Frictional contacts

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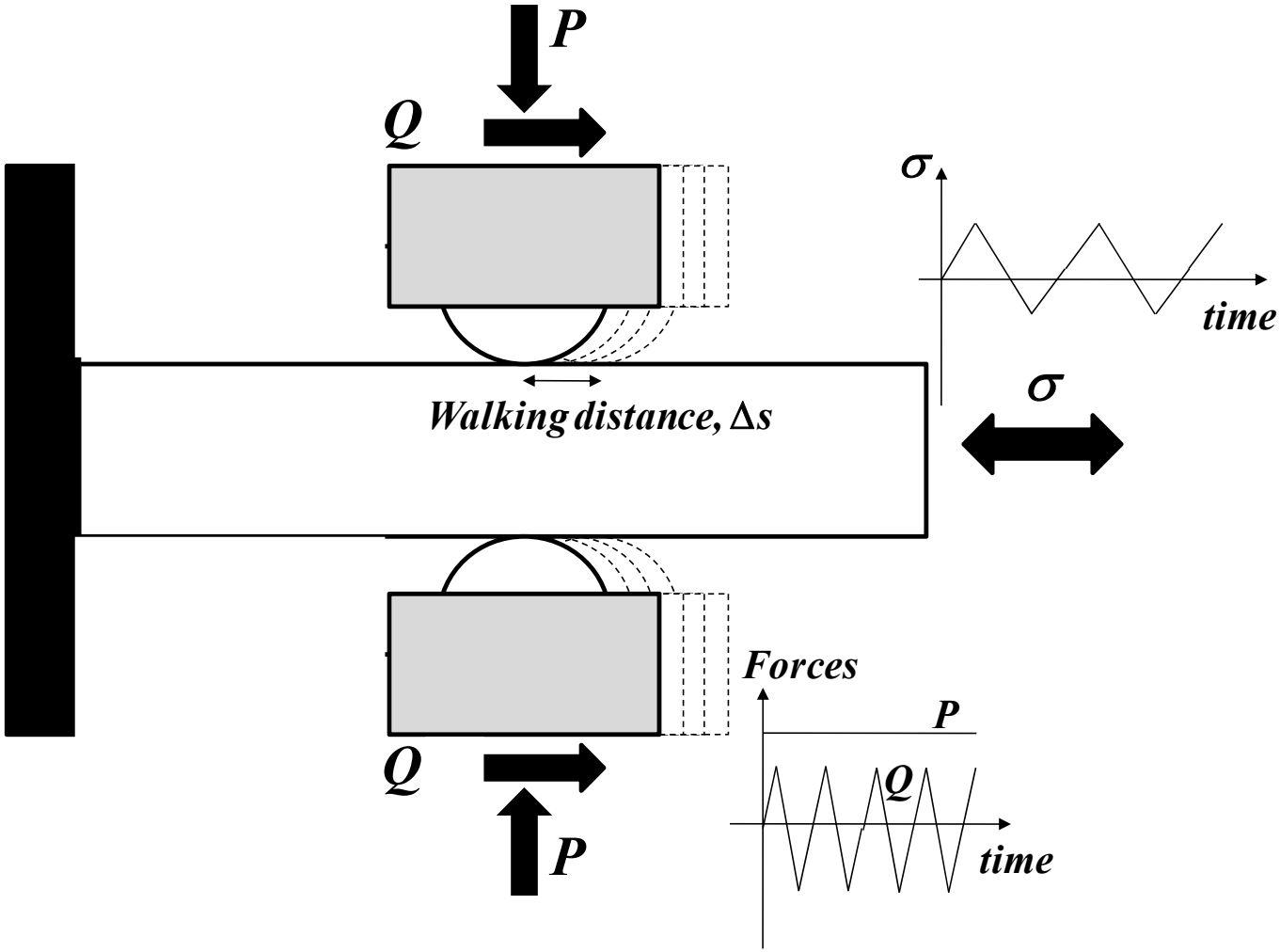
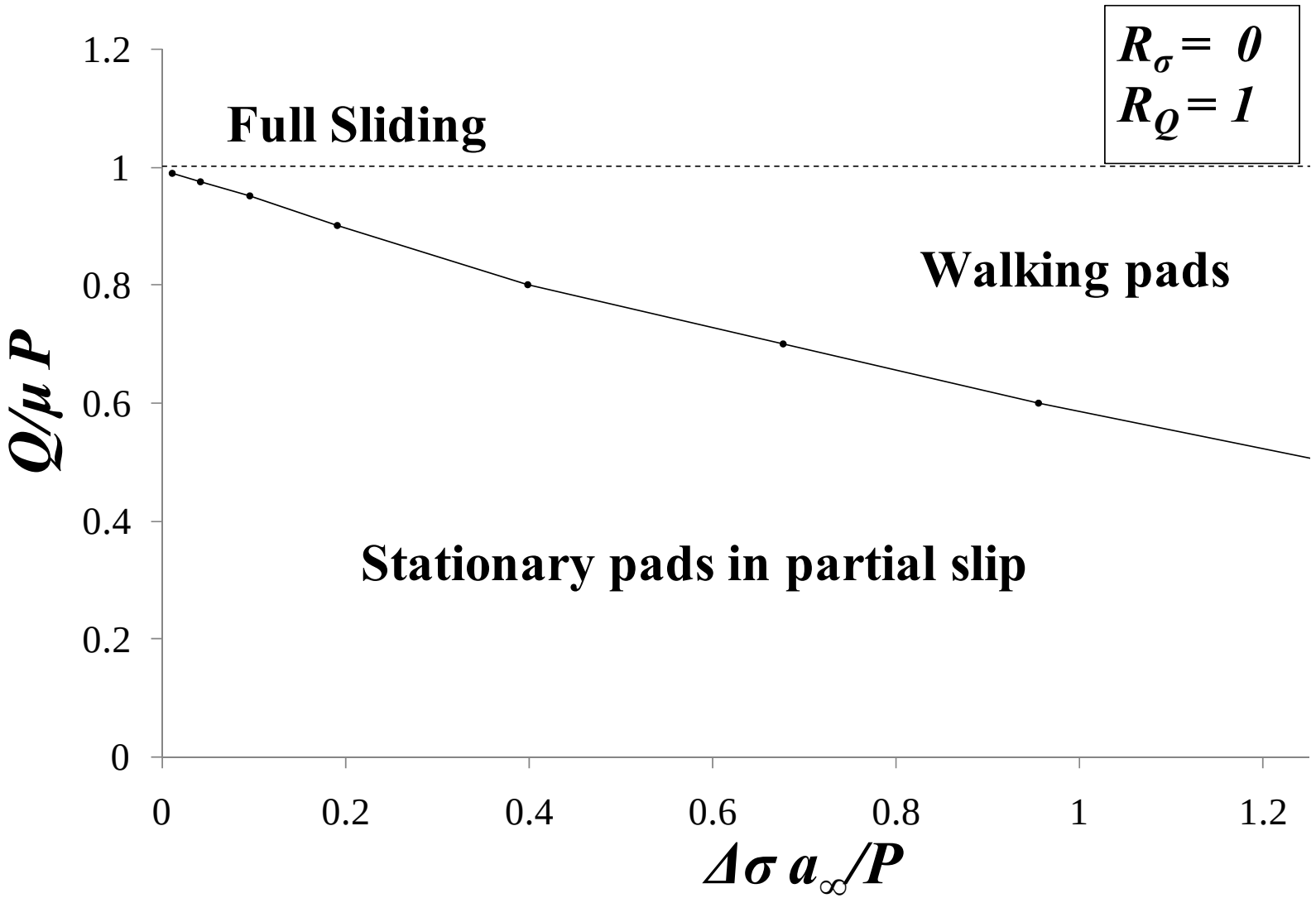
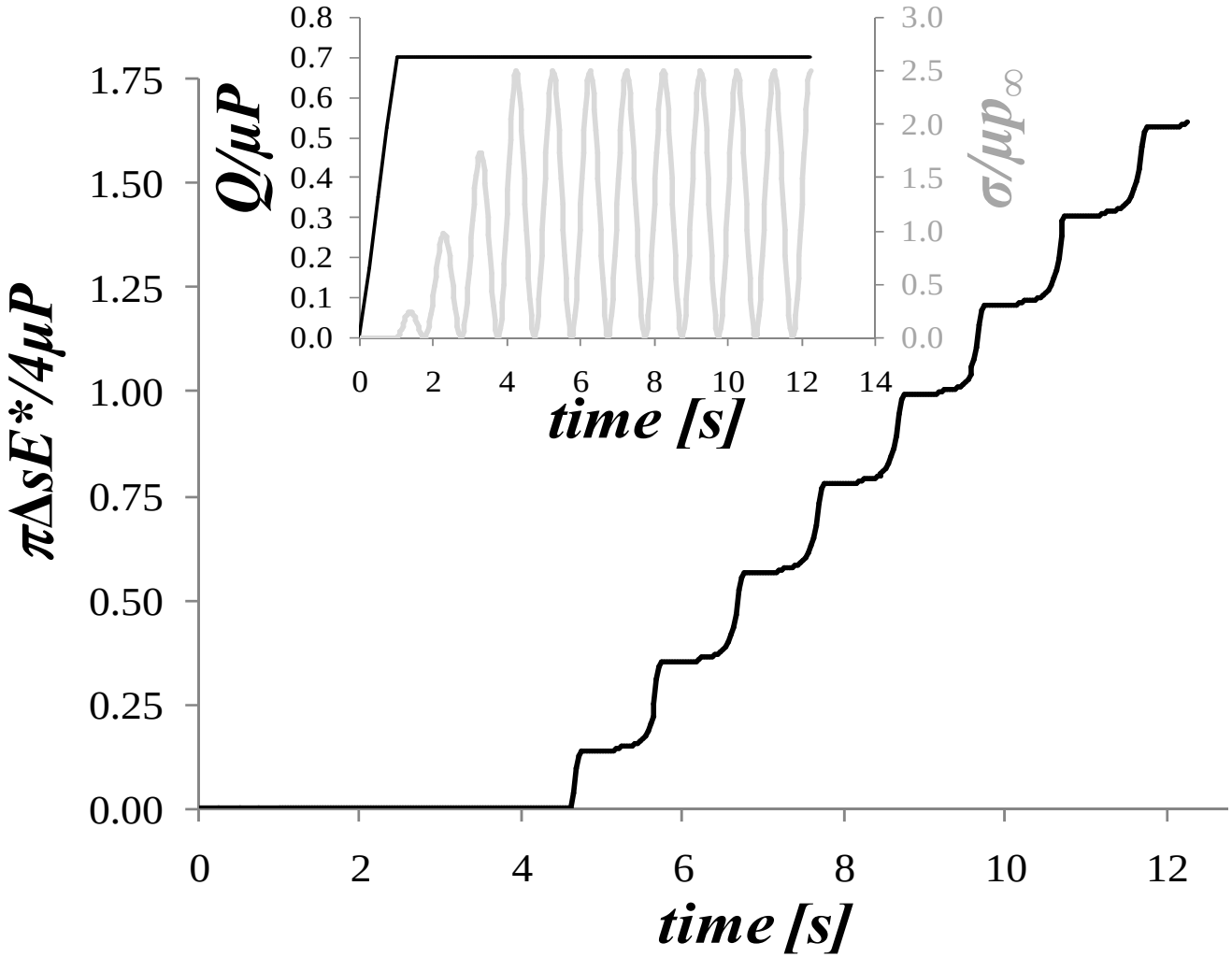
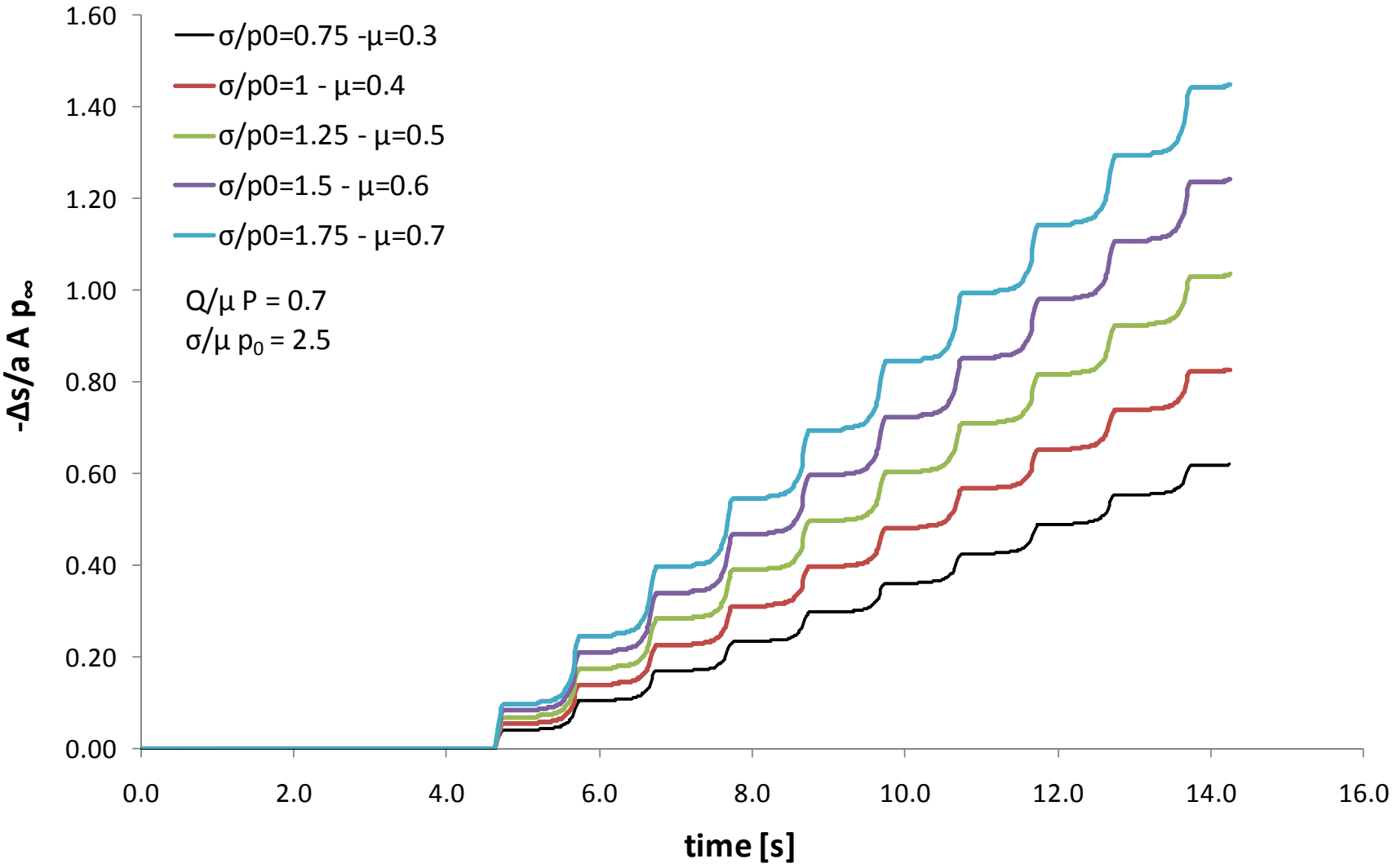
Rolls-Royce

Friction Measurements without Sliding



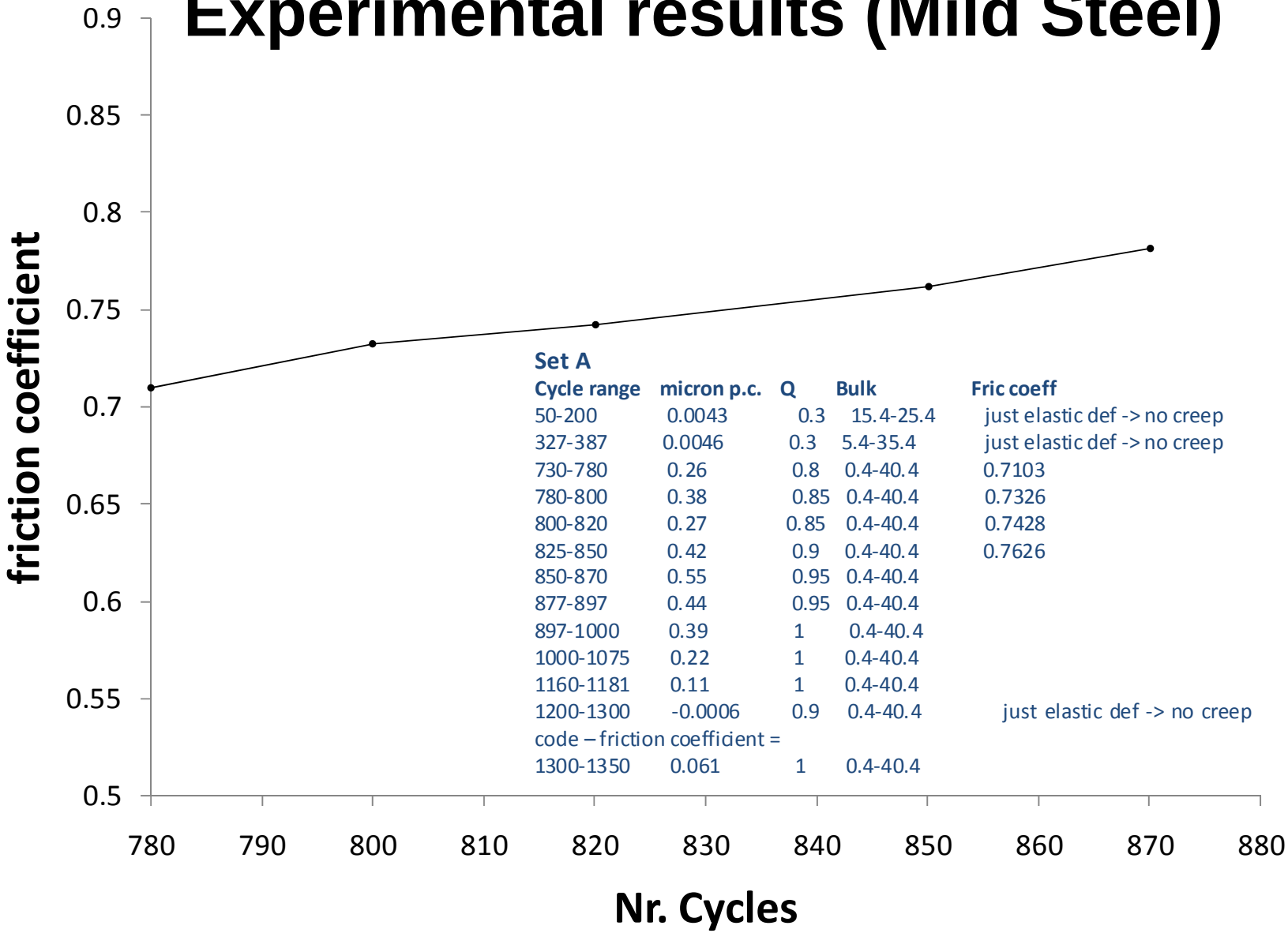

$R_\sigma = 0$
$R_Q = 1$
Full Sliding
Walking pads
Stationary pads in partial slip
$Q/\mu P$
$\Delta\sigma\, a_\infty/P$
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
1.2


πΔsE*/4μP
Q/μP
σ/μp∞
time [s]
time [s]
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
2
4
6
8
10
12
14


σ/p0=0.75 -μ=0.3
σ/p0=1 - μ=0.4
σ/p0=1.25 - μ=0.5
σ/p0=1.5 - μ=0.6
σ/p0=1.75 - μ=0.7
Q/μ P = 0.7
σ/μ p0 = 2.5
-Δs/a A p∞
time [s]
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0

Rolls-Royce

Experimental results (Mild Steel)

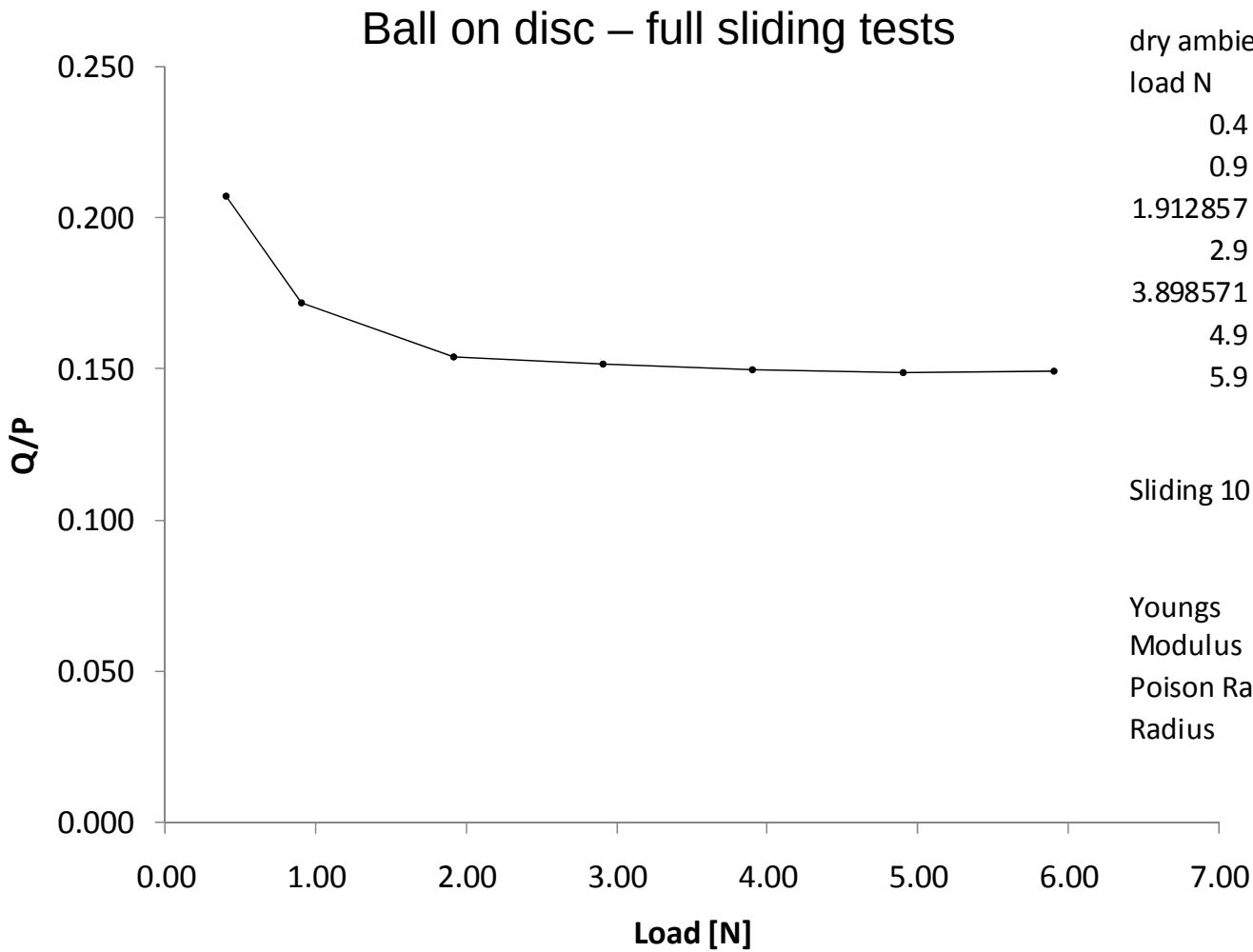


Set A

Cycle range	micron p.c.	Q	Bulk	Fric coeff
50-200	0.0043	0.3	15.4-25.4	just elastic def -> no creep
327-387	0.0046	0.3	5.4-35.4	just elastic def -> no creep
730-780	0.26	0.8	0.4-40.4	0.7103
780-800	0.38	0.85	0.4-40.4	0.7326
800-820	0.27	0.85	0.4-40.4	0.7428
825-850	0.42	0.9	0.4-40.4	0.7626
850-870	0.55	0.95	0.4-40.4	
877-897	0.44	0.95	0.4-40.4	
897-1000	0.39	1	0.4-40.4	
1000-1075	0.22	1	0.4-40.4	
1160-1181	0.11	1	0.4-40.4	
1200-1300	-0.0006	0.9	0.4-40.4	just elastic def -> no creep
code – friction coefficient =				
1300-1350	0.061	1	0.4-40.4	

Rolls-Royce

Pressure dependent friction?



dry ambient

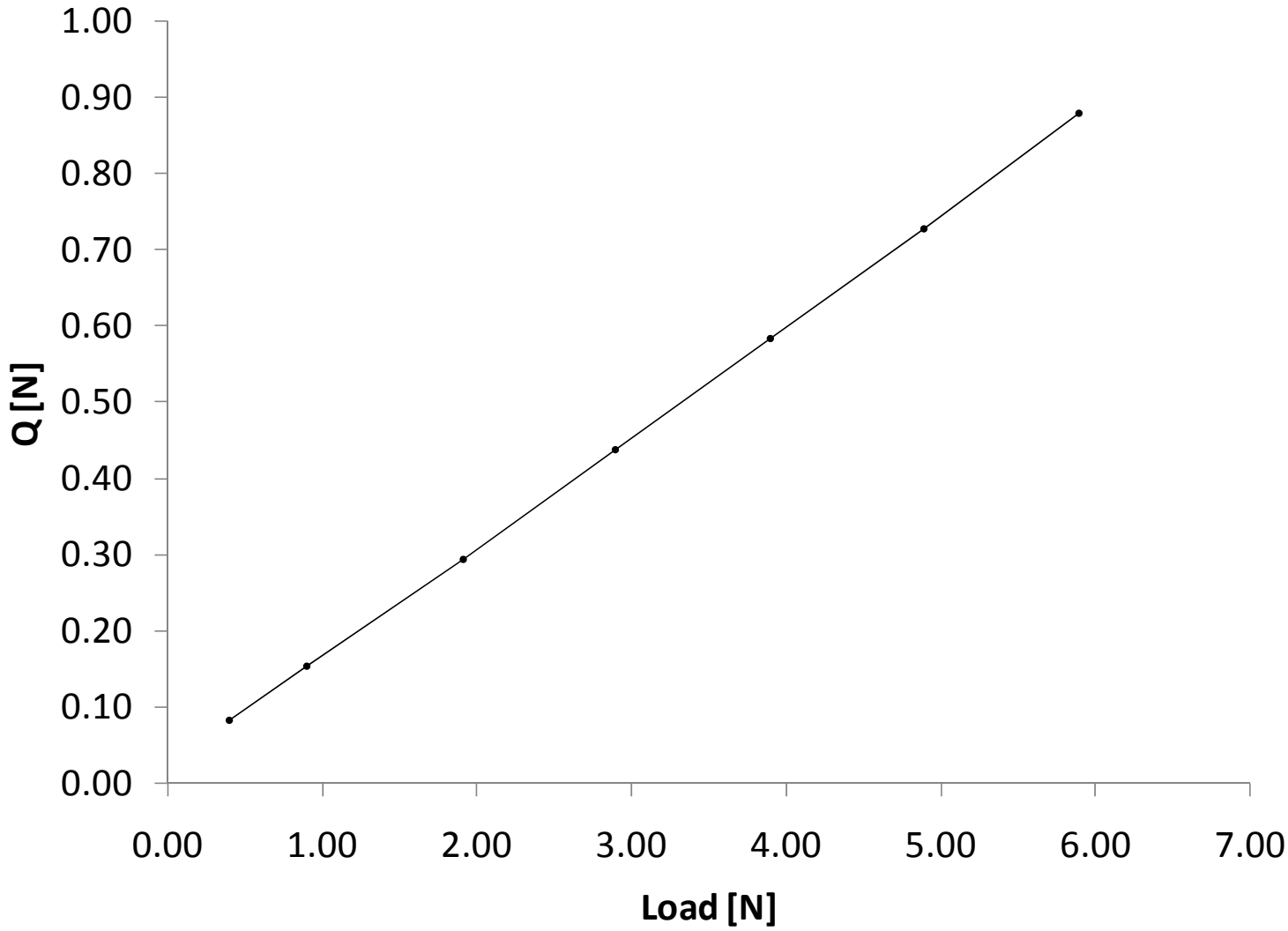
load N	friction coef
0.4	0.206947329
0.9	0.1714776
1.912857	0.153897914
2.9	0.151195286
3.898571	0.149629586
4.9	0.1485512
5.9	0.149006757

Sliding 10 mm/s

	Disc	Ball
Youngs Modulus	1.20E+08	2.07E+11
Poison Ratio	0.05	0.3
Radius		9.53E-03

Rolls-Royce

Pressure dependent friction?



Rolls-Royce

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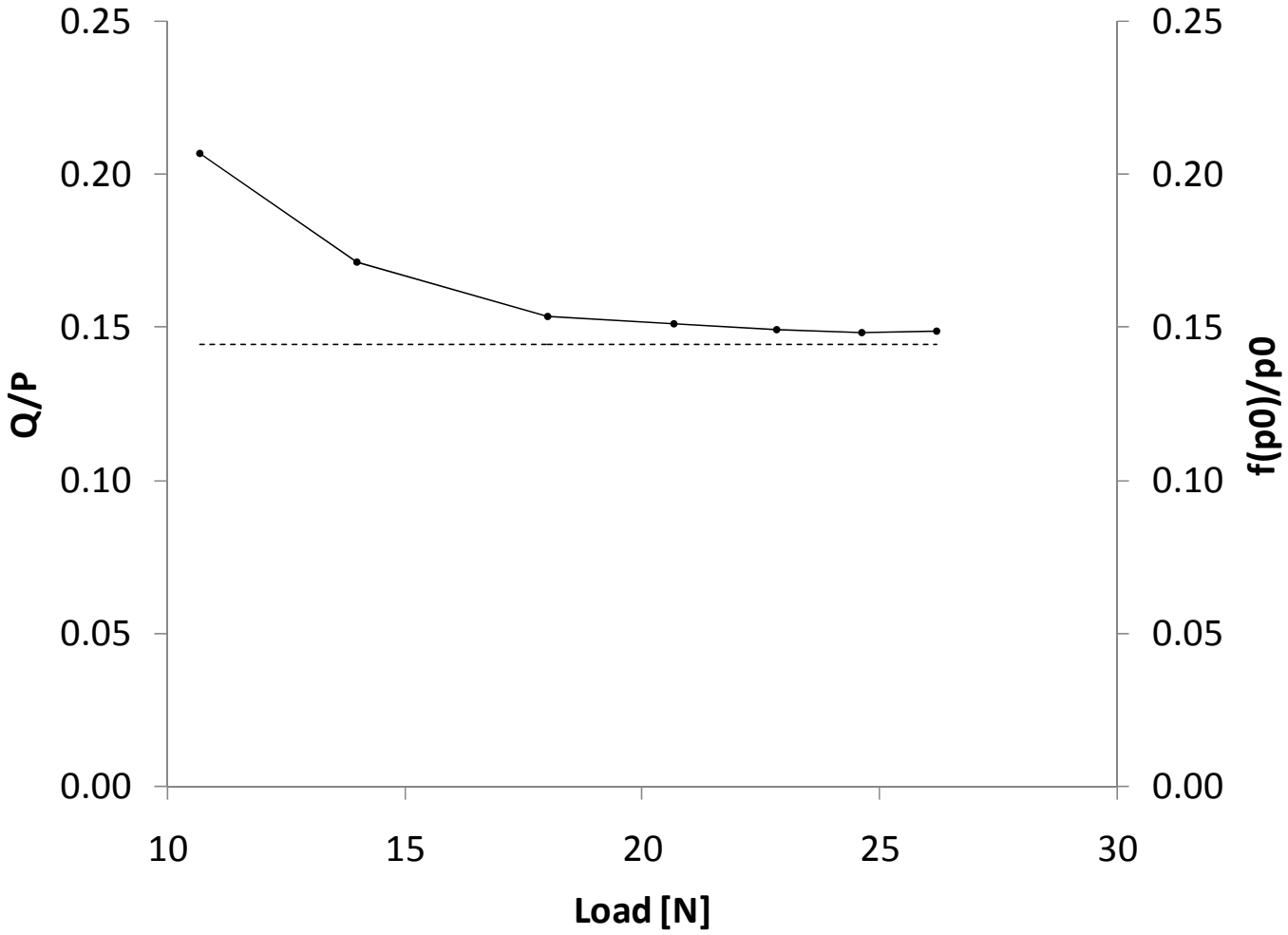
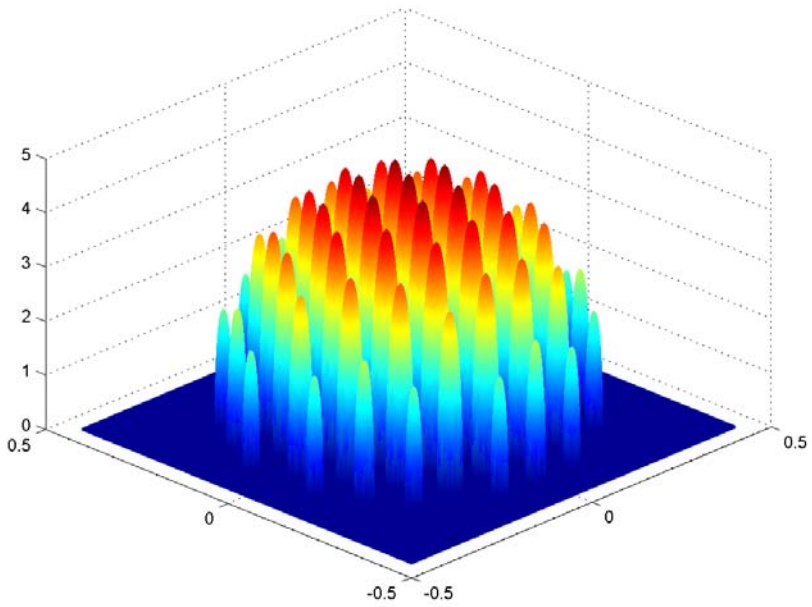
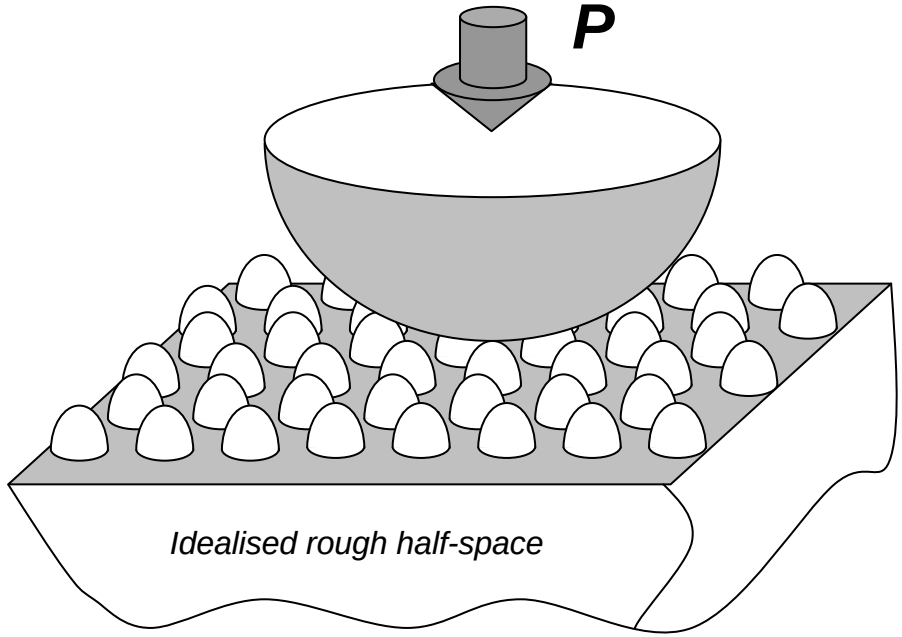


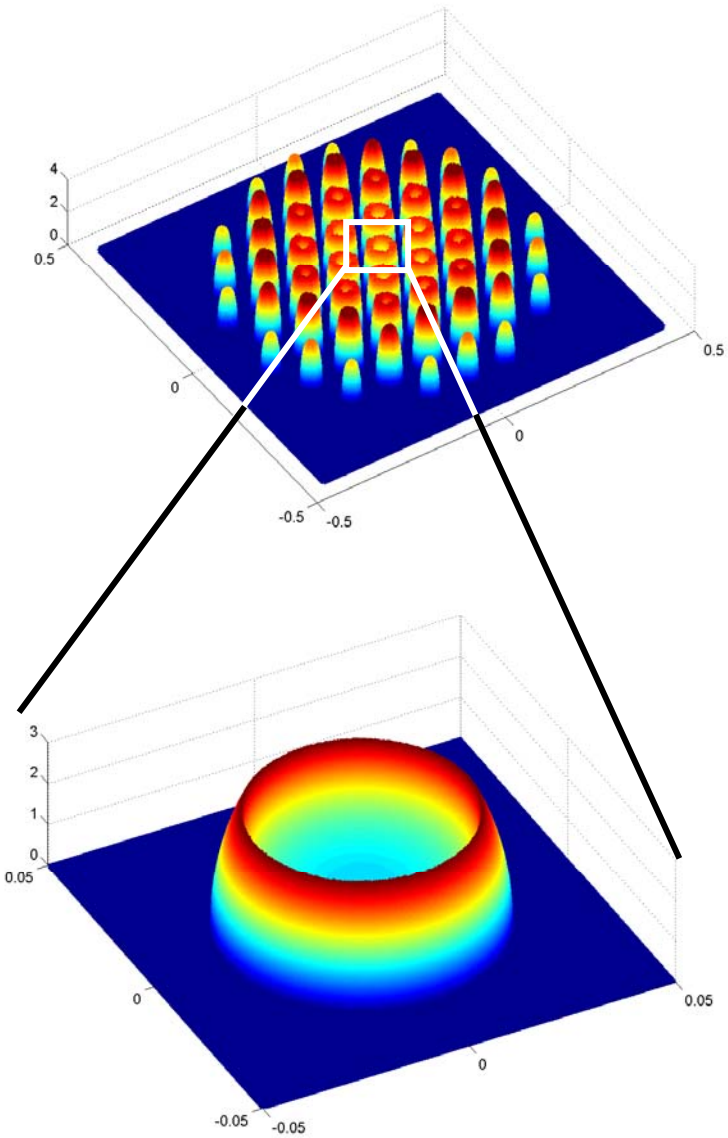
Rolls-Royce

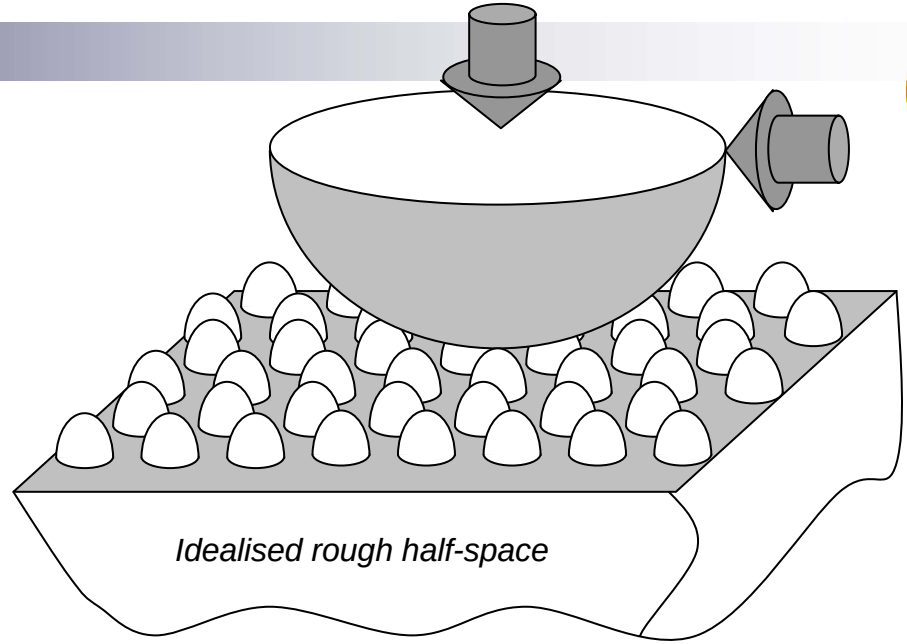
Energy Dissipation in Rough Contacts

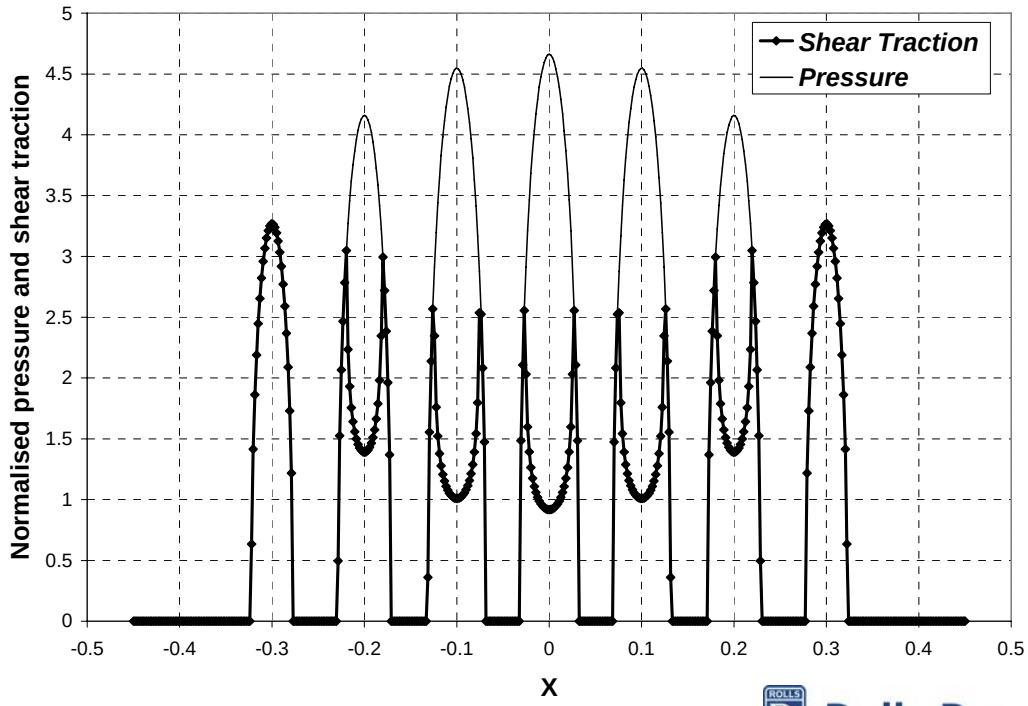


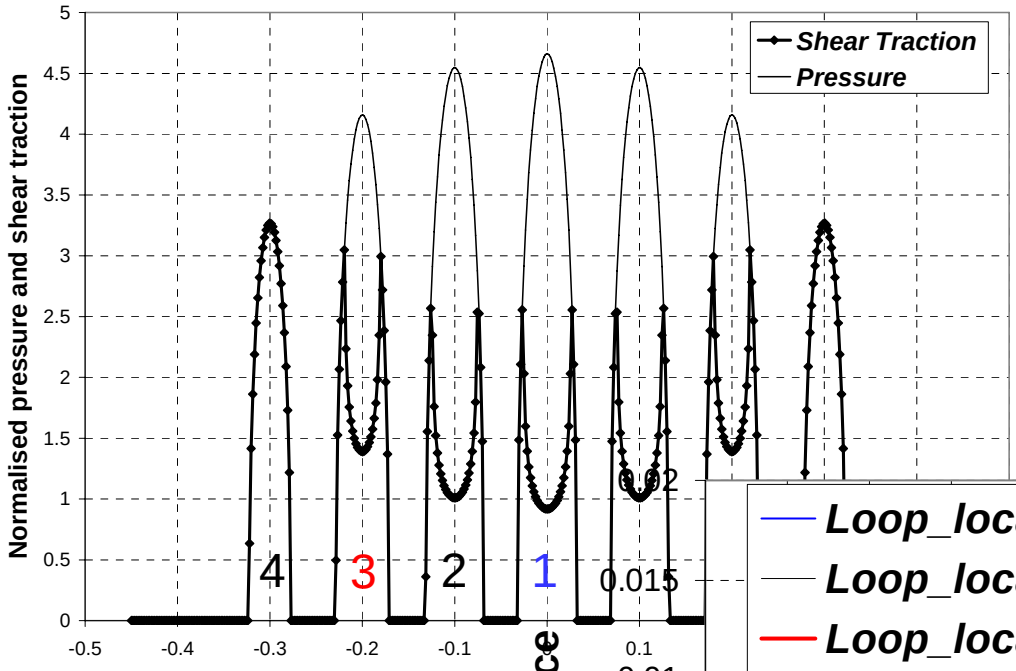


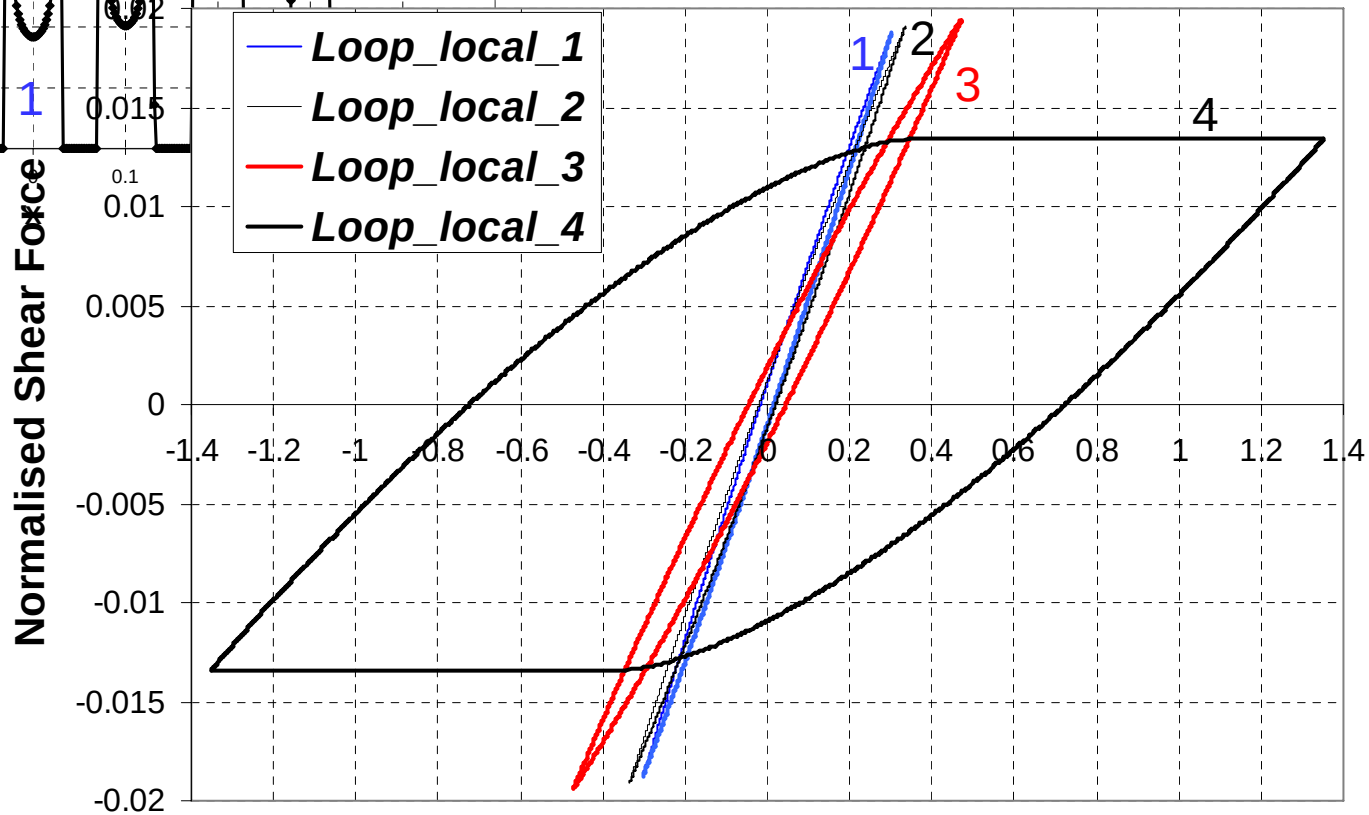
Rolls-Royce

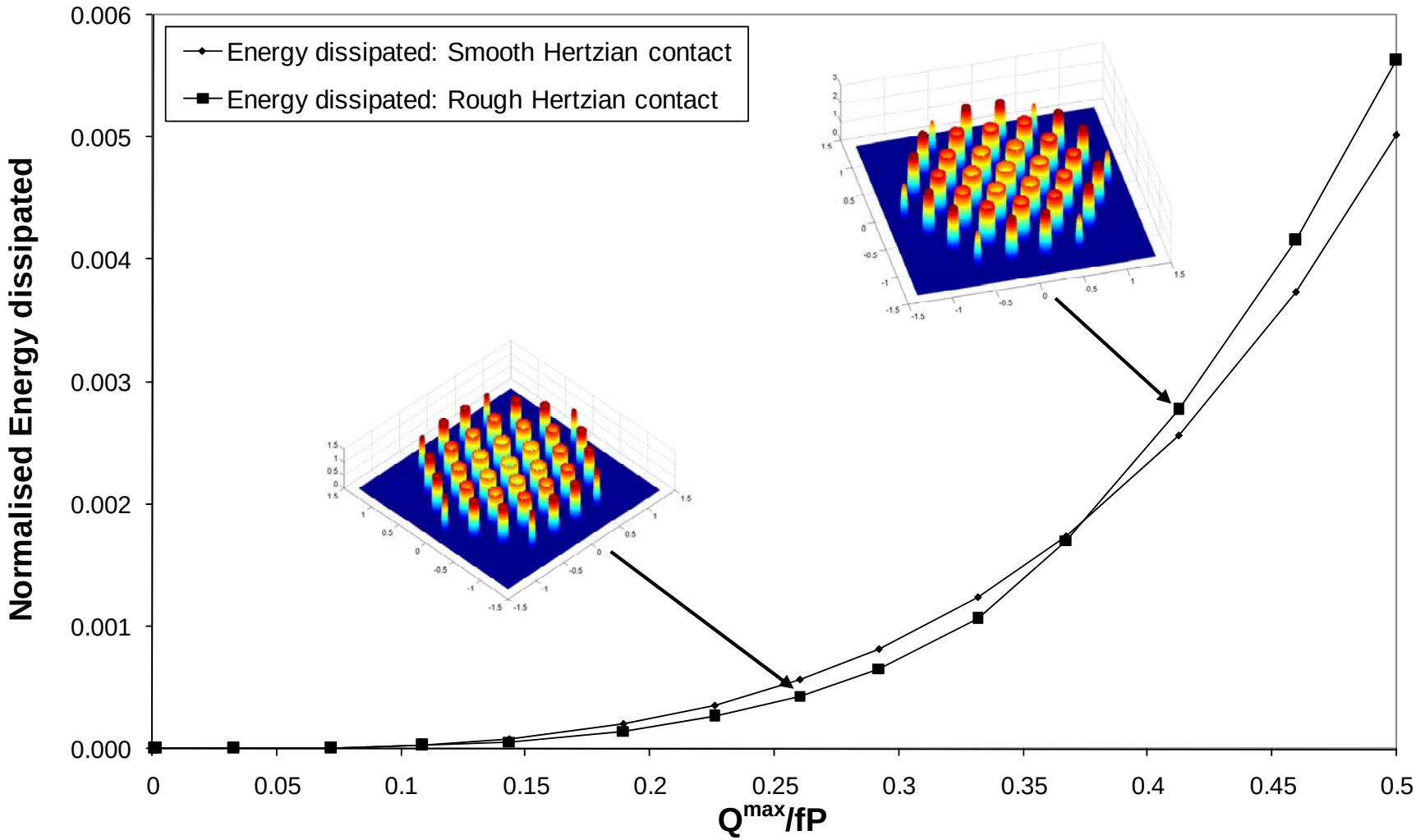

4
2
0
0.5
0
-0.5
-0.5
0
0.5
3
2
1
0
0.05
0
-0.05
-0.05
0
0.05


Idealised rough half-space

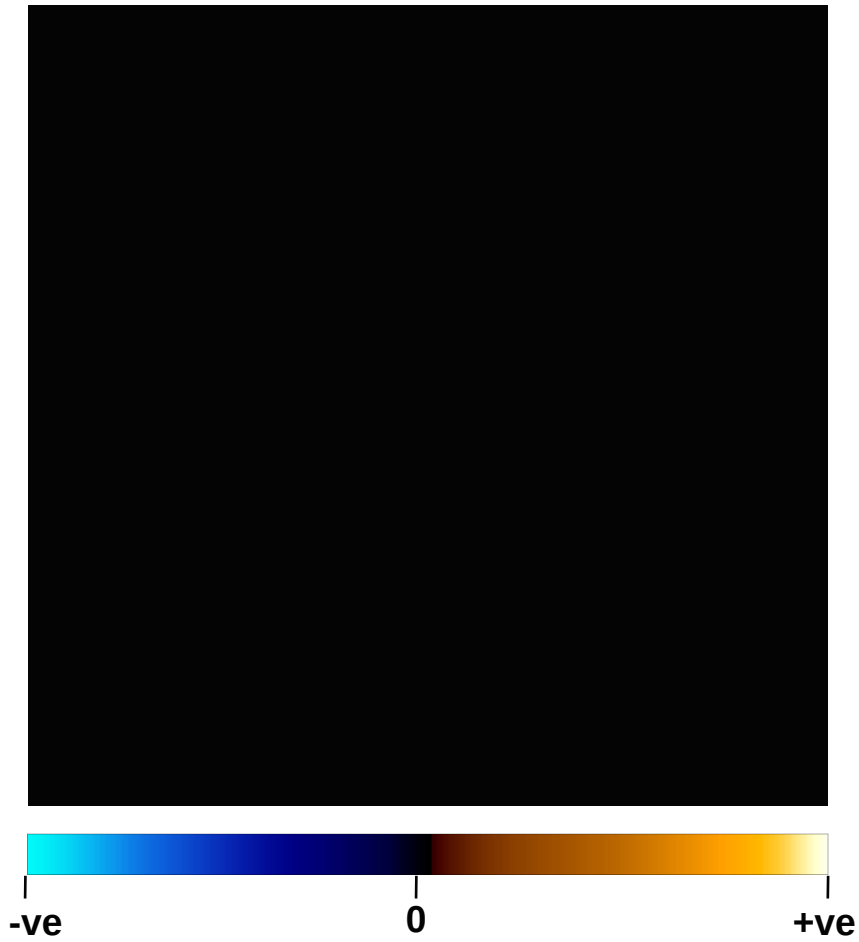

Shear Traction
Pressure
Normalised pressure and shear traction
X
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

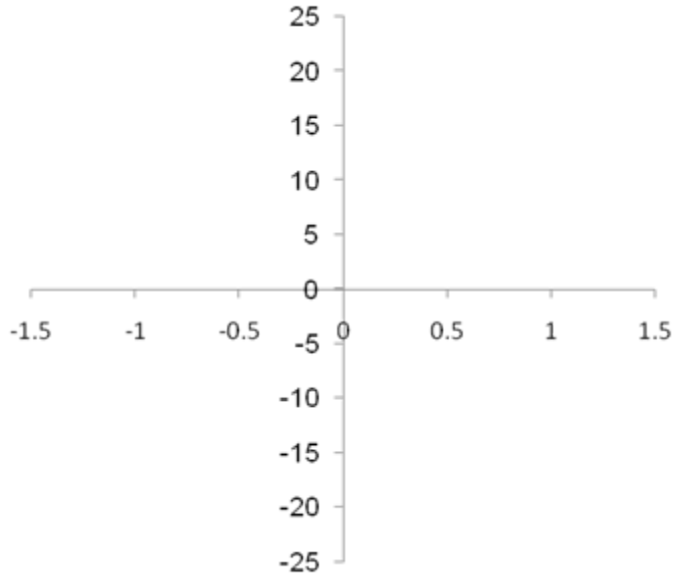

Shear Traction
Pressure
Normalised pressure and shear traction
4
3
2
1


Loop_local_1
Loop_local_2
Loop_local_3
Loop_local_4
Normalised Shear Force
Normalised Displacements
1
2
3
4


Energy dissipated: Smooth Hertzian contact
Energy dissipated: Rough Hertzian contact
Normalised Energy dissipated
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Q^max/fP

Rough surface – Typical friction loop (traction)





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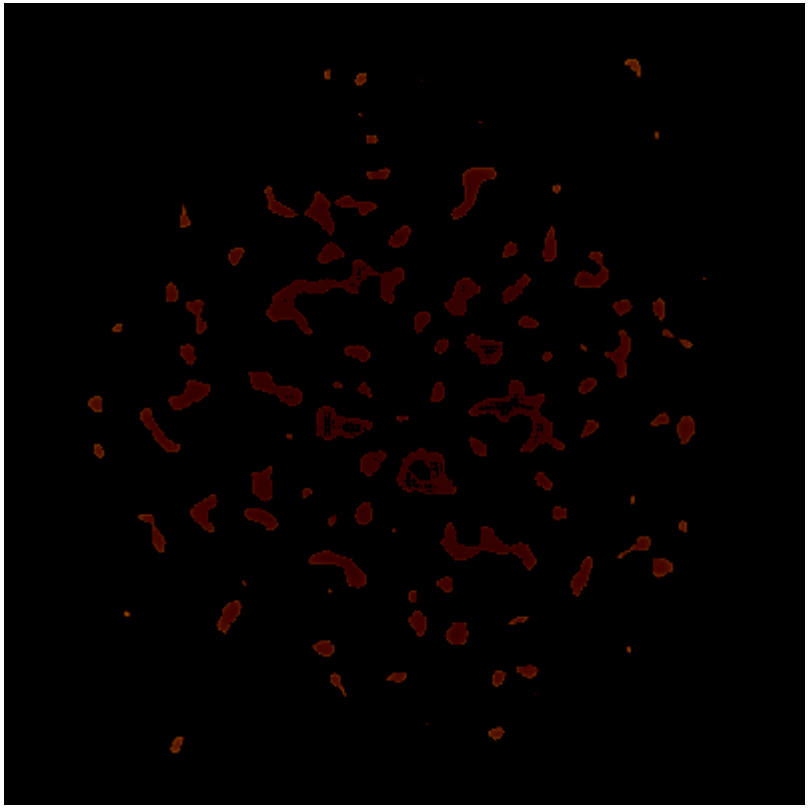

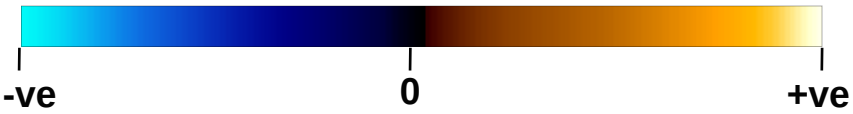

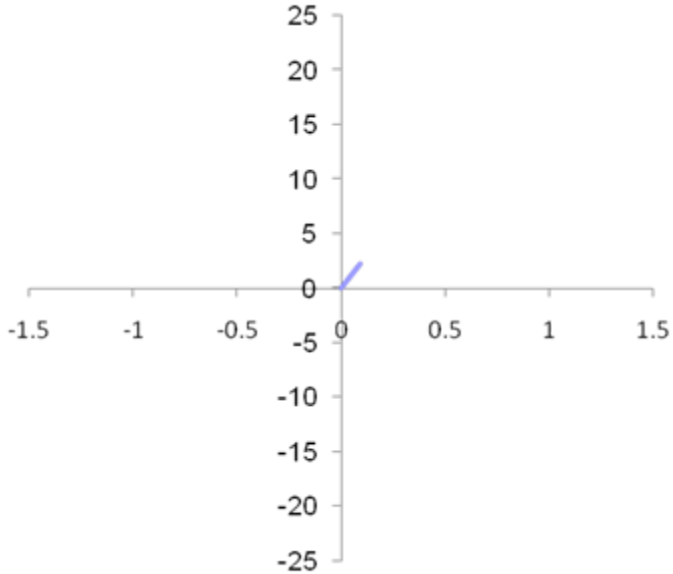

Rolls-Royce

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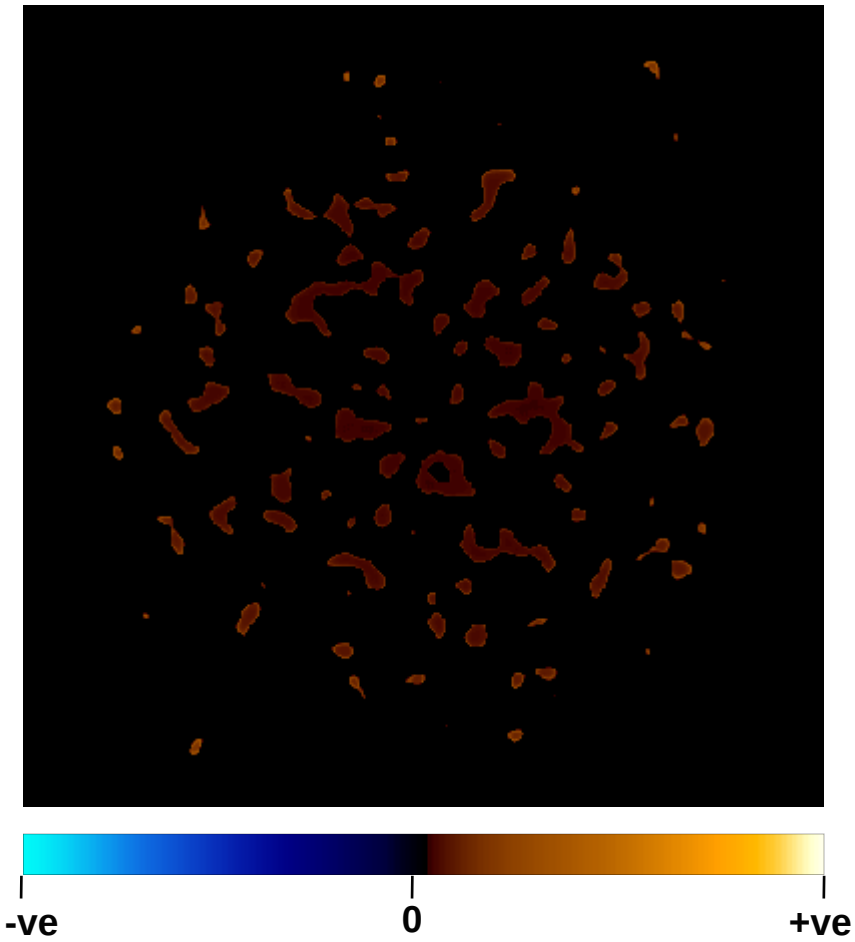

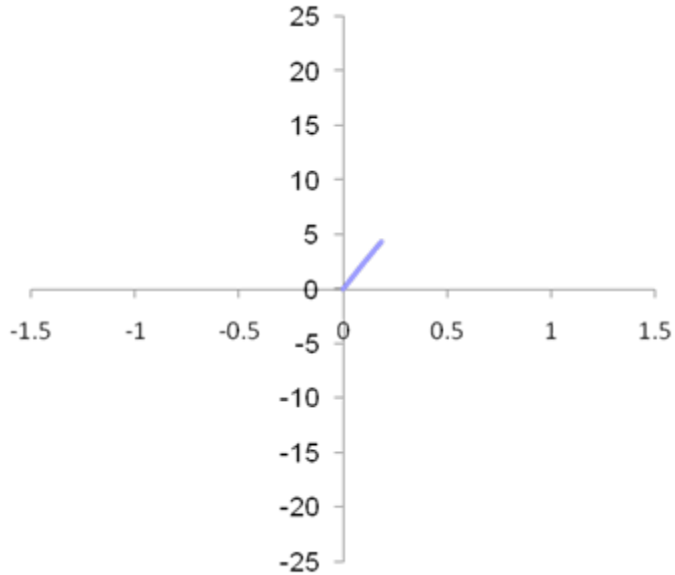

Rolls-Royce

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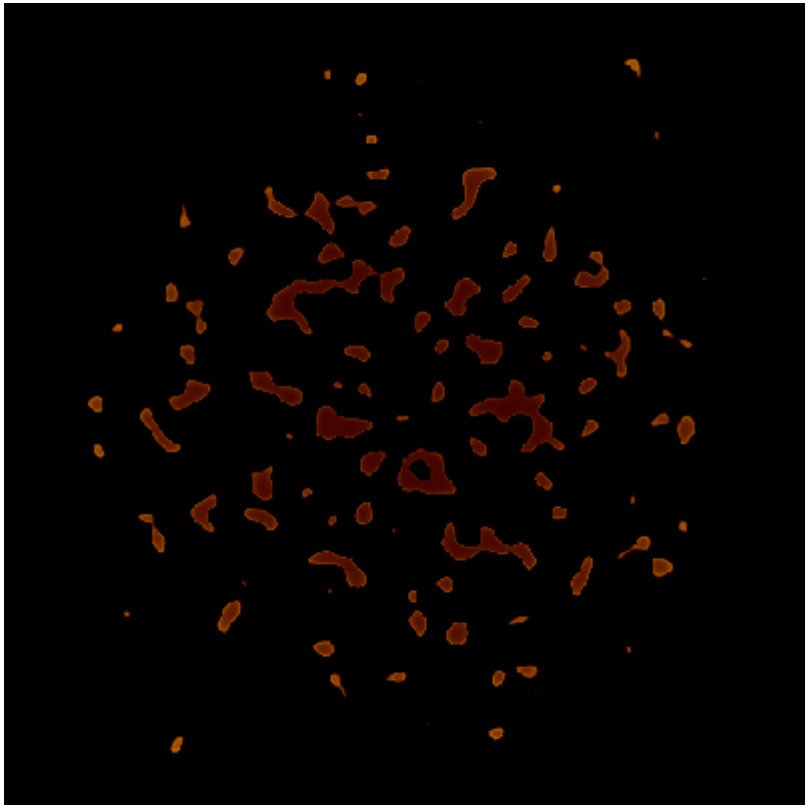
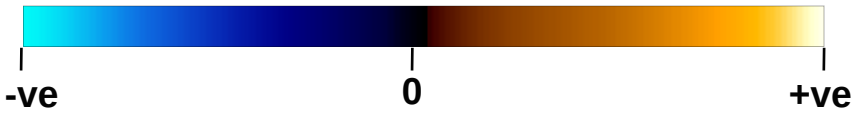
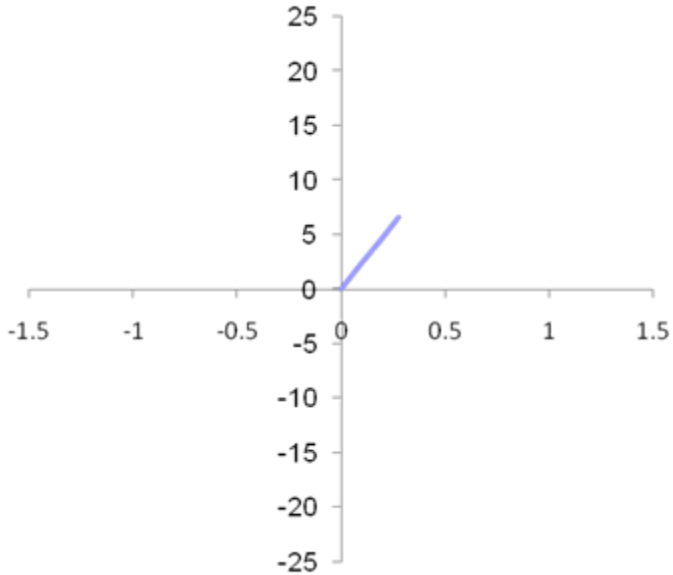
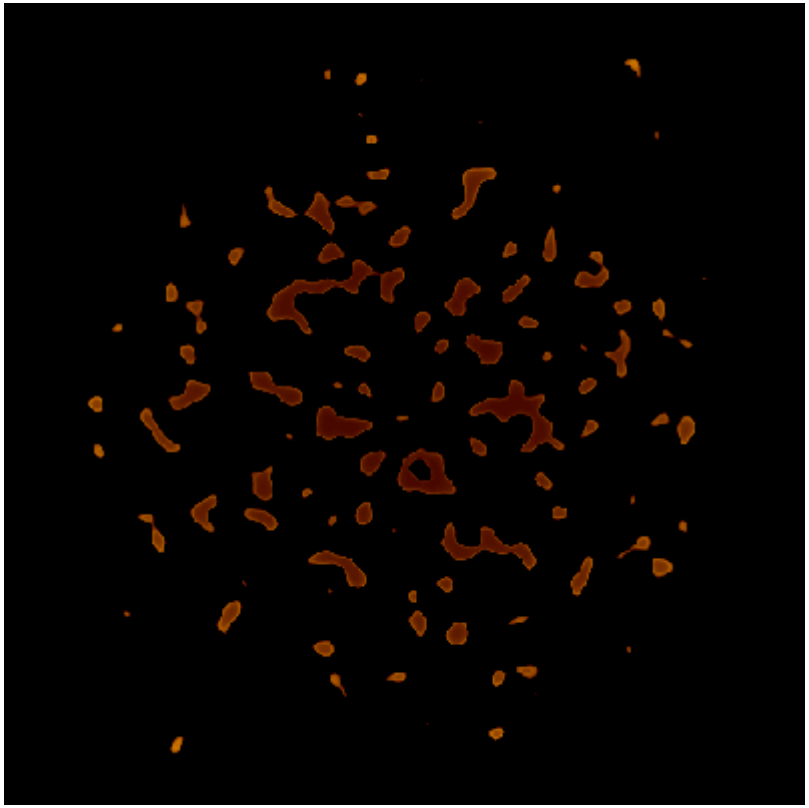


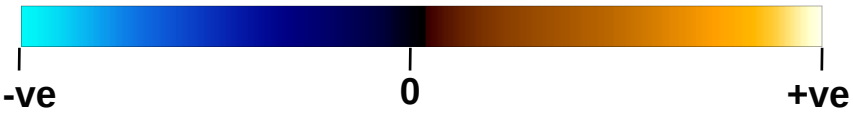


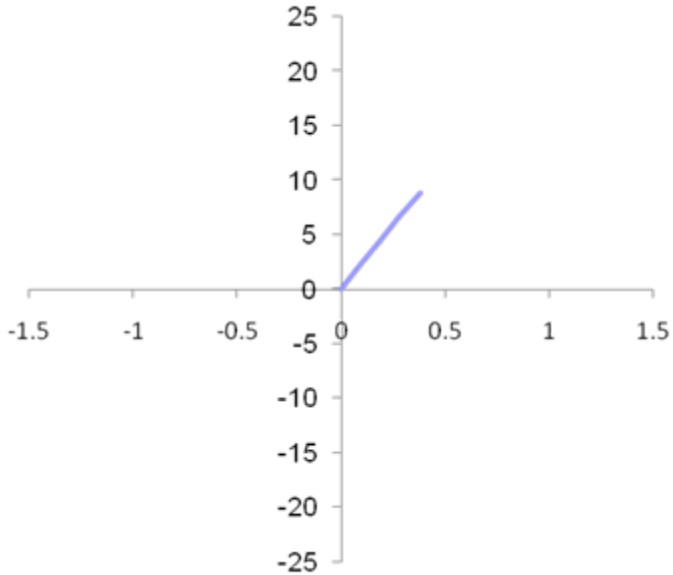


Rolls-Royce

Rough surface – Typical friction loop (traction)

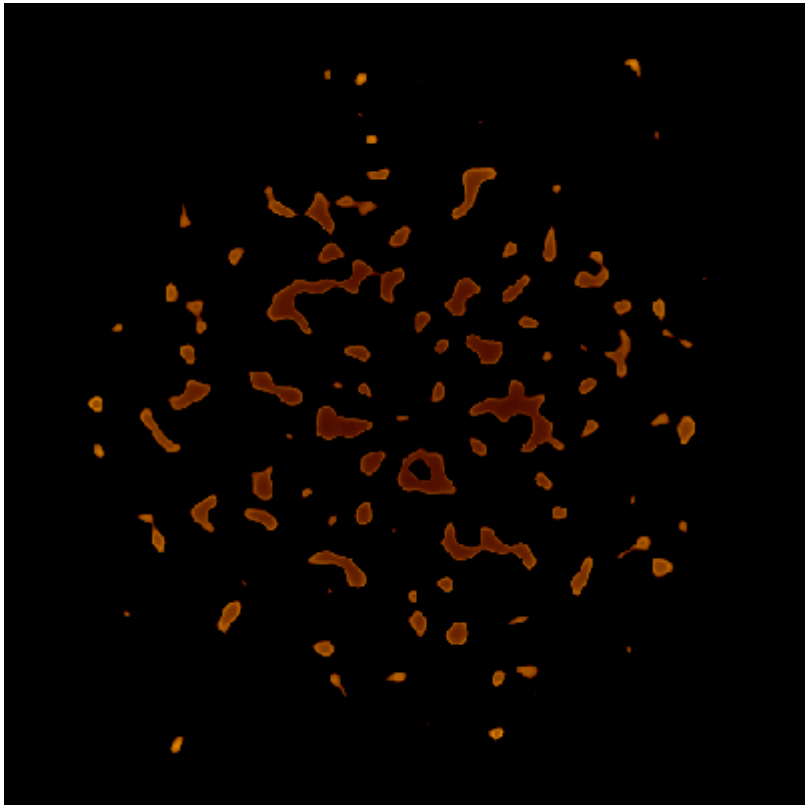


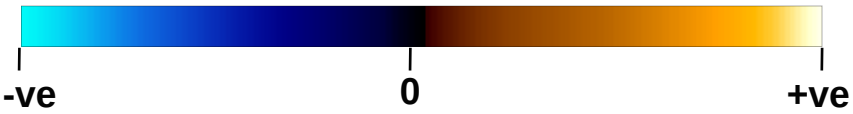


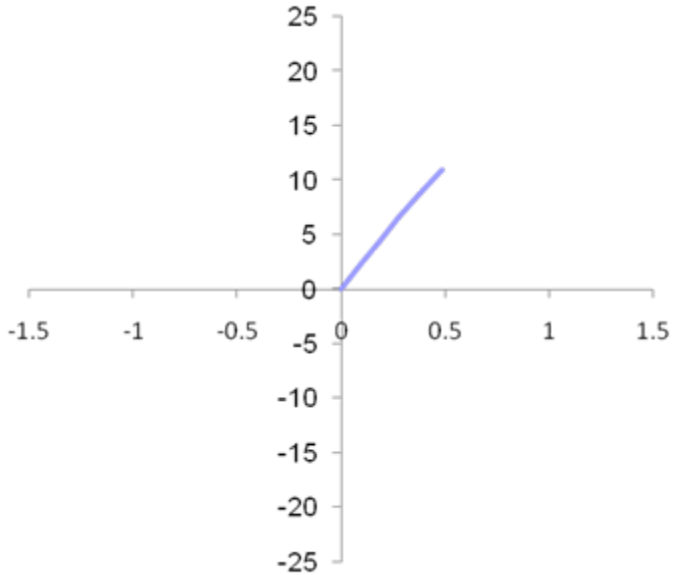


Rolls-Royce

Rough surface – Typical friction loop (traction)







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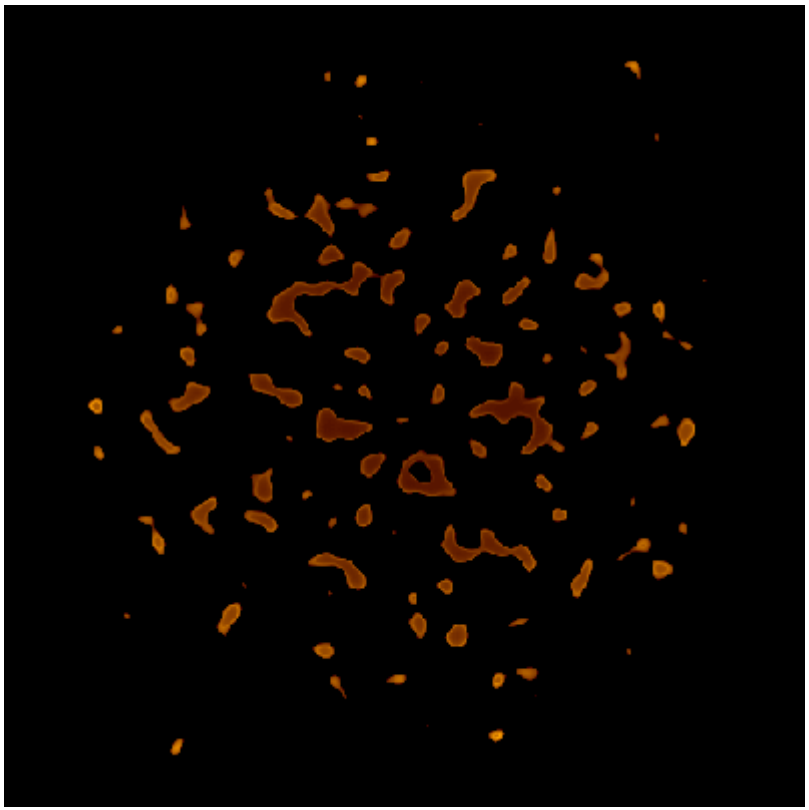
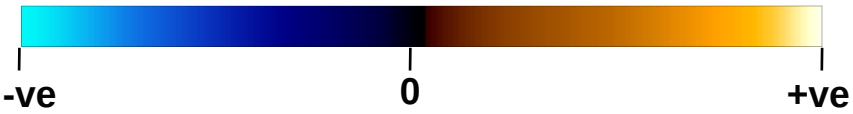
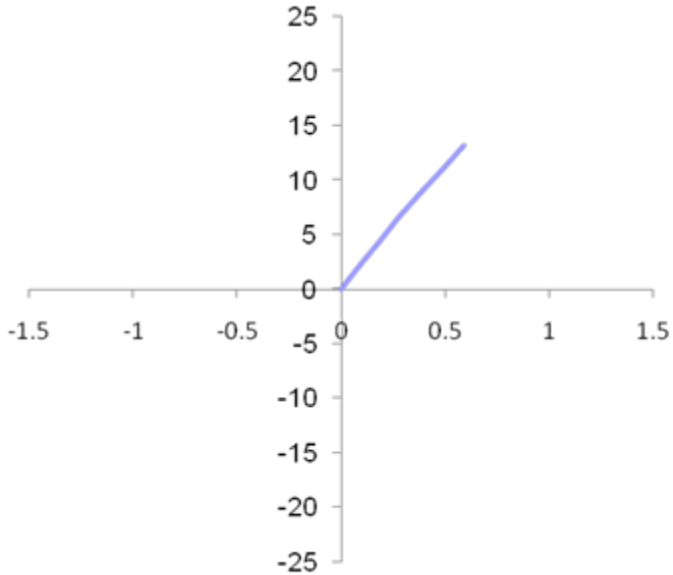
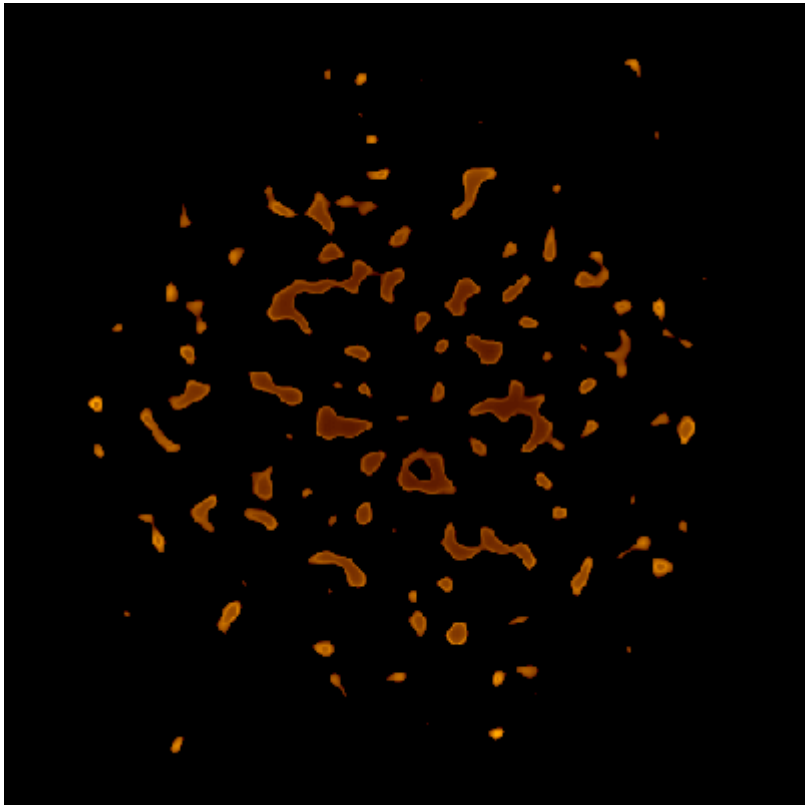


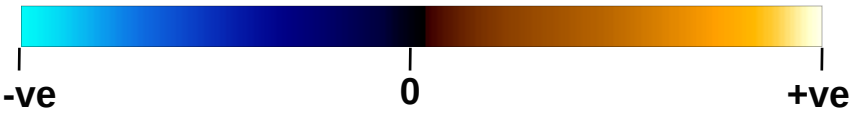


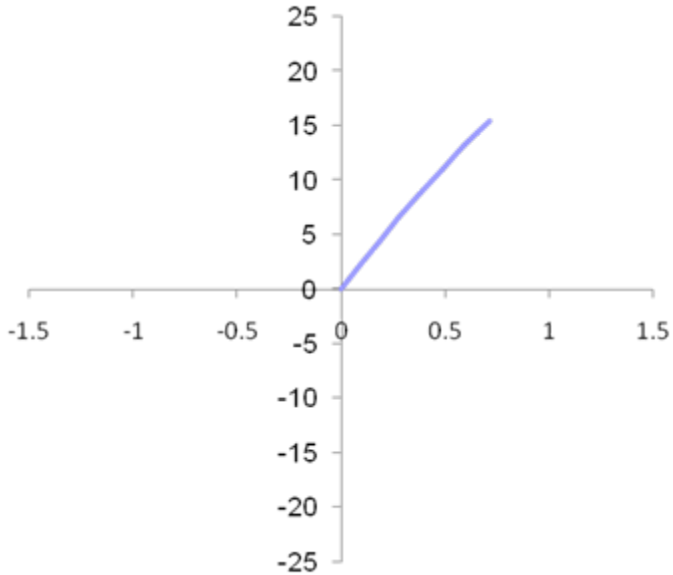


Rolls-Royce

Rough surface – Typical friction loop (traction)

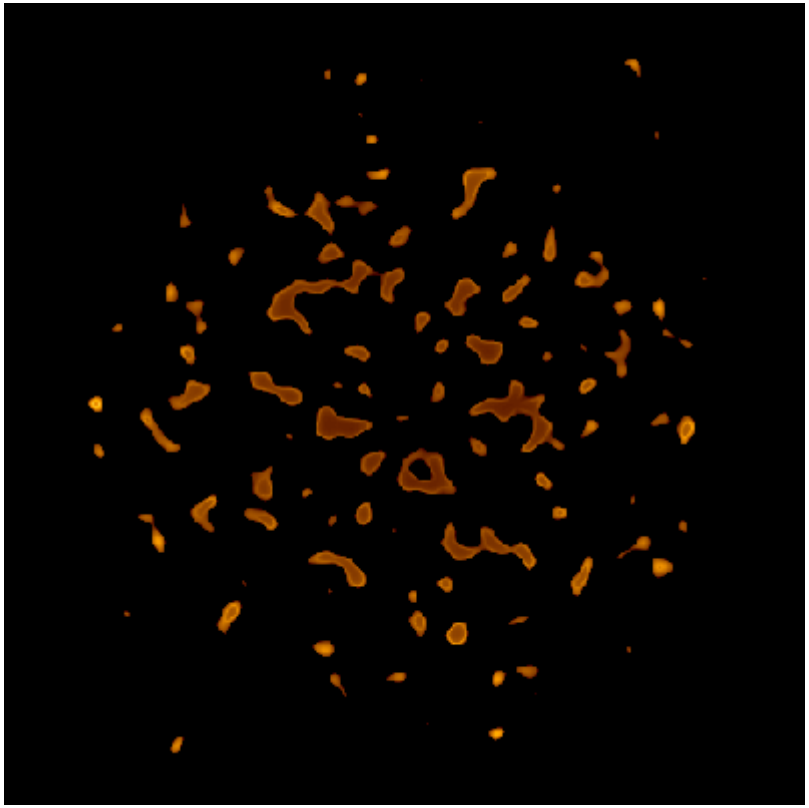


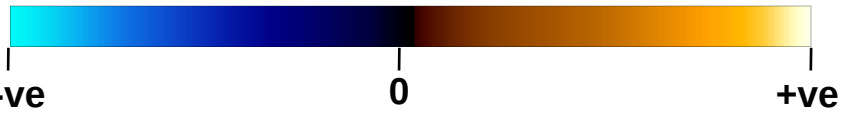


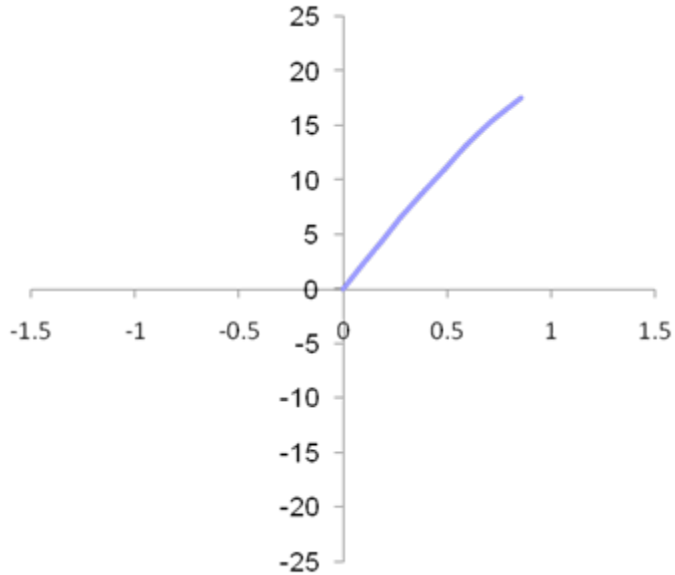


Rolls-Royce

Rough surface – Typical friction loop (traction)

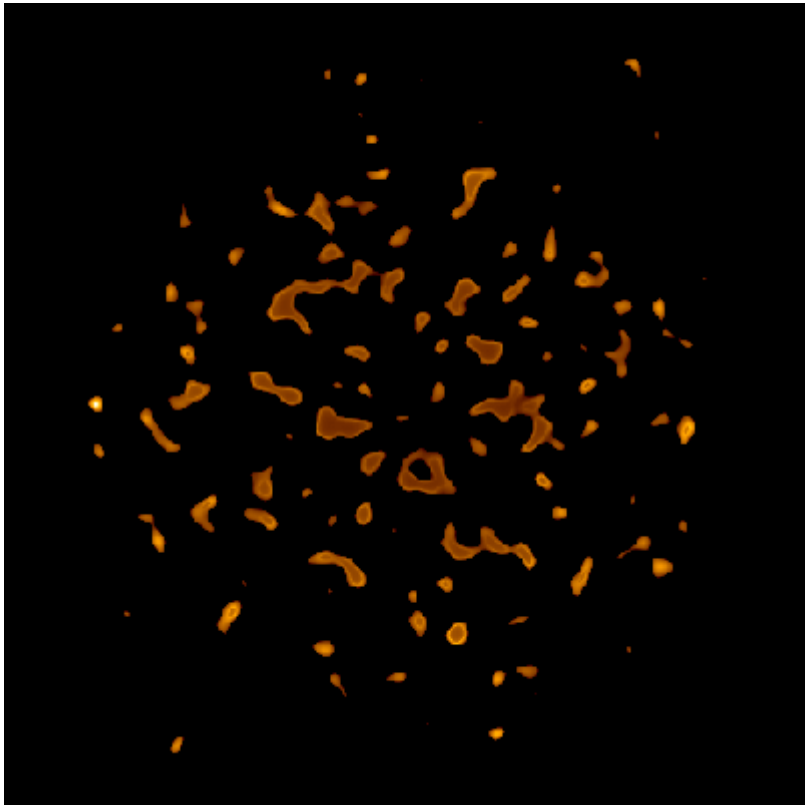


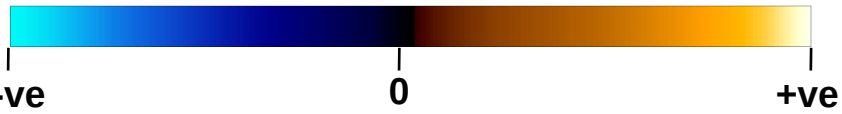


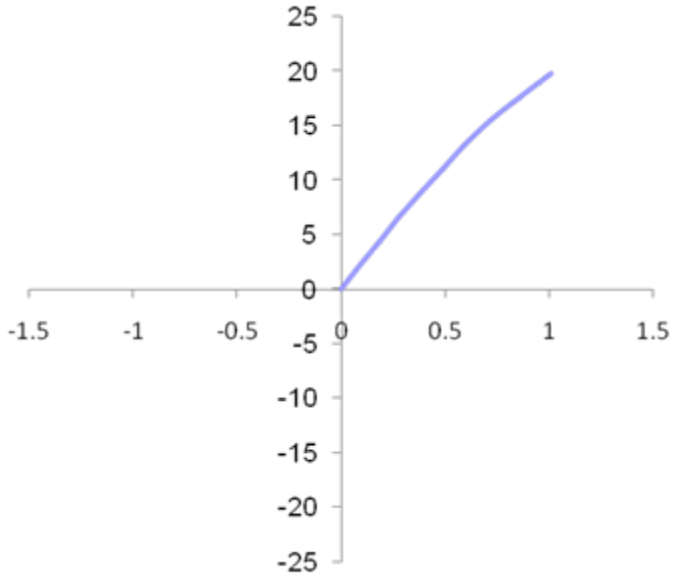


Rolls-Royce

Rough surface – Typical friction loop (traction)







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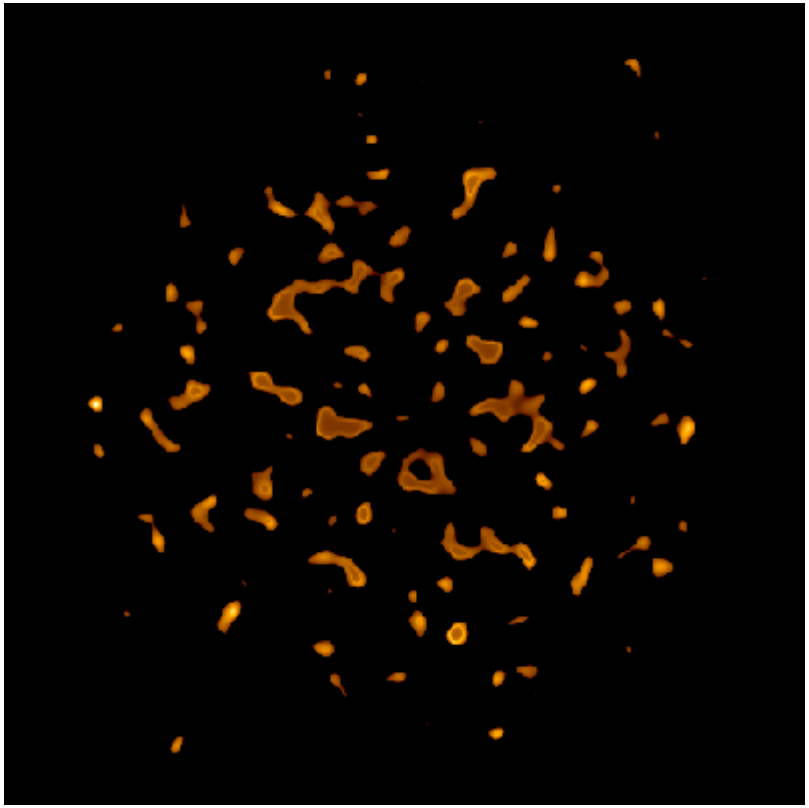
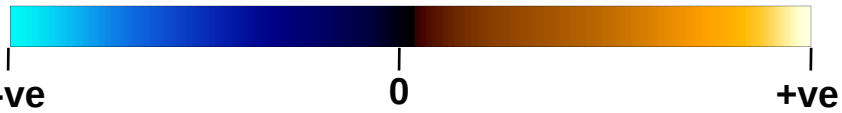
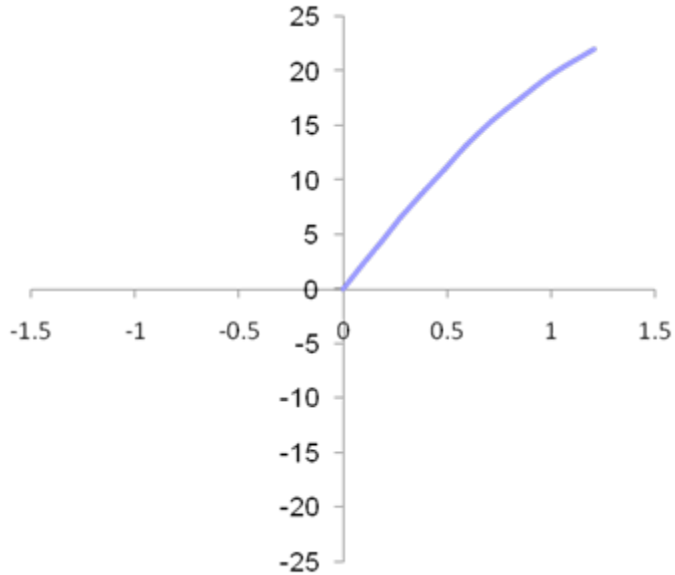
Rough surface – Typical friction loop (traction)

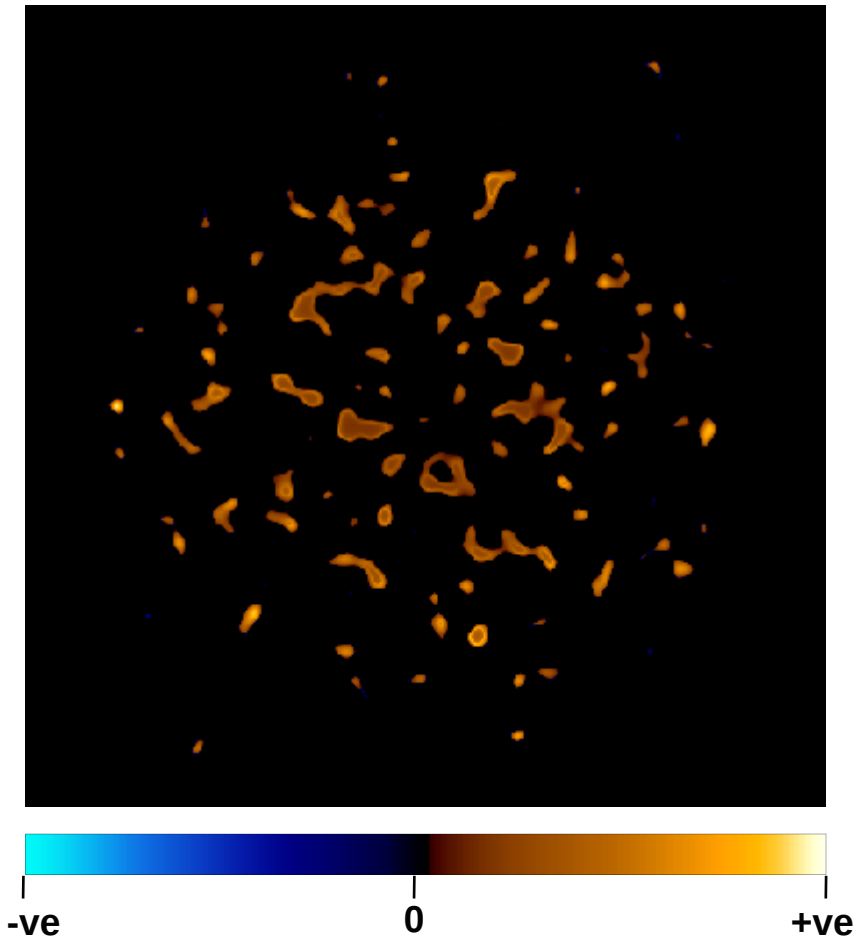


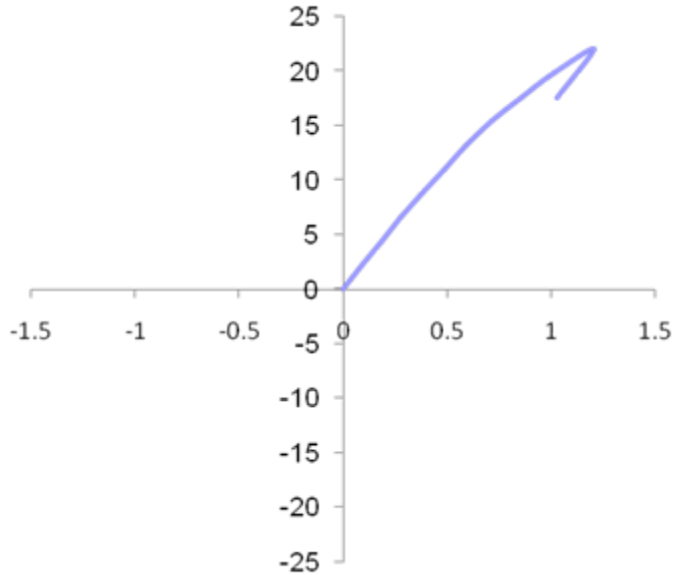




Rolls-Royce

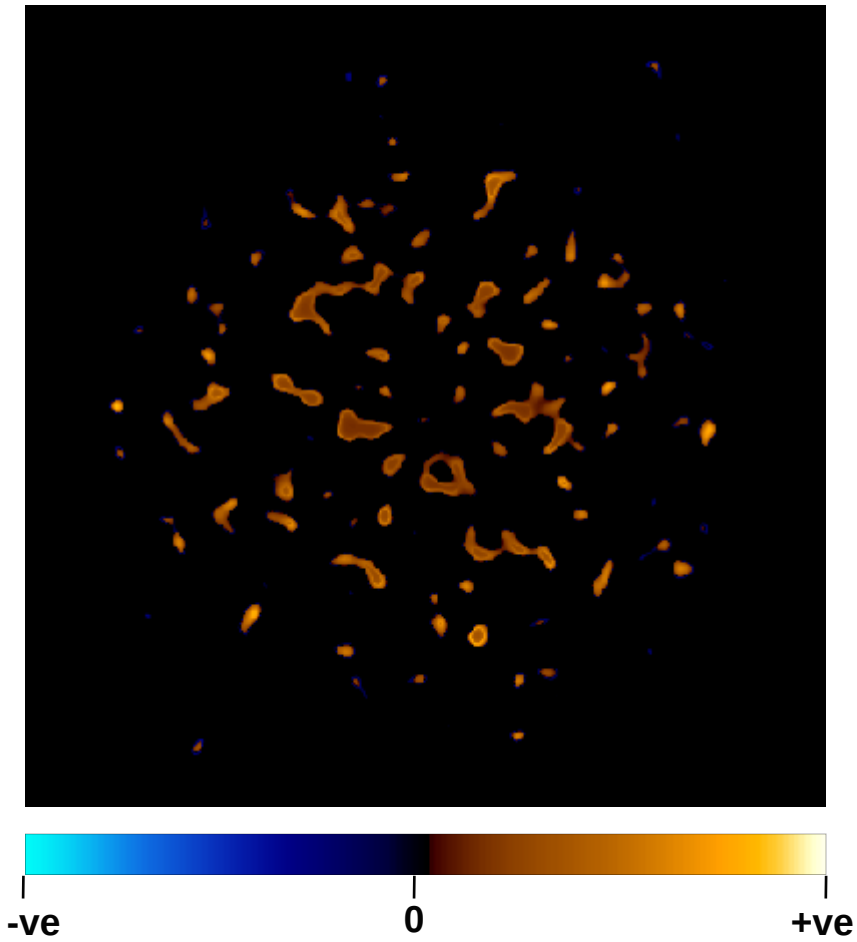
Rough surface – Typical friction loop (traction)

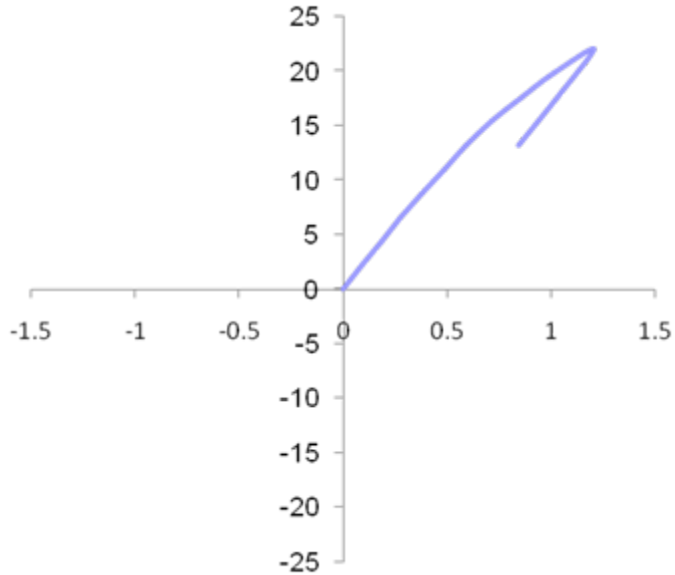




Rolls-Royce

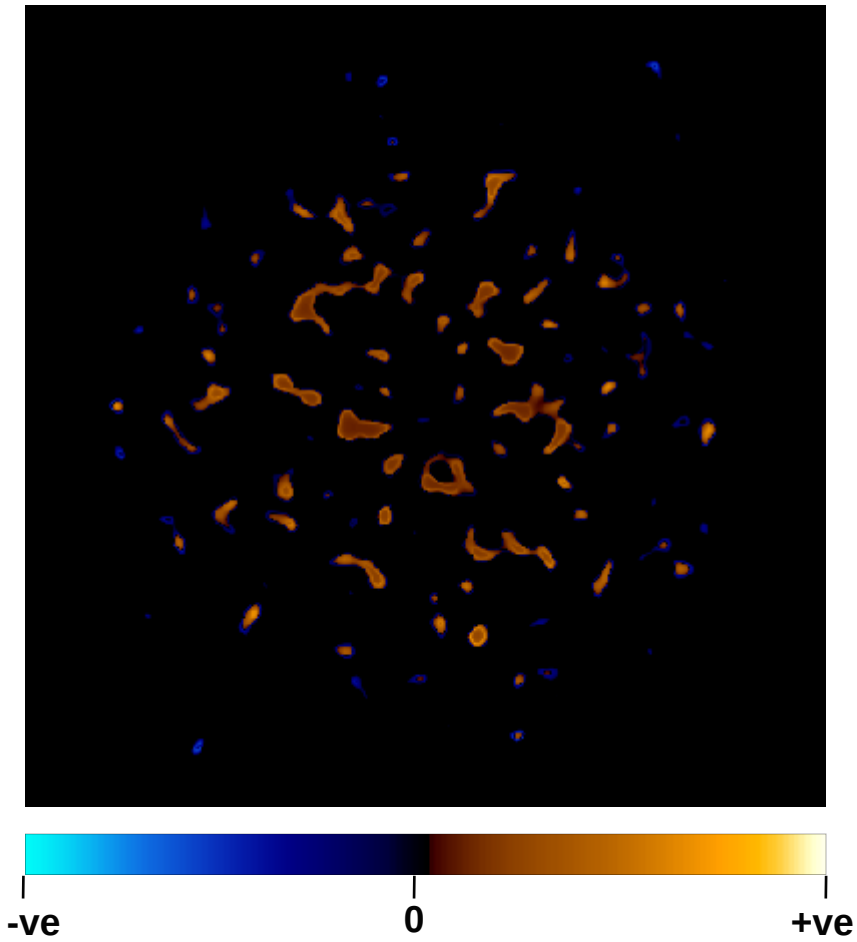
Rough surface – Typical friction loop (traction)

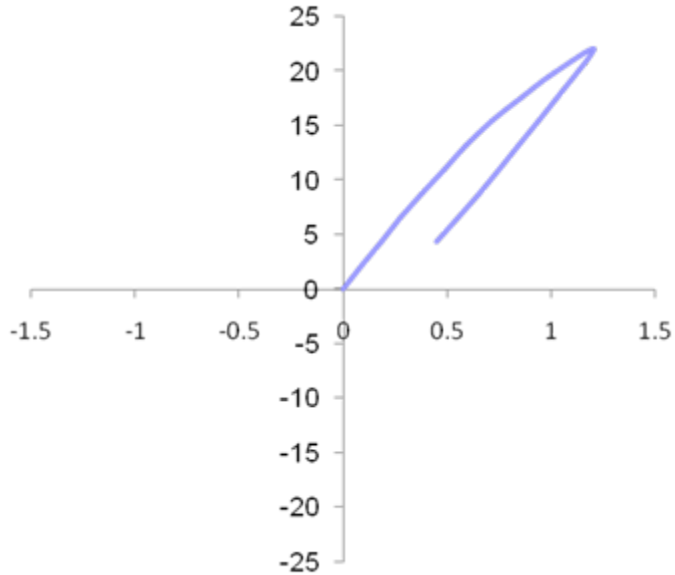




Rolls-Royce

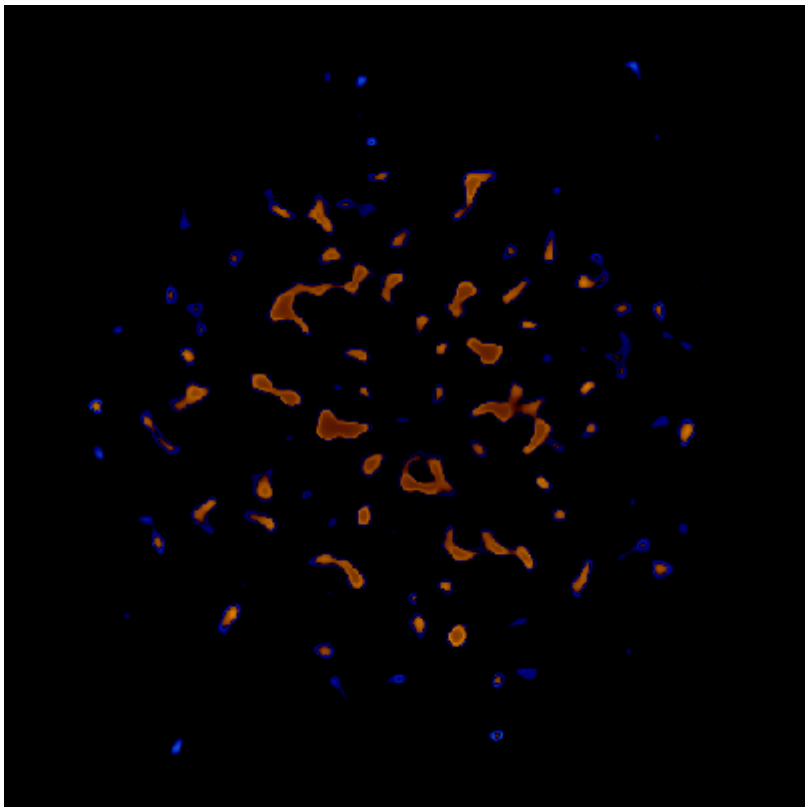
Rough surface – Typical friction loop (traction)

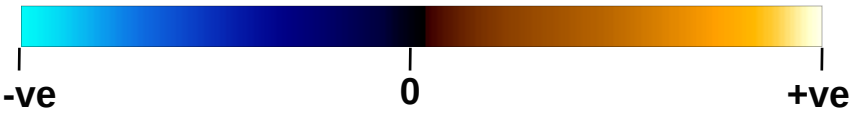


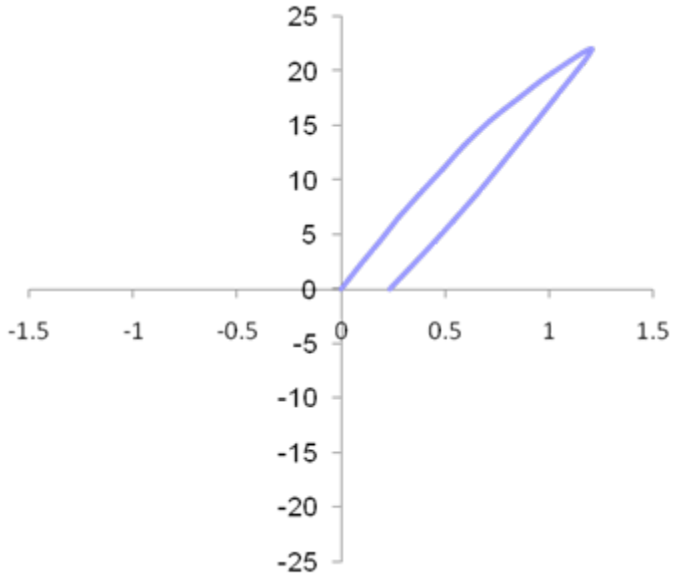


Rolls-Royce

Rough surface – Typical friction loop (traction)

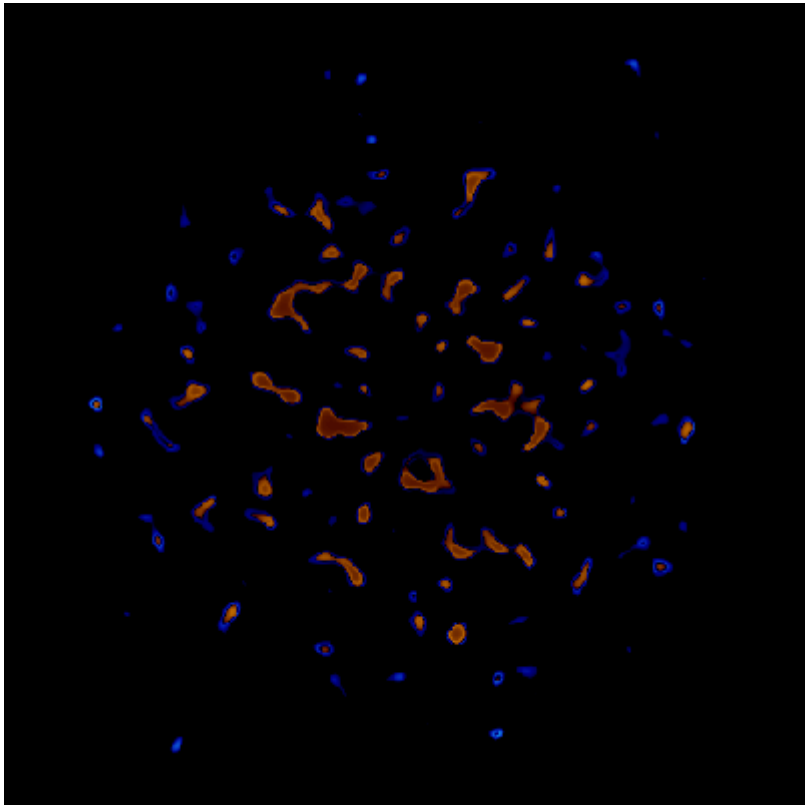


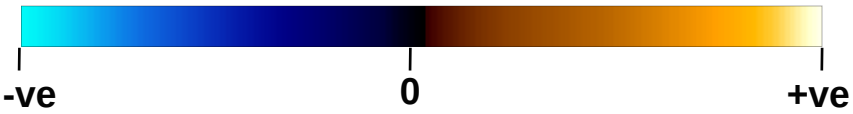


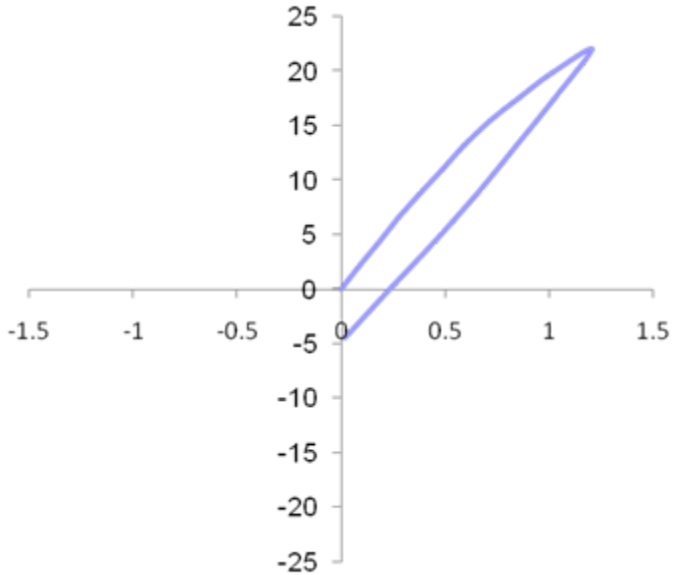


Rolls-Royce

Rough surface – Typical friction loop (traction)

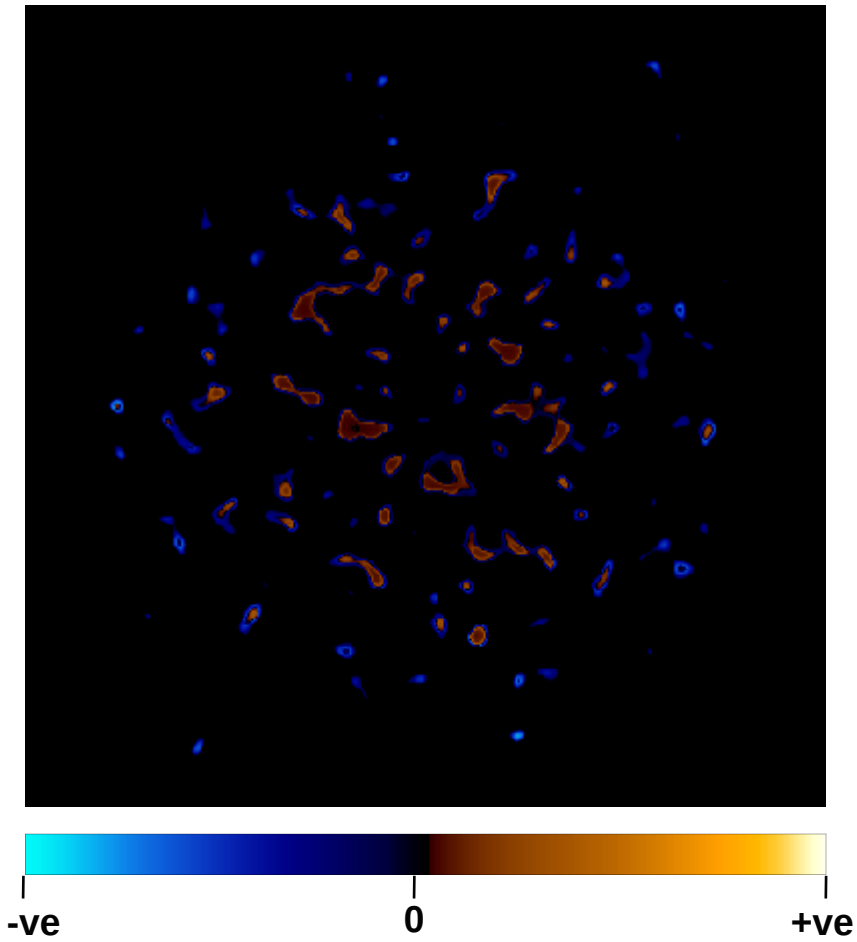


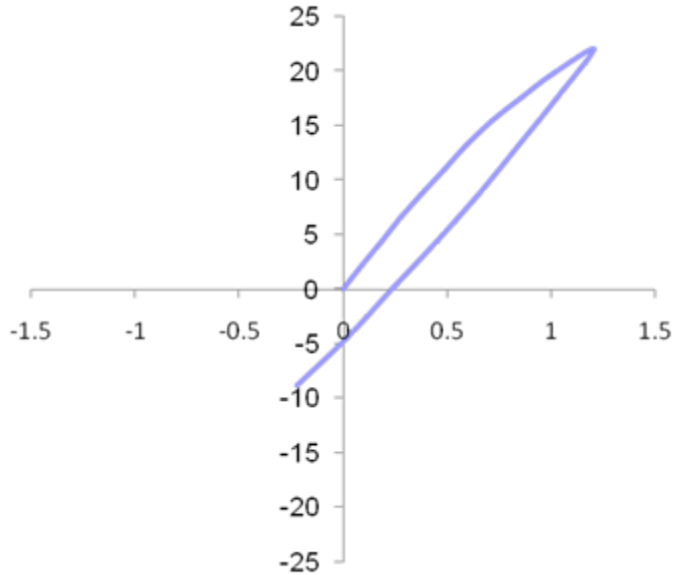




Rolls-Royce

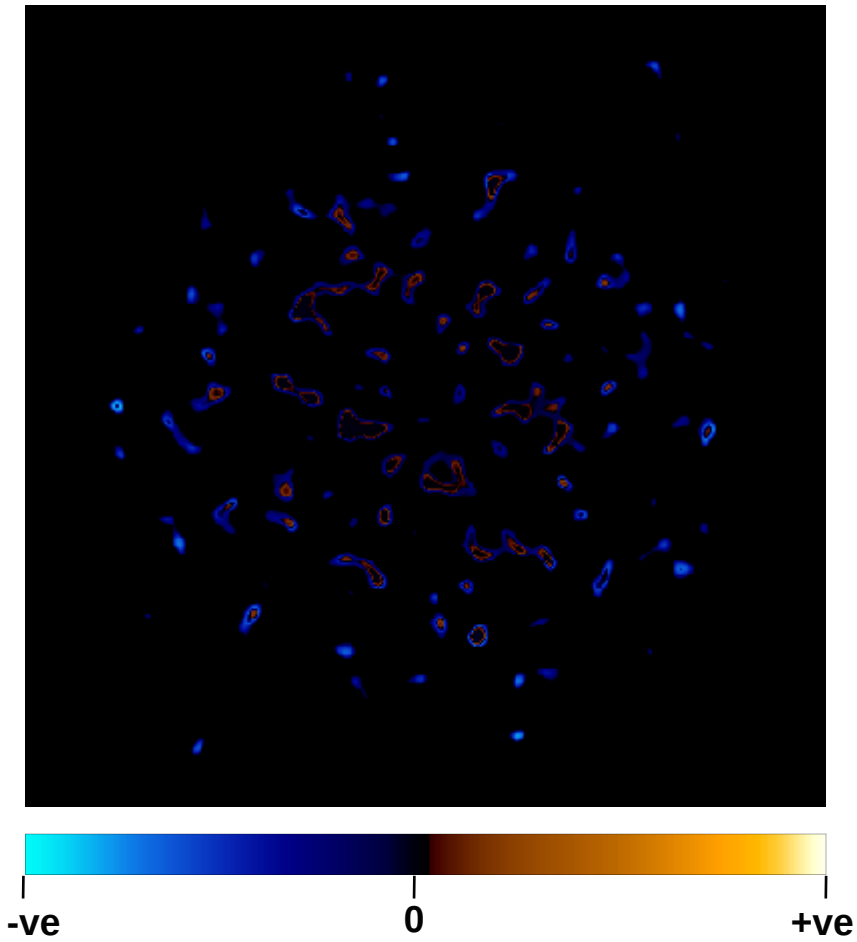
Rough surface – Typical friction loop (traction)

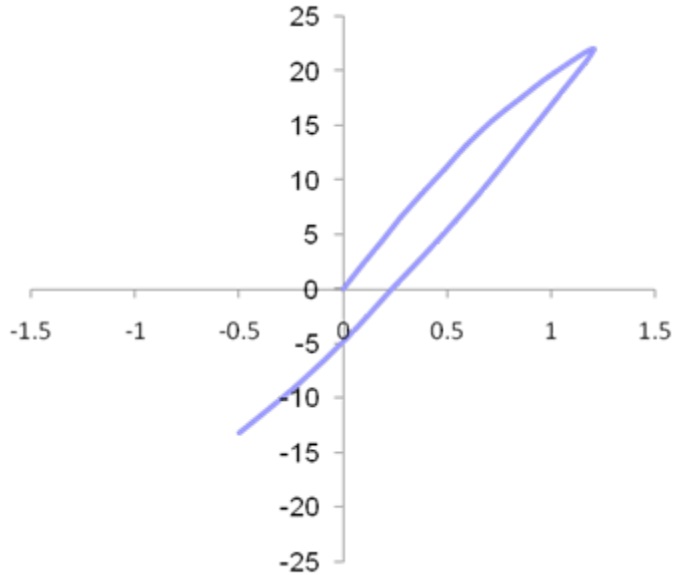




Rolls-Royce

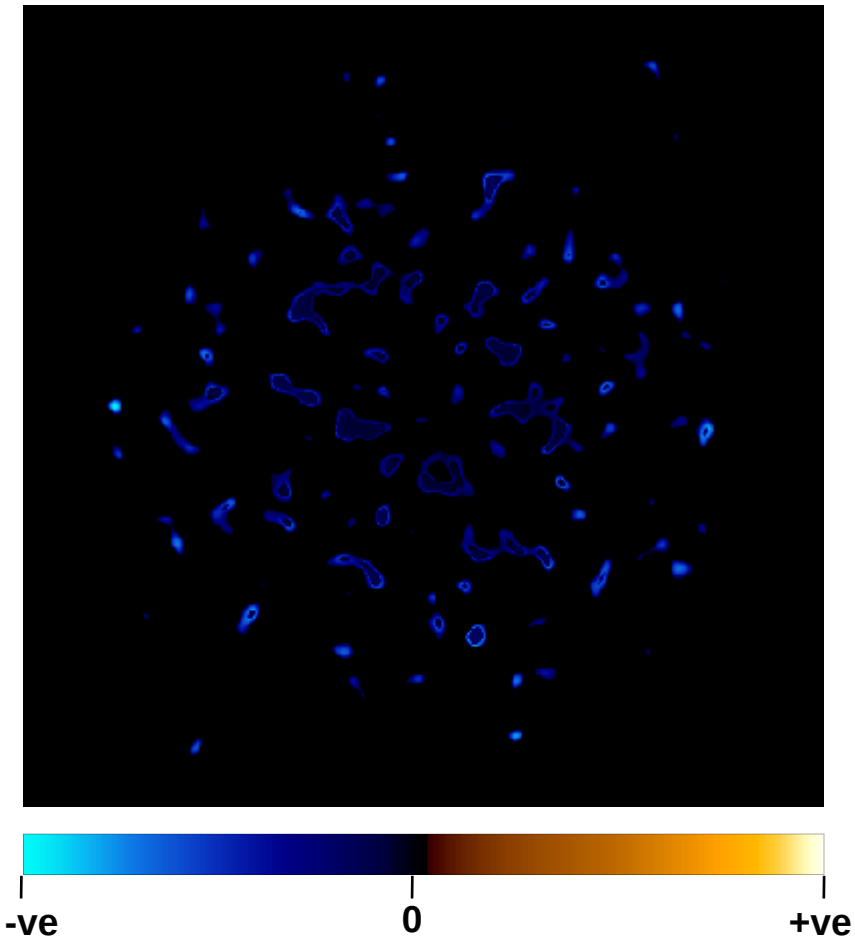
Rough surface – Typical friction loop (traction)

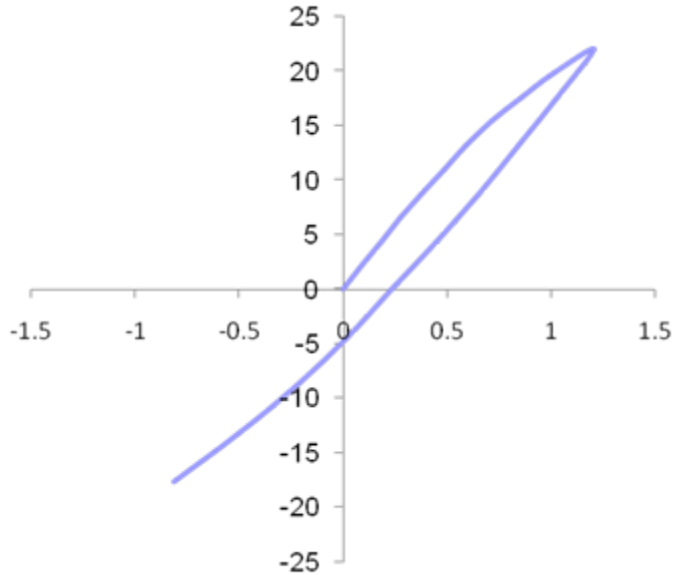




Rolls-Royce

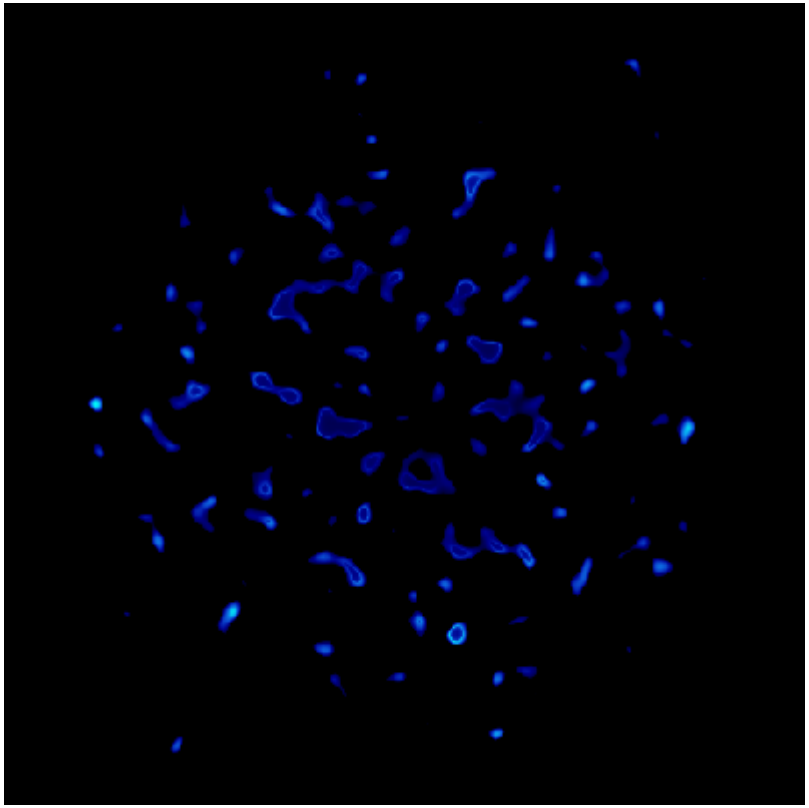
Rough surface – Typical friction loop (traction)

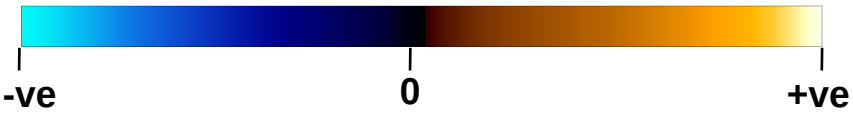


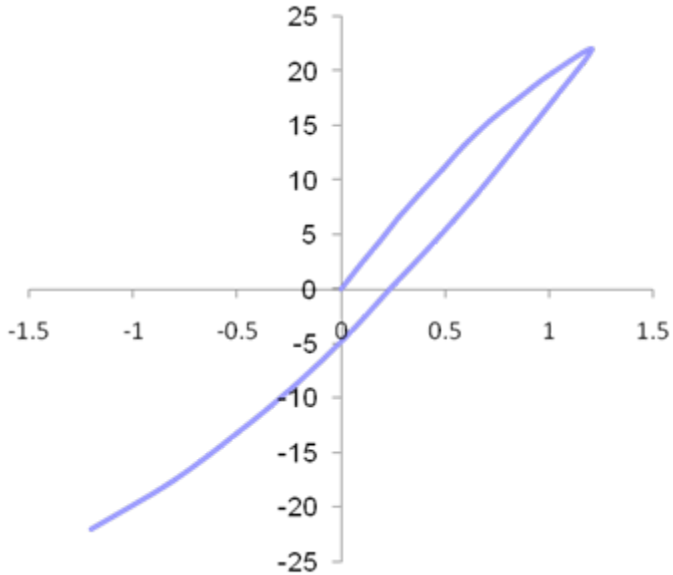


Rolls-Royce

Rough surface – Typical friction loop (traction)

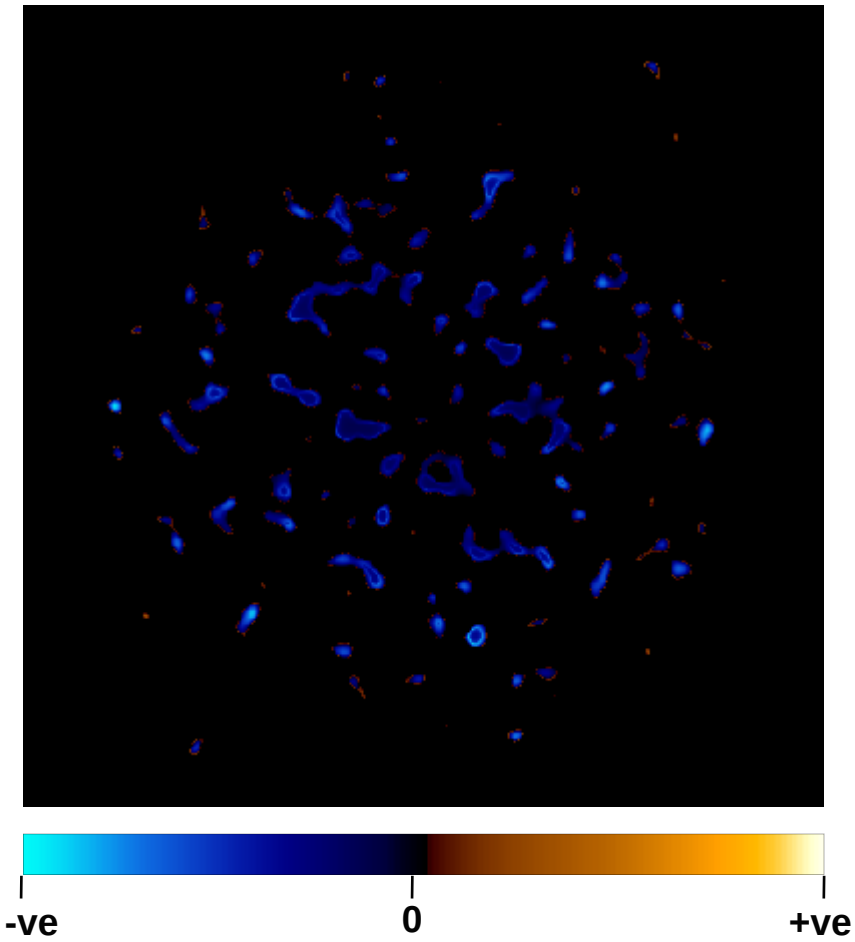


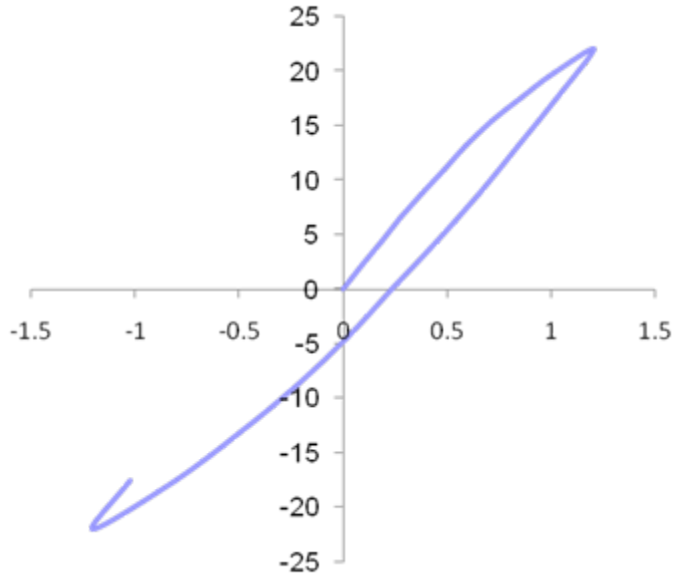




Rolls-Royce

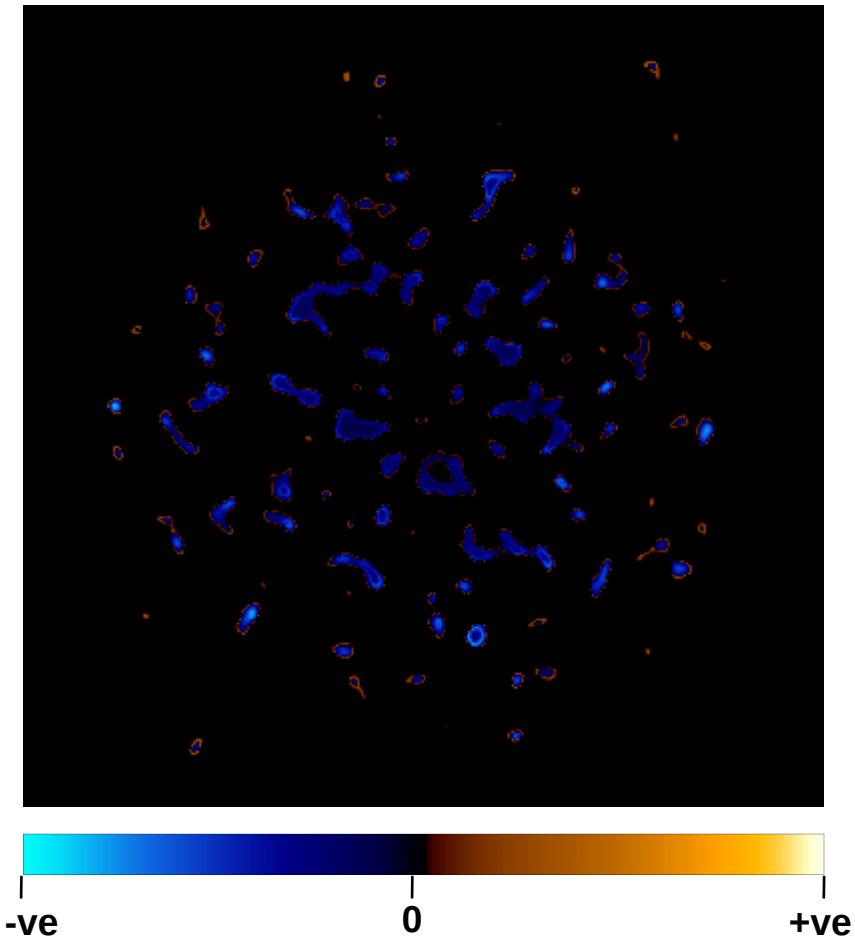
Rough surface – Typical friction loop (traction)

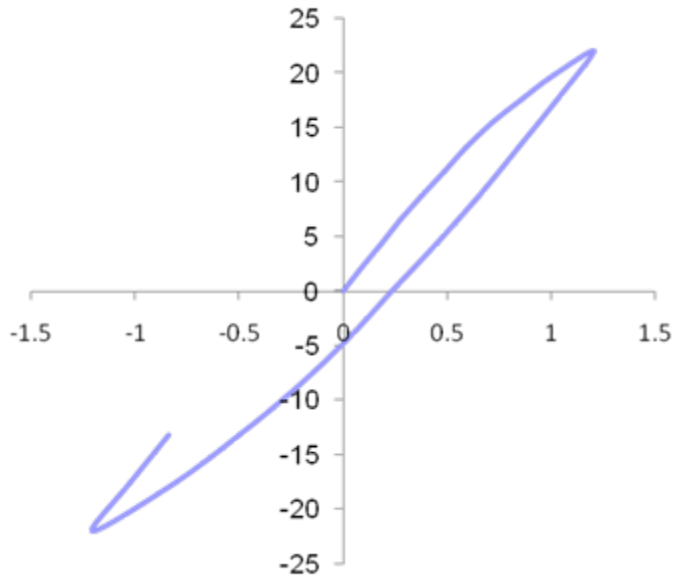




Rolls-Royce

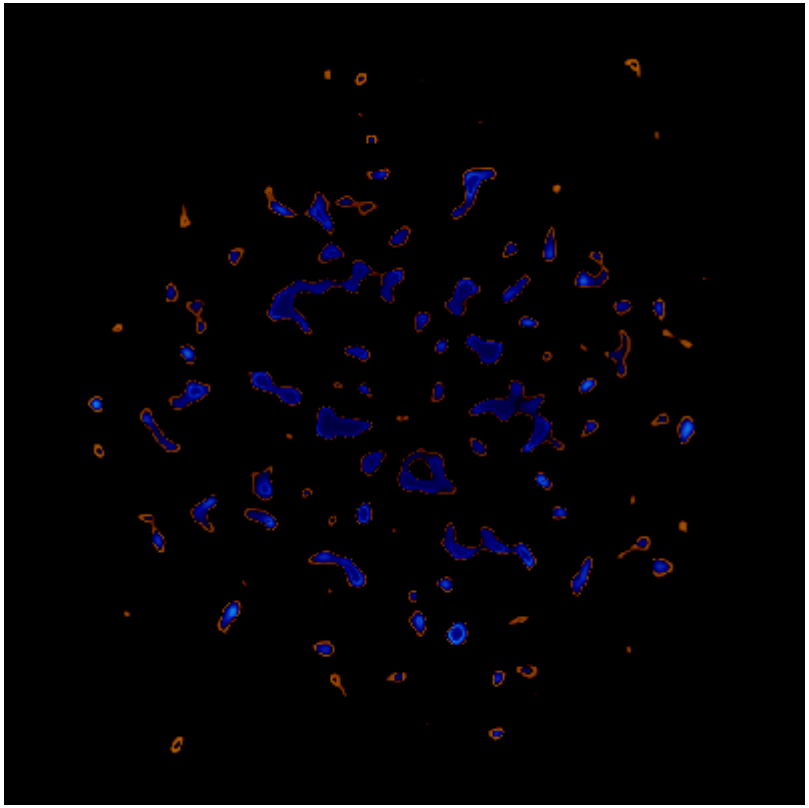
Rough surface – Typical friction loop (traction)

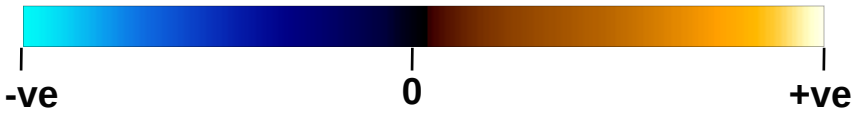


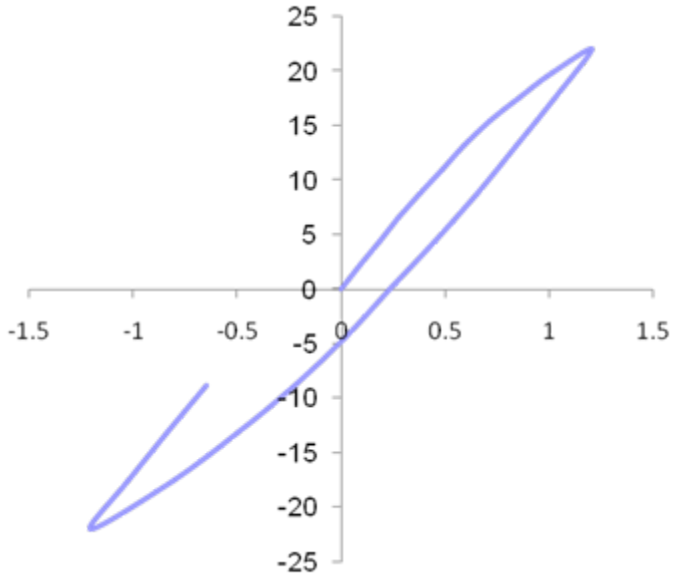


Rolls-Royce

Rough surface – Typical friction loop (traction)

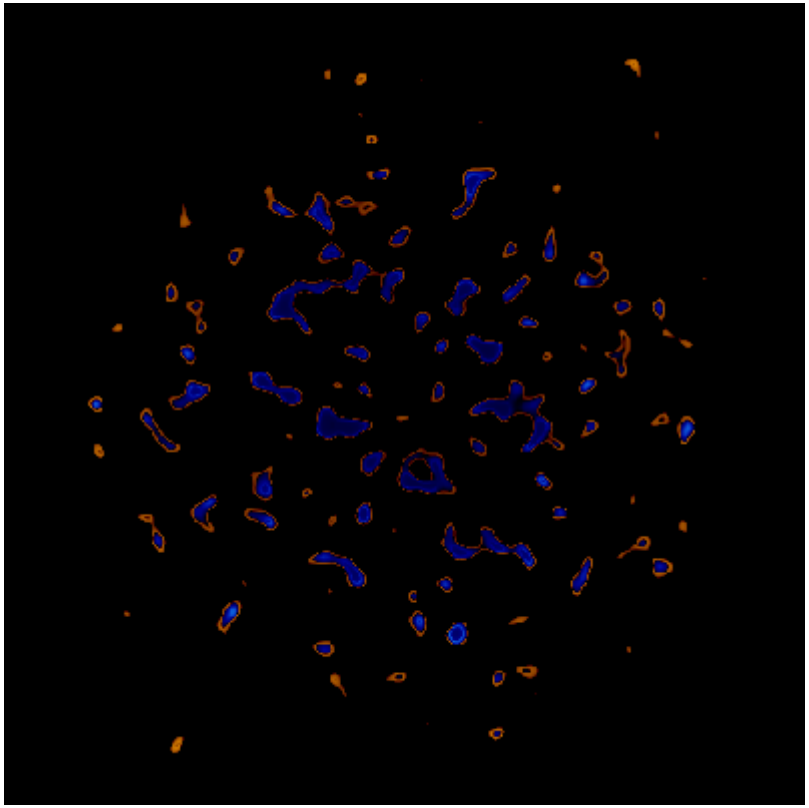


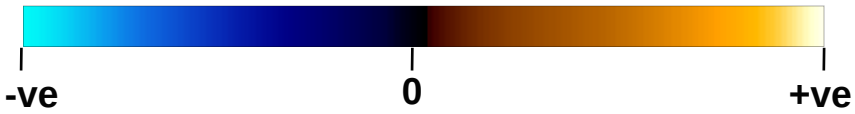


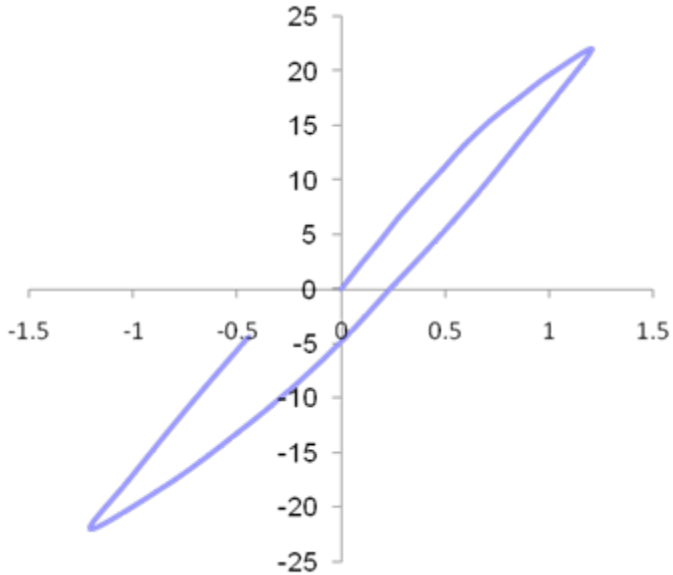


Rolls-Royce

Rough surface – Typical friction loop (traction)

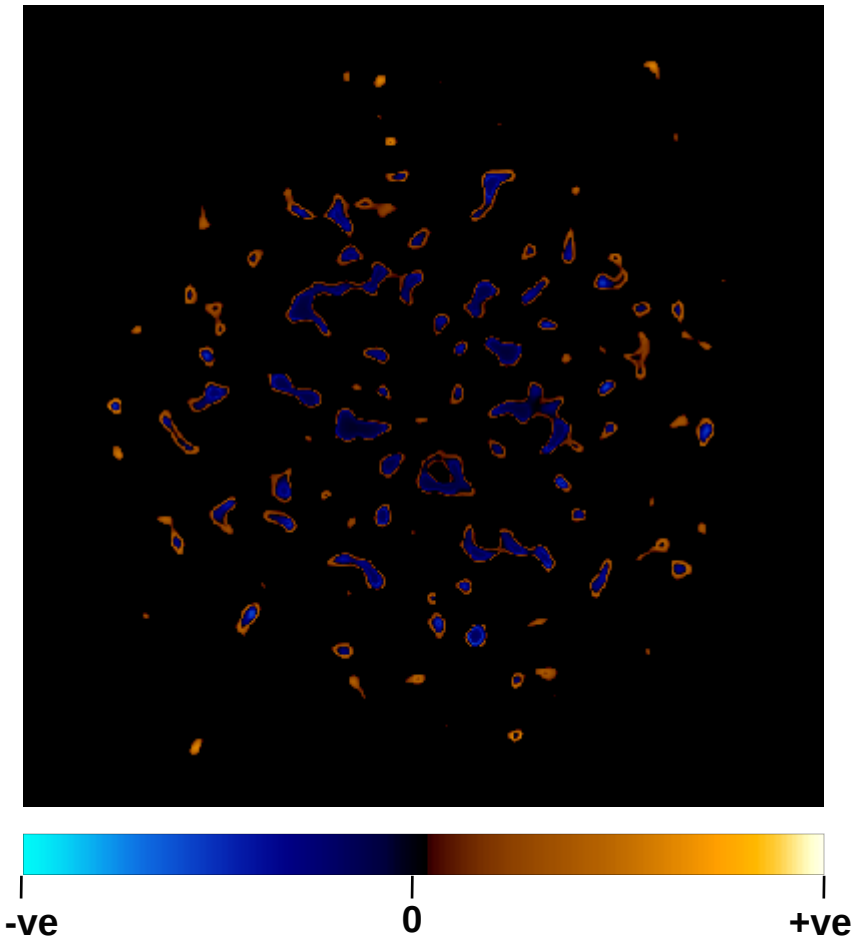


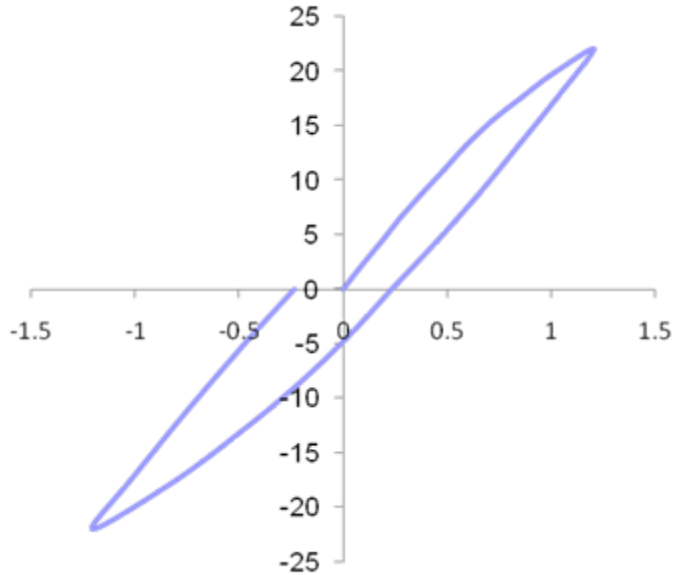




Rolls-Royce

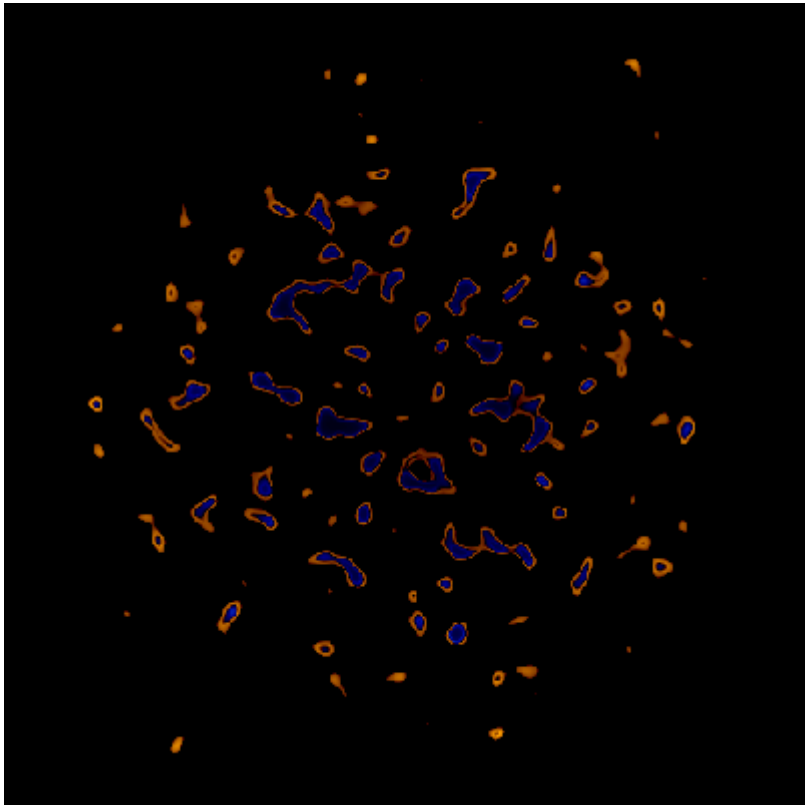
Rough surface – Typical friction loop (traction)

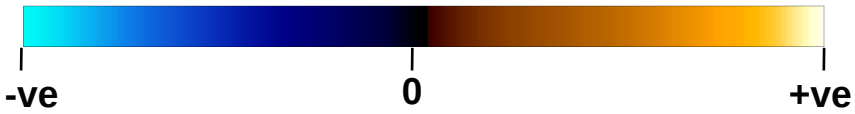


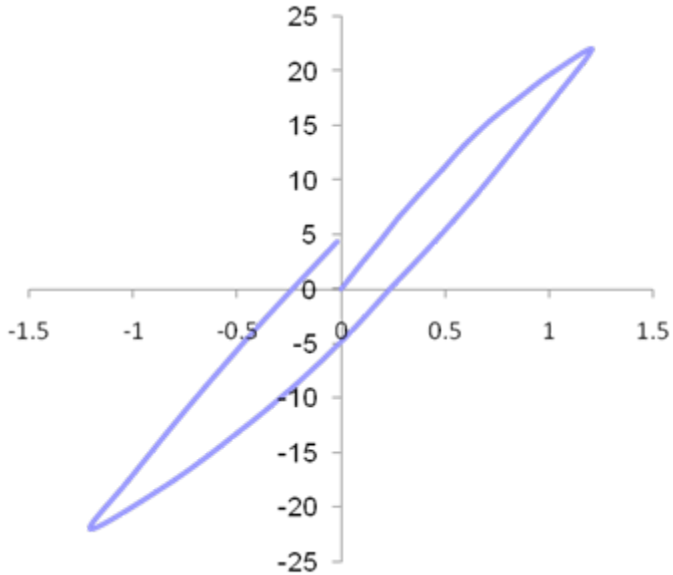


Rolls-Royce

Rough surface – Typical friction loop (traction)

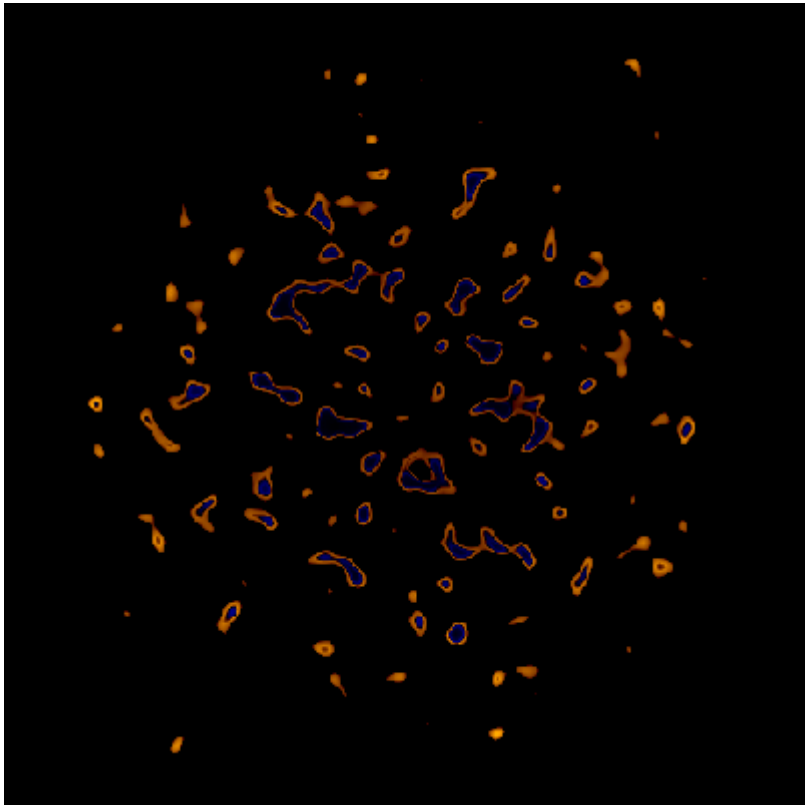


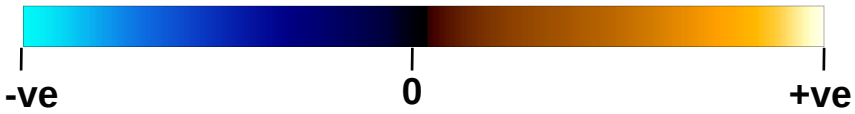


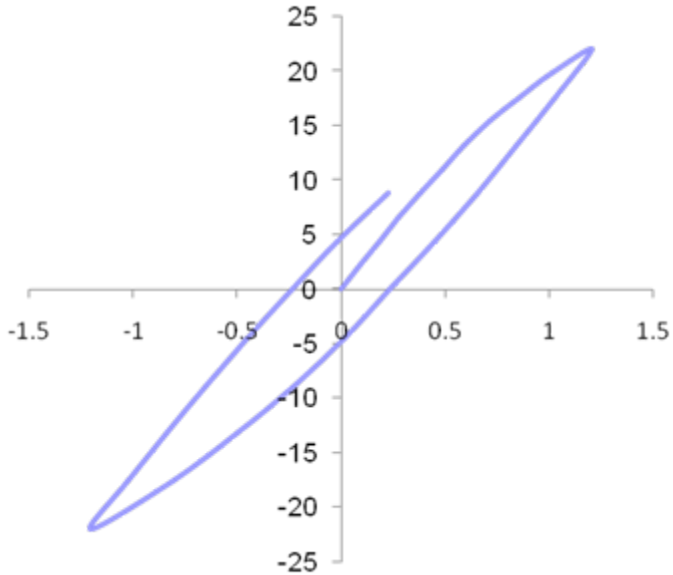


Rolls-Royce

Rough surface – Typical friction loop (traction)

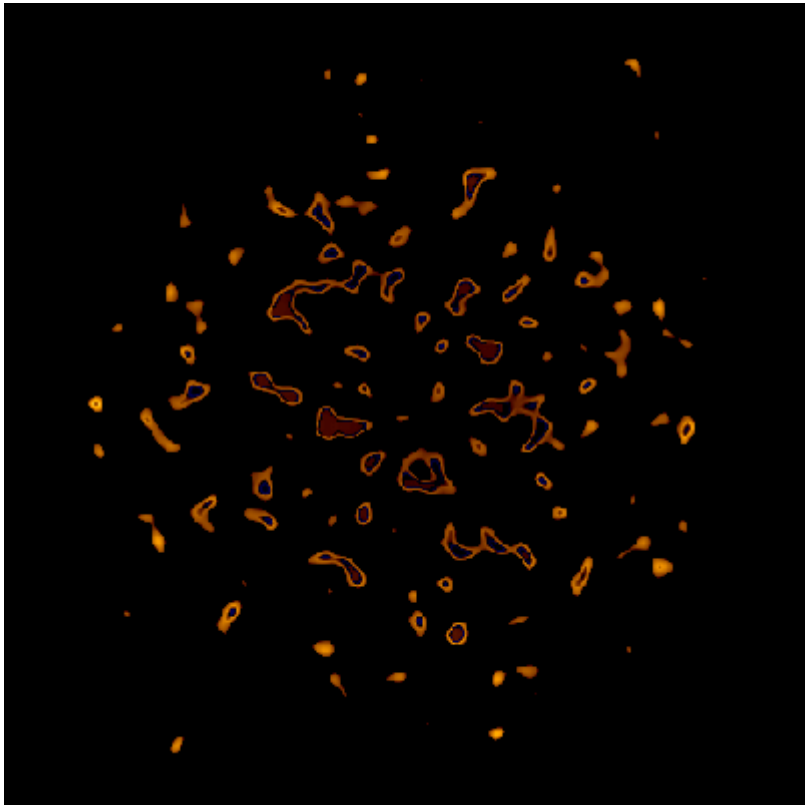


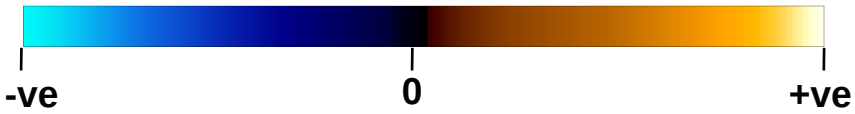


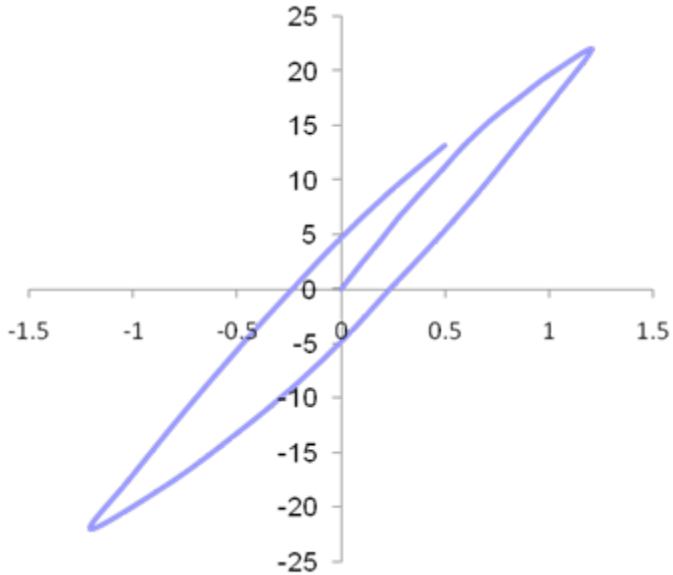


Rolls-Royce

Rough surface – Typical friction loop (traction)

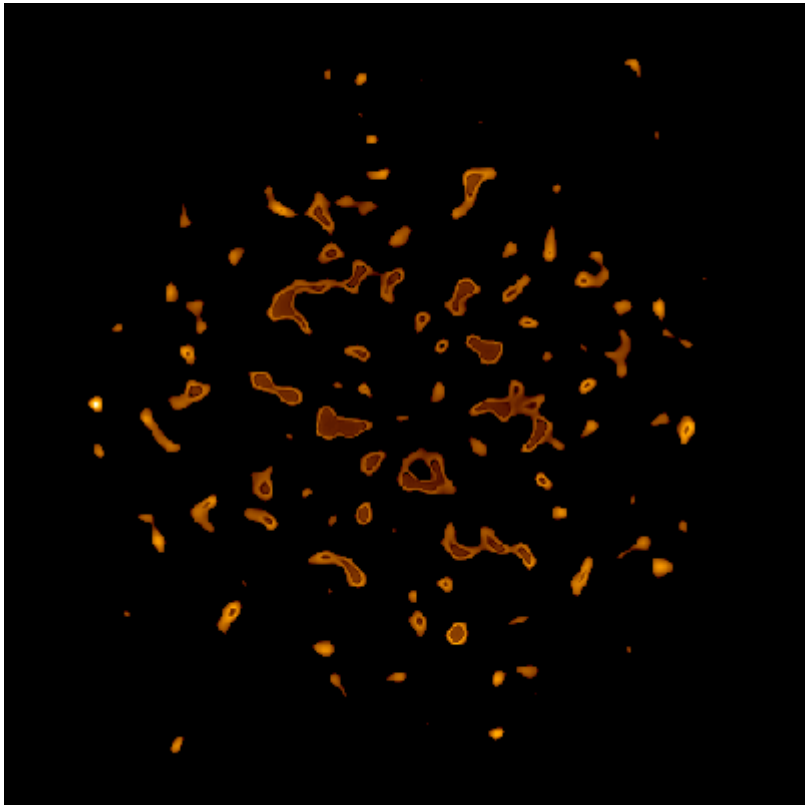


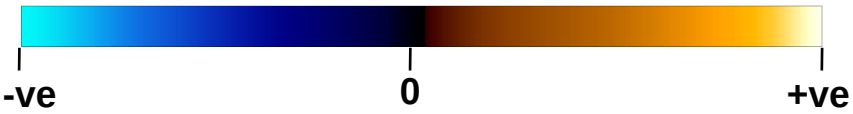


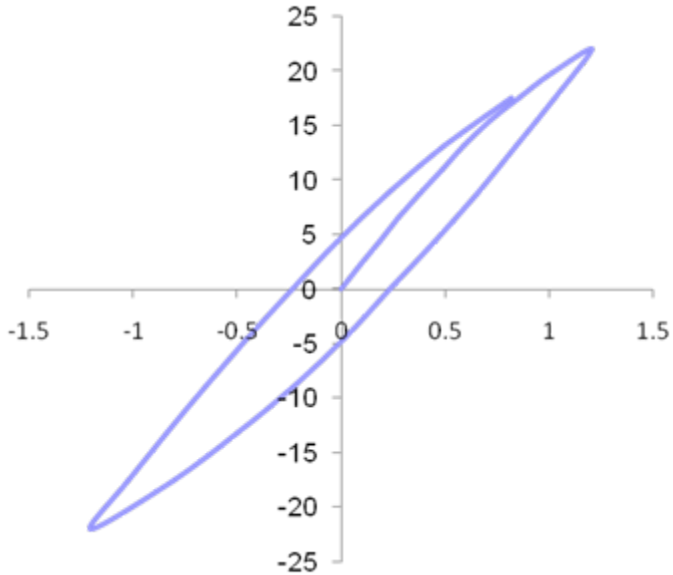


Rolls-Royce

Rough surface – Typical friction loop (traction)

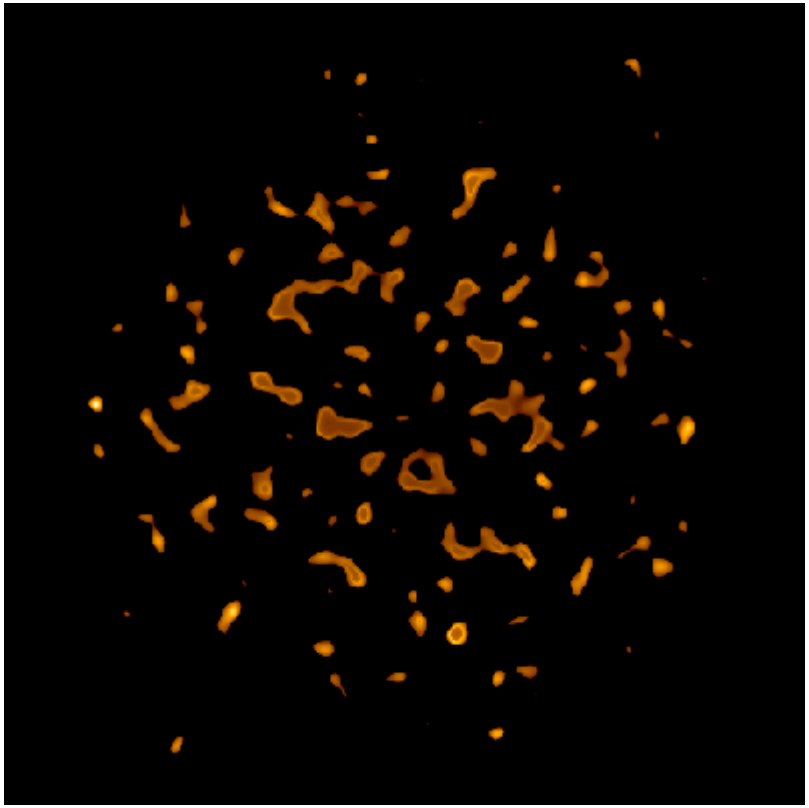


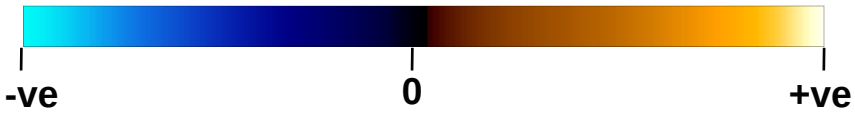


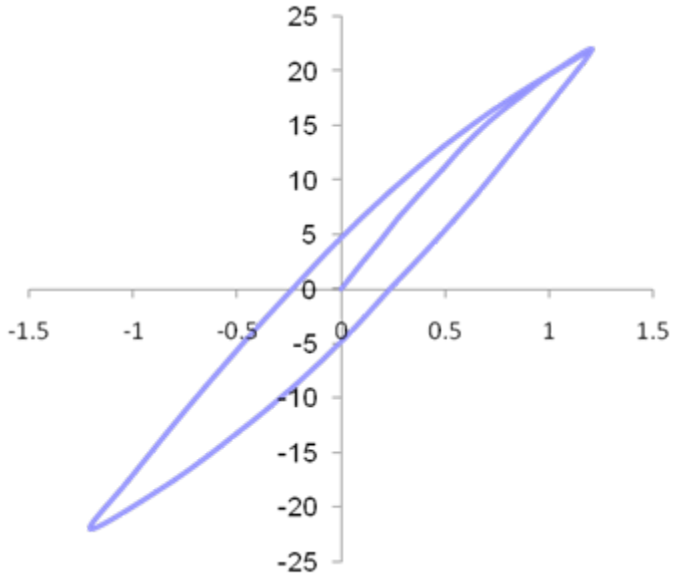


Rolls-Royce

Rough surface – Typical friction loop (traction)

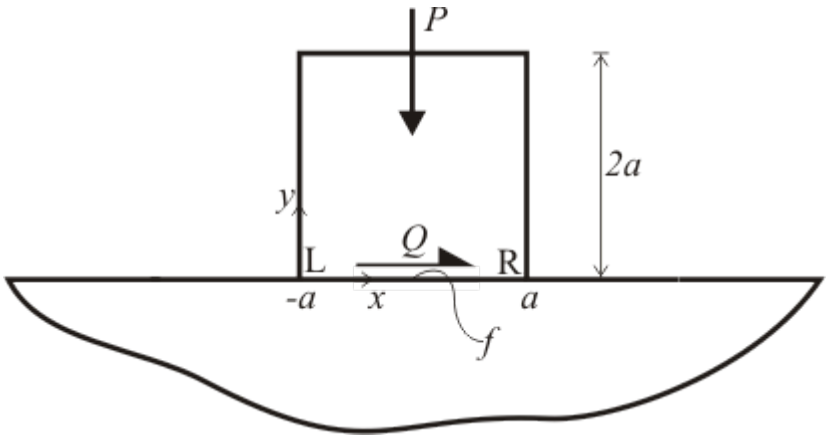




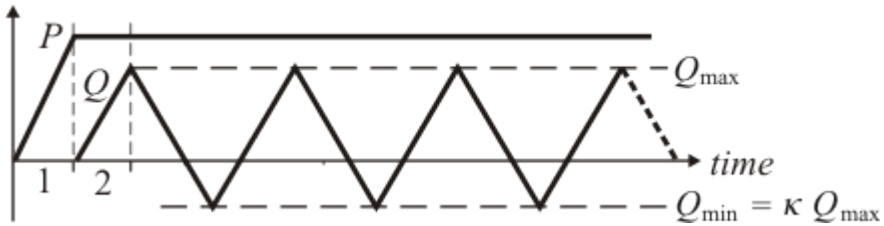


Rolls-Royce

Complete contacts – (1) Static



Example contact geometry



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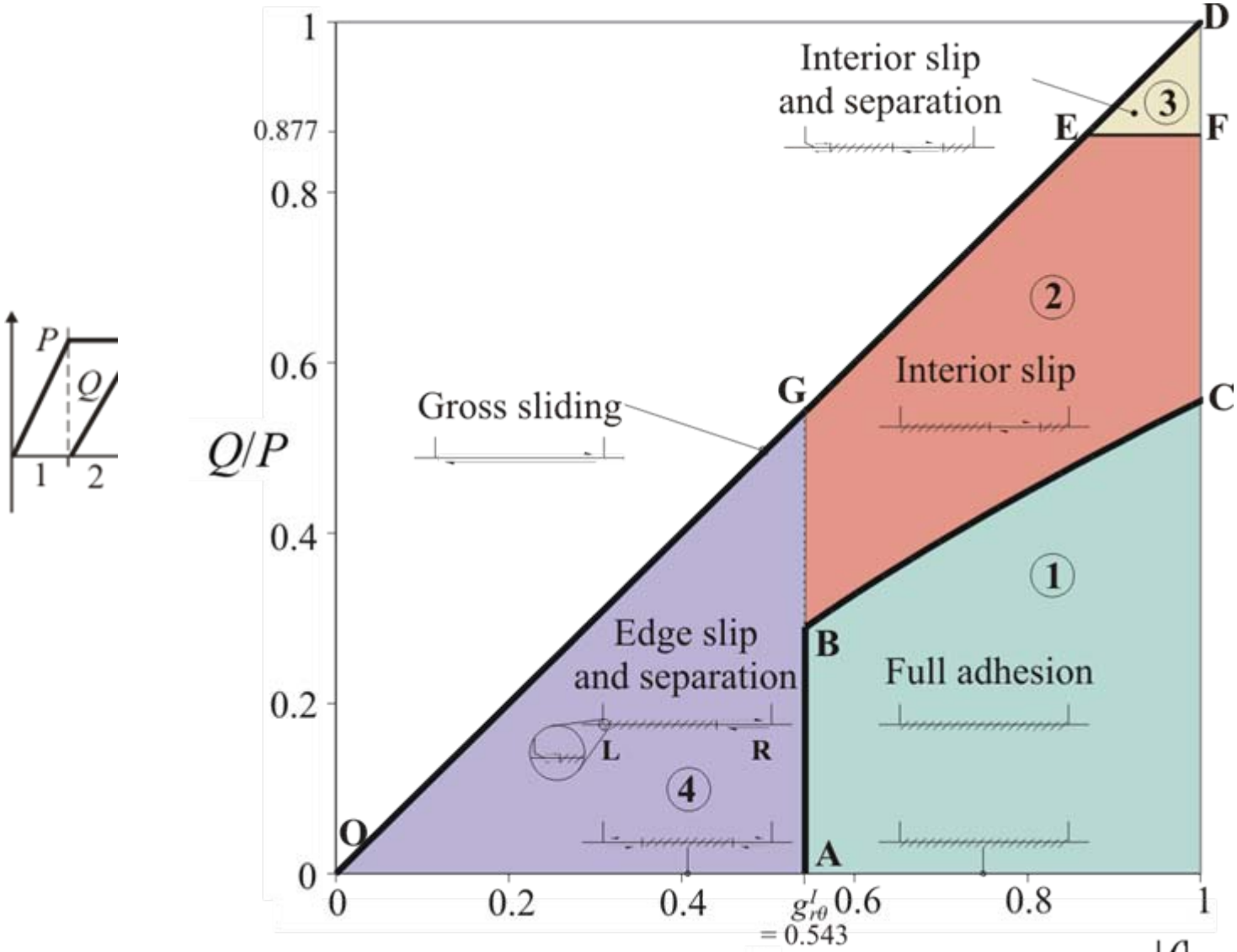
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D
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C
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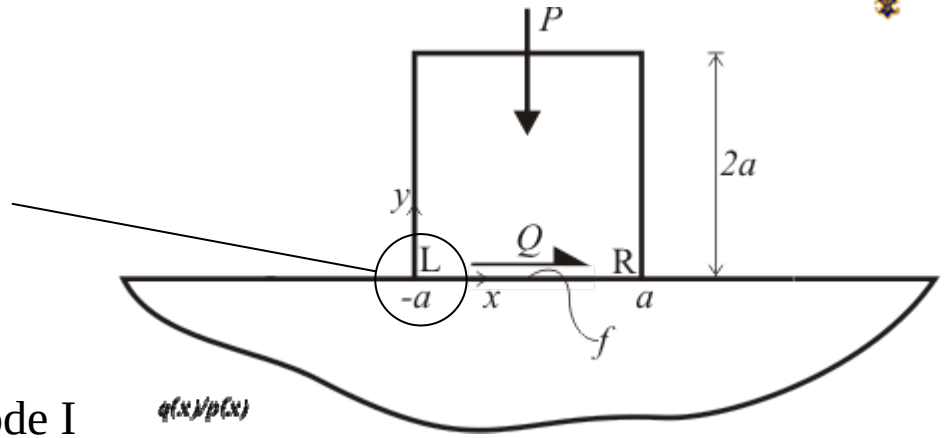
A
O
L
R
Interior slip
and separation
3
2
Interior slip
Gross sliding
1
Edge slip
and separation
Full adhesion
4

Rolls-Royce

The traction ratio near the contact edge is

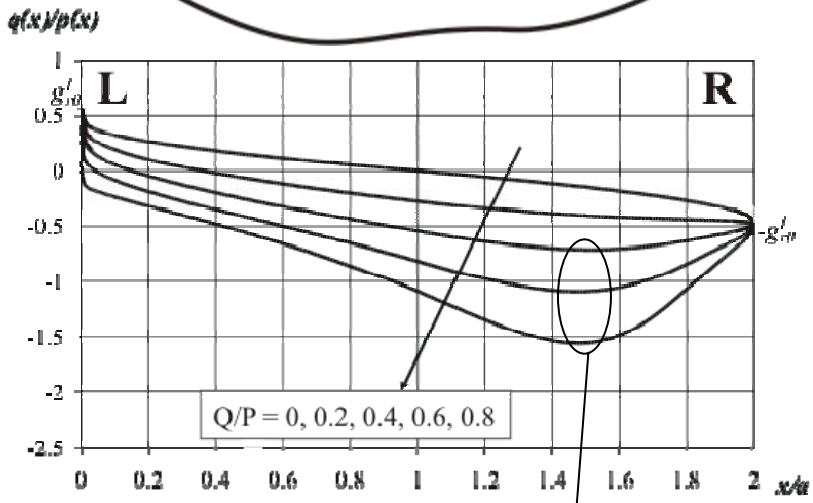
$$\frac{q(x)}{p(x)} = \frac{K_I^o g_{r\theta}^I x^{\lambda_I - 1} + K_{II}^o g_{r\theta}^{II} x^{\lambda_{II} - 1}}{K_I^o x^{\lambda_I - 1} + K_{II}^o x^{\lambda_{II} - 1}}$$



and because $\lambda_I - 1 < \lambda_{II} - 1 < 0$ the mode I singularity dominates the mode II singularity as $x \to 0$ to give

$$\left.\frac{q(x)}{p(x)}\right|_{x\to 0} = g_{r\theta}^I = 0.543$$

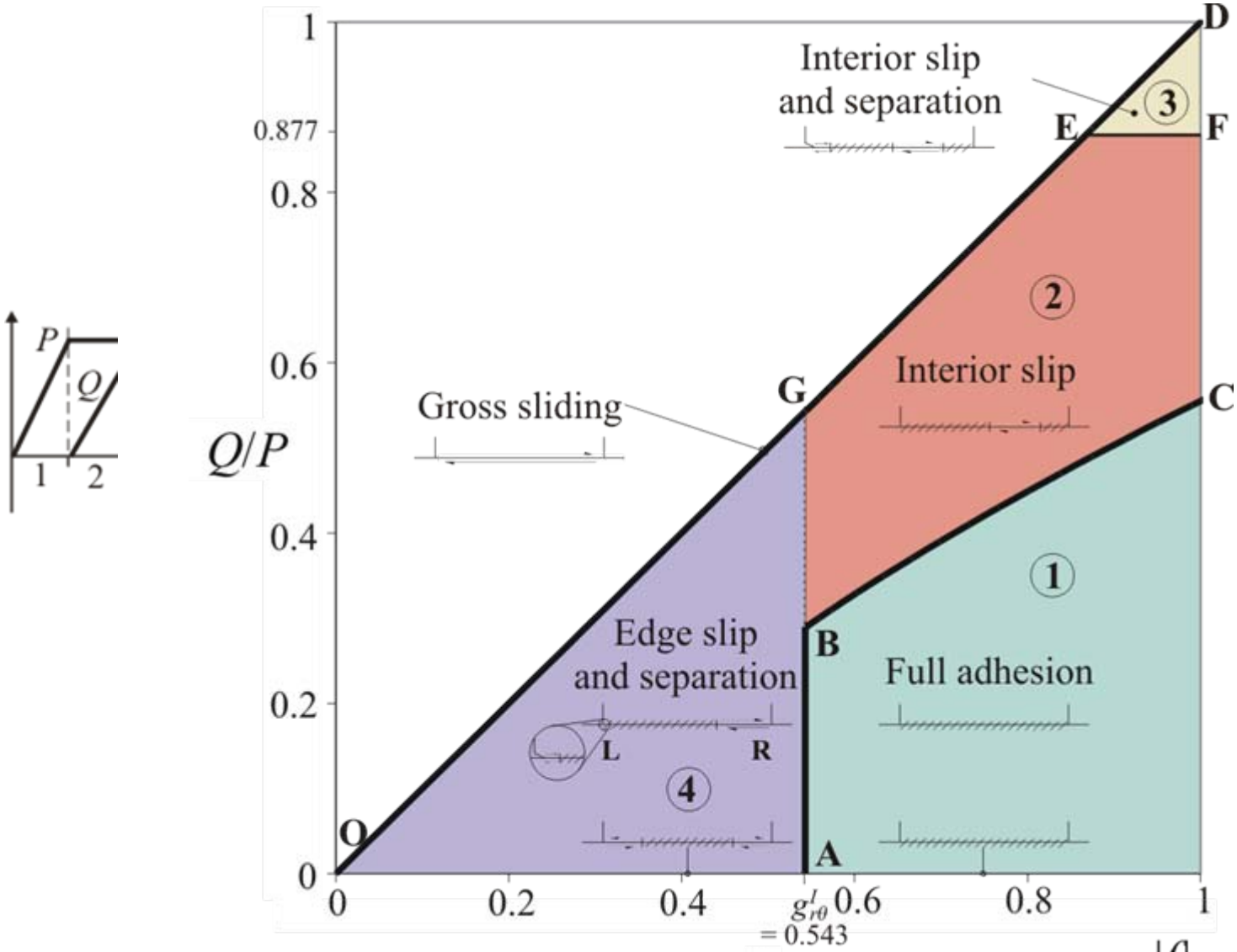
Therefore, *irrespective of the loading applied*, the traction ratio at the corner is **constant**.



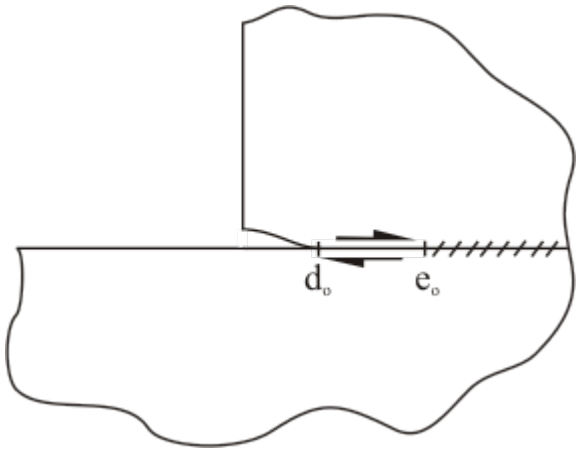
$\lvert f \rvert < 0.543$	Slip at the edge of the contact
$\lvert f \rvert > 0.543$	Adhesion at the edge

If interior maximum in traction ratio exceeds $\lvert f \rvert$ there is slip at an interior point.

Rolls-Royce

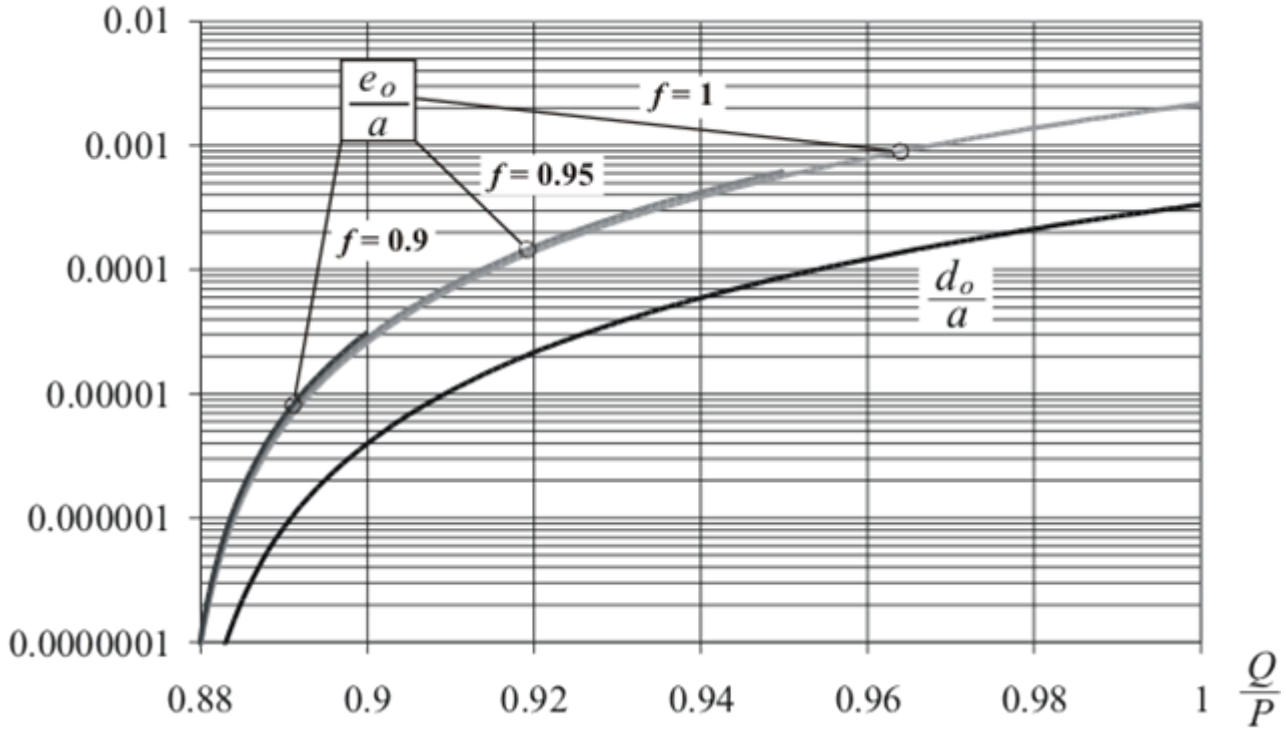

P
Q
1
2
Q/P
1
0.877
0.8
0.6
0.4
0.2
0
0
0.2
0.4
$g'_{t\theta}$ = 0.543
0.6
0.8
1
|f|
D
E
F
C
G
B
A
O
L
R
Interior slip
and separation
3
2
Interior slip
Gross sliding
1
Edge slip
and separation
Full adhesion
4

Rolls-Royce

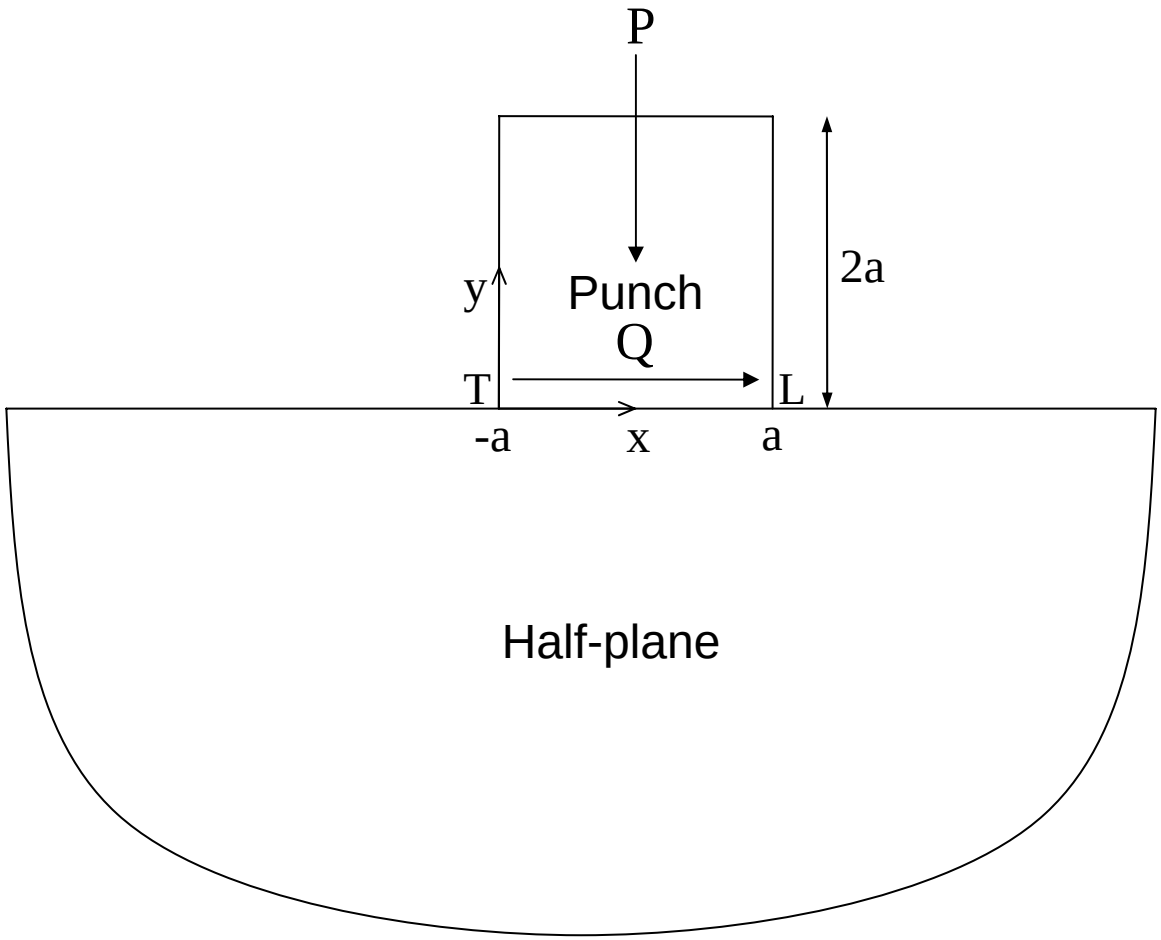


$$d_0 = \left(-\frac{K_I^o}{K_{II}^o} \right)^{\frac{1}{\lambda_{II} - \lambda_I}}$$

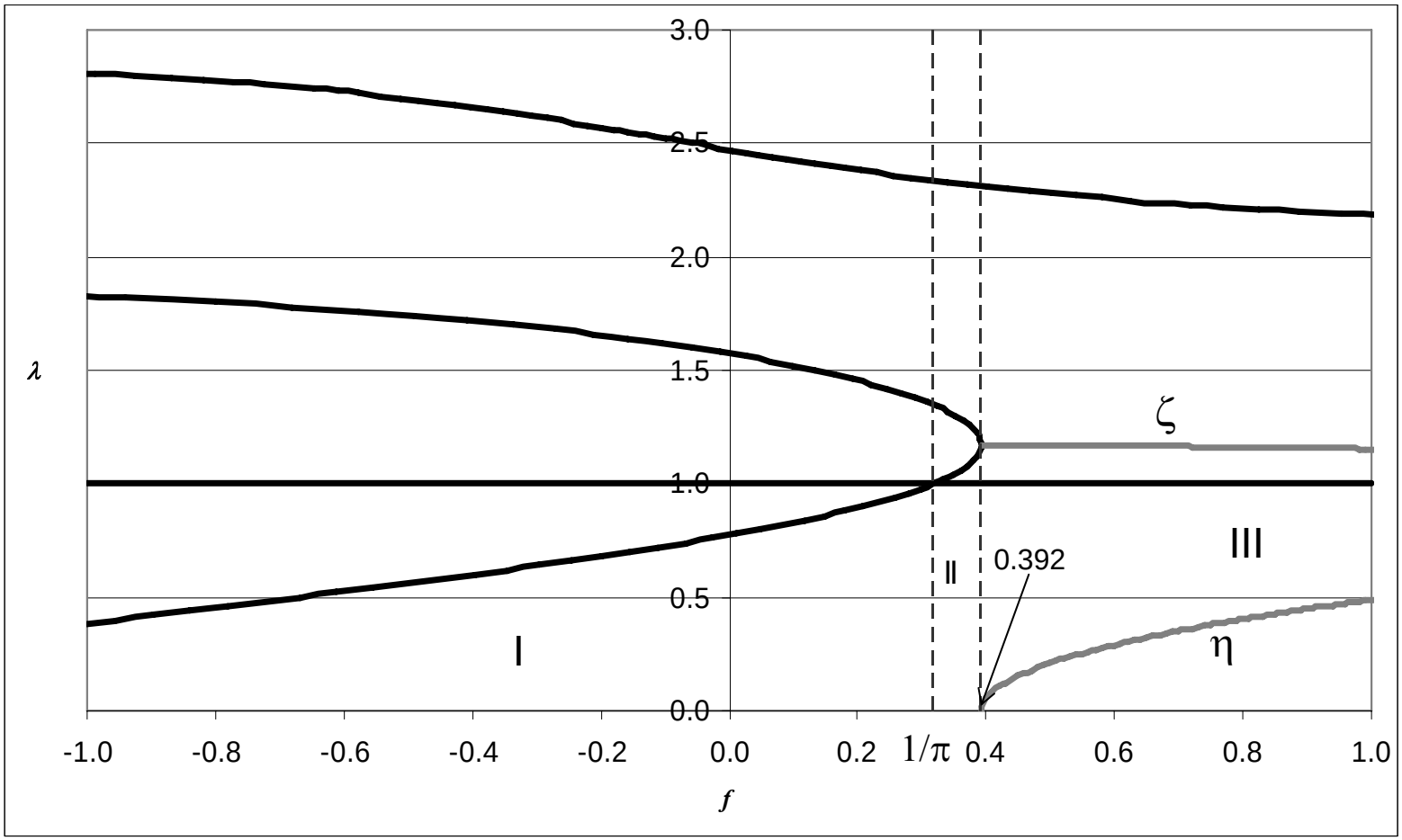
$$e_0 = \left(\frac{|f| + g_{r\theta}^I}{|f| + g_{r\theta}^{II}} \left(-\frac{K_I^o}{K_{II}^o} \right) \right)^{\frac{1}{\lambda_{II} - \lambda_I}}$$



Complete contacts – (2) Sliding



Eigenvalues Plot



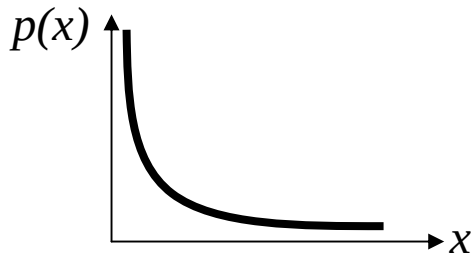
Leading edge

Trailing edge

Fundamental forms of the contact pressure

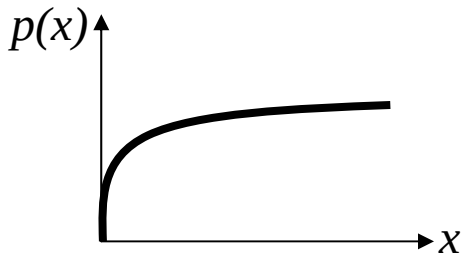
Region I : $f < 1/\pi$ (≈ 0.318)

$$p(x) = K_s x^{\lambda_s - 1} \qquad 0 < \lambda_s < 1$$



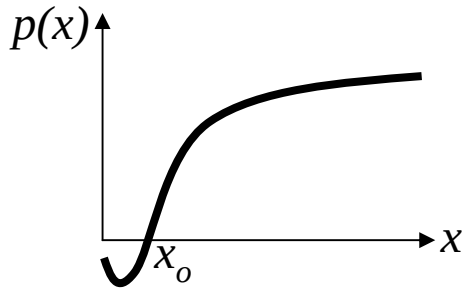
Region II : $0.318 < f < 0.392$

$$p(x) = K_{b1} x^{\lambda_{b1} - 1} + K_{b2} x^{\lambda_{b2} - 1} \qquad 1 < \lambda_{b1}, \lambda_{b2} < 2$$



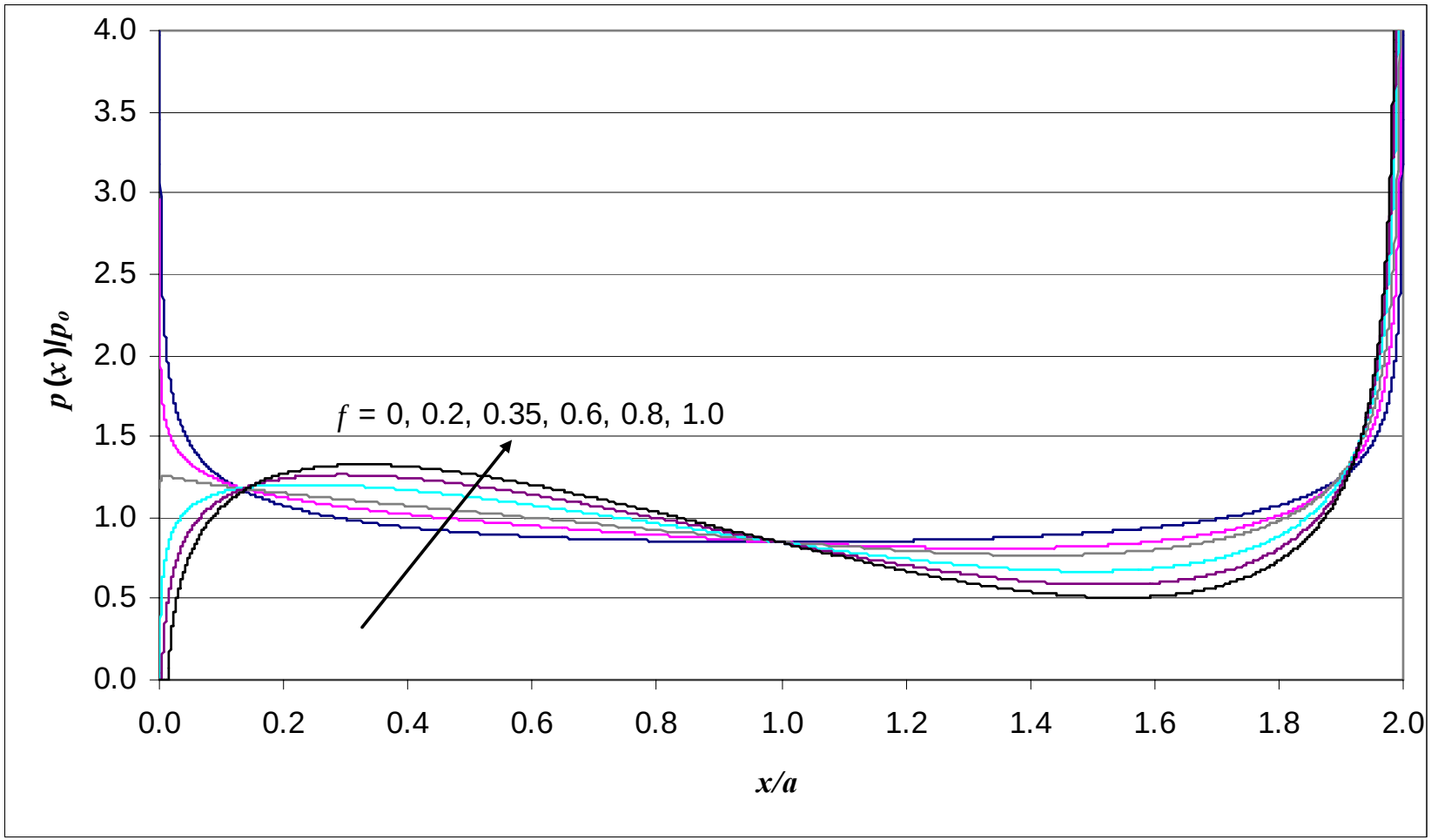
Region III : $f > 0.392$

$$p(x) = K_c x^{\zeta - 1} \sin\left(\eta \ln\left(\frac{x}{x_o}\right)\right) \qquad 1 < \zeta < 2; 0 < \eta < 1$$



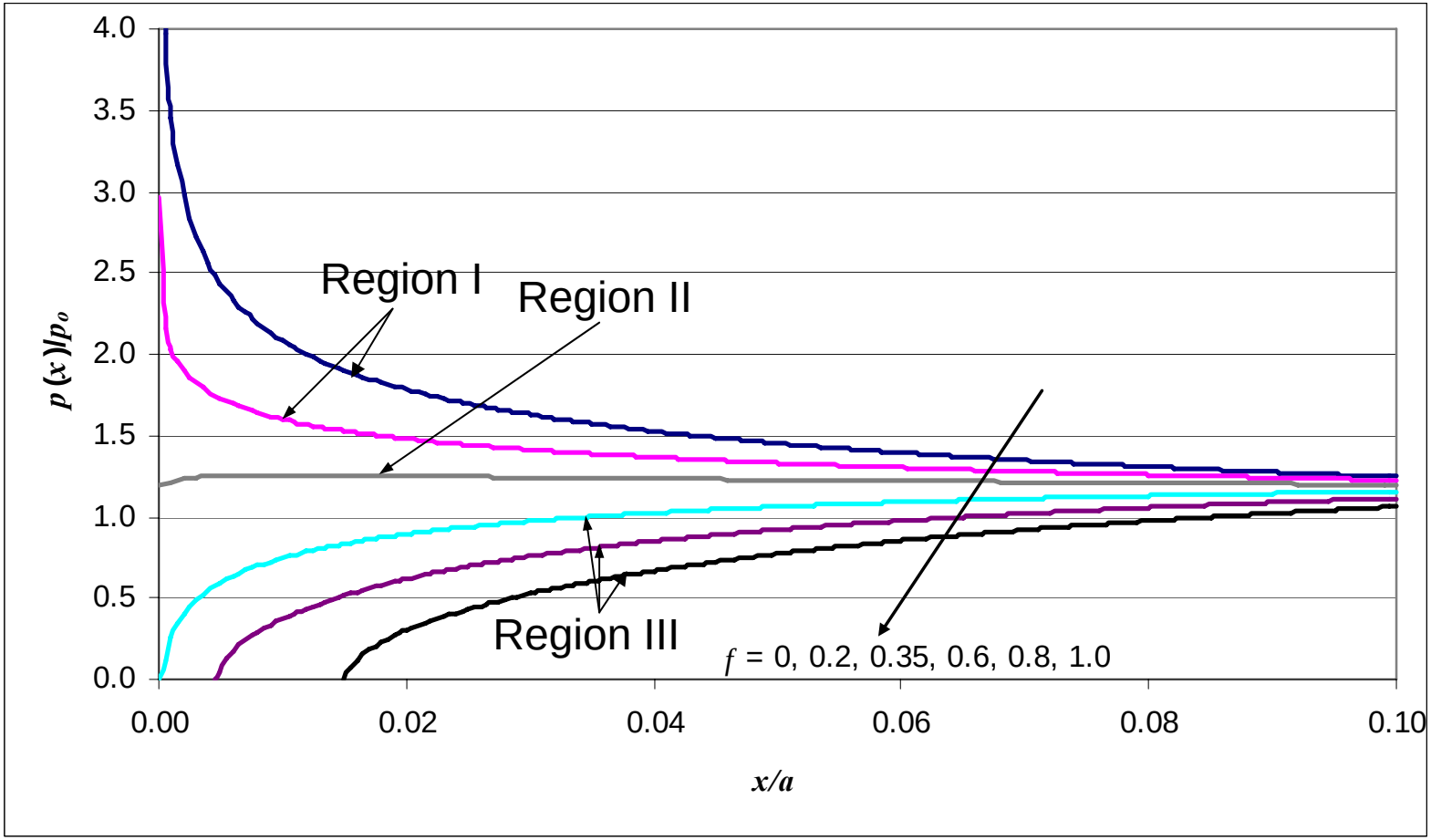
Rolls-Royce

Contact pressure comparison

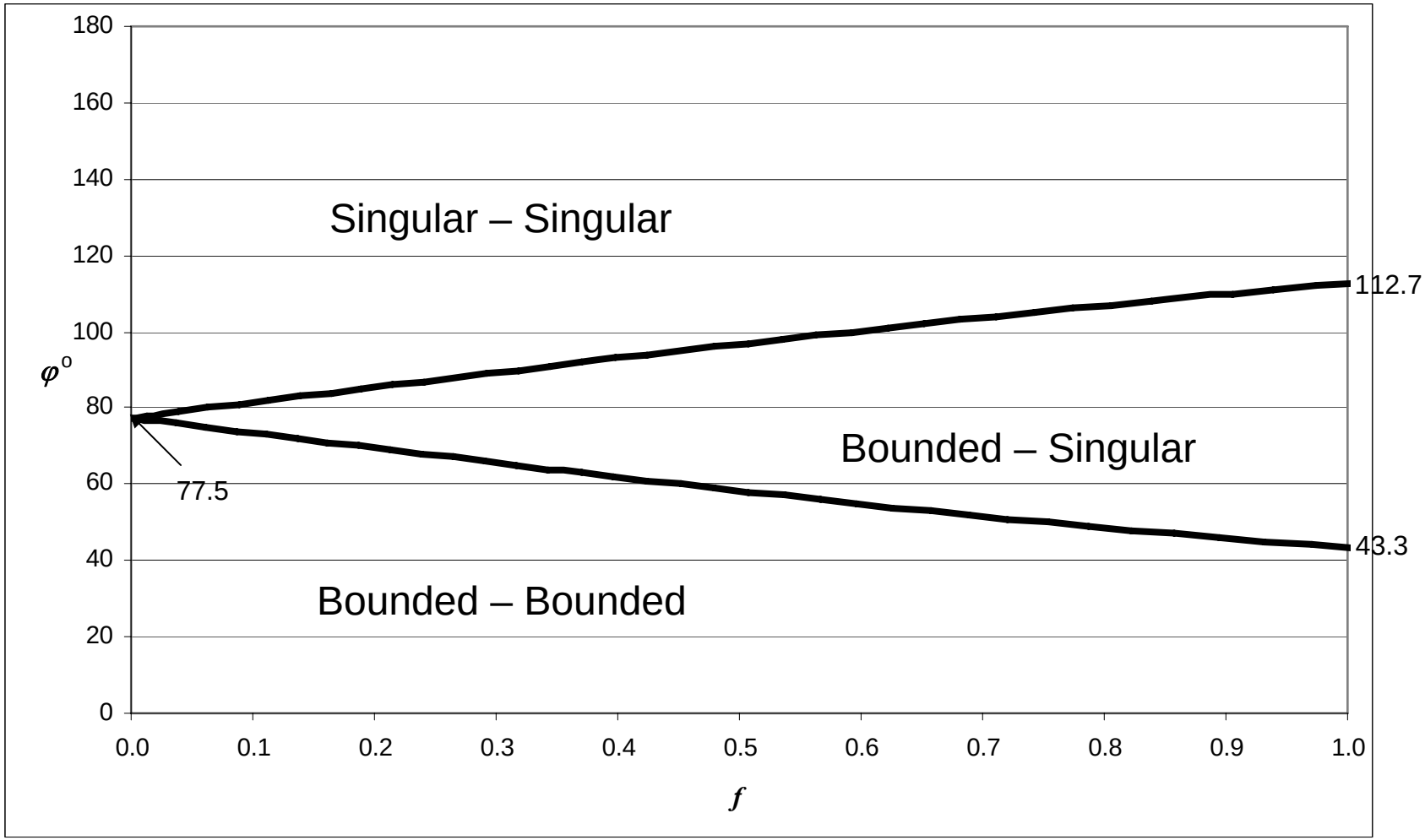


$$p_o = \frac{P}{2a}$$

Contact pressure comparison (trailing edge)



General Behaviour Map of Sliding Contacts



Rolls-Royce