Appendix A
Microjunction Model

This appendix presents a pseudo-code implementation of the microjunction model discussed in Chap. 4, Sect. 4.5. The function `microjunction` provides the evolution rates of the area $\partial A^*/\partial\tau$ and interference $\partial\delta^*/\partial\tau$ for a given outer force loading history $F^*(t)$. The resulting interference and area evolution could be integrated by a standard ODE solver, e.g. a Runge Kutta scheme as indicated in the flowchart of Fig. 4.9.

The hat $\hat{x}$ signifies the numerical approximations of some model value x within the function, e.g. the area evolution rate is written as $\widehat{\frac{\partial A^*}{\partial\tau}}$. For numerical and practical reasons, all variables are normalized to be of approximately unity magnitude. Interference δ, area A and force F are normalized by their critical values δ_c, A_c and F_c and pressure p is normalized by the yield stress σ_Y. The normalized values are denoted by a star, x^*. Comments are denoted by a leading percentage sign %.

function $\left[\widehat{\frac{\partial\delta^*}{\partial\tau}}, \widehat{\frac{\partial A^*}{\partial\tau}}\right]$ = `microjunction` $\left(\delta^*, A^*, F^*, \frac{\partial F^*}{\partial t}\right)$

% Material parameters:
global $\sigma_Y \;\; E \;\; \nu \;\; R \;\; C_1 \;\; C_2$
% Normalization constants:
$C_\nu \leftarrow 1.295\exp(0.736\nu)$
$E' \leftarrow \frac{E}{1-\nu^2}$
$\delta_c \leftarrow \left(\frac{C_\nu\pi\sigma_Y}{2E'}\right)^2 R$
$A_c \leftarrow \pi R\delta_c$
$F_c \leftarrow \frac{4}{3}\left(\frac{R}{E'}\right)^2\left(\frac{1}{2}C_\nu\pi\sigma_Y\right)^3$

% The low-delta augmentation is based on the *maximum*
% interference $\delta^*_{\max}$ in hemisphere creep history
global $\delta^*_{\max}$
$\hat{\delta}^*_{\max} \leftarrow \max(\delta^*_{\max}, \delta^*)$

A. Goedecke, *Transient Effects in Friction*, Engineering Materials,
DOI 10.1007/978-3-7091-1506-0, © Springer-Verlag Wien 2013

`% Hardness according to the JG model, Eq.` (2.13)

$$A^*_{JG,\max} \leftarrow \begin{cases} \hat{\delta}^*_{\max} & \texttt{for } \hat{\delta}^*_{\max} \le 1.9 \\ \hat{\delta}^*_{\max}\left(\frac{\hat{\delta}^*_{\max}}{1.9}\right)^{0.14\exp\left(23\frac{\sigma_Y}{E}\right)} & \texttt{for } \hat{\delta}^*_{\max} > 1.9 \end{cases}$$

$$a \leftarrow \sqrt{\frac{A^*_{JG,\max}A_c}{pi}} \qquad \texttt{\% contact radius}$$

$$H_G \leftarrow$$

$$\begin{cases} 2.84\sigma_Y\left(1-\exp\left(-0.82\left(\frac{a}{R}\right)^{-0.7}\right)\right) & \texttt{for } \frac{a}{R} \le 0.41 \\ \sigma_Y\left(7.32\left(\frac{a}{R}\right)^3 - 14.1\left(\frac{a}{R}\right)^2 + 6.28\left(\frac{a}{R}\right) + 1.52\right) & \texttt{for } 0.41 < \frac{a}{R} \le 1 \\ \sigma_Y & \texttt{for } 1 < \frac{a}{R} \end{cases}$$

`% Normalized time constant according to Eq.` (2.33):

$$t_1 \leftarrow \frac{EC_1}{H_G}$$

`% Creep law, according to Low` δ`-adjustment in Sect.` 4.4:

$$a_{A_1} \leftarrow 1.07727; \quad b_{A_1} \leftarrow -0.34304; \quad c_{A_1} \leftarrow -0.11265$$

$$a_{\alpha_1} \leftarrow 2.19198; \quad b_{\alpha_1} \leftarrow 0.50746; \quad c_{\alpha_1} \leftarrow -0.0874$$

$$a_{A_2} \leftarrow -1.85662; \quad b_{A_2} \leftarrow 1.52833; \quad c_{A_2} \leftarrow -0.05672$$

$$a_{\alpha_2} \leftarrow 4.29534; \quad b_{\alpha_2} \leftarrow 0.89977; \quad c_{\alpha_2} \leftarrow -0.06492$$

$$A_1 \leftarrow EC_1\exp\left(a_{A_1}\left(1+b_{A_1}\exp\left(\hat{\delta}^*_{\max}c_{A_1}\right)\right)\right)$$

$$\alpha_1 \leftarrow \frac{a_{\alpha_1}}{H_G}\left(1+b_{\alpha_1}\exp\left(\hat{\delta}^*_{\max}c_{\alpha_1}\right)\right)$$

$$A_2 \leftarrow EC_1\exp\left(a_{A_2}\left(1+b_{A_2}\exp\left(\hat{\delta}^*_{\max}c_{A_2}\right)\right)\right)$$

$$\alpha_2 \leftarrow \frac{a_{\alpha_2}}{H_G}\left(1+b_{\alpha_2}\exp\left(\hat{\delta}^*_{\max}c_{\alpha_2}\right)\right)$$

$$\hat{p} \leftarrow \frac{F^*F_c}{A^*A_c}\frac{1}{\sigma_Y}$$

$$\widehat{\frac{\partial p}{\partial t}} \leftarrow -\left(A_1\sinh(\alpha_1\hat{p}) + A_2\sinh(\alpha_2\hat{p})\right)$$

$$\widehat{\frac{\partial p^*}{\partial \tau}} \leftarrow \widehat{\frac{\partial p}{\partial t}}\frac{1}{t_1\sigma_Y}$$

`% Stress reinsertion according to Eq.` (3.36):

$$f_A \leftarrow 0.81$$

$$\widehat{\frac{\partial p^*}{\partial \delta^*}} \leftarrow f_A\frac{2E'}{\pi\sqrt{R\delta_c}}\left(A^*\right)^{-1/2}\frac{\delta_c}{\sigma_Y}$$

`% Jackson--Green model for plastic behavior (see page 22):`

$$A^*_{JG} \leftarrow \begin{cases} \delta^* & \texttt{for } \delta^* \le 1.9 \\ \delta^*\left(\frac{\delta^*}{1.9}\right)^{0.14\exp\left(23\frac{\sigma_Y}{E}\right)} & \texttt{for } \delta^* > 1.9 \end{cases}$$

$$\widehat{\frac{\partial A^*_{JG}}{\partial \delta^*}} \leftarrow \begin{cases} 1 & \texttt{for } \delta^* \le 1.9 \\ \left(1+0.14\exp\left(23\frac{\sigma_Y}{E}\right)\right)\left(\frac{\delta^*}{1.9}\right)^{0.14\exp\left(23\frac{\sigma_Y}{E}\right)} & \texttt{for } \delta^* > 1.9 \end{cases}$$

$$a \leftarrow \sqrt{\frac{A_c A^*_{JG}}{\pi}}$$

$$H'_G \leftarrow \begin{cases} 2.84\sigma_Y \left(1 - \exp\left(-0.81 \left(\frac{a}{R}\right)^{-0.7}\right)\right) & \texttt{for } \frac{a}{R} \le 0.41 \\ \sigma_Y \left(7.32 \left(\frac{a}{R}\right)^3 - 14.1 \left(\frac{a}{R}\right)^2 + 6.28 \left(\frac{a}{R}\right) + 1.52\right) & \texttt{for } 0.41 < \frac{a}{R} \le 1 \\ \sigma_Y & \texttt{for } 1 < \frac{a}{R} \end{cases}$$

$$F^*_{JG} \leftarrow \begin{cases} (\delta^*)^{3/2} & \texttt{for } \delta^* \le 1.9 \\ \exp\left(-\frac{1}{4} (\delta^*)^{5/12}\right) (\delta^*)^{3/2} + \frac{4H'_G}{C_\nu \sigma_Y} \delta^* \left(1 - \exp\left(-\frac{1}{25} (\delta^*)^{5/9}\right)\right) & \texttt{for } \delta^* > 1.9 \end{cases}$$

$$\widehat{\frac{\partial F^*_{JG}}{\partial \delta^*}} \leftarrow \begin{cases} \frac{3}{2} (\delta^*)^{1/2} & \texttt{for } \delta^* \le 1.9 \\ \exp\left(-\frac{1}{4} (\delta^*)^{5/12}\right) \frac{3}{2} (\delta^*)^{1/2} - \frac{5}{48} (\delta^*)^{11/12} \exp\left(-\frac{1}{4} (\delta^*)^{5/12}\right) + \frac{4H'_G}{C_\nu \sigma_Y} \left(1 - \exp\left(-\frac{1}{25} (\delta^*)^{5/9}\right)\right) + \frac{4H'_G}{C_\nu \sigma_Y} \frac{1}{45} \exp\left(-\frac{1}{25} (\delta^*)^{5/9}\right) (\delta^*)^{5/9} & \texttt{for } \delta^* > 1.9 \end{cases}$$

% (H'_G-dependence on δ^* neglected)

% loading/unloading control

$\frac{\partial F^*}{\partial \tau} \leftarrow \frac{\partial F^*}{\partial t} t_1$

if $\left(\frac{\partial F^*}{\partial \tau} < 0\right)$
  % unloading, i.e. elastic behavior of force
  $\widehat{\frac{\partial F^*}{\partial \delta^*}} \leftarrow 2E' \sqrt{\frac{A^* A_c}{\pi}} \frac{\delta_c}{F_c}$ % Eqs. (3.30), (3.33)
else
  if $\left(F^* < F^*_{JG}\right)$
    % loading, below plastic curve,
    % i.e. elastic behavior of force
    $\widehat{\frac{\partial F^*}{\partial \delta^*}} \leftarrow 2E' \sqrt{\frac{A^* A_c}{\pi}} \frac{\delta_c}{F_c}$ % Eqs. (3.30), (3.33)
  else
    % plastic behavior of force
    $\widehat{\frac{\partial F^*}{\partial \delta^*}} \leftarrow \widehat{\frac{\partial F^*_{JG}}{\partial \delta^*}}$
  end if
end if

% combined interference creep rate (without load rate):

$R_{\text{res}} \leftarrow \frac{4E'}{3F^* F_c} \left(\frac{A^* A_c}{\pi}\right)^{3/2}$ % Eq. (3.32)

$\left.\widehat{\frac{\partial A^*}{\partial \delta^*}}\right|_{el} \leftarrow \frac{R_{\text{res}}}{R}$ % Eq. (3.29) (normalized)

$\left.\widehat{\frac{\partial \delta^*}{\partial \tau}}\right|_{cr} \leftarrow -\widehat{\frac{\partial p^*}{\partial \tau}} \left(\widehat{\frac{\partial p^*}{\partial \delta^*}} + \frac{F^* F_c}{(A^*)^2 A_c} \widehat{\frac{\partial A^*_{JG}}{\partial \delta^*}}\right)^{-1}$ % Eq. (3.39)

```
% Note: area contribution could be to good approx.
omitted

% Interference rate (including load rate):
```
$\widehat{\frac{\partial \delta^*}{\partial \tau}} \leftarrow \frac{\partial F^*}{\partial \tau} \left(\widehat{\frac{\partial F^*}{\partial \delta^*}} \right)^{-1} + \widehat{\frac{\partial \delta^*}{\partial \tau}}\Big|_{cr}$ `%` Eq. (4.12)

```
% Contact area evolution
```
if $\left(\widehat{\frac{\partial \delta^*}{\partial \tau}} > 0 \right)$
```
   % decreasing interference, i.e. elastic behavior of
area
```
$\widehat{\frac{\partial A^*}{\partial \delta^*}} \leftarrow \widehat{\frac{\partial A^*}{\partial \delta^*}\Big|_{el}}$

else

if $\left(A^* < A^*_{JG} \right)$
```
      % below plastic curve, elastic area behavior
```
$\widehat{\frac{\partial A^*}{\partial \delta^*}} \leftarrow \widehat{\frac{\partial A^*}{\partial \delta^*}\Big|_{el}}$

else
```
      % plastic area behavior
```
$\widehat{\frac{\partial A^*}{\partial \delta^*}} \leftarrow \widehat{\frac{\partial A^*_{JG}}{\partial \delta^*}}$

end if

end if
```
% Area rate:
```
$\widehat{\frac{\partial A^*}{\partial \tau}} \leftarrow \widehat{\frac{\partial A^*}{\partial \delta^*}} \widehat{\frac{\partial \delta^*}{\partial \tau}}$

References

1. ABAQUS Inc.: ABAQUS Analysis User's Manual. ABAQUS Inc., Providence (2004)
2. Abuzeid, O.M.: A linear thermo-visco-elastic creep model for the contact of nominal flat surfaces based on fractal geometry: Kelvin-Voigt medium. J. Qual. Maint. Eng. **9**, 202–216 (2003)
3. Abuzeid, O.M.: A linear viscoelastic creep-contact model of a flat fractal surface: Kelvin-Voigt medium. Ind. Lubr. Tribol. **56**, 334–340 (2004)
4. Abuzeid, O.M., Alabed, T.A.: Mathematical modeling of the thermal relaxation of nominally flat surfaces in contact using fractal geometry: Maxwell type medium. Tribol. Int. **42**, 206–212 (2009)
5. Abuzeid, O.M., Eberhard, P.: Linear viscoelastic creep model for the contact of nominal flat surfaces based on fractal geometry: standard linear solid (SLS) material. J. Tribol. **129**, 461–466 (2007)
6. Akay, A.: Acoustics of friction. J. Acoust. Soc. Am. **111**, 1525–1548 (2002)
7. Alabed, T.A., Abuzeid, O.M., Barghash, M.: A linear viscoelastic relaxation-contact model of a flat fractal surface: a Maxwell type medium. Int. J. Adv. Manuf. Technol. **39**, 423–430 (2008)
8. Ameida, L., Ramadoss, R., Jackson, R.L., Ishikawa, K., Yu, Q.: Study of the electrical contact resistance of multi-contact MEMS relays fabricated using the metalMUMPs process. J. Micromech. Microeng. **16**, 1189–1194 (2006)
9. ANSYS Inc.: ANSYS Theory Manual, Release 11. ANSYS USA, Canonsburg (2007)
10. ANSYS Inc.: Programmer's Manual for ANSYS, Release 11. ANSYS USA, Canonsburg (2007)
11. Archard, R.F.: Elastic deformation and the laws of friction. Proc. R. Soc. Lond. A **243**, 190–205 (1957)
12. Armstrong-Hélouvry, B.: Control of machines with friction. Kluwer, Boston (1991)
13. Ashby, M.F., Jones, D.R.H.: Engineering Materials, vol. 1, 3rd edn. Butterworth-Heinemann, Oxford (2005)
14. Balluffi, R.W., Allen, S.M., Carter, W.C.: Kinetics of Materials. Wiley, Hoboken (2005)
15. Baltazar, A., Rokhlin, S.I., Percorari, C.: On the relationship between ultrasonic and micro-structural properties of imperfect interfaces in layered solids. In: Thompson, D.O., Chimenti, D.E. (eds.) Review of Progress in Quantitative Nondestructive Evaluation, vol. 18B, pp. 1463–1470. American Institute of Physics, New York (1999)
16. Barabási, A.L., Stanley, H.E.: Fractal Concepts in Surface Growth. Cambridge University Press, Cambridge (1995)
17. Baumberger, T., Berthoud, P.: Sliding dynamics at a multicontact interface. In: Wolf, D.E., Grassberger, P. (eds.) Workshop on Friction, Arching, Contact Dynamics, Forschungszentrum Jülich, pp. 3–12. World Scientific, Singapore (1996)

A. Goedecke, *Transient Effects in Friction*, Engineering Materials,
DOI 10.1007/978-3-7091-1506-0, © Springer-Verlag Wien 2013

18. Baumberger, T., Berthoud, P., Caroli, C.: Physical analysis of the state- and rate-dependent friction law: II. Dynamic friction. Phys. Rev. B **60**, 3928–3939 (1999)
19. Baumberger, T., Caroli, C.: Solid friction from stick-slip down to pinning and aging. Adv. Phys. **55**, 279–348 (2006)
20. Belotserkovets, A., Dubois, A., Dubar, M., Dubar, L., Deltombe, R., Vandekinderen, H., Damasse, J.: 2D asperity deformation of stainless steel strip in cold rolling. Int. J. Mater. Form. **1**, 351–354 (2008)
21. Bengisu, M.T., Akay, A.: Stability of friction-induced vibrations in multi-degree-of-freedom systems. J. Sound Vib. **171**, 557–570 (1994)
22. Berger, E.J.: Friction modeling for dynamic system simulation. Appl. Mech. Rev. **55**, 535–577 (2002)
23. Berry, M.V., Lewis, Z.V.: On the Weierstrass-Mandelbrot fractal function. Proc. R. Soc. Lond. A **370**, 459–484 (1980)
24. Berthoud, P., Baumberger, T., G'Sell, C., Hiver, J.M.: Physical analysis of the state- and rate-dependent friction law: I. Static friction. Phys. Rev. B **59**, 14313–14327 (1999)
25. Bhushan, B. (ed.): Handbook of Micro/Nano Tribology. CRC Press, Boca Raton (1995)
26. Bhushan, B., Majumdar, A.: Elastic-plastic contact model for bifractal surfaces. Wear **153**, 53–64 (1992)
27. Blau, P.J.: Friction Science and Technology. Marcel Dekker, New York (1996)
28. Bliman, P.A., Bonald, T., Sorine, M.: Hysteresis operators and tyre friction models: application to vehicle dynamic simulation. In: Proceedings of ICIAM/GAMM 95, Hamburg, Germany, 1996, pp. 309–312
29. Bliman, P.A., Sorine, M.: Friction modelling by hysteresis operators: application to Dahl, stiction and Stribeck effects. In: Proceedings of Conference Models of Hysteresis, Trento, Italy, 1991
30. Bliman, P.A., Sorine, M.: A system-theoretic approach of systems with hysteresis: application to friction modelling and compensation. In: Proceedings of the 2nd European Control Conference, pp. 1844–1849. Groningen, The Netherlands (1993)
31. Bo, L.C., Pavelescu, D.: The friction-speed relation and its influence on the critical velocity of stick-slip motion. Wear **82**, 277–289 (1982)
32. Boettcher, M.S., Marone, C.: Effects of normal stress variation on the strength and stability of creeping faults. J. Geophys. Res. **109**, B03406 (2004)
33. Bora, C.K., Flater, E.E., Street, M.D., Redmond, J.M., Starr, M.J., Carpick, R.W., Plesha, M.E.: Multiscale roughness and modeling of MEMS interfaces. Tribol. Lett. **19**, 37–48 (2005)
34. Borodich, F.M.: Comment on "Elastoplastic contact between randomly rough surfaces". Phys. Rev. Lett. **88**, 069601(1) (2002)
35. Borri-Brunetto, M., Carpinteri, A., Chiaia, B.: Scaling phenomena due to fractal contact in concrete and rock fractures. Int. J. Fract. **95**, 221–238 (1999)
36. Borri-Brunetto, M., Chiaia, B., Ciavarella, M.: Incipient sliding of rough surfaces in contact: a multiscale numerical analysis. Comput. Methods Appl. Mech. Eng. **190**, 6053–6073 (2001)
37. Boucly, V., Nélias, D., Green, I.: Modeling of the rolling and sliding contact between two asperities. J. Tribol. **129**, 235–245 (2007)
38. Bowden, F.P., Tabor, D.: The Friction and Lubrication of Solids. Clarendon Press, Oxford (1950)
39. Bowden, F.P., Tabor, D.: Friction: An Introduction to Tribology. Anchor Press, Garden City (1973)
40. Bowden, F.P., Tabor, D.: The Friction and Lubrication of Solids (Oxford Classic Texts in the Physical Sciences). Oxford University, Oxford (2001)
41. Bower, A.F., Fleck, N.A., Needleman, A., Ogbonna, N.: Indentation of a power law creeping solid. Proc. R. Soc. Lond. A **441**, 97–124 (1993)
42. Braunovic, M., Konchits, V.V., Myshkin, N.K.: Electrical Contacts: Fundamentals, Applications and Technology. CRC Press, Boca Raton (2007)
43. Brechet, Y., Estrin, Y.: The effect of strain rate sensitivity on dynamic friction of metals. Scr. Metall. Mater. **30**, 1449–1454 (1994)

44. Brizmer, V.: Elastic-plastic contact of a sphere and a flat under combined normal and tangential loading. Ph.D. thesis, Technion, Israel (2006)
45. Brizmer, V., Kligerman, Y., Etsion, I.: A model for junction growth of a spherical contact under full stick condition. J. Tribol. **129**, 783–790 (2007)
46. Brockley, C.A., Davis, H.R.: The time-dependence of static friction. J. Lubr. Technol. **90**, 35–41 (1968)
47. Broniec, Z., Lenkiewicz, W.: Static friction processes under dynamic loads and vibration. Wear **80**, 261–271 (1982)
48. Bronstein, I.N., Semendjaev, K.A.: Taschenbuch der Mathematik. Teubner, Leipzig (2003)
49. Brot, C.C., Etsion, I., Kligerman, Y.: A contact model for a creeping sphere and a rigid flat. Wear **265**, 598–605 (2008)
50. Buckingman, E.: On physically similar systems; illustrations of the use of dimensional equations. Phys. Rev. **4**, 345–376 (1914)
51. Bureau, L., Baumberger, T., Caroli, C.: Shear response of a frictional interface to a normal load modulation. Phys. Rev. E **62**, 6810–6820 (2000)
52. Bush, A.W., Gibson, R.D., Thomas, T.R.: The elastic contact of a rough surface. Wear **35**, 87–111 (1975)
53. Canudas de Wit, C., Olsson, H., Åström, K.J., Lischinsky, P.: A new model for control of systems with friction. IEEE Trans. Automat. Contr. **40**, 419–425 (1995)
54. Chang, L., Zhang, H.: A mathematical model for frictional elastic-plastic sphere-on-flat contacts at sliding incipient. J. Appl. Mech. **74**, 100–106 (2007)
55. Chang, W.R., Etsion, I., Bogy, D.B.: An elastic-plastic model for the contact of rough surfaces. J. Tribol. **109**, 257–263 (1987)
56. Chung, J.C., Lin, J.F.: Fractal model developed for elliptic elastic-plastic asperity microcontacts of rough surfaces. J. Tribol. **126**, 646–654 (2004)
57. Church, E.L.: Fractal surface finish. Appl. Opt. **27**, 1518–1526 (1988)
58. Ciavarella, M., Demelio, G.: Elastic multiscale contact of rough surfaces: Archard's model revisited and comparisons with modern fractal models. J. Appl. Mech. **68**, 496–498 (2001)
59. Ciavarella, M., Demelio, G., Barber, J.R., Jang, Y.H.: Linear elastic contact of the Weierstrass profile. Proc. R. Soc. Lond. A **456**, 387–405 (2000)
60. Cochard, A., Bureau, L., Baumberger, T.: Stabilization of frictional sliding by normal load modulation. J. Appl. Mech. **70**, 220–226 (2003)
61. Coulomb, C.A.: Théorie des machines simples. Mém. Math. Phys. Acad. Sci. **10**, 161–331 (1785)
62. Dahl, P.R.: A solid friction model. Technical report, The Aerospace Corporation, El Segundo, CA for Space and Missile Systems Organization, Air Force Systems Command, Los Angeles, CA (1968)
63. Derjaguin, B.V., Push, V.E., Tolstoi, D.M.: A theory of stick-slip sliding of solids. Sov. J. Tech. Phys. (in Russian) **26**, 1329–1342 (1955)
64. Derjaguin, B.V., Push, V.E., Tolstoi, D.M.: A theory of stick-slip sliding of solids. In: Proceedings of the Conference Lubrication and Wear, pp. 265–269. The Institution of Mechanical Engineers, London (1957)
65. Dieterich, J.H.: Time-dependent friction and the mechanics of stick-slip. Pure Appl. Geophys. **116**, 790–806 (1978)
66. Dieterich, J.H.: Modeling of rock friction, 1. Experimental results and constitutive equations. J. Geophys. Res. **84**, 2161–2168 (1979)
67. Dieterich, J.H.: Modeling of rock friction, 2. Simulation of preseismic slip. J. Geophys. Res. **84**, 2169–2176 (1979)
68. Dieterich, J.H.: Experimental and model study of fault constitutive properties. In: Nemet-Nasser, S. (ed.) Solid Earth Geophysics and Geotechnology, pp. 21–30. ASME, New York (1980)
69. Dieterich, J.H.: Constitutive properties of faults with simulated gouge. In: Carter, N.L., Friedman, M., Logan, J.M., Stearns, D.W. (eds.) Mechanical Behavior of Crustal Rocks. Geophysical Monograph Series, vol. 24, pp. 103–120. American Geophysical Union, Washington (1981)

70. Dieterich, J.H.: A model for the nucleation of earthquake slip. In: Das, S., Boatwright, J., Scholz, C.H. (eds.) Earthquake Source Mechanics. Geophysical Monograph Series, vol. 37, pp. 37–47. American Geophysical Union, Washington (1986)
71. Dieterich, J.H.: Nucleation and triggering of earthquake slip: effect of periodic stresses. Tectonophysics **144**, 127–139 (1987)
72. Dieterich, J.H., Kilgore, B.: Direct observation of frictional contacts: new insights for state-dependent properties. Pure Appl. Geophys. **143**, 283–302 (1994)
73. Dieterich, J.H., Linker, M.F.: Fault stability under conditions of variable normal stress. Geophys. Res. Lett. **19**, 1691–1694 (1992)
74. Duan, C., Singh, R.: Influence of harmonically varying normal load on steady-state behavior of a 2dof torsional system with dry friction. J. Sound Vib. **294**, 503–528 (2006)
75. Dupont, P.E.: Friction modeling in dynamic robot simulation. In: Proceedings of the 1990 IEEE International Conference on Robotics and Automation, Sacramento, CA, 1990, pp. 1370–1376
76. Dupont, P.E., Bapna, D.: Stability of sliding frictional surfaces with varying normal force. J. Vib. Acoust. **116**, 237–242 (1994)
77. Dupont, P.E., Dunlap, E.P.: Friction modeling and control in boundary lubrication. In: Proceedings of the American Control Conference, San Francisco, CA, 1993
78. Dupont, P.E., Dunlap, E.P.: Friction modeling and PD compensation at very low velocities. J. Dyn. Syst. Meas. Control **117**, 8–14 (1995)
79. Dutton, R.E., Rahaman, M.N.: Sintering, creep, and electrical conductivity of model glass-matrix composites. J. Am. Ceram. Soc. **75**, 2146–2154 (2005)
80. Dwyer-Joyce, R.S., Drinkwater, B.W., Quinn, A.M.: The use of ultrasound in the investigation of rough surface interfaces. J. Tribol. **123**, 8–16 (2001)
81. Edgar, G.: Measure, Topology, and Fractal Geometry. Springer, Berlin (2008)
82. Etsion, I., Kligermann, Y., Kadin, Y.: Unloading of an elastic-plastic loaded spherical contact. Int. J. Solids Struct. **42**, 3716–3729 (2005)
83. Falconer, K.J.: The Geometry of Fractal Sets. Cambridge University Press, Cambrige (1986)
84. Falconer, K.J.: Fractal Geometry: Mathematical Foundations and Applications. Wiley, Hoboken (2003)
85. Falk, M.L., Langer, J.S.: Dynamics of viscoplastic deformation in amorphous solids. Phys. Rev. E **57**, 7192–7205 (1998)
86. Feeny, B.F., Liang, J.W.: Phase-space reconstructions and stick-slip. Nonlinear Dyn. **13**, 39–57 (1997)
87. Filippov, A.E., Popov, V.L.: Fractal Tomlinson model for mesoscopic friction: from microscopic velocity-dependent damping to macroscopic coulomb friction. Phys. Rev. E **75**, 027,103(4) (2007)
88. Friedman, H.D., Levesque, P.: Reduction of static friction by sonic vibrations. J. Appl. Phys. **30**, 1572–1575 (1959)
89. Frost, H.J., Ashby, M.F.: Deformation-mechanism maps: the plasticity and creep of metals and ceramics. Pergamon Press, Oxford (1982)
90. Fujii, H., Asakura, T.: Roughness measurements of metal surfaces using laser speckle. J. Opt. Soc. Am. **67**, 1171–1176 (1977)
91. Fuller, D.D.: Theory and Practice of Lubrication for Engineers, pp. 336–338. Wiley, Hoboken (1956)
92. Gao, Y.F., Bower, A.F.: Elastic-plastic contact of a rough surface with Weierstrass profile. Proc. R. Soc. Lond. A **462**, 319–348 (2006)
93. Garofalo, F.: Fundamentals of Creep and Creep-Rupture in Metals. Macmillan Publishers, New York (1965)
94. Gitis, N.V., Volpe, L.: Nature of static friction time dependence. J. Phys. D Appl. Phys. **25**, 605–612 (1992)
95. Glocker, C.: Set-valued force laws: dynamics of non-smooth systems. Springer, Berlin (2001)
96. Godfrey, D.: Vibration reduces metal to metal contact and causes an apparent reduction in friction. ASLE Trans. **10**, 183–192 (1967)

97. Goedecke, A.: Kinetische Monte Carlo Simulationen zum Wachstum zweidimensionaler Kristalle. Master's thesis, RWTH Aachen (2003)
98. Goedecke, A., Mock, R.: A new fractal model for dynamic contact phenomena including friction. In: Proceedings of the European COMSOL Conference 2008, Hannover, 2008, p. 6
99. Goedecke, A., Mock, R.: A novel dynamic friction model based on asperity creep. In: Proceedings of the 9th Biennial ASME Conference on Engineering Systems Design and Analysis (ESDA2008) Haifa Israel, 2008, p. 59366(10)
100. Goedecke, A., Mock, R.: Creep relaxation of an elastic-perfectly plastic hemisphere in fully plastic contact. J. Tribol. **131**, 021407(10) (2009)
101. Goedecke, A., Mock, R.: Transient friction effects due to variable normal load in a multi-scale asperity-creep friction model. In: Proceedings of the ASME/STLE International Joint Tribology Conference IJTC 2010 (IJTC2010), San Francisco, California, 2010, p. 41190(3)
102. Greenwod, J.A., Rowe, G.W.: Deformation of surface asperities during bulk plastic flow. J. Appl. Phys. **36**, 667–668 (1965)
103. Greenwood, J.A.: A simplified elliptic model of rough surface contact. Wear **261**, 191–200 (2006)
104. Greenwood, J.A., Tripp, J.H.: The elastic contact of rough spheres. J. Appl. Mech. **34**, 153–159 (1967)
105. Greenwood, J.A., Williamson, J.B.P.: Contact of nominally flat surfaces. Proc. R. Soc. Lond. A **295**, 300–319 (1966)
106. Greenwood, J.A., Wu, J.J.: Surface roughness and contact: an apology. Meccanica **36**, 617–630 (2001)
107. Guinea, F., Louis, E., Katz, J.: Fractures, fractals and foreign physics. Phys. Today **44**, 13 (1991)
108. Haessig, D.A., Friedland, B.: On the modelling and simulation of friction. J. Dyn. Syst. Meas. Control **113**, 354–362 (1992)
109. Hegazy, A.A.H.: Thermal joint conductance of comforming rough surfaces: effect of surface micro-hardness variation. Ph.D. thesis, University of Waterloo, UK (1985)
110. Hertz, H.: Über die Berührung fester elastischer Körper. J. Reine Angew. Math. **92**, 156–171 (1881)
111. Heslot, F., Baumberger, T., Perrin, B., Caroli, B., Caroli, C.: Creep, stick-slip, and dry-friction dynamics: experiments and a heuristic model. Phys. Rev. E **49**, 4973–4988 (1994)
112. Hess, D.P., Soom, A.: Friction at a lubricated line contact operating at oscillating sliding velocities. J. Tribol. **112**, 147–152 (1990)
113. Hess, D.P., Soom, A., Kim, C.H.: Normal vibrations and friction at a Hertzian contact under random excitation: Theory and experiment. J. Sound Vib. **153**, 491–508 (1991)
114. Hinrichs, N.: Reibungsschwingungen mit Selbst- und Fremderregung: Experiment, Modellierung und Berechnung. In: Fortschr.-Ber. VDI, Reihe 11, vol. 240. VDI-Verlag, Dsseldorf (1997)
115. Hobbs, B.E., Brady, B.H.G.: Normal stress changes and the constitutive law for rock friction (abstract). EOS Trans. Am. Geophys. Union **66**, 382 (1985)
116. Höge, M.: Sensorische rückwirkung von piezoelektrischen aktoren und ihre anwendung im kraftfahrzeug. Ph.D. thesis, Johannes Kepler University, Linz, Austria (2007)
117. Howe, P.G., Benton, D.P., Puddington, I.E.: London - Van der Waals attractive forces between glass surfaces. Can. J. Chem. **33**, 1375–1383 (1955)
118. Huber, C.: Modellbasierte regelkonzepte auf der basis sensorischer rückwirkung von schnell schaltenden aktoren. Ph.D. thesis, Johannes Kepler University (2011)
119. Hui, C.Y., Lin, Y.Y., Baney, J.M.: The mechanics of tack: viscoelastic contact on a rough surface. J. Polym. Sci. B Polym. Phys. **38**, 1485–1495 (2000)
120. Hurd, A.J., Weitz, D.A., Mandelbrot, B.B. (eds.): Fractal Aspects of Materials: Disordered Systems. Materials Research Society, Pittsburgh (1987)
121. Hyun, S., Pei, L., Molinari, J.F., Robbins, M.O.: Finite-element analysis of contact between elastic self-affine surfaces. Phys. Rev. E **70**, 026117(12) (2004)
122. Ibrahim, R.A.: Friction-induced vibration, chatter, squeal, and chaos. Part I: Mechanics of contact and friction. Appl. Mech. Rev. **47**, 209–226 (1994)

123. Ibrahim, R.A.: Friction-induced vibration, chatter, squeal, and chaos. Part II: Dynamics and modeling. Appl. Mech. Rev. **47**, 227–253 (1994)
124. Irfan, M.A., Prakash, V.: Time resolved friction during dry sliding of metal on metal. Int. J. Solids Struct. **37**, 2859–2882 (2000)
125. Ishlinsky, A.Y., Kragelsky, I.Y.: On stick-slip in sliding (in Russian). J. Tech. Phys. **14**, 276–282 (1944)
126. Jackson, R.L., Chusoipin, I., Green, I.: A finite element study of the residual stress and deformation in hemispherical contacts. J. Tribol. **127**, 484–493 (2005)
127. Jackson, R.L., Duvvuru, R.S., Meghani, H., Mahajan, M.: An analysis of elasto-plastic sliding spherical asperity interaction. Wear **262**, 210–219 (2006)
128. Jackson, R.L., Green, I.: A finite element study of elasto-plastic hemispherical contact against a rigid flat. J. Tribol. **127**, 343–354 (2005)
129. Jackson, R.L., Green, I., Marghitu, D.B.: Predicting the coefficient of restitution of impacting elastic-perfectly plastic spheres. Nonlinear Dyn. **60**, 217–229 (2009)
130. Jackson, R.L., Streator, J.L.: A multi-scale model for contact between rough surfaces. Wear **261**, 1337–1347 (2006)
131. Johnson, K.L.: Contact Mechanics. Cambridge University Press, Cambridge (1985)
132. Johnson, T.: Time-dependent friction of granite: implications for precursory slip on faults. J. Geophys. Res. **86**, 6017–6028 (1981)
133. Ju, Y., Farris, T.N.: Spectral analysis of two-dimensional contact problems. J. Tribol. **118**, 320–328 (1996)
134. Jung, C.M., Feeny, B.F.: Friction-induced vibration in periodic linear elastic media. J. Sound Vib. **252**, 945–954 (2002)
135. Kadin, Y., Kligerman, Y., Etsion, I.: Unloading an elastic-plastic contact of rough surfaces. J. Mech. Phys. Solids **54**, 2652–2674 (2006)
136. Kadin, Y., Kligerman, Y., Etsion, I.: Jump-in induced plastic yield onset of approaching microcontacts in the presence of adhesion. J. Appl. Phys. **103**, 013513 (2008)
137. Kadin, Y., Kligerman, Y., Etsion, I.: Loading-unloading of an elastic-plastic adhesive spherical microcontact. J. Colloid Interface Sci. **321**, 242–250 (2008)
138. Kadin, Y., Kligermann, Y., Etsion, I.: Multiple loading-unloading of an elastic-plastic spherical contact. Int. J. Solids Struct. **43**, 7119–7127 (2006)
139. Karnopp, D.: Computer simulation of stick-slip friction in mechanical dynamic systems. J. Dyn. Syst. Meas. Control **107**, 100–103 (1985)
140. Kato, S., Matsubayashi, T.: On the dynamic behavior of machine tool slideway. Bull. JSME **13**, 170–179 (1970)
141. Kato, S., Sato, N., Matsubayashi, T.: Some considerations on characteristics of static friction in machine tool slideway. J. Lubr. Technol. **94**, 234–247 (1972)
142. Kim, J.Y., Baltazar, A., Rokhlin, S.I.: Ultrasonic assessment of rough surface contact between solids from elastoplastic loading-unloading hysteresis cycle. J. Mech. Phys. Solids **52**, 1911–1934 (2004)
143. Kligerman, Y., Etsion, I., Brizmer, V., Kadin, Y.: Friction and contact between rough surfaces based on elastic-plastic sphere and rigid flat interaction. In: Wiggers, P., Nackenhorst, U. (eds.) Analysis and Simulation of Contact Problems, pp. 223–229. Springer, Berlin (2006)
144. Kogut, L., Etsion, I.: Elastic-plastic contact analysis of a sphere and a rigid flat. J. Appl. Mech. **69**, 657–662 (2002)
145. Kogut, L., Etsion, I.: A semi-analytical solution for the sliding inception of a spherical contact. J. Tribol. **125**, 499–506 (2003)
146. Kragelsky, I.V., Alisin, V.V., Palkin, F., Palkin, V.: Tribology: lubrication, friction and wear. Wiley, Hoboken (2005)
147. Krallis, M., Hess, D.P.: Stick-slip in the presence of a normal vibration. Tribotest J. **8–3**, 205–219 (2002)
148. Krithivasan, V., Jackson, R.L.: An analysis of three-dimensional elasto-plastic sinusoidal contact. Tribol. Lett. **27**, 31–43 (2007)
149. Kucharski, S., Klimczak, T., Polijaniuk, A., Kaczmarek, J.: Finite-elements model for the contact of rough surfaces. Wear **177**, 1–13 (1994)

150. Lau, J.H. (ed.): Ball Grid Array Technology. McGraw-Hill, New York (1995)
151. Laursen, T.A.: Computational Contact and Impact Mechanics. Springer, Berlin (2002)
152. Lin, L.P., Lin, J.F.: An elastoplastic microasperity contact model for metallic materials. J. Tribol. **127**, 666–672 (2005)
153. Linker, M.F., Dieterich, J.H.: Effects of variable normal stress on rock friction: observations and constitutive equations. J. Geophys. Res. **95**, 4923–4940 (1992)
154. Lockner, D.A., Summers, R., Byerlee, J.D.: Effects of temperature and sliding rate on frictional strength of granite. Pure Appl. Geophys. **124**, 445–469 (1986)
155. Longuet-Higgins, M.S.: Statistical properties of an isotropic random surface. Proc. R. Soc. Lond. A **250**, 157–174 (1957)
156. Lu, C.J., Kuo, M.C.: Coefficients of restitution based on a fractal surface model. J. Appl. Mech. **70**, 339–345 (2003)
157. Luo, J., Liu, S., Wen, S.: Contact ratio and deformation of asperity in nano-partial lubrication. Sci. China A **44**, 78–85 (2001)
158. Majumdar, A., Bhushan, B.: Role of fractal geometry in roughness characterization and contact mechanics of surfaces. J. Tribol. **112**, 205–216 (1990)
159. Majumdar, A., Bhushan, B.: Fractal model of elastic-plastic contact between rough surfaces. J. Tribol. **113**, 1–11 (1991)
160. Majumdar, A., Tien, C.L.: Fractal characterization and simulation of rough surfaces. Wear **136**, 313–327 (1990)
161. Majumdar, A., Tien, C.L.: Fractal network model for contact conductance. J. Heat Transfer **113**, 516–525 (1991)
162. Mandelbrot, B.B.: The Fractal Geometry of Nature. W.H. Freeman and Co., New York (1982)
163. Manners, W., Greenwood, J.A.: Some observations on Persson's diffusion theory of elastic contact. Wear **261**, 600–610 (2006)
164. Marone, C.: Laboratory-derived friction laws and their application to seismic faulting. Annu. Rev. Earth Planet. Sci. **26**, 643–696 (1998)
165. McCool, J.I.: Comparison of models for the contact of rough surfaces. Wear **107**, 37–60 (1986)
166. Michaelis, S.: Entwicklung von mikromechanischen schaltern für neuartige mems-produkte unter aspekten industrieller fertigungsprozesse. Ph.D. thesis, University Bremen (2001)
167. Michely, T., Krug, J.: Islands, Mounds, and Atoms: Patterns and Processes in Crystal Growth Far from Equilibrium. Springer, Berlin (2004)
168. Mikic, B.B.: Thermal contact conductance: theoretical considerations. Int. J. Heat Mass Transf. **17**, 205–214 (1974)
169. Moore, A.C., Tabor, D.: Some mechanical and adhesive properties of indium. Br. J. Appl. Phys. **3**, 299–301 (1952)
170. Moore, A.J.W.: Deformation of metals in static and in sliding contact. Proc. R. Soc. Lond. A **195**, 231–244 (1948)
171. Morag, Y., Etsion, I.: Resolving the contradiction of asperities plastic to elastic mode transition in current contact models of fractal rough surfaces. Wear **262**, 624–629 (2007)
172. Mulhearn, T.O., Tabor, D.: Creep and hardness of metals: a physical study. J. Inst. Met. **89**, 7–12 (1960)
173. Müser, M.H.: Rigorous field-theoretical approach to the contact mechanics of rough elastic solids. Phys. Rev. Lett. **100**, 055,504(4) (2008)
174. Nayak, P.R.: Random process model of rough surfaces. J. Lubr. Technol. **93**, 398–407 (1971)
175. Nayak, P.R.: Random process model of rough surfaces in plastic contact. Wear **26**, 305–333 (1973)
176. Nayak, P.R.: Some aspects of surface roughness measurement. Wear **26**, 165–174 (1973)
177. Nix, W.D., Gao, H.J.: Indentation size effects in crystalline materials: a law for strain gradient plasticity. J. Mech. Phys. Solids **46**, 411–425 (1998)
178. Oden, J.T., Martins, J.A.C.: Models and computational methods for dynamic friction phenomena. Comput. Methods Appl. Mech. Eng. **52**, 527–634 (1985)
179. Ogbonna, N., Fleck, N.A., Cocks, C.F.: Transient creep analysis of ball indentation. Int. J. Mech. Sci. **37**, 1179–1202 (1995)

180. Okamura, K., Matsubara, T., Noro, S., Yamane, T.: Study of frictional vibration (theoretical analysis). J. Jpn. Soc. Precis. Eng. **34**, 31–36 (1968)
181. Olsson, H.: Control systems with friction. Ph.D. thesis, Lund Institute of Technology, Lund, Sweden (1996)
182. Olsson, W.A.: Normal stress history effects on friction in tuff. EOS Trans. Am. Geophys. Union **66**, 1101 (1985)
183. Olsson, W.A.: The effects of changes in normal stress on rock friction. In: Desai, C.S., Krempl, E., Kiousis, P.D., Kundu, T. (eds.) Constitutive Laws for Engineering Materials – Theory and Applications, pp. 1059–1066. Elsevier, New York (1987)
184. Olsson, W.A.: Rock joint compliance studies. Technical Report, SAND86–0177, Sandia National Laboratories Report, Abuquerque (1987)
185. Olsson, W.A.: The effects of normal stress history on rock friction. In: Cundall, P.A., Starfield, A.M., Sterling, R.L. (eds.) Key Questions in Rock Mechanics: Proceedings of the 29th US Symposium on Rock Mechanics, pp. 111–117 (1988)
186. Olsson, W.A.: The effects of shear and normal stress paths on rock friction. In: Barton, N., Stephansson, O. (eds.) Rock Joints: Proceedings of the International Symposium on Rock Joints, pp. 475–479 (1990)
187. Ossa, E.A., Deshpande, V.S., Cebon, D.: Spherical indentation behaviour of bitumen. Acta Mater. **53**, 3103–3113 (2005)
188. Panagiotopoulos, P.D.: Fractals and fractal approximation in structural mechanics. Meccanica **27**, 25–33 (1992)
189. Perfettini, H., Schmittbuhl, J., Rice, J.R., Cocco, M.: Frictional response induced by time-dependent fluctuations of the normal loading. J. Geophys. Res. **106**, 13455–13472 (2001)
190. Persson, B.N.J.: Theory of friction: Stress domains, relaxation, and creep. Phys. Rev. E **51**, 13568–13585 (1995)
191. Persson, B.N.J.: Sliding Friction: Physical Principles and Applications, 2nd edn. Springer, Berlin (2000)
192. Persson, B.N.J.: Theory of time-dependent plastic deformation in disordered solids. Phys. Rev. B **61**, 5949–5966 (2000)
193. Persson, B.N.J.: Elastoplastic contact between randomly rough surfaces. Phys. Rev. Lett. **87**, 116101(4) (2001)
194. Persson, B.N.J.: Theory of rubber friction and contact mechanics. J. Chem. Phys. **115**, 3840–3861 (2001)
195. Persson, B.N.J.: Reply to Borodich's comment on "Elastoplastic contact between randomly rough surfaces". Phys. Rev. Lett. **88**, 069602(1) (2002)
196. Persson, B.N.J.: Contact mechanics for randomly rough surfaces. Surf. Sci. Rep. **61**, 201–227 (2006)
197. Persson, B.N.J.: Relation between interfacial separation and load: a general theory of contact mechanics. Phys. Rev. Lett. **99**, 125502(4) (2007)
198. Persson, B.N.J., Albohr, O., Tartaglino, U., Volokitin, A.I., Tosatti, E.: On the nature of surface roughness with application to contact mechanics, sealing, rubber friction and adhesion. J. Phys. Condens. Matter **17**, R1–R62 (2005)
199. Persson, B.N.J., Bucher, F., Chiaia, B.: Elastic contact between randomly rough surfaces: comparison of theory with numerical results. Phys. Rev. B **65**, 184106(7) (2002)
200. Persson, B.N.J., Tosatti, E. (eds.): Physics of Sliding Friction. In: NATO ASI Series, Series E: Applied Sciences, vol. 311. Kluwer, Dordrecht (1996)
201. Pilipchuk, V.N., Tan, C.A.: Creep-slip capture as a possible source of squeal during decelerated sliding. Nonlinear Dyn. **35**, 259–285 (2004)
202. Pinto da Costa, A., Martins, J.A.C., Figueiredo, I.N., Júdice, J.J.: The directional instability problem in systems with frictional contacts. Comput. Methods Appl. Mech. Eng. **193**, 357–384 (2004)
203. Prakash, V.: Frictional response of sliding interfaces subjected to time varying normal pressures. J. Tribol. **120**, 97–102 (1998)

204. Quicksall, J.J., Jackson, R.L., Green, I.: Elasto-plastic hemispherical contact models for various mechanical properties. Proc. Inst. Mech. Eng. J Eng. Tribol. **218**, 313–322 (2004)
205. Rabinowicz, E.: The instrinsic variables affecting the stick-slip process. Proc. Phys. Soc. **71**, 668–675 (1958)
206. Rabinowicz, E.: Friction and Wear of Materials. Wiley, Hoboken (1965)
207. Ramesh Kumar, M.V., Narasimhan, R.: Analysis of spherical indentation of linear viscoelastic materials. Curr. Sci. **87**, 1088–1095 (2004)
208. Rice, J.R., Lapusta, N., Ranjith, K.: Rate and state dependent friction and the stability of sliding between elastically deformable solids. J. Mech. Phys. Solids **49**, 1865–1898 (2001)
209. Rice, J.R., Ruina, A.L.: Stability of steady frictional slipping. J. Appl. Mech. **50**, 343–349 (1983)
210. Richardson, E., Marone, C.: Effects of normal stress vibrations on frictional healing. J. Geophys. Res. **104**, 28859–28878 (1999)
211. Ruina, A.L.: Friction laws and instabilities: A quasistatic analysis of some dry frictional behavior. Ph.D. thesis, Brown University, Providence, USA (1980)
212. Ruina, A.L.: Slip instability and state variable friction laws. J. Geophys. Res. **88**, 10359–10370 (1983)
213. Russ, J.C.: Fractal Surfaces. Plenum Press, New York (1994)
214. Ryabov, V.B., Ito, H.M.: Multistability and chaos in a spring-block model. Phys. Rev. E **52**, 6101–6112 (1995)
215. Sahoo, P., Banerjee, A.: Asperity interaction in elastic-plastic contact of rough surfaces in presence of adhesion. J. Phys. D Appl. Phys. **38**, 2841–2847 (2005)
216. Scholz, C.H.: Earthquakes and friction laws. Nature **391**, 37–42 (1998)
217. Scholz, C.H.: The Mechanics of Earthquakes and Faulting, 2nd edn. Cambridge University Press, Cambridge (2002)
218. Sellgren, U., Olofsson, U.: Application of a constitutive model for micro-slip in finite element analysis. Comput. Methods Appl. Mech. Eng. **170**, 65–77 (1999)
219. Sextro, W.: Dynamical Contact Problems with Friction: Models, Methods, Experiments and Applications, 2nd edn. Springer, Berlin (2007)
220. Sheng, G.: Friction-Induced Vibrations and Sound: Principles and Applications. CRC Press, Boca Raton (2007)
221. Singer, I.L., Pollock, H.M. (eds.): Fundamentals of Friction: Macroscopic and Microscopic Processes. NATO ASI Series, Series E: Applied Sciences, vol. 220. Kluwer, Dordrecht (1992)
222. Soom, A., Kim, C.: Interactions between dynamic normal and frictional forces during unlubricated sliding. J. Lubr. Technol. **105**, 221–229 (1983)
223. Spurr, R.T.: Creep and static friction. Br. J. Appl. Phys. **6**, 402–403 (1955)
224. Spurr, R.T., Newcomb, T.P.: The adhesion theory of friction. Proc. Phys. Soc. B **70**, 98–101 (1957)
225. Spurr, R.T., Newcomb, T.P.: The variation of friction with velocity. Proc. Phys. Soc. B **70**, 198–200 (1957)
226. Srinivasan, S., Russ, J.C., Scattergood, R.O.: Fractal analysis of erosion surfaces. J. Mater. Res. **5**, 2616–2619 (1990)
227. Stanley, H.M., Kato, T.: An FFT-based method for rough surface contact. J. Tribol. **119**, 481–485 (1997)
228. Stribeck, R.: Die wesentlichen Eigenschaften der Gleit-und Rollenlager. Z. Verein. Deut. Ing. **46**, 1341–1348 (1902)
229. Tabor, D.: The Hardness of Metals. Clarendon Press, Oxford (1951)
230. Tabor, D.: Friction – the present state of our understanding. J. Lubr. Technol. **103**, 169–179 (1981)
231. Tariku, F.A.: Simulation of dynamic mechanical systems with stick-slip friction (master's thesis). Master's thesis, University of New Brunswick, Canada (1998)
232. Tariku, F.A., Rogers, R.J.: Improved dynamic friction models for simulation of one-dimensional and two-dimensional stick-slip motion. J. Tribol. **123**, 661–669 (2001)

233. Taylor, J.H., Kebede, D.: Modeling and simulation of hybrid systems. In: 34th Proceedings of the IEEE Conference on Decision and Control, pp. 2685–2687 (1995)
234. Taylor, J.H., Kebede, D.: Rigorous hybrid systems simulation of an electro-mechanical pointing system with discrete-time control. In: Proceedings of the 1997 American Control Conference, pp. 2786–2789 (1997)
235. Thomas, K.: Cold welding. In: ASM Handbook, vol. 6. Welding, Brazing, and Soldering, pp. 307–310. ASM International, Russell Township (1993)
236. Thompson, M.K., Thompson, J.M.: Considerations for the incorporation of measured surfaces in finite element models. Scanning **32**, 183–198 (2010)
237. Tolstoi, D.M.: Significance of the normal degree of freedom and natural normal vibrations in contact friction. Wear **10**, 199–213 (1967)
238. Tucker, K., Green, I.: Finite element analysis of electromagnetic effects on hemispherical contacts. In: Proceedings of the 9th Biennial ASME Conference on Engineering Systems Design and Analysis (ESDA2008), Haifa Israel, 2008, p. 59040(6)
239. Tworzydlo, W.W., Becker, E.: Influence of forced vibrations on the static coefficient of friction – numerical modeling. Wear **143**, 175–196 (1991)
240. Tworzydlo, W.W., Hamzeh, O.N.: On the importance of normal vibrations in modeling of stick slip in rock sliding. J. Geophys. Res. **102**, 15091–15103 (1997)
241. Ullah, H., Irfan, M.A., Prakash, V.: State and rate dependent friction laws for modeling high-speed frictional slip at metal-on-metal interfaces. J. Tribol. **129**, 17–22 (2007)
242. Wang, W., Scholz, C.H.: Micromechanics of the velocity and normal stress dependence of rock friction. Pure Appl. Geophys. **143**, 303–315 (1994)
243. Wang, Z., Dohda, K., Haruyama, Y.: Effects of entraining velocity of lubricant and sliding velocity on friction behavior in stainless steel sheet rolling. Wear **260**, 249–257 (2006)
244. Warren, T.L., Krajcinovic, D.: Random cantor set models for the elastic-perfectly plastic contact of rough surfaces. Wear **196**, 1–15 (1996)
245. Westergaard, H.M.: Bearing pressures and cracks. J. Appl. Mech. **6**, 49–53 (1939)
246. Williamson, J.B.P., Hunt, R.T.: Asperity persistence and the real area of contact between rough surfaces. Proc. R. Soc. Lond. A **327**, 147–157 (1972)
247. Willner, K.: Elasto-plastic normal contact of three-dimensional fractal surfaces using halfspace theory. J. Tribol. **126**, 28–33 (2004)
248. Wolf, D.E., Grassberger, P. (eds.): HLRZ Workshop on Friction, Arching, Contact Dynamics. World Scientific, Singapore (1997)
249. Wong, P.Z., Bray, A.J.: Small-angle scattering by rough and fractal surfaces. J. Appl. Crystallogr. **21**, 786–794 (1988)
250. Yan, W., Komvopoulos, K.: Contact analysis of elastic-plastic fractal surfaces. J. Appl. Phys. **84**, 3617–3624 (1998)
251. Yang, C., Persson, B.N.J.: Contact mechanics: Contact area and interfacial separation from small contact to full contact. J. Phys. Condens. Matter **20**, 215214(13) (2008)
252. Yang, C., Persson, B.N.J., Israelachvili, J., Rosenberg, K.: Contact mechanics with adhesion: interfacial separation and contact area. Europhys. Lett. **84**, 46004(5) (2008)
253. Yang, C., Tartaglino, U., Persson, B.N.J.: A multiscale molecular dynamics approach to contact mechanics. Eur. Phys. J. E **19**, 47–58 (2006)
254. Yang, J., Komvopoulos, K.: A mechanics approach to static friction of elastic-plastic fractal surfaces. J. Tribol. **127**, 315–324 (2005)
255. Yashioka, N.: A review of the micromechanical approach to the physics of contacting surfaces. Tectonophysics **277**, 29–40 (1997)
256. Zavarise, G., Borri-Brunetto, M., Paggi, M.: On the resolution dependence of micromechanical contact models. Wear **262**, 42–54 (2007)
257. Zhao, Y., Chang, L.: A model of asperity interactions in elastic-plastic contact of rough surfaces. J. Tribol. **123**, 857–864 (2001)
258. Zhuang, W.D., Chang, P.C., Chou, F.Y., Shiue, R.K.: Effect of solder creep on the reliability of large area die attachment. Microelectron. Reliab. **41**, 2011–2021 (2001)

Index

A. Goedecke, *Transient Effects in Friction*, Engineering Materials,
DOI 10.1007/978-3-7091-1506-0, © Springer-Verlag Wien 2013