Twin-Disc Assessment of LoFrix as a friction modifying rail coating

Project Report

Issue 1

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1 Contents

1 Introduction

Testing was carried out at The University of Sheffield to assess the friction characteristics of a novel solid coating, Lofrix, to assess its potential as a railway friction modifier. This was carried out using the Sheffield University Rolling and Sliding (SUROS) twin-disc test rig, which simulates a wheel/rail contact to provide friction and wear data.

2 Test Methodology

The SUROS test rig uses two counter-rotating steel discs, manufactured from rail and wheel steel. The rail discs were machined from a R260 rail and the wheel discs were machined from an E8 wheel.

SUROS rail specimen discs were initially posted to Lofrix Associates Limited, where LoFrix was applied to the rail disc as a thin film, simulating a coated railhead. The discs were returned to Sheffield and twin disc tests were carried out, running a Lofrix coated rail disc against a non-coated wheel disc, to establish the following:

- The effect of LoFrix on the twin disc friction coefficient (the "effective friction")
- The "retentivity" (how long the product remains active) of LoFrix in the twin disc contact (see Figure 1)

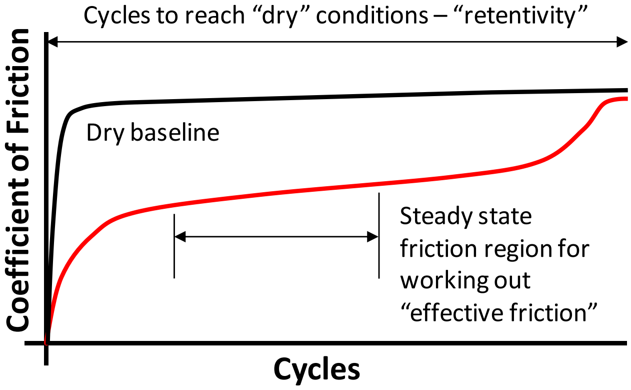

Figure 1 An example graph used to establish "effective friction" and "retentivity" of a rail coating [1]

Wheel/rail contact conditions were fixed at 900MPa and 3% slip to represent braking/accelerating conditions or a rail gauge corner/wheel flange contact (Table 1). The nominal rotational disc speed is 400 rpm, resulting in a surface speed of approximately 1 m/s. The traction coefficient was recorded during the test and the tests were run until dry values were reached. Mass, roughness data and surface images were taken before and after testing to assess wear and any surface effects.

A dry baseline test, with a non-coated rail and wheel disc was carried out as a comparison to the coated tests. Two repeats of the coated tests were carried out, running a Lofrix coated rail disc against a non-coated wheel disc, new discs were used for each test. The tests and conditions are shown in Table 1.

Test number	Contact conditions	Disc conditions
1 (dry baseline)	900 MPa, 3% slip	Clean wheel and rail discs

2 (Lofrix repeat 1, 2)	900 MPa, 3% slip	Lofrix coated rail disc, clean wheel disc

Table 1- Test conditions

2.1 Test Equipment

The University of Sheffield Rolling and Sliding (SUROS) machine is a twin disc test rig capable of carrying out a variety of tests to simulate wheel/rail contact conditions [2]. Figure 2 shows the test rig which is based on a Colchester lathe fitted with an AC motor to provide rotation to each of the discs individually. Load is applied via a hydraulic actuator and friction measured on the lathe side shaft via a torque transducer. Figure 3 shows the dimensions of the discs typically used and how they are machined out of real wheel and rail steel.

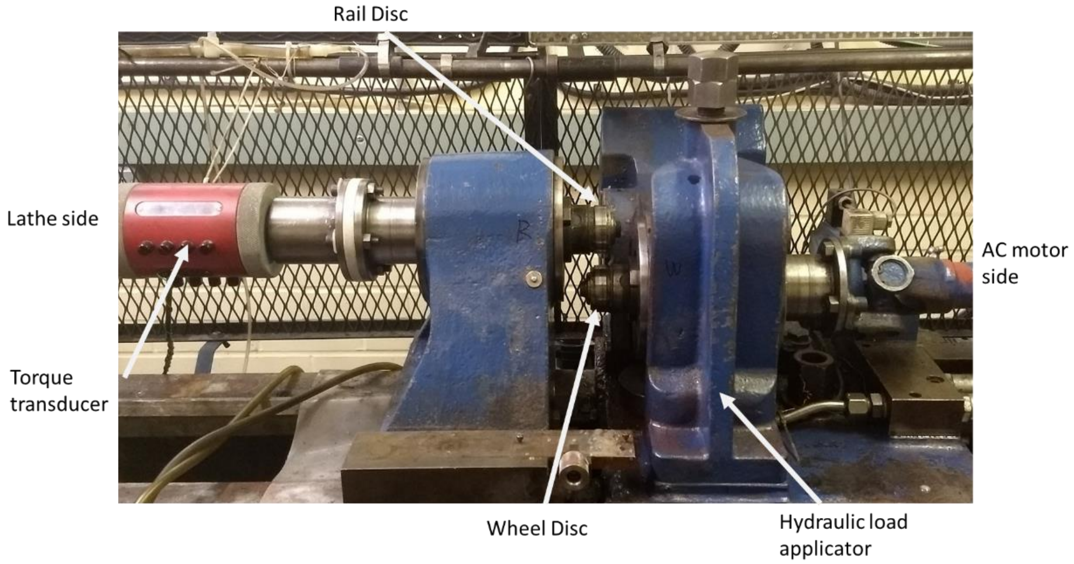

Figure 2- Photograph of SUROS test area

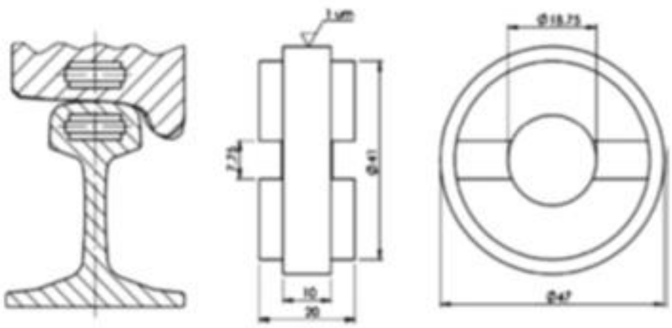

Figure 3- Dimensions of SUROS disc

3 Results

The Lofrix coating covered the entirety of the rail discs as a transparent coating. Despite the layer also being on the disc keyway, the Lofrix coating did not interfere with disc fitment to the test rig.

Images of the wheel and rail discs for both repeats, before and after testing are shown in Figure 4 to Figure 7. The Lofrix coating was transparent before the test, but visible as a darker surface layer after testing.

The average roughness (R_a), before and after testing measured using a stylus profileometer, for each disc is shown in Table 2. For both repeats and for both wheel and rail discs, the roughness decreased during the test.

Figure 4 Repeat 1 wheel disc before (L) after (R)

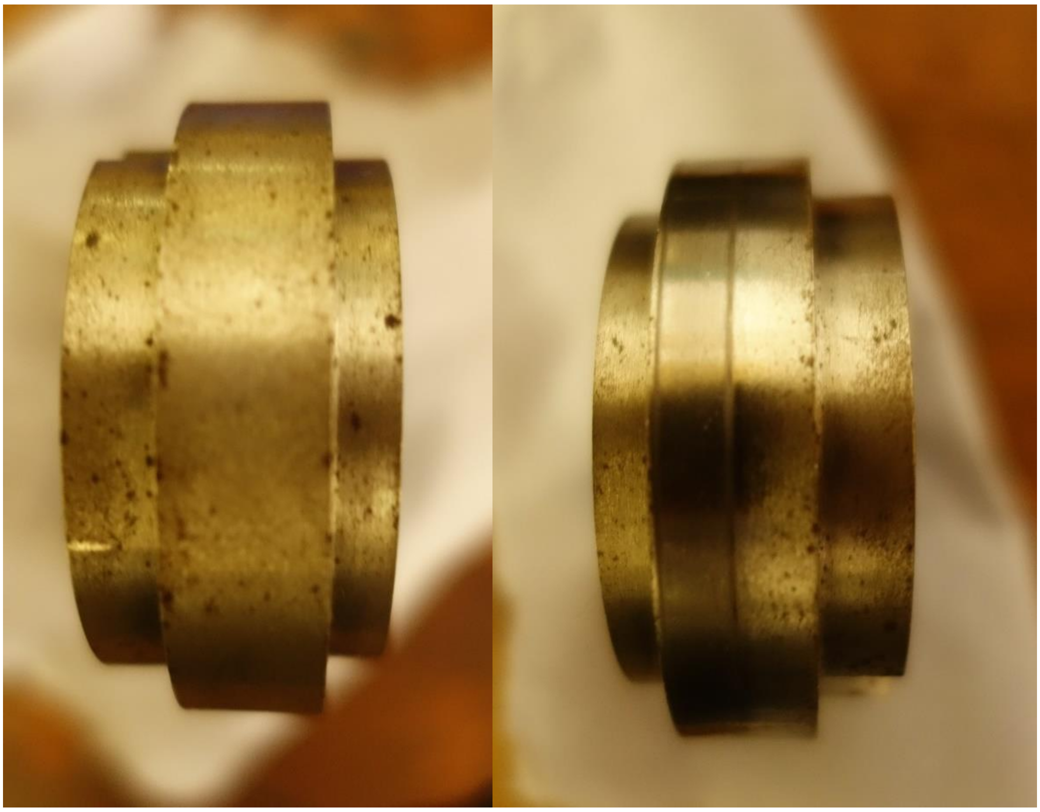

Figure 5 Repeat 1 Rail disc before (L) after (R)

Figure 6 Repeat 2 Wheel disc before (L) after (R)

Figure 7 Repeat 2 Rail disc before (L) after (R)

Disc	Roughness (R_a) before testing (µm)	Roughness (R_a) after testing (µm)
Wheel (repeat 1)	1.34	1.08
Rail (repeat 1)	1.76	1.12
Wheel (repeat 2)	1.13	0.85
Rail (repeat 2)	1.08	0.95

Table 2 Roughness values of wheel and rail discs, before and after testing

A graph of the traction coefficient plotted against number of SUROS cycles, including the two Lofrix repeats and the dry baseline is shown in Figure 8. The performance criteria for each repeat is shown in Table 3. The mass of disc specimens before and after testing is shown in Table 4.

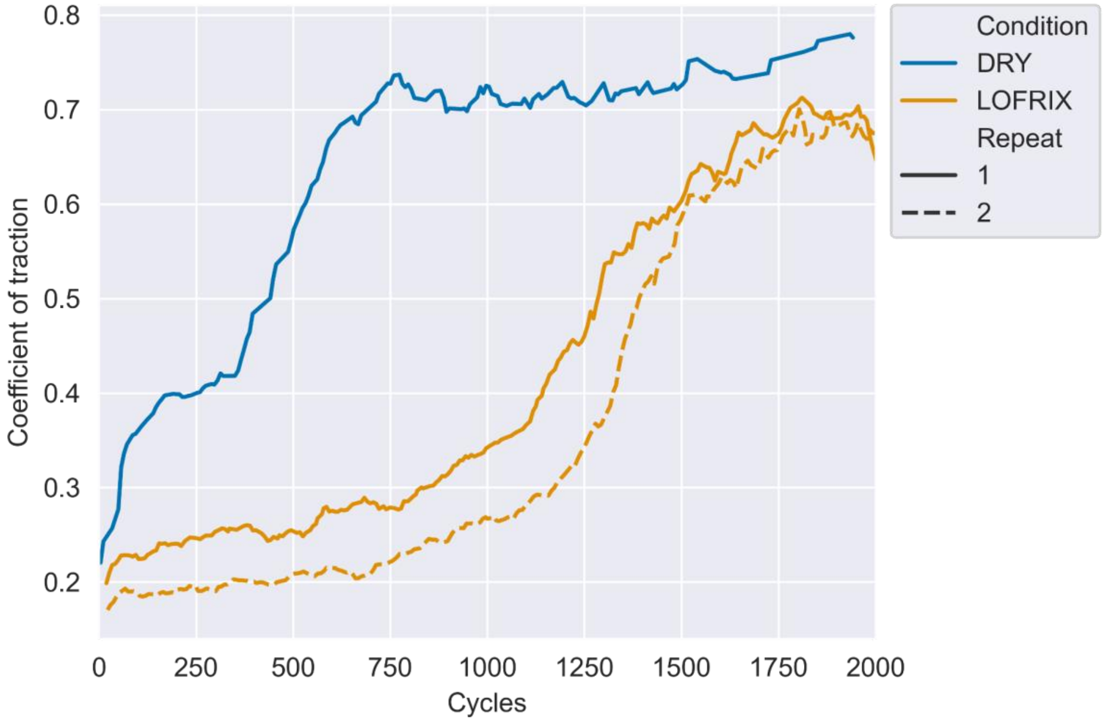

Figure 8 Traction coefficient plotted against number of cycles for the Lofrix coating and dry baseline

	Minimum traction coefficient	Average traction coefficient for first 1000 cycles ("effective friction")	Cycles to reach a traction coefficient of 0.4 ("retentivity")
Repeat 1	0.15	0.26	1140
Repeat 2	0.15	0.20	1324

Table 3 Coating performance criteria

Disc	Mass before (g)	Mass after (g)	Mass change (g)
Wheel (repeat 1)	169.9091	169.9116	0.0025
Rail (repeat 2)	169.1523	169.1458	-0.0065
Wheel (repeat 2)	169.9455	169.9449	-0.0006
Rail (repeat 2)	169.9091	169.908	-0.0011
Wheel (dry baseline)	169.3686	169.3729	0.0043
Rail (dry baseline)	169.2429	169.2286	-0.0143

Table 4 Mass changes of wheel and rail discs before and after testing

4 Discussion

The Lofrix coating resulted in a lower traction coefficient than the dry baseline. Using the approach shown in Figure 2 and previously published work [1], the "retentivity" for the

Lofrix coating (number of cycles to reach a dry traction coefficient of 0.4) was approximately 1300 cycles.

The coating was worn away during the test, initially the traction coefficient slowly increases before rising more steeply between 1100 and 1500 cycles. The traction coefficient plateaus at high values where it meets the dry baseline test.

The remaining coating is visible on the discs as a darker layer in the images after testing and it appears that some of the coating has transferred from the rail disc to the wheel disc during the test. This often occurs on the twin disc test rig and is shown as an increase in the wheel mass for repeat 1 in Table 4. The disc pairs which included a Lofrix coating had a lower wear rate than the dry baseline.

The minimum traction coefficient was 0.15 and for the first 1000 cycles, the average traction coefficient was 0.24 (averaged over both repeats). This is higher than would typically be specified for lubricants used to reduce wear in gauge face/wheel flange contact situations (which are usually tested at 3% creep and above), where the required friction coefficient is below 0.1 (Figure 9).

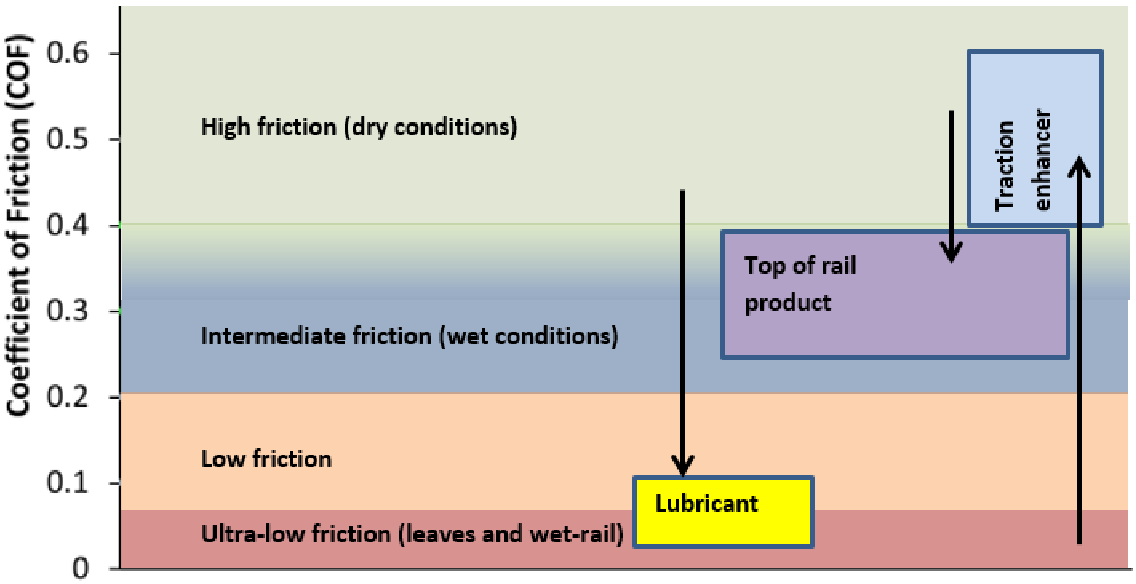

Figure 9 Wheel/rail friction regimes and actions required by friction management products [1]

Lofrix, when a coated rail disc was run against a non-coated wheel disc, operated in the intermediate friction regime that top-of-rail friction modifiers are designed to operate in. These products are designed to reduce wear and rolling contact fatigue cracking as well as reducing noise and energy consumption [3] [4]. These products are typically tested at 1 % creep to more closely represent rolling conditions, unless assessing their effect on braking performance.

These initial results with a Lofrix coated rail disc at 3 % show potential when compared to liquid products that are already on the market, with this coating reducing friction in the contact for a longer period of time than published results using a liquid friction modifier [4], but comparison is difficult at 3% creep and further testing at 1% (where the coating would be expected to last for an increased number of cycles) would be recommended for a comparison to existing liquid top of rail products.

5 Conclusion

The Lofrix testing at 3% creep and 900 MPa initially produced a minimum traction coefficient of 0.15 and then an average friction coefficient of 0.24 for the first 1000 cycles. A dry friction coefficient (0.4) was reached after an average of 1300 cycles.

The coating operated in the “intermediate” friction regime so could be suited to top of rail use, where an intermediate friction coefficient is required to reduce wear and energy consumption, but not so low that it impedes braking performance.

Future work could be carried at 1% creep, where the coating would be expected to last for an increased number of cycles, to determine if the product could remain effective for longer under conditions that more closely represent rolling rather than braking or wheel flange/rail gauge contact.

References

[1] B. White, Z. S. Lee, and R. Lewis, “Towards a Standard Approach for the Twin Disc Testing of Top-Of Rail Friction Management Products,” *Lubricants*, vol. 10, no. 6, p. 124, 2022.

[2] D. I. Fletcher and J. H. Beynon, “Development of a Machine for Closely Controlled Rolling Contact Fatigue and Wear Testing,” *J. Test. Eval.*, vol. 28, no. 4, 2000.

[3] R. Stock *et al.*, “Material concepts for top of rail friction management – Classi fi cation , characterisation and application,” *Wear*, vol. 366–367, pp. 225–232, 2016.

[4] D. V. Gutsulyak, L. J. E. Stanlake, and H. Qi, “Twin disc evaluation of third body materials in the wheel/rail interface,” *Tribol. - Mater. Surfaces Interfaces*, vol. 15, no. 2, pp. 115–126, 2021.