

University of Groningen

## Fast-moving dislocations in high strain rate deformation

Roos, Arjen

**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:*

1999

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

*Citation for published version (APA):*

Roos, A. (1999). *Fast-moving dislocations in high strain rate deformation*. s.n.

### 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.

Rijksuniversiteit Groningen

FAST-MOVING DISLOCATIONS  
IN  
HIGH STRAIN RATE DEFORMATION

PROEFSCHRIFT

ter verkrijging van het doctoraat in de  
Wiskunde en Natuurwetenschappen  
aan de Rijksuniversiteit Groningen  
op gezag van de  
Rector Magnificus, dr. D.F.J. Bosscher,  
in het openbaar te verdedigen op  
vrijdag 17 december 1999  
om 16.00 uur

door

ARJEN ROOS

geboren op 24 maart 1971  
te Hoogezand

Promotores: Prof.Dr. J.Th.M. De Hosson  
Prof.Dr.Ir. E. van der Giessen

Print – Groningen University Press

Cover – The shear stress component of a dislocation. The dislocation is of pure edge character and moves in the  $x$ -direction at a velocity of 98% of the speed of sound in Cu (equation (2.3–11) on page 15 of this thesis).

ISBN 90–367–1166–5

The work described in this thesis is part of the research program of Senter, IOP-Metalen (Den Haag) under project number IOP-C94703.RG.TN.

# CONTENTS

CHAPTER 1 – INTRODUCTION .....	1
CHAPTER 2 – FAST-MOVING DISLOCATIONS .....	7
2.1 Introduction .....	7
2.2 The balance of momentum .....	8
2.3 Discrete dislocation plasticity .....	11
2.4 Constitutive rules .....	16
2.4.1 Obstacles to dislocation motion .....	17
2.4.2 Mapping of obstacle properties in the computational cell .....	18
2.4.2.1 Friedel limit .....	21
2.4.2.2 Mott–Labusch limit .....	22
2.4.2.3 Orowan looping .....	24
2.4.3 Boundaries .....	25
2.4.4 Generation of dislocations .....	25
2.5 Summary .....	27
2.6 Literature .....	27
CHAPTER 3 – DISLOCATION DRAG MECHANISMS .....	29
3.1 Introduction .....	29
3.2 Thermally activated motion .....	32
3.3 Dislocation drag mechanisms .....	35
3.3.1 Phonon viscosity .....	36
3.3.2 Electron viscosity .....	43
3.3.3 Impurity viscosity .....	48
3.3.4 Summary and discussion .....	51
3.4 Relativistic regime .....	53
3.5 Concluding remarks .....	55
3.6 Literature .....	57
CHAPTER 4 – FAST DISLOCATION PLASTICITY .....	59
4.1 Introduction .....	59
4.2 Obstacle properties .....	60

4.2.1	Solutes .....	60
4.2.2	Forest dislocations.....	61
4.2.3	Precipitates .....	62
4.3	Dislocation velocities and accelerations.....	66
4.4	Numerical issues.....	70
4.4.1	Mesh size.....	71
4.4.2	Size of the computational cell.....	72
4.5	Relativistic versus conventional dislocation fields.....	73
4.6	Literature.....	77
CHAPTER 5 – THERMAL EFFECTS .....		79
5.1	Introduction .....	79
5.2	Thermal effects on microstructural parameters .....	81
5.2.1	Temperature dependence of obstacle strength .....	82
5.2.2	Temperature dependence of the drag coefficient.....	84
5.3	The heat equation.....	85
5.4	Sources of heat.....	86
5.5	Solutions of the heat equation.....	90
5.5.1	Analytical solution .....	90
5.5.2	Finite-element solution.....	94
5.6	Thermal plasticity .....	98
5.6.1	Discrete dislocation plasticity at constant ambient temperature ...	98
5.6.2	Consistency of analytical and finite-element solutions.....	99
5.6.3	Localisation of heat .....	100
5.7	Literature.....	102
Appendix 5A Source term of the temperature field.....		103
Appendix 5B Diffusion term of the temperature field .....		106
5.B.1	First time increment $k = 0$ .....	106
5.B.2	Second time increment $k = 1$ .....	107
CHAPTER 6 – SUMMARY AND OUTLOOK .....		113
6.1	Summary.....	113
6.2	Discussion and Outlook.....	116
6.2.1	Accelerations.....	116
6.2.2	Temperature rise and cracks.....	117
6.3	Fracture dynamics and discrete dislocation plasticity .....	122
6.4	Literature.....	126
SAMENVATTING .....		127
DANKWOORD .....		131