SEECCM III Conference

III South-East European Conference on Computational Mechanics

12-14 June 2013, Kos Island, Greece

Identification of interface constitutive law from global stiffness data: a numerical optimization approach

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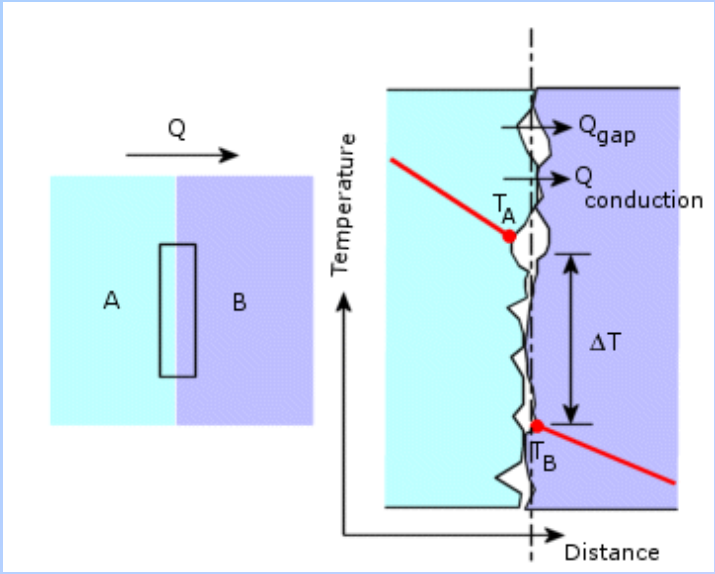
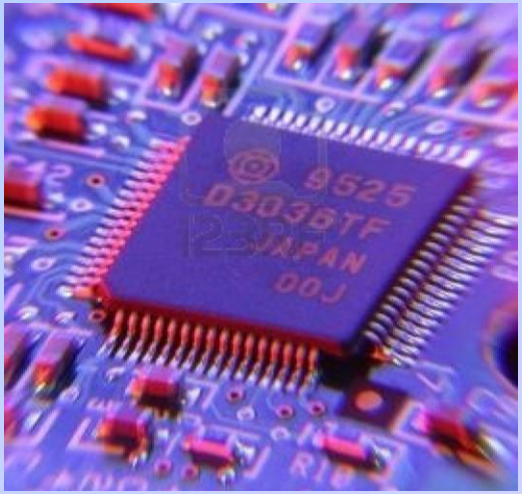
Outline

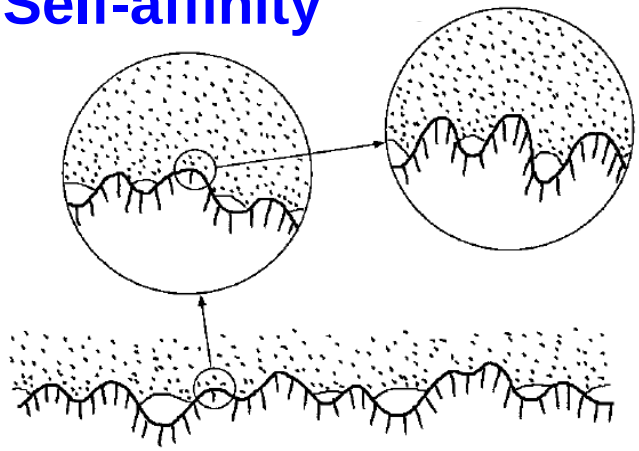
1. Interface contact conductance and the role of boundary conditions
2. An inverse problem
3. Results of the identification analysis
4. A size-independent interface constitutive law due to roughness
5. Conclusions

Interface contact conductance: motivations



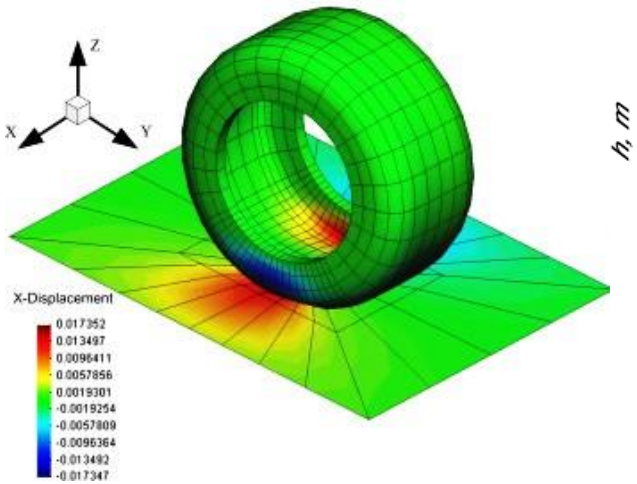


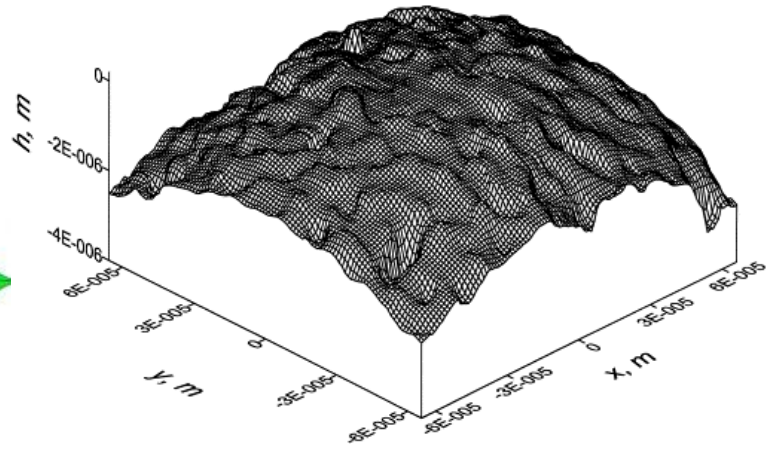
Self-affinity



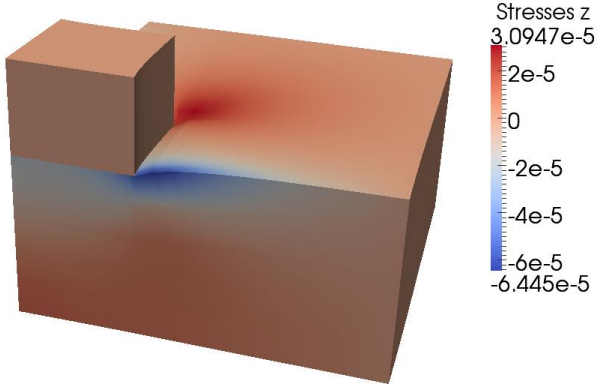
Inverse problem

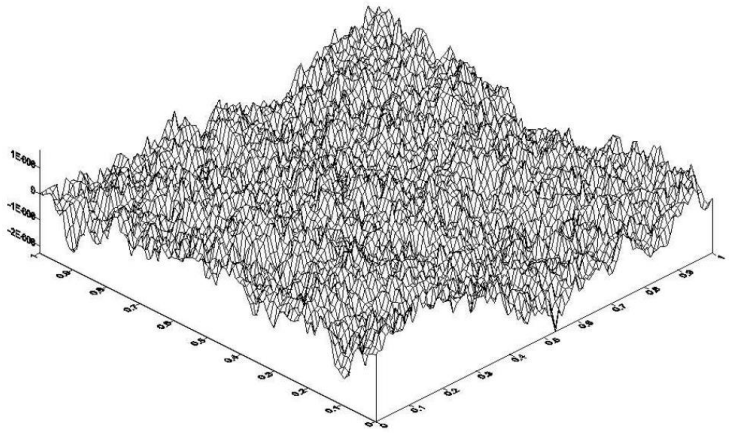
Aim: identify the interface contact conductance from global stiffness data





Macroscopic curvature effects

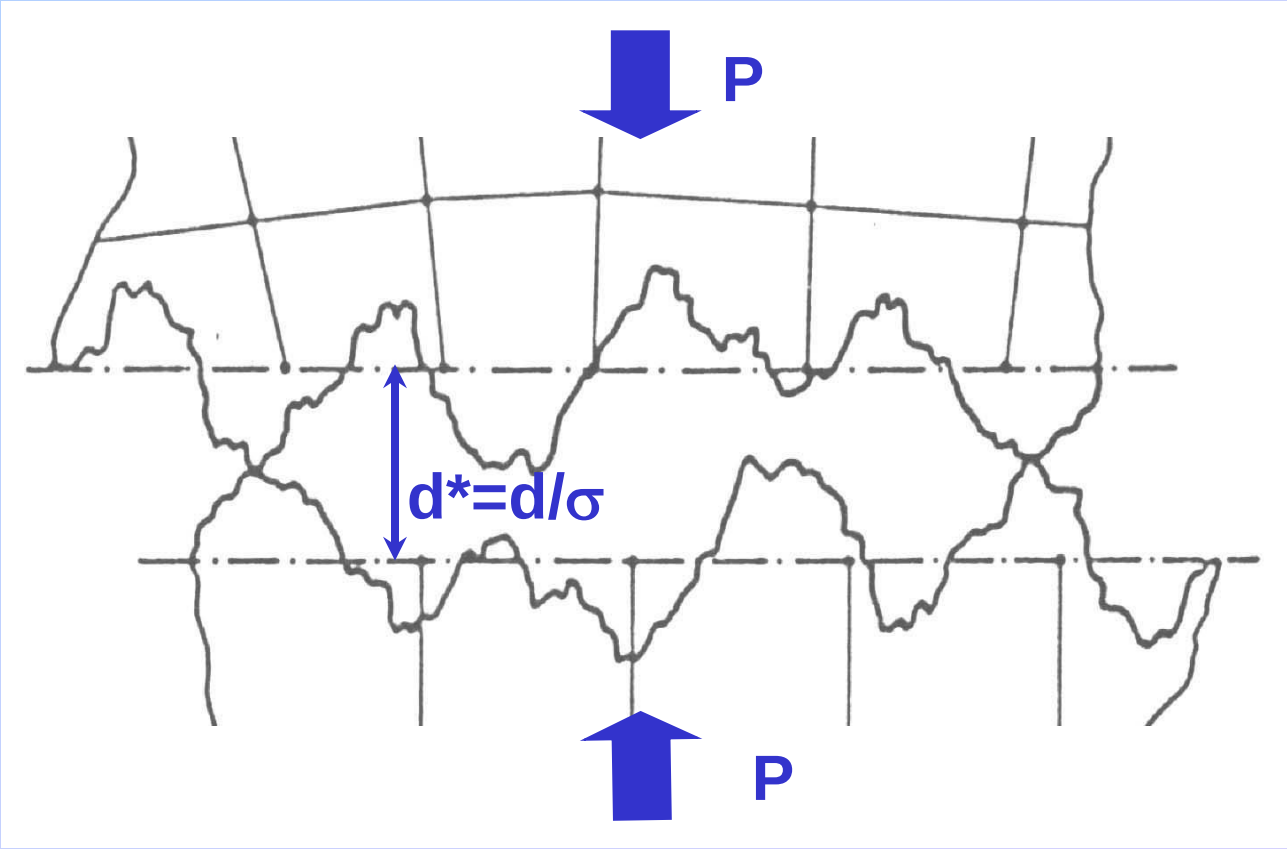




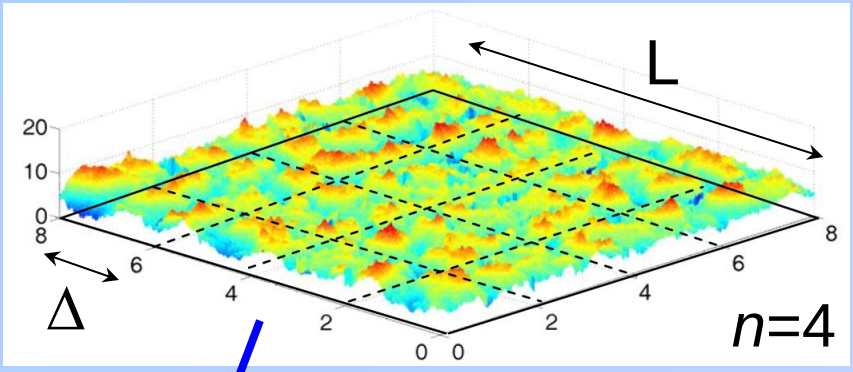
Finite size effects (boundary effects)

Interface contact conductance

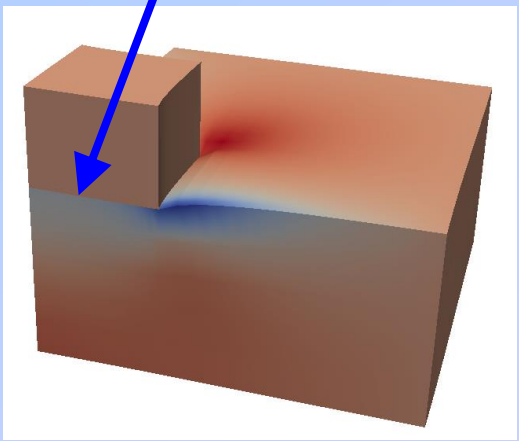
The contact conductance is proportional to the contact stiffness (Barber, PRS 2003; Paggi and Barber, IJHMT 2011)

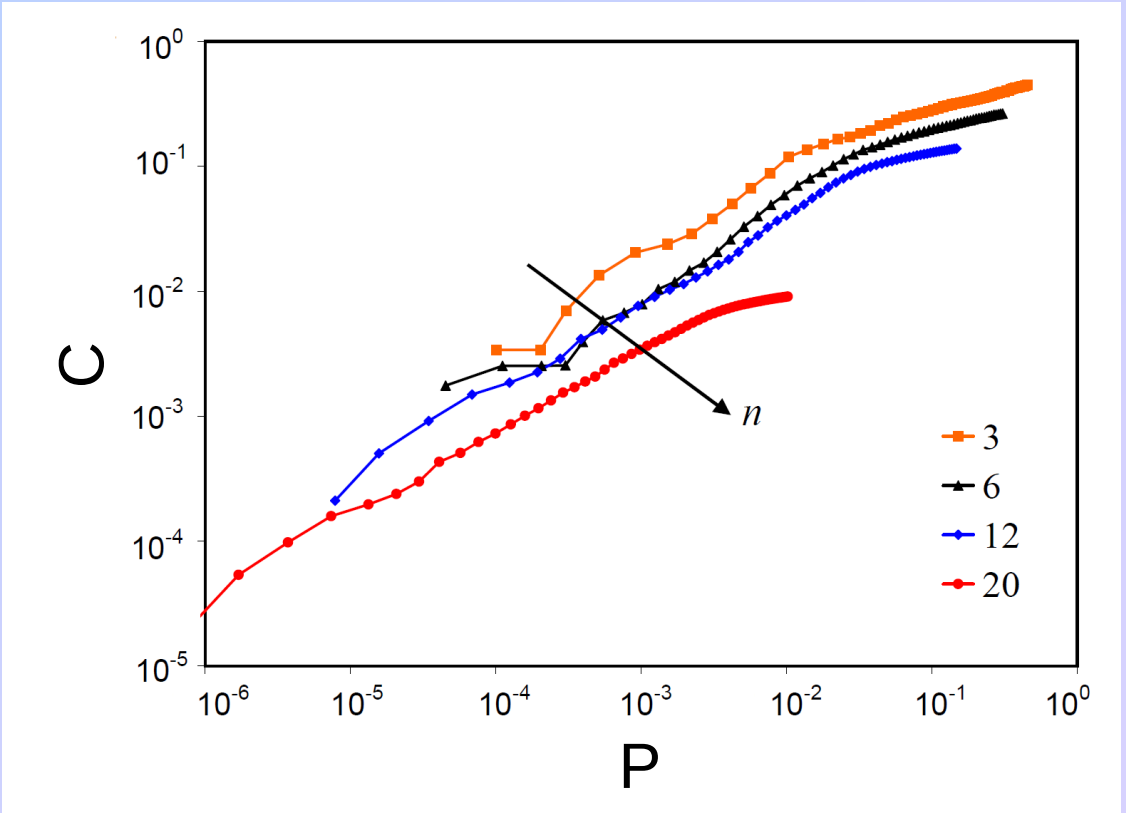


Reference BEM solution by varying the surface size

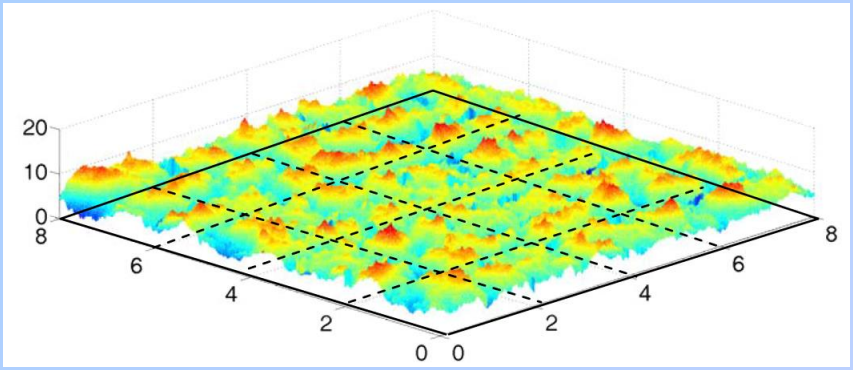


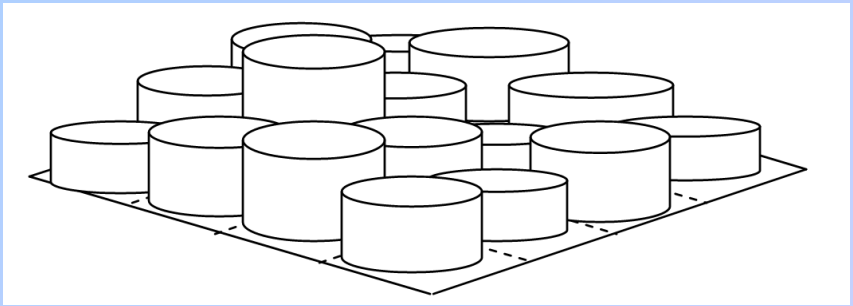
Rough punch composed of *n* x *n* RMD patches (D=2.3)

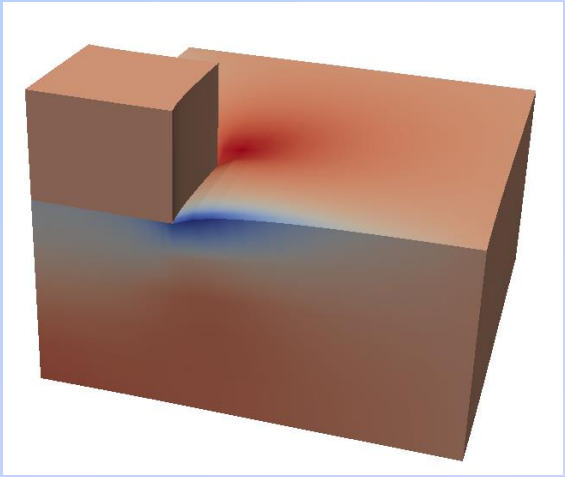




Identification of the interface constitutive law







1. Solve the contact problem using BEM (P)

2. Imagine the surface as a collection of punches with constitutive law $\tilde{p}(d^*)$ to be identified

3. Solve the new contact problem $(\hat{P})$ and identify the constitutive law by minimizing the error w.r.t. BEM solution:

$$\text{Error} = \frac{1}{(s_{max} - s_{min})} \sum_{i=s_{min}}^{s_{max}} \left(\hat{P}_i - P_i\right)^2$$

Cubic splines approximation

$$\tilde{p} = \begin{cases} s_1(d^*) & \text{if } d_1^* \leq d^* < d_2^* \\ s_2(d^*) & \text{if } d_2^* \leq d^* < d_3^* \\ \dots & \dots \\ s_{l-1}(d^*) & \text{if } d_{l-1}^* \leq d^* < d_l^* \end{cases}$$

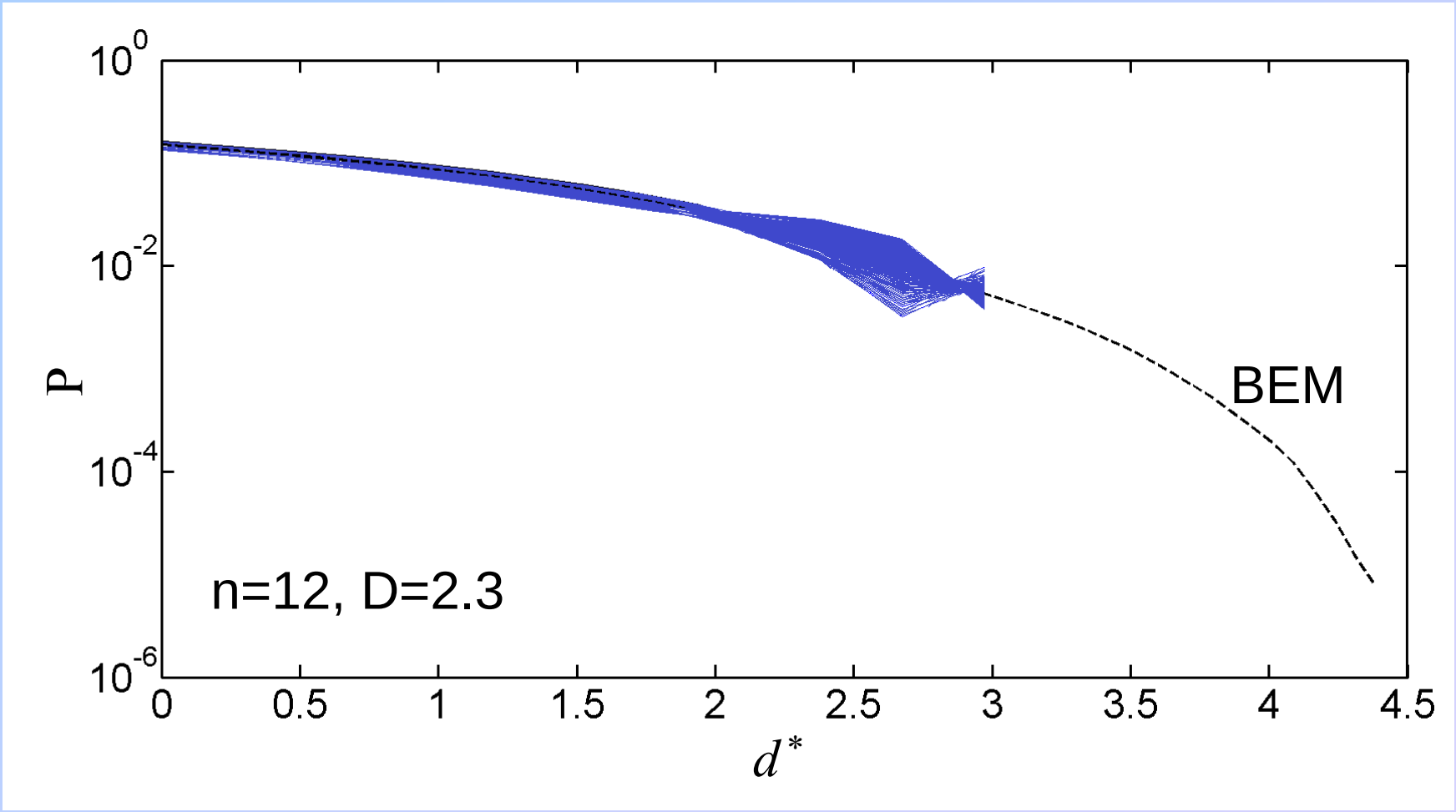
$$s_i(d^*) = a_i(d^* - d_i^*)^3 + b_i(d^* - d_i^*)^2 + c_i(d^* - d_i^*) + e_i$$

l=5 (4 intervals, 5 nodal points to be identified)

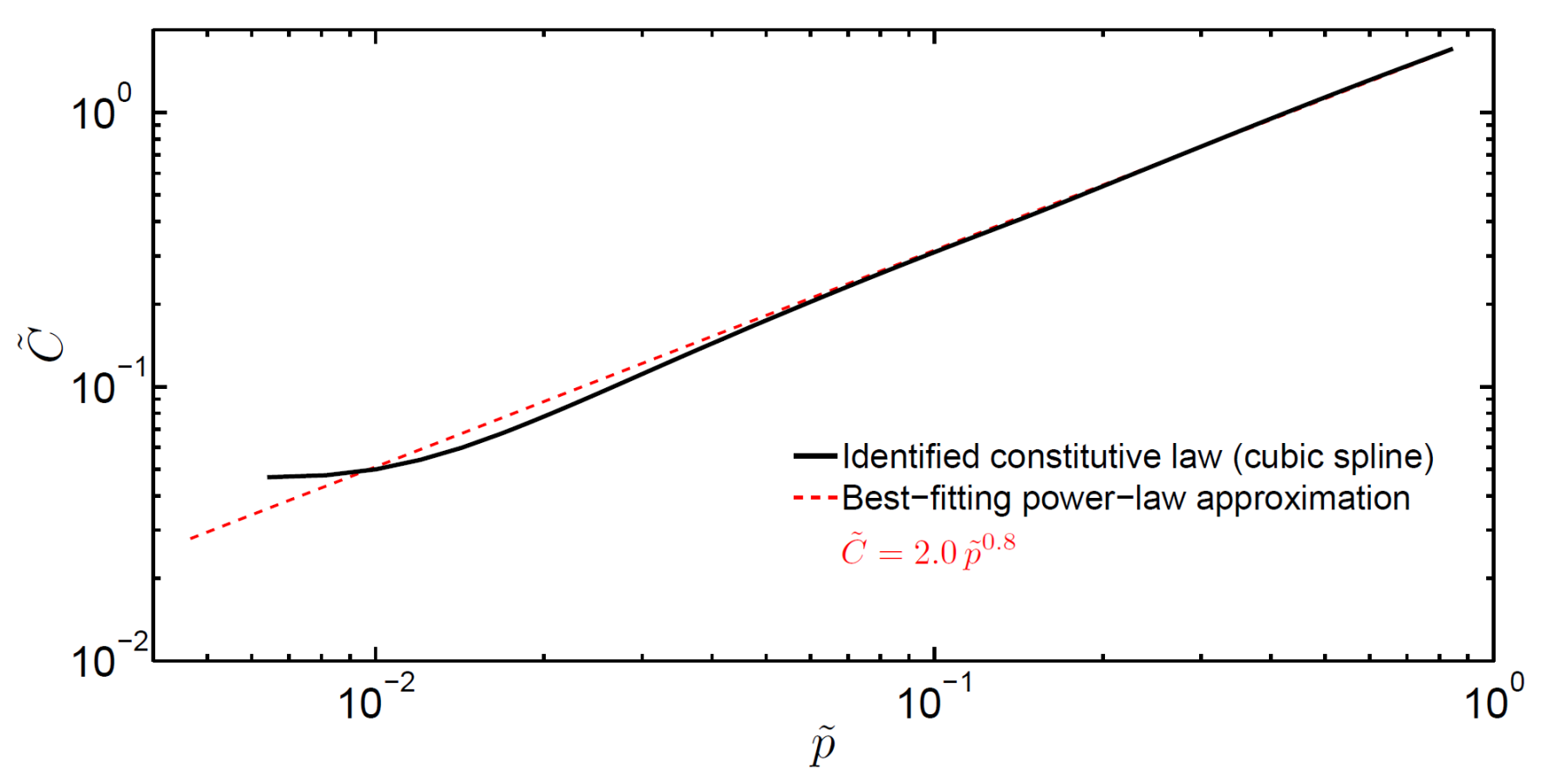
Parametric analysis with 5 values for each parameter,
10 contact steps for each set: $10 \times 5^5 = 31250$ contact steps

4 days of computing time

Cubic splines approximation



Cubic splines approximation



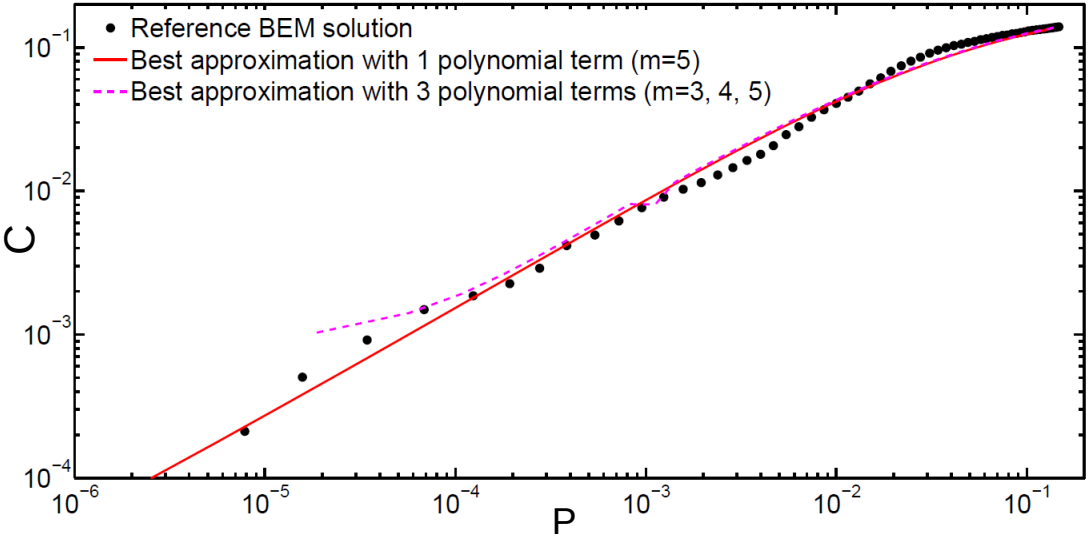
$$\widetilde{C} = \Phi\,\widetilde{p}^{\beta}$$

$$\widetilde{p} = \left[\frac{\Phi}{2}(1-\beta)\,(d_0^* - d^*)\right]^{\frac{1}{1-\beta}} = A\,(d_0^* - d^*)^{\frac{1}{1-\beta}}$$

Polynomial series expansion

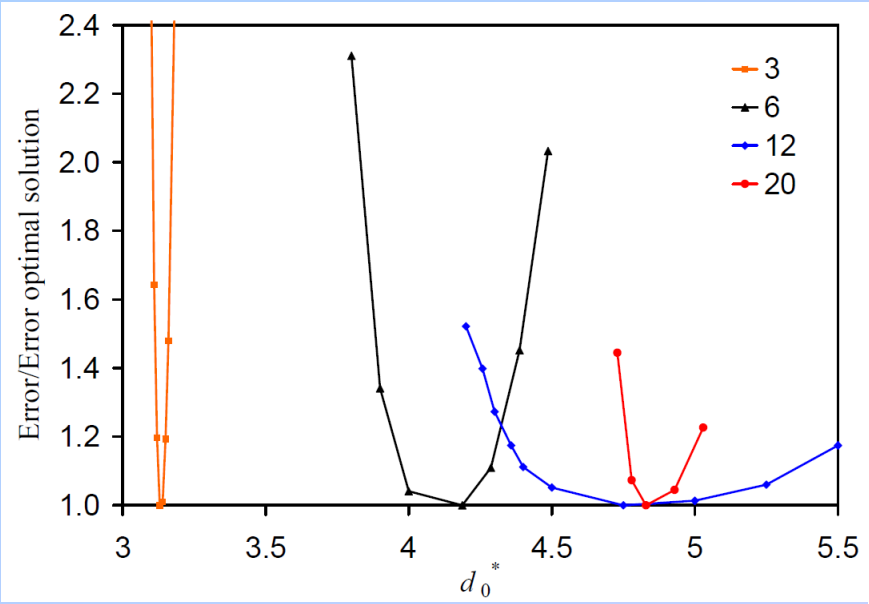
$$\tilde{p} = \sum_m A_m \left(d^*_{0,m} - d^* \right)^m$$

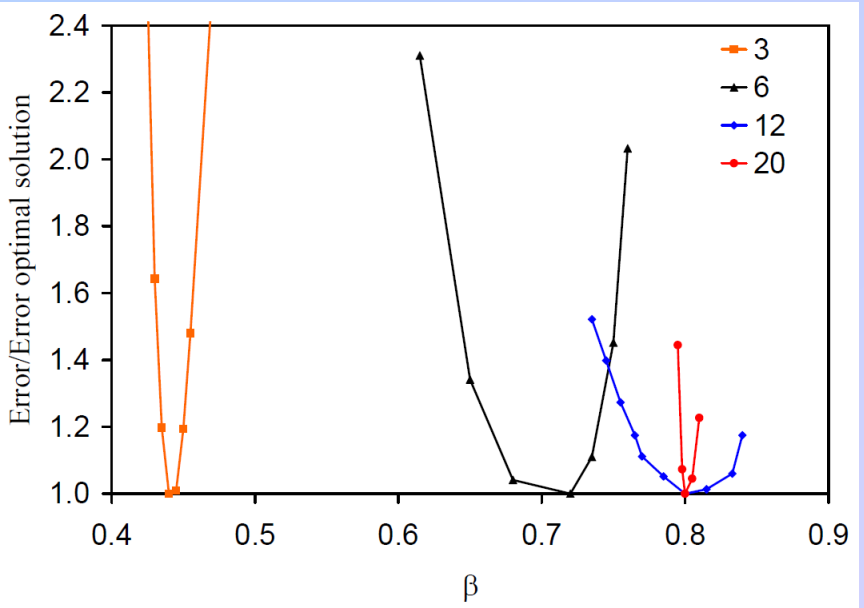
β=0.8 → m=5

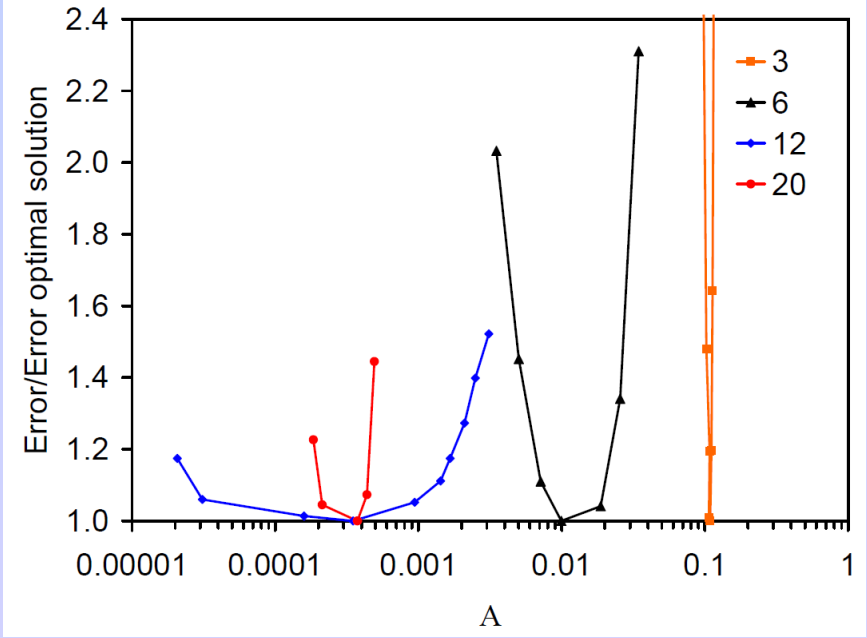


m	A_m	$d^*_{0,m}$	Error $(\times 10^{-3})$
5	3.5×10^{-4}	4.75	5.0
4	-1.3×10^{-4}	4.75	30.0
	-2.6×10^{-4}	4.75	76.7
	1.3×10^{-4}	4.75	6.5
	2.6×10^{-4}	4.75	23.1
	5.2×10^{-4}	4.75	100.0
	2.6×10^{-4}	3.80	5.7
	2.6×10^{-4}	4.17	4.3
	2.6×10^{-4}	4.39	5.3
3	9.3×10^{-5}	4.17	4.3
	1.9×10^{-4}	4.17	4.6
	3.7×10^{-4}	4.17	6.1
	-9.3×10^{-5}	4.17	4.6
	-1.9×10^{-4}	4.17	5.1
	9.3×10^{-5}	3.80	4.3
	9.3×10^{-5}	3.44	4.2

1 term polynomial (m=5): the effect of sample size







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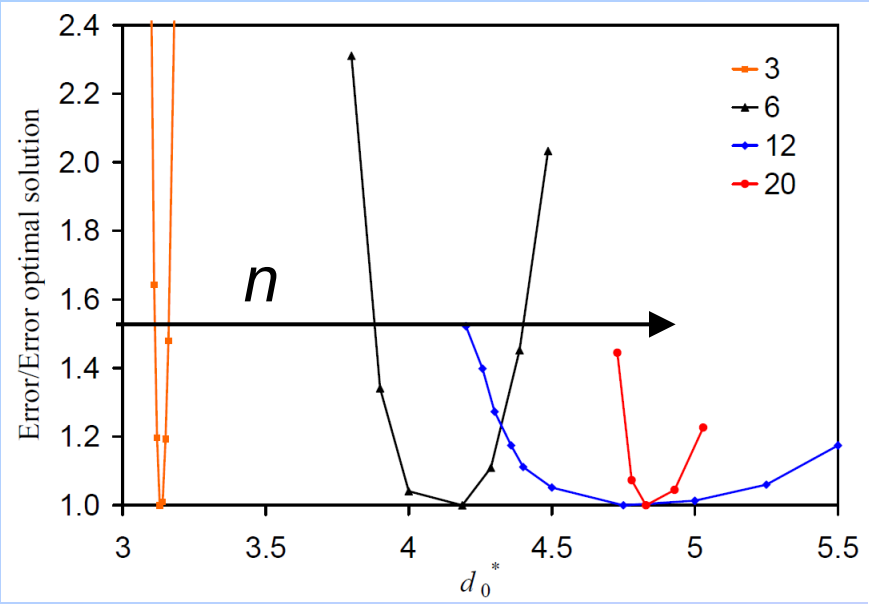
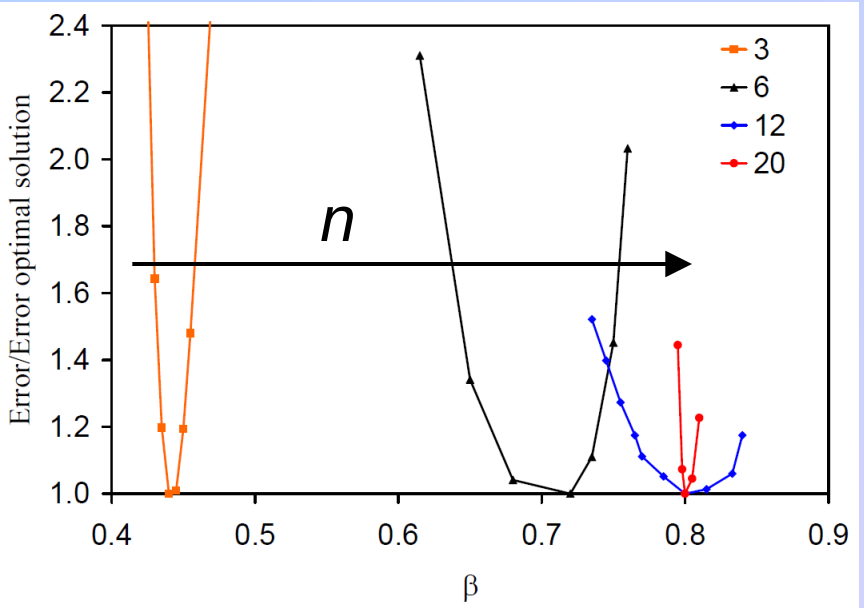
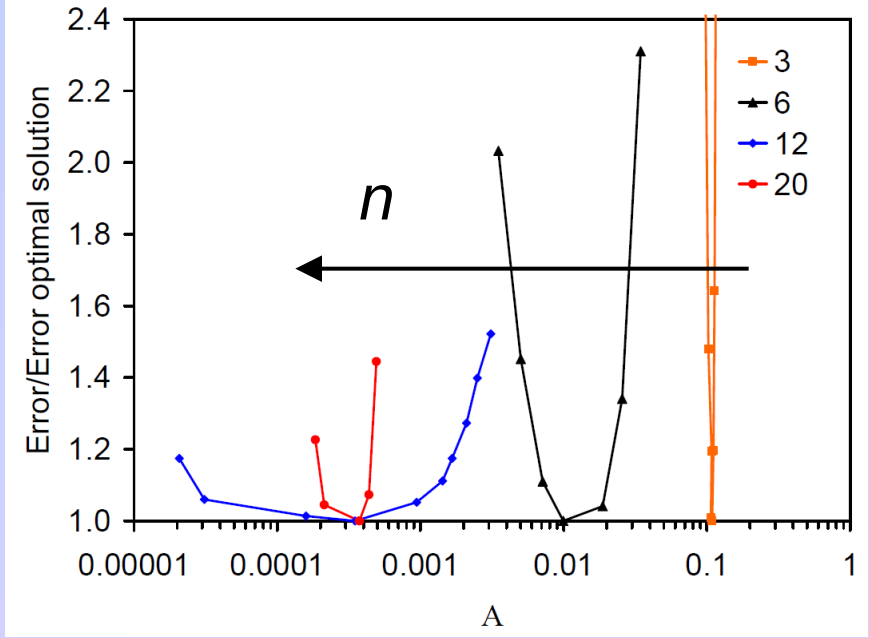




Identified solution independent of BCs for n>12:

$$\tilde{p} = 3.7 \times 10^{-4} \left(4.83 - d^*\right)^5$$

$$\tilde{C} = 2.0\,\tilde{p}^{0.8}$$



Conclusions

A pressure-separation relation due to roughness has been identified by solving an otpimization problem

A critical examination of the identification results supports the existence of a power-law relation between contact conductance and contact pressure, in agreement with previous dimensional analysis considerations

The identified interface constitutive law is proven to be size-scale independent

Acknowledgements

FIRB Future in Research 2010 RBFR107AKG
Structural Mechanics Models
for Renewable Energy Applications

Please contact marco.paggi@polito.it
for PhD and post-doc positions