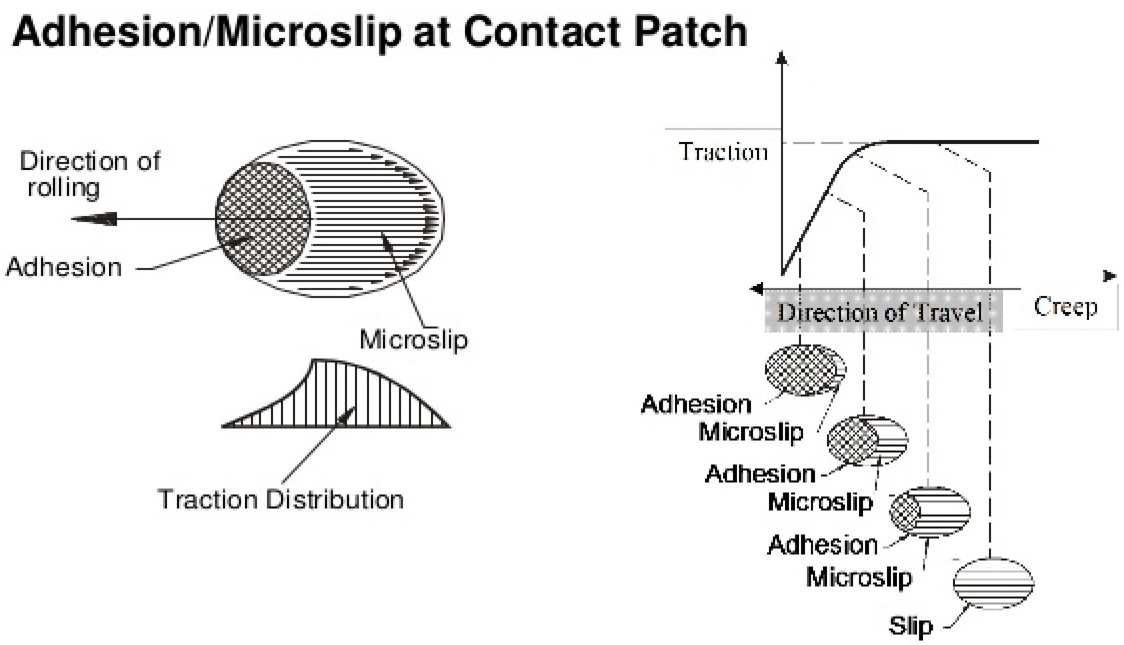
Guidance - Modelling Traction in Wheel Rail Contact

Contact to be modelled

When it comes to modelling the rail-wheel interface, it is important to start with an understanding of what is going on in the real application, then to decide whether this can be modelled adequately in a model system, including the requirement for adequate contact scale and sufficient torsional stiffness. The starting point is to recognise that different things are going on at different places in the contact; the contact patch is elliptical, with regions of slip and no slip.



Line Contact

Elliptical Contact

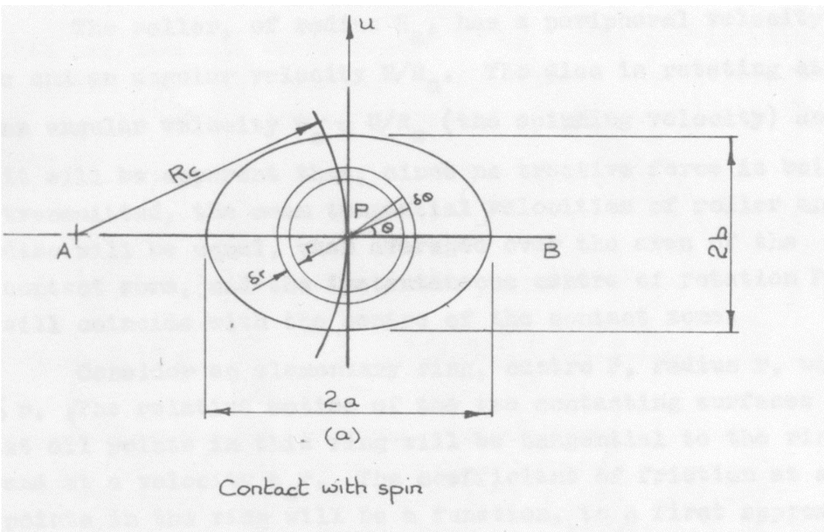
Note how, with an elliptical contact, the adhesion patch progressively decreases in size until it eventually disappears. It gets smaller and smaller in two dimensions, heading towards a singularity. With the elliptical contact, the decrease in the lemon-shaped adhesion zone with increasing creep will be asymptotic, but not so, with a line contact and certainly not so if one takes into account the geometric stress concentration at either end of a finite width line contact.

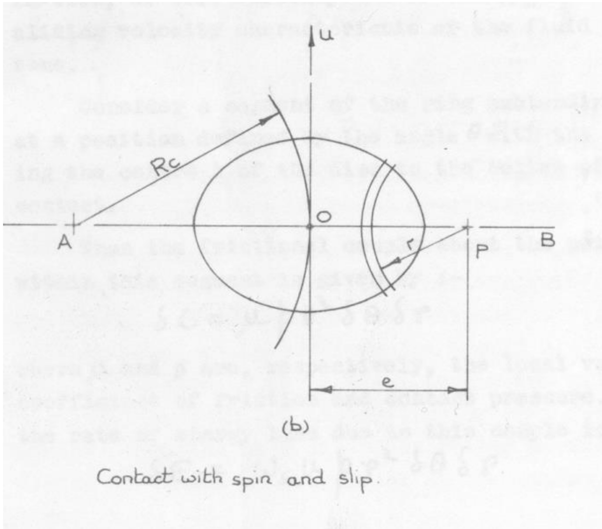
Now consider what happens if we have a line contact? The contact patch is rectangular and it will get smaller in one dimension only and this decrease will be essentially linear. Now think what happens at the moment when the patch is on the point of disappearing! It approaches a line, not a singularity! There is a step change at this point as opposed to a gradual change as seen with an elliptical contact and this may provide the mechanism to promote "chattering", which is common in line contacts as in spur gears. With an elliptical contact, the transition to gross slip will be smooth and potentially reversible, whereas with a line contact the transition will be somewhat more violent and not reversible.

So it probably does not matter what two roller machine one uses, a line contact is going to behave in this way and it will be different from an elliptical contact. This is probably why, with a line contact, we can end up with chattering in both rollers and spur gears.

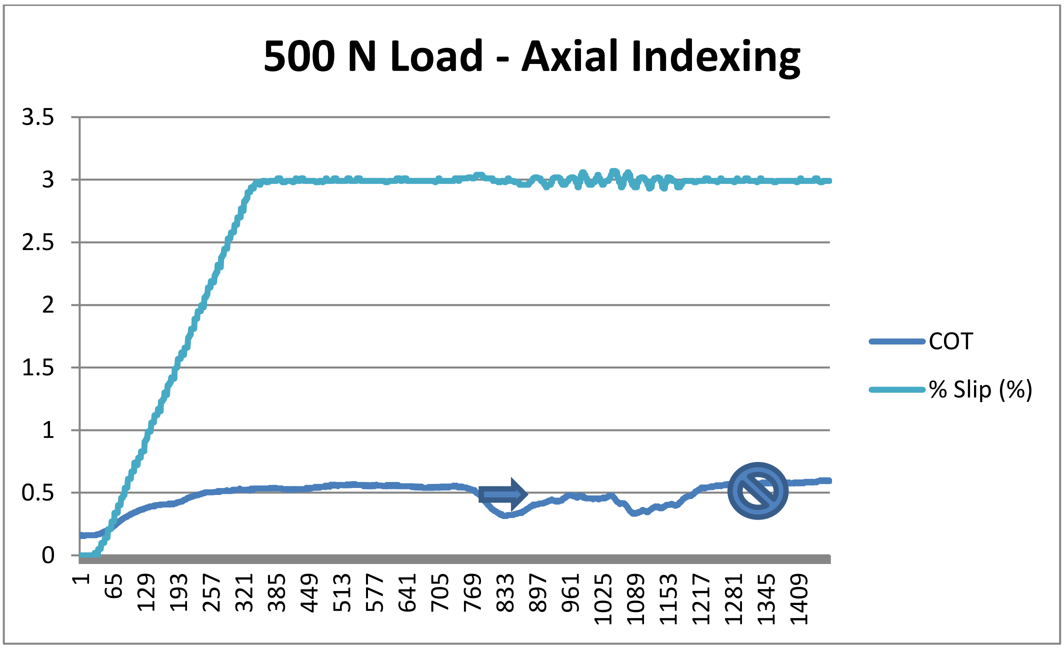
John Williams - Engineering Tribology has a nice illustration of growth of the slip zone for a traction contact of equal sphere on equal sphere, so a hertzian point contact (Page 426). There is also a good description of the limiting conditions with a line contact (Page 422). It is clear that 2-D and 3-D contacts are not the same!

Contact Spin/Skew/Lateral Slip





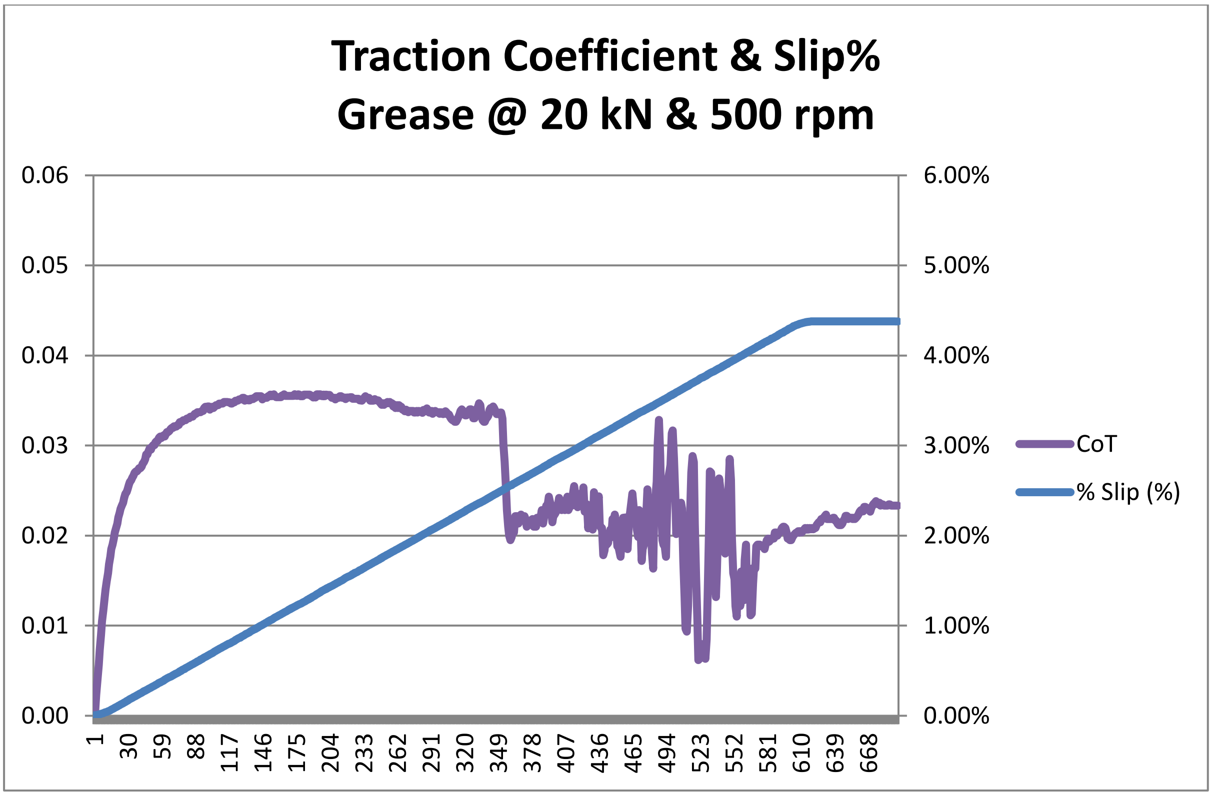
It is important to understand the impact of spin, skew and lateral slip on traction. The test rig should have suitable means for adjusting skew. Contact spin can only be introduced by incorporation of a three disc spin adapter. Lateral slip can be introduced by providing means for axial indexing of one roller relative to the other.

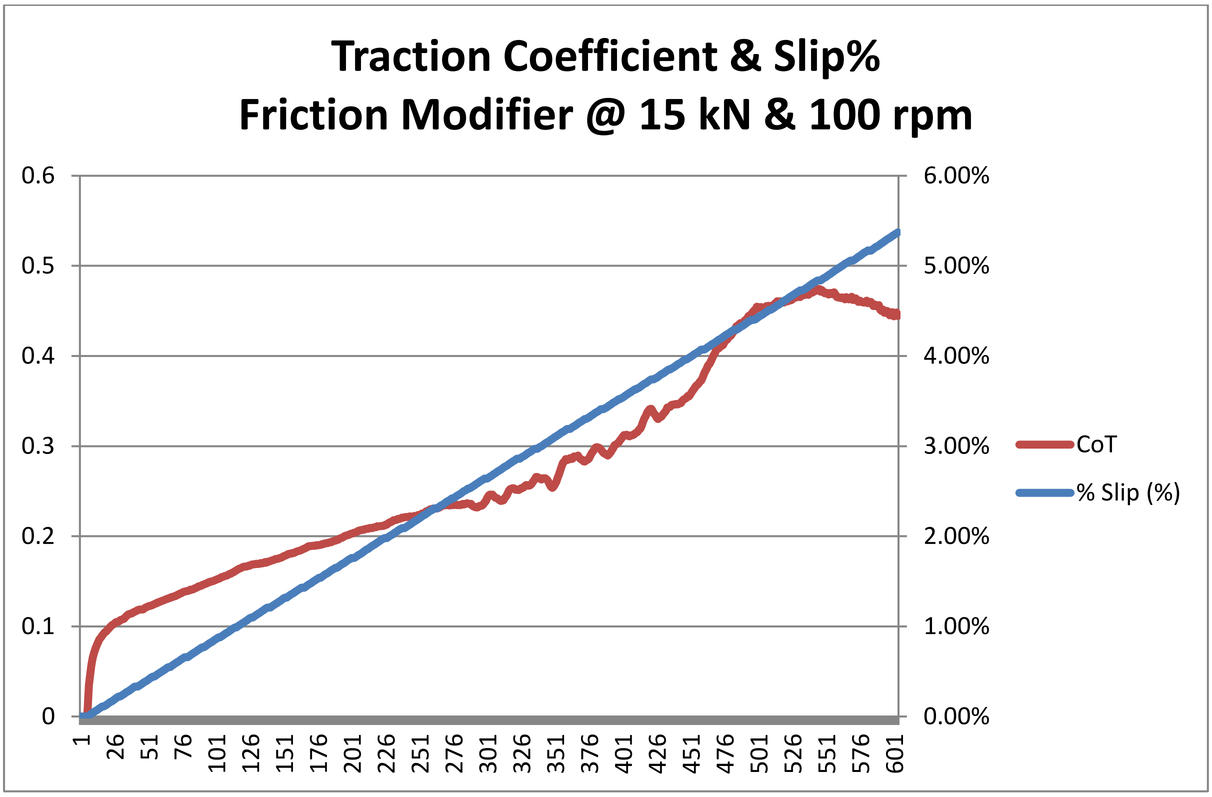


A test was run with dry rollers at 500 N load, 500 rpm master speed and 3% slip. Once steady state running was achieved, the linear slide was manually indexed backwards and forwards to introduce lateral movement in the contact. This action causes an expected reducing in traction coefficient. Once the motion is stopped, the traction coefficient recovers.

Automating this motion would produce a more stable result than can be achieved moving the slide by hand. This would in effect be duplicating the traversing system on the rail traction rig designed in the 1970s for British Rail Research:

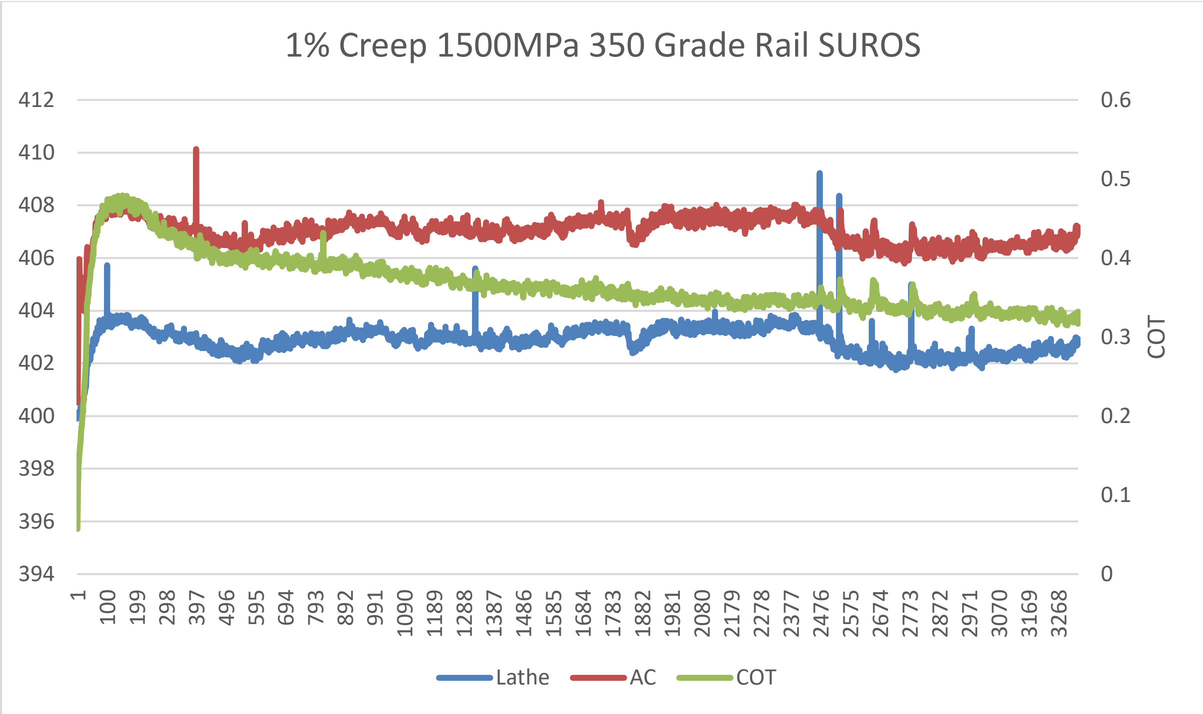
System Instability





The above traces show traction plotted against variable slip running at a fixed speed. It will be apparent from the first result that considerable instability is generated as soon as the contact reaches saturation. Under these conditions, it is apparent that the test machine drives will themselves be subjected to torsional instability and the machine structure to vibration. It is essential that the drives and machine structure are both stiff enough to continue to operate satisfactorily under this kind of instability.

If the drive is not stiff enough, as with the SUROS machine, which includes a flat belt drive, instead of inducing slip in the contact, slip is induced in the drive to the rollers, as indicated by the spikes in encoder speed reading in the following trace:



1% Creep 1500MPa 350 Grade Rail SUROS
412
410
408
406
404
402
400
398
396
394
0.6
0.5
0.4
0.3
0.2
0.1
0
COT
1
100
199
298
397
496
595
694
793
892
991
1090
1189
1288
1387
1486
1585
1684
1783
1882
1981
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2179
2278
2377
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3070
3169
3268
Lathe
AC
COT