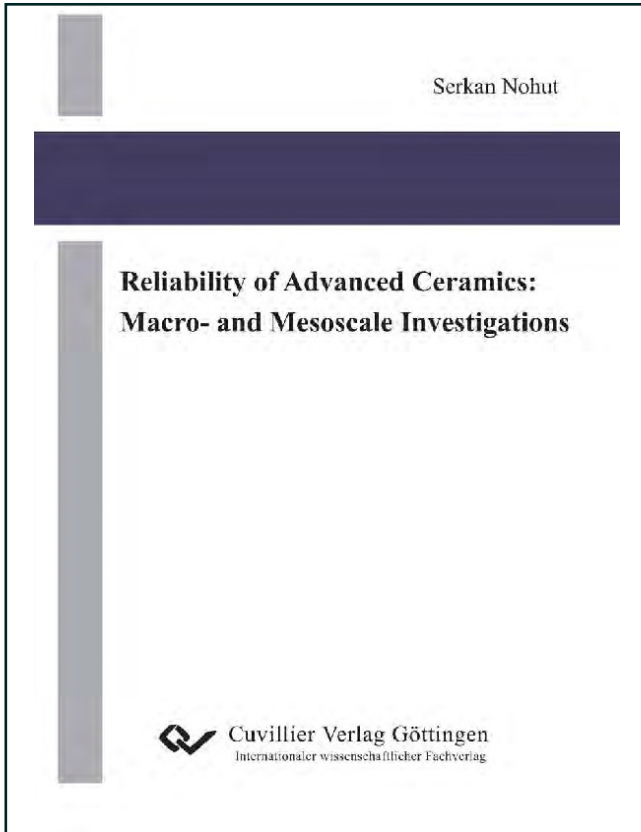




Serkan Nohut (Autor)

## **Reliability of Advanced Ceramics: Macro- and Mesoscale Investigations**



<https://cuvillier.de/de/shop/publications/935>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,  
Germany

Telefon: +49 (0)551 54724-0, E-Mail: [info@cuvillier.de](mailto:info@cuvillier.de), Website: <https://cuvillier.de>

# Contents

<b>Acknowledgements</b>	<b>iii</b>
<b>Nomenclature</b>	<b>iv</b>
<b>List of Figures</b>	<b>viii</b>
<b>List of tables</b>	<b>xi</b>
<b>1 Introduction</b>	<b>1</b>
<b>2 Principles of Brittle Fracture</b>	<b>3</b>
2.1 Importance of Fracture Mechanics . . . . .	3
2.2 Strength of Defect Free Solids . . . . .	5
2.3 Stress Concentrators . . . . .	6
2.4 The Griffith Energy Balance Concept . . . . .	8
2.5 The Irwin Formulation of Fracture Mechanics . . . . .	10
2.5.1 The Stress Approach . . . . .	10
2.5.2 The Energy Approach . . . . .	13
2.5.3 Equivalence of $G$ and $K$ parameters . . . . .	16
2.6 R-Curve Behavior . . . . .	17
2.6.1 Alumina ( $\text{Al}_2\text{O}_3$ ) . . . . .	18
2.6.2 Silicon Nitride ( $\text{Si}_3\text{N}_4$ ) . . . . .	18
2.6.3 Zirconia ( $\text{ZrO}_2$ ) . . . . .	18
2.6.4 Piezoelectric Ceramics (Lead zirconate titanate - PZT) . . . . .	19
<b>3 Reliability and Statistical Treatment of Strength</b>	<b>20</b>
3.1 Reliability of Ceramics . . . . .	20
3.2 The Weibull Distribution . . . . .	21
3.2.1 Homogeneous Uniaxial Stress Distribution . . . . .	22
3.2.2 Inhomogeneous Uniaxial Stress Distribution . . . . .	23
3.3 Determination of Weibull Parameters . . . . .	25
3.3.1 Graphical Method (Linear Regression Method) . . . . .	25
3.3.2 Numerical Method (Maximum Likelihood Method) . . . . .	27
3.4 The Size Effect . . . . .	28
3.5 Multiaxial Failure Criteria . . . . .	30
3.5.1 Multiaxial Weibull Distribution . . . . .	31
3.5.2 Criteria for Mixed-Mode Failure . . . . .	34

<b>4</b>	<b>Design and Failure Probability Analysis of Ceramic Components</b>	<b>37</b>
4.1	Calculation of Failure Probability of Ceramics . . . . .	37
4.2	Prediction of the Strength of Advanced Ceramics under Multiaxial Stress State . . . . .	38
4.2.1	Experimental Setup . . . . .	39
4.2.2	Numerical Calculation of Effective Volume . . . . .	41
4.2.3	Comparison of the Experimental and Numerical Results . . . . .	41
4.3	Failure Probability of Ceramic Coil Springs . . . . .	43
4.3.1	Coil Springs . . . . .	45
4.3.2	Analytical Scaling of Failure Probability . . . . .	47
4.3.3	Numerical Failure Probability Analysis . . . . .	50
4.3.4	Proof Test . . . . .	53
4.4	Effect of Shape Optimization on Failure Probability of Ceramics . . . . .	54
4.4.1	Shape Optimization with ANSYS . . . . .	55
4.4.2	Shape Optimization of a Beam . . . . .	56
4.4.3	Construction of Ceramic Displacing Piston of a Stirling Engine . . . . .	58
4.4.4	Shape Optimization of Ceramic Finger-rings . . . . .	65
4.5	Interdisciplinary Design of a New Ceramic Finger-ring . . . . .	72
4.5.1	Workshop - 1 . . . . .	72
4.5.2	Workshop - 2 . . . . .	77
4.5.3	Design of a New Ceramic Finger-ring . . . . .	79
<b>5</b>	<b>Investigation of the Effect of Grain Size on Crack-tip Toughness of Alumina in Mesoscale with Distinct Element Method (DEM)</b>	<b>85</b>
5.1	Experimentally Reported Relationship Between Grain Size and Crack-tip Toughness of Alumina . . . . .	86
5.2	Distinct Element Method (DEM) . . . . .	89
5.2.1	Theoretical Background . . . . .	90
5.3	Determination of Microparameters for DEM Model . . . . .	94
5.4	Computation of Fracture Toughness through DEM Model of SENB Test	98
5.5	Results . . . . .	99
<b>6</b>	<b>Summary and Conclusion</b>	<b>106</b>
	<b>References</b>	<b>108</b>

# Acknowledgements

This dissertation was carried out between the years 2005 and 2008 at the Institute of Advanced Ceramics at Hamburg University of Technology. The financial support provided by Deutsche Forschungsgemeinschaft(DFG) Graduiertenkolleg “Kunst und Technik” is gratefully acknowledged.

First of all, I would like to express my sincere gratitude to my supervisor Prof. Gerold A. Schneider for his willingness to take me into his group and unconditional warm welcome to me. During my three-years occupation in his institute, he did not only provide an impassioned support but also encouraged me throughout my academic program. This dissertation could not have been written without his stimulating and helpful suggestions. I would also like to thank to Prof. Margarete Jarchow for her contributions to the artistic aspects of this work. I have furthermore to thank to Prof. Dieter Krause for his acceptance to become co-referee for my thesis.

I am thankful to all my work colleagues for the pleasant and friendly atmosphere at the Institute of Advanced Ceramics. I am also very grateful to Felix Müller, Jan-Hendrik Woldt and Hüseyin Özcoban whom I supervised during their thesis. Their work contributed directly and indirectly to the dissertation. In particular, the direct contributions by Jan-Hendrik Woldt and Hüseyin Özcoban to Chapter 4 are acknowledged.

I would like to express my appreciation to Ali Genc, Haktan Gündüzeri and their families who supported me morally during my studies in Stuttgart and in Hamburg.

My most sincere thanks go to a special friend Hüseyin Özcoban whom I know since the first day of my occupation at the Institute of Advanced Ceramics. I had many helpful and interesting scientific discussions with him which undoubtedly helped me during my work. In addition he always helped and encouraged me to improve my German knowledge and to have a more active social life.

I owe my loving thanks to my uncles Ali Kadifeci and Murat Kadifeci, to my aunt Ünzüle Gündüz and to my grandmother Elmas Kadifeci for their encouragement.

Finally, I would like to express my eternal gratitude to my father Mehmet Nohut and to my mother Ayfer Nohut for their everlasting love and support all through my life. My brothers Serdar Nohut, Sahin Nohut and Ibrahim Halil Nohut, with whom I am always proud of, deserve the most special appreciation and thanks here.