended that further analysis be undertaken to better understand the performance of infrastructure-mounted lubricators. Improved measurements of the width of the grease bulbs should be collected to develop a true 3D bulb shape. Further improvements to the model could then be to develop a moving wheel interaction with the 3D grease shapes. Correlation between the shapes of interaction shown on the computer model with measured results could be generated from the measurements already taken. This would improve the relevance of the model to the field and further variations of wheel profile could then be modelled at relevant ranges of displacement. Extrapolation to a wider range of displacements would only be realistic if additional tests were conducted.

It is also necessary to compare the grease output and pick-up data with simulated vehicle motion (lateral displacements and patterns) to enable bespoke settings and positioning of lubrication equipment and further inform how provision of lubrication could be improved, particularly where multiple vehicle types operate on a route.

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