

Contents

| | |
|--|------------|
| Abstract | VII |
| Zusammenfassung | IX |
| 1 Introduction | 1 |
| 1.1 Overview of Metal Fatigue | 1 |
| 1.2 Effects of Shot Peening on Fatigue | 3 |
| 1.3 Objectives | 7 |
| 2 Residual Stress Relaxation | 8 |
| 2.1 Causes for Residual Stress Relaxation | 8 |
| 2.1.1 Thermal Loading | 8 |
| 2.1.2 Quasi-Static Loading | 9 |
| 2.1.3 Cyclic Loading | 11 |
| 2.2 Experiments for Large Plastic Deformations | 13 |
| 2.3 Variations of Residual Plastic Strain | 16 |
| 2.4 Finite Element Analysis | 17 |
| 2.4.1 Simulation Based on Cyclic Plasticity | 17 |
| 2.4.2 Simulation Based on Multi-Layer Model | 19 |
| 2.4.3 Simulation Based on Compressive Stress-Strain Curves | 20 |
| 2.5 Analytical Solution for Cyclic Loading | 22 |
| 2.6 Summary | 27 |
| 3 Fatigue Life Prediction of Shot-Peened Materials | 29 |
| 3.1 Approach to Fatigue Life | 29 |
| 3.2 Multiaxial Fatigue Life Models | 30 |
| 3.2.1 Findley Criterion | 30 |
| 3.2.2 Integration of Shot Peening in Findley Criterion | 32 |
| 3.3 Prediction of Fatigue Life | 36 |
| 3.3.1 Nonlocal Treatment | 36 |
| 3.3.2 Case Study | 38 |
| 3.4 Summary | 41 |
| 4 Cohesive Zone Model for Fatigue Crack Growth | 43 |
| 4.1 Damage Tolerant Design | 43 |
| 4.2 Cohesive Zone Model and Implementation | 45 |
| 4.2.1 Description of the Model | 45 |
| 4.2.2 Finite Element Implementation | 50 |
| 4.3 Validation of Cohesive Zone Model | 51 |
| 4.3.1 Parameter Identification | 51 |

| | | |
|----------|--|-----------|
| 4.3.2 | Short Crack Effect | 55 |
| 4.4 | Summary | 58 |
| 5 | Fatigue Crack Growth Analysis in Shot-Peened Material | 59 |
| 5.1 | Two-Dimensional Fatigue Crack Simulation | 59 |
| 5.1.1 | Finite Element Modeling | 59 |
| 5.1.2 | Fatigue Crack Growth | 61 |
| 5.1.3 | Relaxation of Residual Stress | 69 |
| 5.2 | Three-Dimensional Fatigue Crack Simulation | 72 |
| 5.2.1 | Finite Element Modeling and Mesh Sensitivity | 72 |
| 5.2.2 | Fatigue Crack Growth | 77 |
| 5.2.3 | Relaxation of Residual Stress | 85 |
| 5.3 | Summary | 89 |
| 6 | Conclusions and Outlooks | 91 |
| 6.1 | Conclusions | 91 |
| 6.2 | Outlooks | 92 |
| | Bibliography | 93 |