Guidance- Scuffing in Reciprocating Tribometers

Background

"The term "scuffing" is used specifically to describe the onset of adhesive wear between lubricated surfaces which has arisen from the breakdown or failure of the lubricant film for whatever reason".

(John Williams – Engineering Tribology – Oxford Science Publications)

Correlation Criterion

Any tribological test that purports to model a real application should reproduce the wear and/or failure mechanisms of that application.

If the wear and/or failure mechanism in the laboratory emulation is not the same as the wear and/or failure mechanism in the real system, the test model is probably wrong.

It follows that a bench test designed to model scuffing in a real system should produce scuffing, not some other wear or failure mechanism.

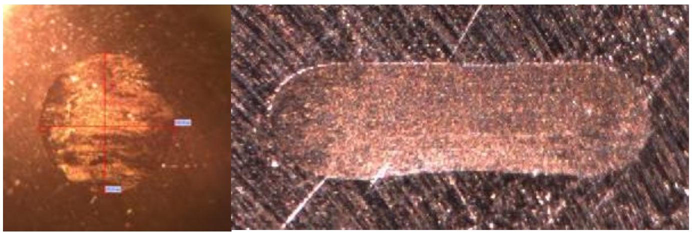
Test Surface Topography

Scuffing events are surface area propagated and involve interaction at an asperity level. Scuffing in real systems is invariably preceded by low or mild wear regimes, with the scuff event indicating a wear transition to a more severe regime.

The following will not provide an adequate model for a scuffing test:

1. A contact geometry that results in destruction of the surface topography, at the very start of a test.
2. A test in which the sample contact is effectively at the level of sub-surface material, as opposed to at an asperity level.

A sliding hertzian point contact, which invariably destroys the surface topography within the first few strokes, cannot sensibly be used for a scuffing test. Sliding hertzian point contact tests effectively start by failing the surface through severe adhesive wear. If the test starts with severe adhesive wear it cannot possibly be used subsequently to show a transition to adhesive wear.



Hertzian Point Contact Test – Surface Topography Obliterated

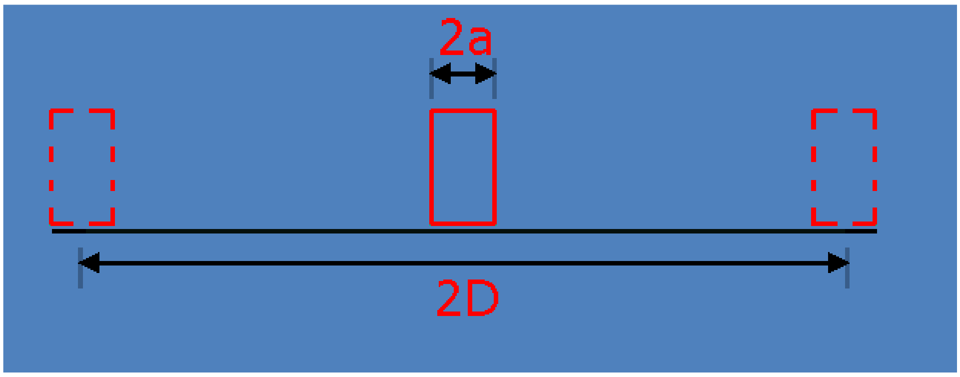
As scuffing involves interaction at an asperity level, it makes no sense to use test specimens with polished or lapped surface finishes. Contacts that, with sensible running-in, preserve the original surface topography, until subsequently disrupted by a scuffing event, include line and area contacts. A scuffing test has to start with mild wear.

Overlap Parameter

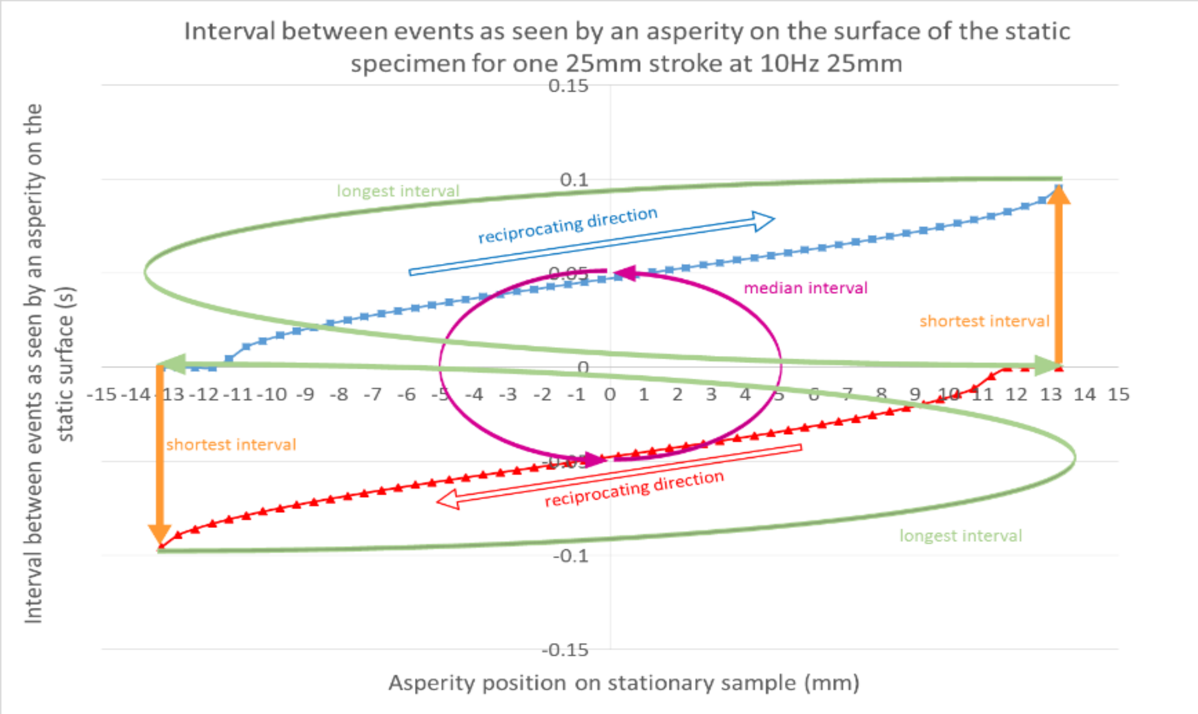
The "overlap parameter" (Czichos) is defined as the ratio of sliding distance for "body" divided by sliding distance for "counter body".

The overlap parameter influences how the wear is shared between to contacting bodies. It also has a significant impact on the design of any scuffing test.

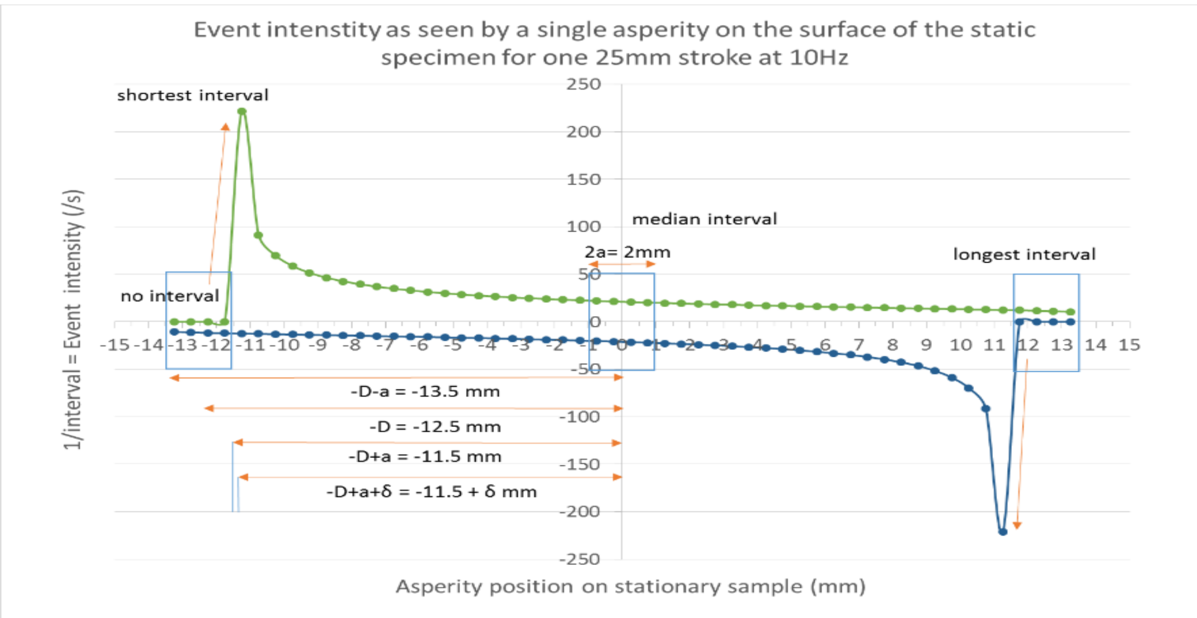
Consider a lubricated area contact with contact length 2a reciprocating at stroke 2D:



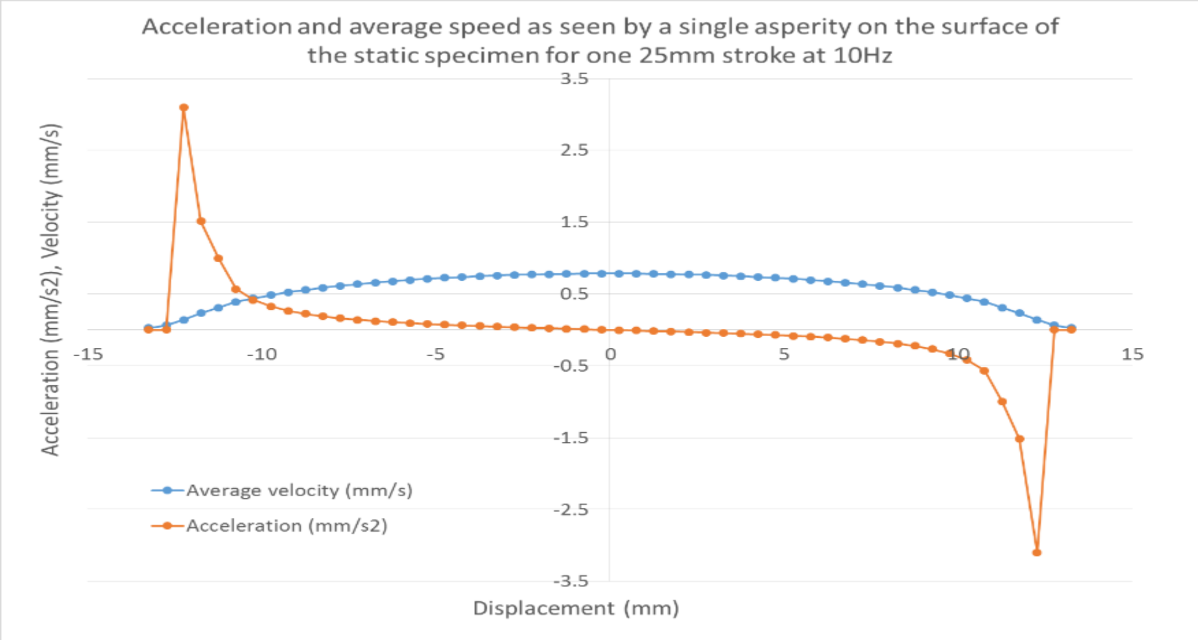
For this example, a = 1 mm, D = 12.5 mm and the frequency is 10 Hz.



Moving left to right, the event interval is plotted against asperity position for one stroke, where an event is defined as asperity to asperity contact.

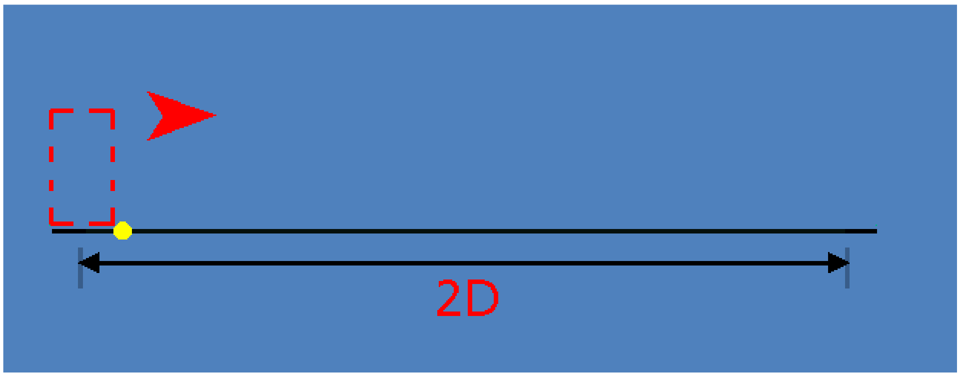


Considering an asperity at −D+a or at D-a, the imparted energy is greatest as the continuous sliding distance is maximum. Most severe contact conditions occur at this point.

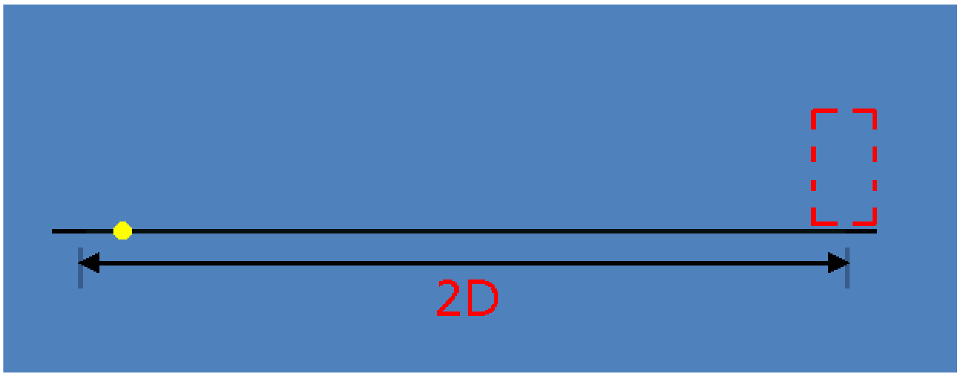


The reciprocating sample velocity is maximum at position 0. It experiences an identical event interval in each direction, consequently there is time for heat generated during an event to dissipate and for chemical additives to react with the asperity tips.

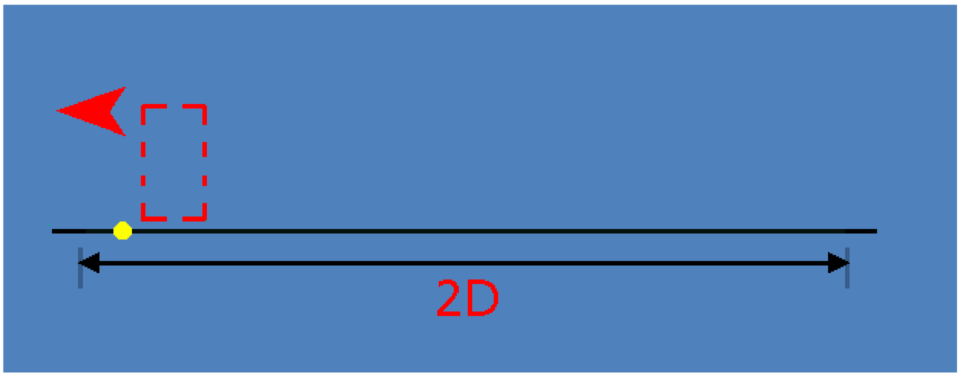
Now consider the sequence of events at an asperity just over +a from the end of the stroke.



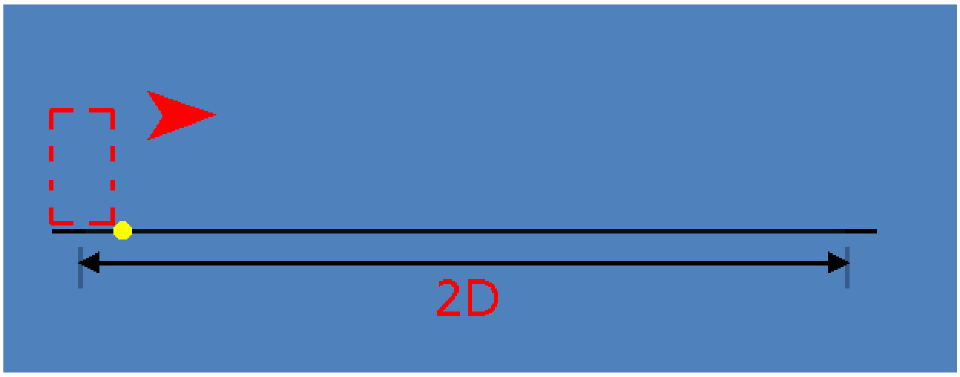
At the start of the stroke, the asperity sees the moving body slide past, with low entrainment velocity.



There is then the maximum interval in events as the moving body travels to the end of the stroke before returning to pass the asperity again.

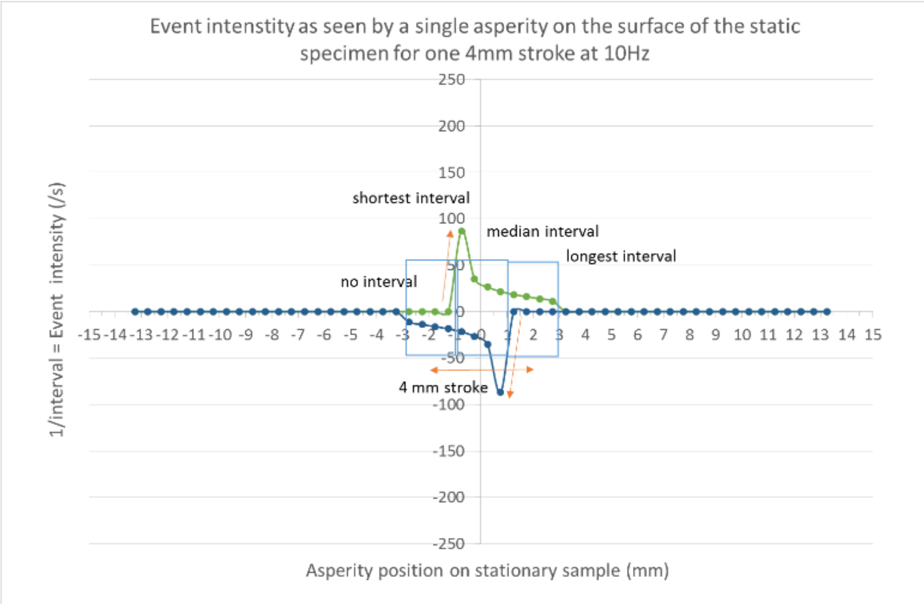


The asperity is subjected to an event in one direct, followed more or less immediately by an event in the other direction.



This may help to explain the observation that scuffing appears to initiate immediately after stroke reversal.

Now consider what happens if the stroke is reduced.

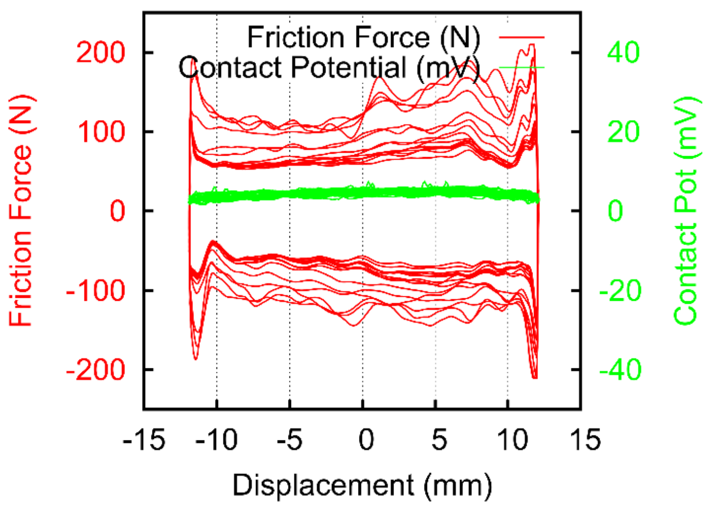


At mid stroke (asperity = 0) event intensity depends upon reciprocating frequency only – not stroke length. The maximum velocity and intensity decrease with decreasing stroke length.

Reduced acceleration increases interval time at the reversal zone. This decreases asymmetry of stroke.

It will be apparent that as the reciprocating stroke length relative to the contact length is reduced, the overlap parameter collapses, both in terms of spatial and time resolution. The loss of spatial resolution means that it becomes impossible to differentiate between localised scuffing and global failure.

Drive System

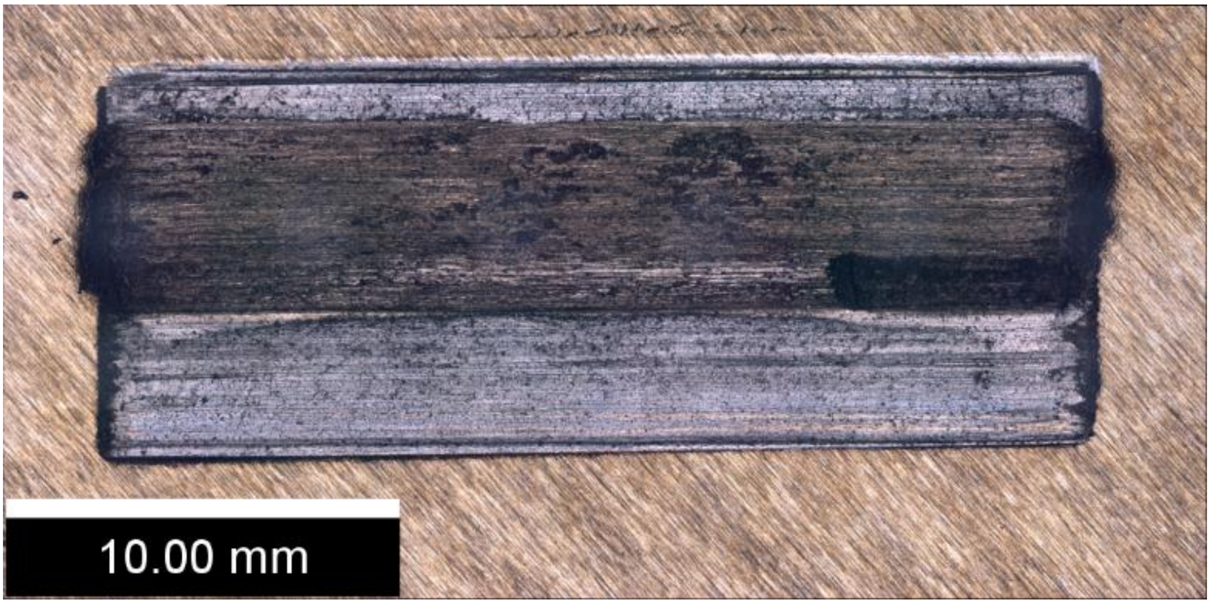


The graph above shows a force-displacement curve as a scuffing event unfolds. This comprises 1 second of high speed data at 15 Hz reciprocating frequency, hence 15 consecutive cycles, with the friction rapidly increasing in magnitude.

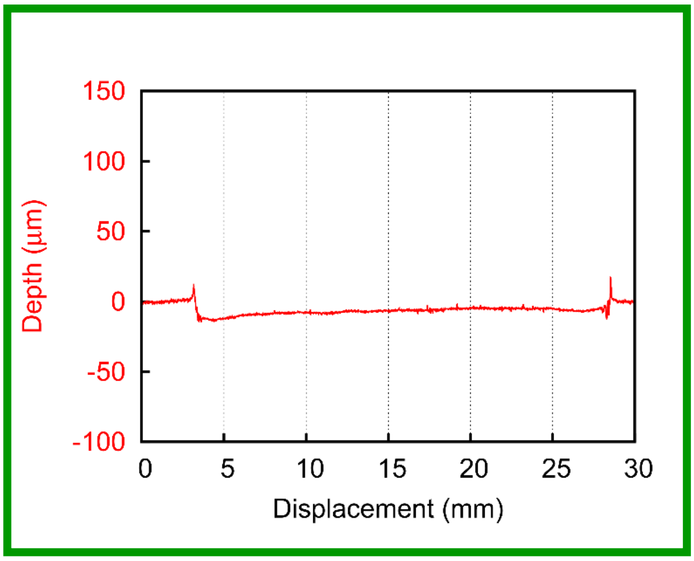
It follows, that in order to generate this type of behaviour, the tribometer drive system must be stiff enough to drive the contact through this transition. A drive system that either changes stroke or stalls when presented with a transient increase in resistance is not an adequate means of actuation. Force generating drive systems, such as electro-magnetic oscillators, are unlikely to be able to maintain the motion during a scuffing event.

Example of Mild and Severe Scuffing

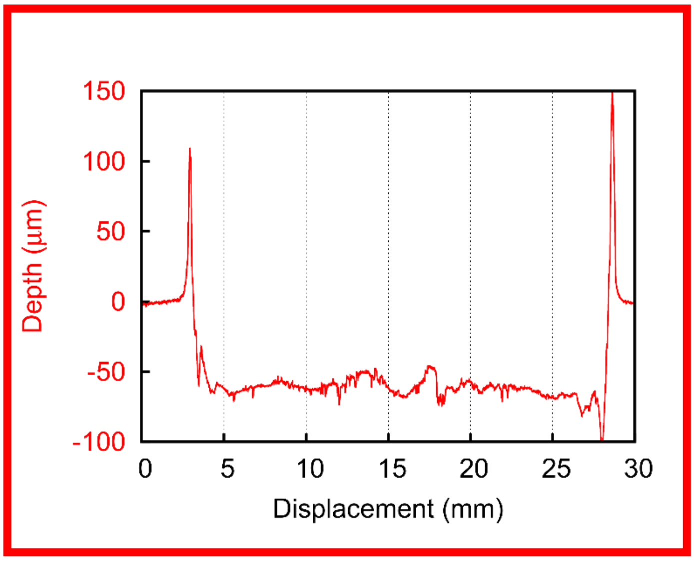
As with the transition from mild wear to mild scuffing, a further transition may occur between mild and severe scuffing. Most real systems can tolerate an accumulation of mild scuffs, without precipitating catastrophic failure. The transition to severe scuffing usually results in the end of serviceable life for the component or system.



This cast iron sample, which has been ground at 45 degrees to the reciprocating direction in order to generate a suitable surface topography, illustrates the transition from mild scuffing (the outer areas) and severe scuffing (the inner band), with mild scuffing across the full contact width preceding the advent of severe scuffing.



In the mild scuff area the wear volume is small and the surface is smooth.



In the severe scuff area the wear volume is substantially higher and the surfaces are rough. A large amount of wear debris has been generated, which accumulates at the stroke end.

Conclusion

In order to produce a scuffing test in a reciprocating tribometer we need:

1. A test geometry that does not start with destruction of the surface topography, hence a line or area contact.
2. Specimen surface finish of sufficient roughness to allow meaningful asperity interaction.
3. Long enough stroke length to give sufficient spatial and time resolution, thus avoiding collapse of the overlap parameter.

4. A driving system capable of driving the motion through the scuff event, without stalling or changing stroke.