

University of Groningen

Size-dependent plasticity in contact/friction: from discrete dislocation dynamics inside an asperity to statistical summation over asperities

Song, Hengxu

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Song, H. (2016). *Size-dependent plasticity in contact/friction: from discrete dislocation dynamics inside an asperity to statistical summation over asperities*. Rijksuniversiteit Groningen.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

**Size-dependent plasticity in contact/friction:
from discrete dislocation dynamics inside an
asperity to statistical summation over
asperities**

Hengxu Song

Size-dependent plasticity in contact/friction: from discrete dislocation dynamics inside an asperity to statistical summation over asperities

Hengxu Song
PhD Thesis
University of Groningen
The Netherlands

Zernike Institute PhD thesis series 2016-11
ISSN: 1570-1530
ISBN: 978-90-367-9311-7 (Printed version)
ISBN: 978-90-367-9310-0 (Electronic version)



**university of
 groningen**

faculty of mathematics and
 natural sciences

zernike institute for
 advanced materials



rijksuniversiteit
 groningen

Size-dependent plasticity in contact/friction: from discrete dislocation dynamics inside an asperity to statistical summation over asperities

PhD thesis

to obtain the degree of PhD at the
University of Groningen
on the authority of the
Rector Magnificus Prof. E. Sterken
and in accordance with
the decision by the College of Deans.

This thesis will be defended in public on
Tuesday 29 November 2016 at 9.00 hours

by

Hengxu Song

born on 8 August 1988
in Jilin, China

Supervisor

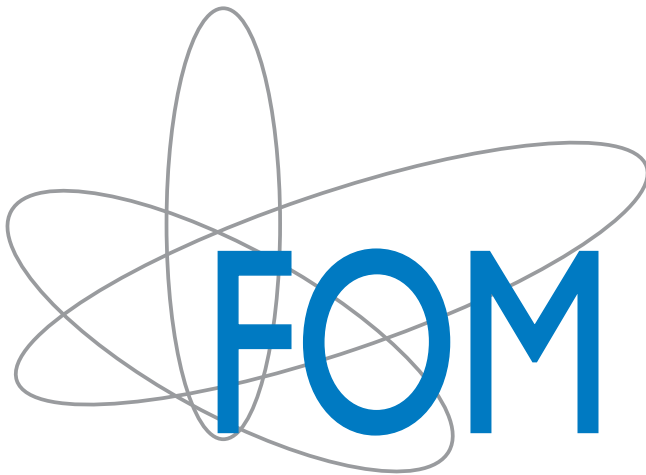
Prof. E. van der Giessen

Assessment committee

Prof. G. Palasantzas

Prof. J.F. Molinari

Prof. A. Benzerga



This research was supported by Foundation for Fundamental Research on Matter (FOM), which is part of the Netherlands Organisation for Scientific Research (NWO), grant no. 13POF07-1.

Contents

1	General introduction	1
1.1	Technological background	2
1.2	Physical mechanisms of friction	2
1.3	Research questions	3
1.4	Outline of the thesis	6
	References.	7
2	Statistical Model of Asperity Interaction In Rough Surfaces	
	Contact	11
2.1	Introduction.	12
2.2	A probabilistic model of asperity interaction.	13
2.3	The mechanics of multiasperity contact	15
2.4	The effect of the order of interaction	18
2.5	Influence of roughness and material properties.	20
2.6	Comparison with models based on a finite surface area A	21
2.7	Summary and Conclusions.	23
	References.	23
3	Obstacles and sources in dislocation dynamics: Strengthening and statistics of abrupt plastic events in nanopillar compression	25
3.1	Introduction.	26
3.2	Model description and Methods	28
3.3	Strengthening size effects and statistical behavior of plasticity.	32
	3.3.1 Yield stress and plastic flow stress fluctuations.	33
	3.3.2 Statistics of abrupt events	35
	3.3.3 The role of surface dislocation sources for yield strength size effects and plastic burst distributions.	35
3.4	Source vs. obstacle strength and the role for yield strength, size effects and statistical behavior	39
3.5	Summary	43
	References.	44

4	Strain gradient plasticity analysis of elasto-plastic contact between rough surfaces	51
4.1	Introduction	52
4.2	Methodology	54
4.2.1	Rough surfaces	54
4.2.2	Constitutive model	56
4.3	Flattening of a 3D sinusoidal asperity by a rigid flat	58
4.4	Contact between a rigid flat and a 3D deformable rough surface	62
4.4.1	Load dependence of real contact area	62
4.4.2	Statistics of the contact pressure	63
4.5	Summary and conclusion	66
	References	68
5	Statistical model of rough surface contact accounting for size dependent plasticity and asperity interaction	73
5.1	Introduction	74
5.2	Description of the problem	76
5.3	Mechanical response of a single asperity	77
5.3.1	Multiscale modeling of sinusoidal asperity flattening	78
5.3.2	Curve-fitted force-interference equations	81
5.4	Statistical analysis of rough surface contact	83
5.5	Comparison between FEM predictions and statistical model predictions	86
5.6	Discussion and Conclusions	89
	References	90
6	Discrete dislocation plasticity analysis of loading rate dependent static friction	95
6.1	Introduction	96
6.2	Formulation	98
6.2.1	Rate-dependent plasticity in tension	101
6.3	Rate dependent friction at fixed adhesion strength	102
6.4	Slip velocity dependent adhesion strength	107
6.5	Discussion	108
6.6	Conclusions	110
	References	114

7 Plastic ploughing of a sinusoidal asperity on a rough surface	117
7.1 Introduction	118
7.2 Formulation	119
7.3 Effect of ploughing depth	123
7.4 Size dependence of self-similar asperities	126
7.5 The role of the asperity	127
7.6 Comparison with two contact models	128
7.7 Conclusions	131
References	131
Summary	135
Samenvatting	139
Curriculum Vitæ	143
List of Journal Publications of this Work	145
Acknowledgements	147

